



Benefits of the CSGN

A valuation estimate of six major potential benefits of the CSGN

Central Scotland Green Network Trust and the Scottish Government's
Rural and Environment Science and Analytical Services Division (RESAS)

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Hume, J. 2015, 'CSGN Benefits Valuation Report', *Scottish Government*

Additional reports available:

Hislop, M and Corbett, A. 2014, 'Costing the CSGN – Capital cost estimates for the major components of the CSGN', *CSGNT and the GCV Green Network Partnership*

Hislop, M. 2016, 'Resourcing the CSGN – Potential sources of funding for the capital costs of the CSGN', *GCV Green Network Partnership for CSGNT*

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1 Executive Summary

A sizeable body of evidence demonstrates that a healthy and attractive natural environment can contribute positively to social welfare and help achieve Scotland's strategic objectives. To help realise the opportunities a greener environment offers, Scotland's second National Planning Framework introduced the Central Scotland Green Network (CSGN). The CSGN is designed to help public organisations and other stakeholders to co-ordinate their activities to provide widely accessible and consistently excellent natural environments across Scotland's central belt.

This report is one of three studies undertaken on behalf of the CSGN to help plan and communicate its strategic objectives. The first of these was a costing study which estimated the capital cost of delivering an ambitious range of green infrastructure projects across the central belt. Concurrent to this benefits report, a second resourcing study examines what funding is available to deliver these projects. In this third study, the Scottish Government selected six major potential benefits of the CSGN's proposals for valuation. This represents only a small subset of the full suite of benefits which expert opinion suggests would result from the CSGN programme. These six benefits were selected due to the strength of supporting evidence, the ability to easily communicate how these improvements would affect people, and crucially, the existence of quantitative research that allows monetisation of their impacts.

The report details the valuation results and methodology used for:

1. The crime reduction achievable through providing attractive natural features throughout urbanised areas;
2. The physical health benefits of providing high-quality greenspace within a five-minute walk of all homes;
3. The mental health benefits of providing high-quality greenspace within a five-minute walk of all homes;
4. The carbon sequestered by restoring all the 62,000 hectares of restorable peatland across the CSGN;
5. The carbon sequestered by planting 85,500 hectares of new broadleaf woodland;
6. The flooding damage averted by installing green infrastructure networks across the CSGN.

In total, our central estimates value these benefits at around £6 billion over the 35 years to 2050. A breakdown of benefits is presented in Table 1 below.

Table 1: The composition of our £6 billion valuation

Benefit	Peak annual value of benefits	Estimated total net present value of benefits to 2050
Crime reduction	£25m	£513m
Improved physical health	£36m	£742m
Improved mental health	£62m	£1,290m
Peatland carbon sequestration	£15m in 2050	£246m

Forest carbon sequestration	£129m in 2040	£2,065m
Reduced flood damage	£43m	£1,206m
Total	£310m	£6,062m

We have calculated what we believe to be a relatively conservative central estimate of these benefits, and have also performed a number of sensitivity analyses which show the impact of changing key assumptions in our calculations. When these six benefits are totalled, we estimate that their potential value ranges from £4,145m – 9,276m to the year 2050.

It is notable that these benefits will continue to accrue beyond 2050. The 2050 cut-off point was chosen to align with the timescale set for achievement of the CSGN Vision. For example, the bulk of the carbon benefits of peatland restoration occur after 2050 when the peatland is back to near natural condition and sequesters carbon at the maximum rate. The total net present value of carbon sequestration until 2100 is £843m, rather than the £246m when cut-off at 2050.

The assumptions in the health benefit calculations are based on evidence regarding the likely increase in physical activity. To realise these benefits – or even go beyond them – it is important that the greenspace created is attractive and that investments are flanked by appropriate measures to encourage people to change their behaviours.

These headline figures do not capture all the benefits of the interventions.

Among the benefits which are not valued, evidence shows that greenspace investments can lead to:

- Better air quality;
- Better water quality;
- Abatement of noise pollution;
- Shifts to more sustainable means of transport;
- Reduced building heating requirements;
- Enhanced biodiversity and enlarged habitat;
- More attractive environments for shoppers, tourists and employees;
- Greater resource availability for sustainable industries;
- A more engaged local community; and
- Increased opportunities for formal and informal education activities.

This range of further benefits illustrates that the overall value of CSGN investments will be well above this report's £6 billion estimate.

2 Introduction

2.1 The Client

This report has been prepared for the Central Scotland Green Network Trust (CSNT).

2.2 Background

A sizeable body of evidence demonstrates that a healthy and attractive natural environment can contribute positively to social welfare and help achieve Scotland's strategic objectives. To help realise the opportunities a greener environment offers, Scotland's second National Planning Framework introduced the Central Scotland Green Network (CSGN). The CSGN is designed to help public organisations and other stakeholders to co-ordinate their activities to provide widely accessible and consistently excellent natural environments across Scotland's central belt.

This report is one of three studies undertaken on behalf of the CSGN to help plan and communicate its strategic objectives. Taken together the reports are intended to set out the capital costs of realising the CSGN, quantify the value of the benefits that might be realised by this investment and explore how delivery can be resourced.

2.3 The authors

This study report has been written by Jamie Hume of the Rural and Environment Science and Analytical Services Division (RESAS) of the Scottish Government. The author has drawn on reports and research from a number of sources which are cited as footnotes. The report has benefitted from the valuable support and guidance of colleagues within Scottish Government, Forestry Commission Scotland and SEPA.

2.4 Selected benefits and overall findings

The Scottish Government selected six major potential benefits of the CSGN's proposals for valuation. This represents only a small subset of the full suite of benefits which expert opinion suggests would result from the CSGN programme. These six benefits were selected due to the strength of supporting evidence, the ability to easily communicate how these improvements would affect people, and crucially, the existence of quantitative research that allows monetisation of their impacts.

The report details the valuation results and methodology used for:

1. The crime reduction achievable through providing attractive natural features throughout urbanised areas;
2. The physical health benefits of providing high-quality greenspace within a five-minute walk of all homes;
3. The mental health benefits of providing high-quality greenspace within a five-minute walk of all homes;
4. The carbon sequestered by restoring all the 62,000 hectares of restorable peatland across the CSGN;
5. The carbon sequestered by planting 85,500 hectares of new broadleaf woodland;
6. The flooding damage averted by installing green infrastructure networks across the CSGN.

In total, our central estimates value these benefits at around £6 billion over the 35 years to 2050. A breakdown of benefits is presented in Table 2 below.

Table 2: The composition of our £6 billion valuation

Benefit	Peak annual value of benefits	Estimated total net present value of benefits to 2050
Crime reduction	£25m	£513m
Improved physical health	£36m	£742m
Improved mental health	£62m	£1,290m
Peatland carbon sequestration	£15m in 2050	£246m
Forest carbon sequestration	£129m in 2040	£2,065m
Reduced flood damage	£43m	£1,206m
Total	£310m	£6,062m

We have calculated what we believe to be a relatively conservative central estimate of these benefits, and have also performed a number of sensitivity analyses which show the impact of changing key assumptions in our calculations. When these six benefits are totalled, we estimate that their potential value ranges from £4,145m – 9,276m to the year 2050.

To align our benefits study to the headline costs presented in the costing study, we assume that the required investments and the stream of resulting benefits begin with immediate effect starting in 2016. It is notable that these benefits will continue to accrue beyond 2050. The 2050 cut-off point was chosen to align with the timescale set for achievement of the CSGN Vision. For example, the bulk of the carbon benefits of peatland restoration occur after 2050 when the peatland is back to near natural condition and sequesters carbon at the maximum rate. The total net present value of carbon sequestration until 2100 is £843m, rather than the £246m when cut-off at 2050.

The assumptions in the health benefit calculations are based on evidence regarding the likely increase in physical activity. To realise these benefits – or even go beyond them – it is important that the greenspace created is attractive and that investments are flanked by appropriate measures to encourage people to change their behaviours.

These headline figures do not capture all the benefits of the interventions. The planned interventions provide more than one benefit – for example, the literature suggests that a natural environment which reduces crime is also likely to improve mental health. The individual sections in this report provide further ideas of the additional benefits we might expect from each intervention.

Among the benefits which are not valued, evidence shows that greenspace investments can lead to:

- Better air quality;
- Better water quality;
- Abatement of noise pollution;
- Shifts to more sustainable means of transport;
- Reduced building heating requirements;
- Enhanced biodiversity and enlarged habitat;
- More attractive environments for shoppers, tourists and employees;
- Greater resource availability for sustainable industries;
- A more engaged local community; and
- Increased opportunities for formal and informal education activities.

This range of further benefits illustrates that the overall value of CSGN investments will be well above this report's £6 billion estimate.

The valuation results and methodology for each of the benefits are explained in the following chapters.

3 Valuing the crime reduction attained through urban greening

We estimated the value of the crime reduction achievable through ensuring that all citizens within the CSGN area enjoy a high standard of natural environmental features around their homes. Our approach estimates a total annual benefit of £25m, which translates into a total net present value of benefits of £513m to 2050.

We have performed a second analysis which shows the impact of increasing the target population of our intervention. Alongside our central estimate this leads to a range of potential benefits to the year 2050 of between £513m - £770m.

Studies have demonstrated that, even when other risk factors are controlled for, greener and better cared-for environments are linked to lower crime in local areas. By ensuring all CSGN residents who are currently unhappy with their area's environmental features can enjoy these green environments we estimate that this could alleviate just under 1% of the annual cost of crime in the CSGN area.

Existing evidence shows that greener urban environments also provide a range of other benefits. These include improved mental health, biodiversity, flood management, air quality and increasing the appeal of local shopping districts. These benefits, among others, were beyond the scope of this report and are not included in the estimates shown above.

3.1 Methodology

Our calculation relies on the principle that integrating natural environments into urban areas results in reduced crime, in keeping with the findings of Kuo and Sullivan.¹ Their study found that 8% of crime prevalence could be explained by the density of vegetation in urban areas.

To assess how people felt about the greenspace in their local areas, we used data from the Scottish Household Survey². This showed that 9% of respondents were dissatisfied with their local greenspace in 2014. We then used 9% as our affected population, whose areas would see investment in green infrastructure.

Our estimates on the cost of crime in Scotland came from two studies performed by the Home Office. The first estimated the total cost of crime to be £60Bn across England and Wales in the year 2000³. The costs of the main component, crimes affecting individuals and households, were then updated in 2005⁴. We calibrated these results to 2016 prices and calculated the population share of the CSGN area.

¹ Environment and Crime in the Inner City: Does Vegetation Reduce Crime? Kuo and Sullivan, 2001: <http://www.outdoorfoundation.org/pdf/EnvironmentAndCrime.pdf>

² 2014 Scottish Household Survey. The Scottish Government, 2015: <http://www.gov.scot/Publications/2014/08/7973>

³ The Economic and Social Costs of Crime. Brand and Price, 2000: <http://webarchive.nationalarchives.gov.uk/20110218135832/rds.homeoffice.gov.uk/rds/pdfs/hors217.pdf>

⁴ The Economic and Social Costs of Crime against Individuals and Households. Dubourg and Hamed, 2005: <http://webarchive.nationalarchives.gov.uk/20110218135832/rds.homeoffice.gov.uk/rds/pdfs/hors217.pdf>

This value does not take into account changes in crime levels subsequent to the year 2000. To account for this, it is possible to adjust the numbers of recorded crimes to our most recent data. In the year 2000, there were 423,172 offences recorded in Scotland⁵. In the figures for 2014/15 this had decreased to 256,350. We adjusted down the cost of crime estimated by the Home Office to the most recently published figures and the population of the CSGN area. Using this method, the current cost of crime across the CSGN area is around £3.5bn per year.

By assuming a reduction in crime of 8% in the 9% of areas which are affected, we arrived at an annual benefit of £25m. This value was discounted until 2050 according to the Government's Green Book appraisal guidelines, resulting in a total cumulative benefit of £513m.

3.2 Expanding the programme to affect more citizens

Our central estimate uses a binary measure of vegetation which only considers those who are dissatisfied. We are therefore likely to miss the nuances where populations experience middling levels of local vegetation. The survey also records that 9% of respondents were neither satisfied or dissatisfied and 6% had no opinion. There may be scope to benefit these groups which is missed by our calculation.

A second calculation was therefore conducted. We assumed indifference to the natural environment on the part of the 6% who held no opinion on the local environment. However, we then assumed that it may be possible to improve the natural environment for the group who were neither satisfied or dissatisfied. Given we would not expect such a large impact on those who were not so dissatisfied with their area we halved the effect of our intervention on this group. Our affected population would therefore increase 4.5%, resulting in annual benefits of £37m. Results for both calculations are presented in Table 3.

Table 3: A comparison of our crime reduction valuations

Scenario	Annual value of benefits	Estimated total net present value of benefits to 2050
Central estimate	£25m	£513m
High estimate	£37m	£770m

3.3 Further Discussion

There is a range of literature⁶ which demonstrates that increased vegetation in a neighbourhood is associated with reduced crime. For example, Wolfe and Mennis (2012)⁷ found that increased tree cover in Philadelphia was correlated to lower levels of violent crime, even once socio-economic status was considered. Quality of greening may be an important

⁵ Recorded Crime in Scotland. 2001, The Scottish Government, 2002: <http://www.gov.scot/Publications/2002/04/14616/3740>

⁶ Green Cities: Good Health. Urban Greening Research, 2016: https://depts.washington.edu/hhwb/Thm_Crime.html

⁷ Does Vegetation Encourage or Suppress Urban Crime? Evidence From Philadelphia, PA. Wolfe and Mennis, 2012: <http://www.sciencedirect.com/science/article/pii/S0169204612002502>

consideration however. Despite finding an overall crime-reducing effect of vegetation, Troy et al (2012)⁸ found that in some neighbourhoods near industrial areas this effect is reversed. The authors hypothesize that this may be vegetation found on vacant plots of land, which is not properly maintained. Clearly this is not the sort of greenspace the CSGN's programme means to supply, and in fact converting vacant and derelict land into social use is an explicit ambition of the CSGN. Garvin et al (2012)⁹ found that where vacant land was cleared and vegetation planted, perceptions of safety increased significantly and crime levels also dropped, albeit not at a statistically significant level.

Various explanations have been put forward as to why this crime-reducing effect of greenspace could occur¹⁰. But when considering cross-sectional econometric evidence, it is important to consider the possibility that certain variables, like crime and vegetation, may be correlated to other factors we have not examined and which are not controlled for. The study we have used, like many others, demonstrates a negative correlation between crime levels and greenspace. In this valuation it has been necessary to make the assumption that greenspace is a causative factor in deterring crime, but it's worth bearing in mind that this has not been conclusively proven.

There are other potential sources of uncertainty in our calculations. Notably, the findings of Kuo and Sullivan result from a study in Chicago and behavioural differences could mean the impact differs in Scotland.

The Chicago study also used different criteria for vegetation abundance from our calculation. It considered aerial photographs of neighbourhoods, assigning them to a five-point scale based on level of vegetation. Our own method used subjective responses from the 9% of Scottish Household Survey respondents who were dissatisfied with local greenspace.

Data from the Scottish Household Survey shows that disadvantaged areas tend to have poorer levels of satisfaction with the local natural environment. Survey results suggest that deprived areas are much less satisfied with local greenspace meaning that effects will be primarily concentrated in areas which experience the greatest crime levels. Our study does not consider the distributional aspects of benefits and how these are likely to relatively favour deprived areas.

We also did not consider the possibility of displacement wherein crime that would otherwise have taken place in an affected area is caused to take place elsewhere by our intervention. This is more likely if by only targeting areas of dissatisfaction, nearby areas with initially better but not ideal natural environments become more attractive venues for crime by comparison.

The costing studies by the Home Office were thorough in considering the direct impacts of crime but did not capture possible secondary effects. In addition to costs to victims, crimes

⁸ The Relationship between Tree Canopy and Crime Rates across an Urban-Rural Gradient in the Greater Baltimore Region. Troy et al, 2012:

<http://www.sciencedirect.com/science/article/pii/S0169204612000977>

⁹ Greening Vacant Lots to Reduce Violent Crime: a randomised controlled trial. Garvin et al, 2012
<http://injuryprevention.bmj.com/content/19/3/198.short>

¹⁰ How Cities Use Parks to... Create Safer Neighborhoods. American Planning Association, 2007:
<https://www.planning.org/cityparks/briefingpapers/saferneighborhoods.htm>

can impose a cost to members of a victim's social network, the community of an area and local business. By not considering these secondary effects our study is likely to underestimate the full social and economic benefits of crime reduction.

We have also assumed the same broad patterns of crime in England and Wales are prevalent in the CSGN area. Although results have been scaled down alongside reduced crime rates, our calculation assumes the relative shares of crime incidence in Scotland are equivalent to England and Wales in the year 2000.

4 Valuing increased physical activity attained through greenspace

We estimated the value of the potential health benefits that can be achieved through increased physical activity caused by providing formal greenspace within a short walk of every home within the CSGN area. Our approach results in a total annual benefit of £36m, which translates into a total net present value of benefits of £742m to 2050.

The estimate includes potential savings to the NHS, benefits to individuals via avoided disease and the economic cost of sickness absence which could be avoided through greenspace investment. The estimated net present value of benefits achieved through 2050 is shown in Table 4.

Table 4: The components of physical health benefits

Benefit	Annual costs avoided	Estimated total net present value of benefits to 2050
Savings to the NHS	£3m	£71m
Averted individual costs of ischaemic heart disease	£17m	£351m
Averted individual costs of cerebrovascular disease	£2m	£36m
Averted individual costs of breast cancer	£3m	£65m
Averted individual costs of colorectal cancer	£3m	£68m
Averted individual costs of diabetes	£0m	£4m
Averted sickness absence	£7m	£147m
Total	£36m	£742m

We have performed a second analysis which shows the impact of changing a key assumption of our calculation. Alongside our central estimate this leads to a range of potential benefits to the year 2050 of between £742m - £2,012m.

This report focuses on the health benefits of physical activity during adulthood. Physical activity is as important for children as it is for adults, however the benefits to children are not included here because we are unaware of studies which provided a basis to value the health effects on children.

Promoting behavioural change is complex, but Natural England (2011)¹¹ provide evidence that easy availability of formal greenspace leads to a greater probability of meeting physical activity recommendations. However, the benefits we calculate require greenspace to be of a quality that proves attractive to local people.

There is strong evidence to suggest that failing to make greenspace sufficiently appealing will not result in increased physical activity. On the other hand, particularly good design could potentially result in benefits greater than those suggested by the studies on which we base our calculations. Maximising these benefits is best achieved through a wider programme of engagement with local communities, employers and the physically inactive¹².

Evidence also exists to show that high-quality local greenspace provides a range of other benefits. These include improved mental health among those who view the greenspace, greater biodiversity, improved flood management, a new meeting place for local people and attracting new people and businesses to live in an area. These benefits, among others, were beyond the scope of this report and are not included in the estimates shown above.

4.1 Methodology

4.1.1 Calculating the target population of our intervention

Natural England (2011) examined patterns of greenspace use in Bristol. The paper finds that when ranked by proximity to formal greenspace, the top quartile of participants (those within 830 metres) were 31% more likely to meet physical activity recommendations than the bottom quartile (those further than 2250 metres).

Our calculation assumes that the project's ambition is to ensure high-quality greenspace becomes available within a five- minute walk of everyone living in the CSGN area. We used the 2014 Scottish Household Survey¹³ to measure the target population of our intervention. 12% of people across Scotland reported that they did not live within a ten-minute walk of greenspace and, since this is a close estimate of the time it takes to walk 830 metres, we took this as representative of those whose exercise levels would be most affected by greenspace installation. The affected population therefore totalled 12% of the 3.7m people living in the CSGN area, or around 440,000 people.

We assumed that these 440,000 became as likely to exercise as the remainder of the population with better greenspace access. The 2014 Scottish Health Survey¹⁴ shows that across Scotland 37% of respondents failed to meet physical activity recommendations. This is probably similar to activity levels in Bristol, given findings in England show 33% of survey respondents reported that they failed to meet recommendations¹⁵. Using Natural England's

¹¹Green Space Access, Green Space Use, Physical Activity and Overweight. Natural England, 2011: <http://publications.naturalengland.org.uk/file/80007>

¹² Assessing Physical Activity in Public Parks in Brazil Using Systematic Observation. Parra et al, 2010: https://www.researchgate.net/publication/44683503_Assessing_Physical_Activity_in_Public_Parks_in_Brazil_Using_Systematic_Observation

¹³ 2014 Scottish Household Survey. The Scottish Government, 2015: <http://www.gov.scot/Publications/2015/08/3720>

¹⁴ 2014 Scottish Health Survey. The Scottish Government, 2015: <http://www.gov.scot/Publications/2015/09/6648>

¹⁵ Health Survey for England – 2012. Health & Social Care Information Centre, 2013:

findings, it was possible to estimate that around 69,000 of the 440,000 receiving greenspace would become newly physically active. This accounted for around 5% of the total physically inactive population across the CSGN. We used this figure as a basis to estimate the costs avoided by preventing 5% of the social mal-effects of physical inactivity across the CSGN.

4.1.2 NHS savings

NHS Health Scotland (2013)¹⁶ estimated the overall cost of physical inactivity to the Scottish Health service to be £94m in 2010/11. National costs were downscaled to the CSGN area, resulting in a cost of £65m. We assigned the costs of inactivity to the 37% of people who did not meet physical activity targets.

5% of this £65m results from the physical inactivity of citizens who would be expected to exercise with better greenspace access. Our estimate represents the costs to the NHS averted by causing this group to become active.

The 2010-11 estimated cost to the NHS was inflated into 2016 prices and future values discounted. Using this approach NHS savings were estimated at £3m in 2015, totalling £71m to 2050.

4.1.3 The value to individuals of mortality reduction

The personal cost of physical inactivity was found using 'population attributable fractions' published by the World Health Organisation¹⁷. These fractions represent the proportion of disease incidence which can be attributed to insufficient physical activity. These are presented in Table 5.

Table 5: Population attributable fractions of physical inactivity

Disease	Fraction of disease attributable to physical inactivity
Coronary heart disease	0.23
Cerebrovascular disease (Stroke)	0.12
Breast cancer	0.11
Colorectal cancer	0.16
Diabetes	0.15

These attributable fractions were used alongside data from the NHS' Information Services Division on the incidence and mortality associated with these 5 causes of disease in 2013. We first calculated the incidence of each disease attributable to physical activity. Then incidences

<http://www.hscic.gov.uk/catalogue/PUB13218>

¹⁶ Costing the Burden of Ill Health Related to Physical Inactivity for Scotland. NHS Health Scotland, 2012:

<http://www.healthscotland.com/uploads/documents/20437-D1physicalinactivityscotland12final.pdf>

¹⁷ The World Health Report 2002. World Health Organisation, 2002:

http://www.who.int/whr/2002/en/whr02_en.pdf

due to inactivity were downscaled to the CSGN population and, similar to our calculation on NHS costs, we calculated the benefits of avoiding 5% of this incidence.

For example, the World Health Organization estimates that 23% of ischaemic heart disease in developed countries can be attributed to physical inactivity. Of the 7, 239 cases of mortality in Scotland, the CSGN's population share is 69%, or 4,999. 23% of these cases, or 1,150 were attributed to inactivity. Our intervention causes 5% of people to become physically active, meaning 58 cases of premature mortality would be avoided. The results of this calculation for each disease are presented in Table 6.

Table 6: Number of people suffering physical activity-affected disease in Scotland and the impact of greenspace investment

Disease	2013 Mortality (Scotland)	Avoided Mortality (CSGN)	2013 Non- Fatal Incidence (Scotland)	Avoided Incidence (CSGN)
Coronary heart disease	7,239	58	11,437	92
Cerebrovascular disease	4,452	19	7,962	33
Breast cancer	1,020	4	3,677	14
Colorectal cancer	1,578	9	2,234	12
Diabetes	N/A	N/A	18,701	98

To account for the benefits of avoided early death, we assumed that physical activity will improve the health of affected people to the population average. To quantify this impact we used the population life expectancy to estimate the average number of life-years gained.

We deducted the average age of death¹⁸, for those killed by the four diseases from Scottish life expectancy to estimate how premature the average age of death was for each. The life years used for each disease are shown in Table 7.

Table 7: Valuation of life expectancy adjusted mortality reductions

Disease	Avoided Mortality (CSGN)	Average years until life expectancy was met by sufferers
Coronary heart disease	58	4.7

¹⁸ Vital Events Reference Tables 2014. National Records of Scotland, 2015: <http://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/vital-events/general-publications/vital-events-reference-tables/2014/section-6-deaths-causes>

Cerebrovascular disease	19	1.2
Breast cancer	4	13
Colorectal cancer	9	5.9

A value of £60,000 per year lived in good health per citizen was used in line with prevailing practices in the Department of Health. Combining these averted mortality costs results in a total annual benefit of £24m. Over the full period to 2050 the total benefit from reduced mortality is £497m. Table 8 shows the monetary estimates for mortality reduction.

Table 8: Harm avoided to individuals by preventing premature mortality

Mortality source	Annual value	Estimated total net present value of benefits to 2050
Coronary heart disease	£16m	£341m
Cerebrovascular disease	£1m	£29m
Breast cancer	£3m	£63m
Colorectal cancer	£3m	£65m
Total	£24m	£497m

4.1.4 The value to individuals of morbidity reduction

To estimate the cost of morbidity 'Disability-adjusted life year' (DALY) weightings were used from the World Health Organization (2004)¹⁹. DALYs are less commonly used in developed countries than 'Quality-adjusted life-years' (QALYs) but are more readily available for our purposes of estimating the burden of a range of specific diseases across a hypothetical treatment group.

The social cost of one year's incidence of a given disease can be found by multiplying the value of a life year (£60,000) by the DALY multiplier suggested by the WTO. These DALY multipliers are shown in Table 9.

Table 9: The DALY weighting of various disease morbidities

Disease	DALY multiplier
Coronary heart disease	0.095
Cerebrovascular disease	0.171

¹⁹ Global Burden of Disease 2004 Update: Disability Weights for Diseases and Conditions. World Health Organization, 2004:
http://www.who.int/healthinfo/global_burden_disease/GBD2004_DisabilityWeights.pdf?ua=1

Breast cancer	0.09
Colorectal cancer	0.2
Diabetes	0.033

The value of morbidity benefits was calculated by multiplying the DALY of each disease by avoided incidence. The full range of costs averted across these five diseases is shown in Table 10.

Table 10: Costs to the individual avoided by preventing morbidity

Disease	Annual value	Estimated total net present value of benefits to 2050
Coronary heart disease	£0.5m	£11m
Cerebrovascular disease	£0.3m	£7m
Breast cancer	£0.1m	£2m
Colorectal cancer	£0.1m	£3m
Diabetes	£0.2m	£4m
Total	£1.3m	£27m

4.1.5 Sickness absence

Jacobsen and Aldana (2001)²⁰ examined the effects of exercise on sickness absence in the US. Respondents were asked how many days per week they performed any kind of exercise, such as walking, for 20 minutes or more. Their responses were cross-referenced with sickness absence records, finding that respondents who did 20 minutes of exercise at least one day per week were 23% less likely to be sick for 7 days or more over the year than those who did not.

We based the cost of sickness absence on the 2014 CIPD Absence Management report²¹. The organisations surveyed reported an average cost of sickness absence of £760 per employee per year, which we upscaled to 2016 prices. ONS records show that 2.6m people are employed in Scotland. We multiplied down this figure by the share of Scottish population in the CSGN, to give 1.8m employees. Multiplying the number of employees across the CSGN

²⁰ Relationship between Frequency of Aerobic Activity and Illness-Related Absenteeism in a Large Employee Sample. Jacobsen and Aldana, 2001:

<http://www.ncbi.nlm.nih.gov/pubmed/11765673>

²¹ Annual Survey Report 2014. CIPD, 2014:

http://www.cipd.co.uk/binaries/absence-management_2014.pdf

area by the average cost per employee gives a total annual cost of sickness absence of £1.4bn.

Of the 1.8m employees, we assumed 37% were inactive based on information from the Scottish Household survey, totalling 667,000. These people are overrepresented in the sickness absence figures because they are 23% more likely to be off sick from work.

We used these figures to estimate a counterfactual scenario where 12% of the workforce gained access to greenspace, and became more likely to be physically active. This would lead to a reduction in the sickness absences among the affected population. Under these circumstances £7m of the annual £1.4bn cost of sickness absence was averted, reaching £147m totalled to 2050.

4.2 Expanding the programme to affect more citizens

The CSGN's ambition is to provide high-quality greenspace within a five-minute walk of every home in the CSGN's Local Authorities. Our central calculation was based on those respondents from the Scottish Household Survey who did not have greenspace within a 10-minute walk. This was designed to fit closely alongside the findings of the Natural England study, where the bottom quartile of people (when ranked by distance from formal greenspace) who were less likely to exercise was much more than just a five-minute walk away from greenspace (2,250m).

The relationship between formal greenspace access and exercise was highly statistically significant for this quartile, as was a 27% increased likelihood of obesity. The study also found that those in the 2nd and 3rd quartile of distance from formal greenspace were less likely to exercise, and this effect was of a comparable level, though the statistical significance of these relationships was not as high. It was considered that due to the reduced statistical significance of the relationship for these quartiles, the possible effects were best accounted for by a sensitivity analysis. We examined a situation where not only the 12% of people outside a ten-minute walk were affected, but the total of 31% outside a five-minute walk. This effect was assumed to be as strong for those within five to ten minutes as for those outside ten-minutes and the results are presented in Table 11.

Table 11: A comparison of our physical activity valuations

Scenario	Annual value	Estimated total net present value of benefits to 2050
Central estimate	£36m	£742m
High estimate	£97m	£2,012m

4.3 Further discussion

There is an extensive literature examining the relationships between greenspace and physical activity, with mixed results. The Greenhealth project²², prepared by the James Hutton Institute

²² Green Health. James Hutton Institute, 2014:
<http://www.hutton.ac.uk/research/projects/green-health>

on behalf of the Scottish Government, found little evidence that greater *quantity* of greenspace improved health outcomes. This study was thorough and controlled for many other socio-economic variables that could influence health outcomes. These findings are supportive of the view that simply having natural areas is not enough to improve health outcomes in Scotland. However due to the limitations of the study's dataset, it could not measure quality, and this made it impossible for the study to differentiate between the effect of different types of greenspace.

The relevant point of contention is whether higher quality, or "formal" greenspace, as examined by Natural England, is more likely than poorly maintained greenspace, or greenspace which isn't explicitly designed for social use, to see an increase in use and physical activity. Veitch et al (2012)²³ prepared a useful study to consider the extent of the possible impact of greenspace quality. They used the upgrading of a park in Australia to examine the effect on visitor numbers, and their light and strenuous physical activity while in the park. A year after the upgrading had taken place, visitor numbers had increased four-fold, walking had more than doubled and strenuous activity increased eight-fold. A similar impact was found by Tester and Baker (2009)²⁴ when they examined park improvements in San Francisco.

Cohen et al (2009)²⁵ examined specific features of parks according to the Environmental Assessment of Public Recreation Spaces (EAPRS) Tool. As one might expect, parks with more attractive features saw more use and physical activity. In particular those with sports facilities and nature walks were much more likely to be used for physical activity.

Considered together, there is some encouraging evidence that high-quality greenspace encourages physical activity. But it is important to recognise that evidence is still mixed²⁶ in this area and our understanding how greenspace affects physical activity could benefit from further research.

For our purposes, Natural England's study offered the data most readily applicable to the CSGN's programme. The study controls for many socio-economic factors and demonstrates a correlation between vicinity to formal greenspace and physical activity. However it did not explicitly identify causality of greenspace and physical activity. There remains the simple possibility that those who wish to exercise in greenspace choose to live closer. The extent of this influence is unknown, but as discussed, evidence exists of greenspace upgrading

²³ Park Improvements and Park Activity. Veitch et al, 2012:

[http://www.ajpmonline.org/article/S0749-3797\(12\)00141-9/abstract](http://www.ajpmonline.org/article/S0749-3797(12)00141-9/abstract)

²⁴ Making the Playfields Even: Evaluating the Impact of an Environmental Intervention on Park Use and Physical Activity. Tester and Baker, 2009:

https://www.researchgate.net/publication/222249511_Making_the_playfields_even_Evaluating_the_impact_of_an_environmental_intervention_on_park_use_and_physical_activity

²⁵ Effects of Park Improvements on Park Use and Physical Activity. Cohen et al, 2009:

https://www.researchgate.net/publication/40038056_Effects_of_Park_Improvements_on_Park_Use_and_Physical_Activity

²⁶ The Impact of Interventions to Promote Physical Activity in Urban Green Space: A Systematic Review and Recommendations for Future Research. Hunter et al, 2015:

https://www.researchgate.net/publication/269039299_The_Impact_of_Interventions_to_Promote_Physical_Activity_in_Urban_Green_Space_A_Systematic_Review_and_Recommendations_for_Future_Research

resulting in more physical activity within. This gives us some reason to believe this effect is not large.

The study focuses on greenspace in Bristol, which may not be representative of behaviour in the CSGN area. A possible concern may be that even with equal greenspace availability, a warmer climate in Bristol may lead to more enthusiastic greenspace use than in Scotland. Consideration of available data suggests this is unlikely to be a great concern.

A 2014 Bristol City Council survey²⁷ shows that 84.1% of residents were satisfied with the quality of their parks and greenspaces. This figure is higher than that reported by the Scottish Household Survey, which reported 76% satisfaction. Despite this, the Natural England study finds that only 34% of respondents visited greenspace once or more per week in 2011, while the Scottish Survey finds 36% of respondents visited greenspace once per week or more. These results suggest that Scottish people will visit greenspace at a roughly equivalent rate, or slightly more so, for a given standard of greenspace satisfaction. Comparing these varying studies may be subject to unrecognised issues, but the comparison does suggest this factor will not cause our estimate to be overstated.

A larger issue is that the findings we employ from the Natural England study refer specifically to formal greenspace, defined as greenspace “with an organised layout and structured path network, and generally well-maintained”. We use the Scottish Household Survey to estimate our target population, and this does not specifically highlight ‘formal green space’. We are unaware of any broadly applicable data source detailing greenspace which was specifically formal and, more importantly, the population share living within a certain radius of such greenspace. The lack of consistency across these measures is a source of uncertainty in our calculation. Scottish survey responses show that 31% of respondents do not live within a five-minute walk of any greenspace, which is less stringent a requirement than being within a five-minute walk of formal greenspace. It is likely more than 31% are more than a five-minute walk from formal greenspace, which would mean the scale of the required intervention and the size of the target population are underestimated.

Our study uses a nationwide average to represent the availability of greenspace in the CSGN area. The CSGN area is more urbanised than Scotland as a whole and therefore this is likely to understate the numbers of people affected by our intervention. Additionally, deprived areas are much less likely to have easily available greenspace than more affluent areas. Citizens in deprived areas are also more likely to experience early onset of the diseases covered by our study. Therefore providing greenspace in these areas would target health problems more precisely than if national averages were applied, again implying our values are understated.

The five diseases we consider in our study are among the greatest risks to public health in Scotland. They are responsible for a substantial proportion of early mortality but in addition to this their incidence is also a contributory factor to a range of other illnesses which can disable and prove fatal in their own right. Our study does not capture the second order effects of disease i.e. how these five diseases can contribute to other disease. This is particularly relevant in the case of diabetes, which is a major risk factor for a large range of other medical conditions, but is not considered a source of premature mortality in our study. It is therefore

²⁷ The Quality of Life in Bristol. Bristol City Council, 2015:
<http://www.bristol.gov.uk/page/council-and-democracy/quality-life-bristol>

expected that our study significantly understates the true cost of morbidity across the five diseases discussed.

Our calculation makes no account for uneven distribution of physical activity rates across the adult population. The Scottish Health Survey shows that inactivity rates were higher in older respondents. This could have several implications for our calculation. If we believe that inactivity is addressed in older age groups most at risk of the diseases we have covered, this would increase the value of many of the components in our valuation. However this does suggest overestimation of the sickness absence estimates, given that a proportionally greater share of those affected will have already left the workforce.

The nature of the benefits we consider means that our calculation focuses on the health benefits of physical activity during adulthood. Where greenspace is sufficiently appealing to attract adults it is also likely to increase physical activity for children. A wide body of evidence demonstrates that physical activity during childhood is important for physical development and can improve health both immediately and in later life. These effects may be substantial but we were unaware of studies that could provide a basis on which to value this effect, therefore it has been excluded.

As discussed, the elderly are more likely to be inactive and therefore make up a greater share of our affected population. Elderly people and those affected by one of the diseases discussed are significantly more likely to suffer from other illness and therefore experience poorer overall health. However we use a standard life year value of £60,000 for all morbidity and mortality calculations, equivalent to a life year lived in perfect health. A smaller figure per life year would be appropriate, but we lacked sufficient data to confidently estimate an appropriate value. Failure to account for this means that our valuation of the private cost of averted disease is overestimated in so far as it covers people who are not in perfect health at the outset.

5 Valuing mental health benefits attained through greenspace

We estimated the value of the mental health benefits achievable by providing formal greenspace within a short walk of every home within the CSGN area. Our approach results in a total annual benefit of £62m, with a total net present value of costs avoided to 2050 of £1,290m.

We performed secondary analyses which show the impact of changing key assumptions of our calculation. These resulted in potential range of benefits to the year 2050 of between £528m - 1,821m.

These estimates are based on evidence demonstrating the linkages between greenspace availability, active use of that greenspace and lower risk of poor mental health. Academic studies also provide strong evidence that additional pathways exist through which mental health can be improved by interaction with greenspace. For example, a range of evidence suggests that a view of natural environments also reduces stress levels and improves overall health.^{28,29} Greenspace also provides socialisation opportunities which allow people of different demographic groups to interact with those they might be unlikely to encounter otherwise. We exclude these alternate pathways, and do not account for the disproportionately large impact on deprived areas which experience poorer mental health, due to a lack of data that would allow us to make a monetary estimate.

Our valuation focuses on the mental health of adults. Where greenspace is sufficiently appealing to attract adults it is also likely to be used by children. Evidence shows that high stress levels during childhood affects brain development, with effects that persist through later life. Greenspace may help abate high stress levels, but we are unaware of studies that provide a basis on which to value this effect, therefore it has been excluded.

The evidence used only allows us to consider the effect on those who experience what could be diagnosed as 'poor mental health' whose mental health improves enough to prevent this diagnosis. Greenspace could also alleviate the worst effects of poor mental health for severe sufferers who remain at some risk, or improve further the mental health of those who would not be medically diagnosed as at risk. The exclusion of several potentially major mental health benefits makes it likely our estimate undervalues the true mental health benefits achieved.

Poor mental health can cause people to be less likely to visit public places and providing attractive spaces can remove an important barrier to socialisation and enjoyment of the natural environment. But those who suffer from poor mental health still experience other significant barriers to participation. Therefore these benefits would be best achieved alongside supporting programmes to encourage socialisation and physical activity.

The academic literature demonstrates that high-quality greenspace also provides a range of other benefits. These include greater biodiversity, improved flood management, supplying a new meeting place for local people and attracting new people and businesses to an area.

²⁸ Windows in the Workplace: Sunlight, View, and Occupational Stress. Leather et al., 1998: <http://eab.sagepub.com/content/30/6/739.short>

²⁹ Health Effects of Viewing Landscapes – Landscape Types in Environmental Psychology. Velarde et al, 2007: <http://www.sciencedirect.com/science/article/pii/S1618866707000416>

These benefits, among others, were beyond the scope of this report and are not included in the estimates shown above.

5.1 Methodology

The basis for this calculation is found in our earlier valuation, which examined the effect of better formal greenspace access on physical activity. The earlier work estimated that just under 2% of the population could be expected to become physically active as a result of providing this greenspace within a five-minute walk.

This finding has important implications in the context of Mitchell (2013)³⁰. His work found mental health benefits where open spaces and parks are used at least once a week for physical exercise. When assessed via General Health Questionnaire the likelihood of poor mental health was 43% lower in those exercising in green space than in those who did not.

Our calculation then assumed that among the 69,000 people newly reaching physical activity targets, 43% would be removed from the pool of people with poor mental health. This translates into around 30,000 people when considered across the CSGN area.

Mental health cost estimates were taken from a study by the Centre for Mental Health (2011)³¹. This study comprised three types of social cost imposed by poor mental health, with total Scottish costs of poor mental health of £10,784m in 2009/10, as shown in Table 12.

Table 12: The components of 2009/10 mental health costs in Scotland

Cost measured	Annual cost of poor mental health in Scotland
Human costs	£5,576m
Output losses	£3,288m
Health and social care costs	£1,920m
Total	£10,784m

The largest of these, human costs, is composed of the negative quality of life impacts imposed on those who suffer from poor mental health and associated premature mortality. Output losses include the unemployment resulting from poor mental health, sickness absences and the effects of premature mortality on economic productivity. Finally, health and social care costs represent the costs imposed on the NHS and social care services as well as the demands placed on informal carers.

³⁰ Is Physical Activity in Natural Environments Better for Mental Health than Physical Activity in other Environments? Mitchell, 2012:

<http://www.ncbi.nlm.nih.gov/pubmed/22705180>

³¹ What's it Worth Now? The Social and Economic Costs of Mental Health Problems in Scotland. Centre for Mental Health, 2012:

<http://www.centreformentalhealth.org.uk/whats-it-worth-now>

For our calculation we adjusted these costs by deducting the £439m the study attributed to sickness absence. This is because this calculation was performed alongside another which examined how physical activity in parks can reduce sickness absence. We were therefore concerned that inclusion of this element of mental health costs would result in double counting. As a result we assumed a total cost of poor mental health across Scotland of £10,345m, which was then transformed into 2016 values using the GDP deflator.

By calculating the share of these costs attributable to the 30,000 who are expected to benefit from better mental health we can estimate the value of the mental health improvements resulting from making high quality greenspace available to every home in the CSGN area. The results of our calculation are presented in Table 13.

Table 13: The value of averted mental health costs by component

Benefit	Annual value	Estimated total net present value of benefits to 2050
Human costs avoided	£34m	£695m
Economic costs avoided	£17m	£355m
Health and social care costs avoided	£12m	£239m
Total	£62m	£1,290m

5.2 Accounting for different levels of participation

The Mitchell study found a range of exercise effects on mental health across different greenspace types. The most sizeable effect was found among people who exercised in woods or forest twice a week. Rather than the 43% risk reduction achieved by exercising once per week in greenspace, exercising twice a week in woods or forest was associated with a 60.7% reduction.

If the CSGN were able to cause a change of this scale the value of the intervention would increase to £88m per year. This figure represents the high end of potential benefits.

An important concern for our study was whether the incidence of poor mental health could itself be a barrier to exercise and experiencing public space. If this were the case it would be overly optimistic to assume that providing greenspace would lead to such a substantial improvement in mental health. To consider this, a further analysis was performed based on willingness to participate in depression prevention schemes.

Action on Depression (2010)³² commissioned a survey which found 93% of participants would be willing to take part in a scheme to prevent depression. Of this 93%, a total 44% who would

³² Mood Matters, Action on Depression, 2010:

<http://www.actionondepression.org/sites/default/files/mood-matters-research-report.pdf>

prefer to take part in schemes which used relaxation or exercise to help avoid or abate depression.

We used these figures in our calculation, assuming that of the 93% willing to participate in depression prevention, 44% would use greenspace for relaxation or exercise. This resulted in an affected population which was 40.9% of our central calculation. As a result, the annual benefits of the programme would decrease to £25m. This figure represents the low end of potential benefits. A comparison of the values found by our three calculations is shown in Table 14.

Table 14: A comparison of our mental health valuations

Scenario	Annual value	Estimated total net present value of benefits to 2050
Low estimate	£25m	£528m
Central estimate	£62m	£1,290m
High estimate	£88m	£1,821m

5.3 Further Discussion

There is an abundance of evidence that demonstrates natural environments improve mental health.³³³⁴³⁵³⁶³⁷ If we consider that mental health demonstrably improves around green environments, it is perhaps intuitive that exercise while within greenspace would have the same effect. It may in part be due to this that the question of whether exercise in greenspace is better for mental health than exercise elsewhere is less often studied. The recent Greenhealth study finds lesser likelihood of poor mental health when exercise occurs in woods/ forest. These findings also find support from studies where exercise occurs while exposed to green environments³⁸.

³³ A plasma display window? – The Shifting Baseline Problem in a Technologically Mediated Natural World. Kahn Jr. et al., 2008:

http://www.vsdesign.org/publications/pdf/kahn_2008JEP.pdf

³⁴ Do Green Areas Affect Health? Results from a Danish survey on the use of Green Areas and Health Indicators. Nielsen et al, 2007:

<http://www.sciencedirect.com/science/article/pii/S1353829207000160>

³⁵ Would you be Happier Living in a Greener Urban Area? A Fixed-Effects Analysis of Panel Data. White et al., 2012:

<http://pss.sagepub.com/content/early/2013/04/23/0956797612464659.abstract>

³⁶ The Association of Neighbourhood Psychosocial Stressors and Self-Rated Health in Amsterdam, The Netherlands. Agyemang et al., 2007:

<http://jech.bmj.com/content/61/12/1042.short>

³⁷ Social Contacts as a Possible Mechanism Behind the Relation between Green Space and Health. Maas et al., 2009:

<http://www.sciencedirect.com/science/article/pii/S1353829208001172>

³⁸ The Mental and Physical Health Outcomes of Green Exercise. Pretty et al., 2005:

https://www.researchgate.net/publication/7355171_The_mental_and_physical_health_outcomes_of_green_exercise_Int_J_Environ_Health_Res

The results of this calculation are based on the central estimate of earlier work on the physical activity effects of greenspace. As such they remain subject to the issues discussed within that chapter

Our study uses a nationwide average to represent the availability of greenspace in the CSGN area. The CSGN area is more urbanised than Scotland as a whole and therefore this is likely to understate the scale of the intervention required as well as the numbers of people affected by our intervention. Additionally, the Scottish Household Survey confirms deprived areas are much less likely to have easily available greenspace than more affluent areas. Those living in poverty are also demonstrated to be at greater risk of poor mental health³⁹. Providing greenspace in these areas would target mental health problems more precisely than if national averages were applied.

Our calculation assumes that better greenspace access leads to more exercise in green areas which results in mental health benefits. However, it is possible that people who suffer from poor mental health are less inclined to visit public environments. If sufferers of poor mental health are likely to be underrepresented in those who become physically active then these results are likely to be overstated. Our low estimate attempts to address this concern, but only 33% of the respondents in survey results used for the analysis were currently experiencing depression. Whether this concern is pertinent depends on the channel through which greenspace exercise improves mental health. Should it be preventative rather than curative greenspace exercise could prevent those at risk from experiencing worse mental health even if it did not counteract it in those already afflicted.

Finally, our calculation focusses on the pathway of improved mental health through exercise in greenspace. This is a rather narrow view of the ways in which natural environments improve mental health. By only considering those who begin to meet physical activity targets we do not recognise two categories of people who could also benefit: -

1. Those who still fail to reach physical activity targets but begin to perform at least moderate exercise in greenspace at least once per week
2. Those who already met physical activity targets (i.e. they are not included in the 24% who begin to meet them) but now receive mental health benefits from exercising in a natural environment

Our study also fails to consider other pathways in which natural environments can improve mental health. For example, a range of evidence suggests that simply viewing natural environments also reduces stress levels and overall health. Attempting to value these benefits generates the risk of double counting the effects of our intervention. Nonetheless the exclusion of other pathways means that our calculation probably understates the mental health benefits of greenspace.

³⁹ Mental Health and Social Exclusion: Social Exclusion Unit Report Summary. Office of the Deputy Prime Minister, 2004:
http://www.nfao.org/Useful_Websites/MH_Social_Exclusion_report_summary.pdf

6 Valuing the carbon sequestered by peatland restoration

We estimated the value of the carbon sequestration achievable through protection and enhancement of peatlands across the CSGN area. Our approach results in a central estimate of £246m worth of carbon sequestration by the year 2050. DECC publish a range of non-traded carbon price projections. The result of using different levels of these are shown in Table 15.

Table 15: The value of carbon sequestration at published carbon prices

Carbon price	Total net present value of sequestration to 2050
Non-traded carbon price, low estimate	£123m
Non-traded carbon price, central estimate	£246m
Non-traded carbon price, high estimate	£369m

Scientific evidence on peatland carbon sequestration is still evolving, but current evidence is strong enough to support peatland restoration as a viable investment. Sequestration continues to accrue and even accelerate after 2050. Even when discounted according to the Government's Green Book appraisal guidelines, annual benefits continue to increase, peaking in 2059 in our central estimate.

These figures do not capture the full value of projects which restore peatland. Healthy peatlands also provide other benefits, such as improved biodiversity, water quality and flood management, and benefits to recreational users. These benefits, among others, were beyond the scope of this report and are not included in the estimates shown above.

6.1 Methodology

The CSGN costing study estimated a total area of 62,032 hectares of restorable peatland exists within the CSGN area. Sequestration per hectare of restored peatland was estimated using the underlying data of a model prepared by the James Hutton Institute for the Scottish Government.

In the model carbon capture in restored peatland is a process which begins slowly before sequestering a peak of 4.5 tonnes of CO₂e per hectare per year. We assume that annual sequestration gradually increases over 45 years until 2059, at which point it levels off and the rate of sequestration stabilises at the maximum. We also have assumed that all peatland is restored in 2016, which is a simplification to make the benefit comparable to the costs. This assumption ensures the stream of benefits begins to accrue when the cost of restoring peatland is incurred.

The Department of Energy and Climate Change (DECC) publish a variety of time series of carbon prices⁴⁰, based on different estimates of future values and whether these apply to

⁴⁰ A Brief Guide to the Carbon Valuation Methodology for UK Policy Appraisal. Department of Energy and Climate Change, 2011:

tradeable or non-tradeable carbon. These prices were inflated to 2016 prices and are presented in Table 16.

Table 16: Carbon price estimates published by DECC

Carbon price estimate	2016 Carbon price per tCO ₂ e
Traded carbon price, low estimate	£15.19
Traded carbon price, medium estimate	£22.79
Traded carbon price, high estimate	£29.30
Non- traded carbon price, low estimate	£32.56
Non -traded carbon price, medium estimate	£65.11
Non- traded carbon price, high estimate	£97.67

The sequestration benefit was valued for each of this range of carbon prices. Our central estimate is based on the medium estimate of non-traded carbon prices published by DECC (2011).

Below we present the benefit calculations using the different carbon price series for both 2050 and 2100 to illustrate the substantially higher benefit over the long run that is not captured over the period to 2050. Discount rates were applied in line with the Government's Green Book appraisal guidelines. The results of our calculations are presented in Table 17.

Table 17: The value of sequestration over 35 and 85 year time periods

Carbon price	Total net present value of sequestration in 2050 (£2016)	Total net present value of sequestration in 2100 (£2016)
Non- traded carbon price, low estimate	£123m	£389m
Non -traded carbon price, medium estimate	£246m	£918m
Non- traded carbon price, high estimate	£369m	£1,447m
Traded carbon price, low estimate	£119m	£385m

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48184/3136-guide-carbon-valuation-methodology.pdf

Traded carbon price, medium estimate	£236m	£908m
Traded carbon price, high estimate	£352m	£1,430m

7 Valuing the carbon sequestered by afforestation

We estimated the value of the carbon sequestration achievable through extensive planting and cultivation of new woodland across the CSGN area. Our approach results in a central estimate of £2,065m worth of carbon sequestration by the year 2050. DECC publish a range of non-traded carbon price projections. The result of using different levels of these are shown in Table 18.

Table 18: The value of carbon sequestration at published carbon prices

Carbon price	Total net present value of sequestration to 2050 (£2016)
Non-traded carbon price, low estimate	£1,033m
Non-traded carbon price, central estimate	£2,065m
Non-traded carbon price, high estimate	£3,098m

Our valuation utilises existing Forestry Commission Carbon lookup tables to estimate the effect of planting 85,500 hectares of broadleaf woodland in soil of modest fertility. Although the full extent of benefits take time to develop, the values estimated are indicative of why the Scottish Government actively funds expansion of Scottish forests, in part to aid efforts to meet greenhouse gas emission targets.

These figures do not capture the full value of expanding Scottish forests. A recently published report estimates that forests in Scotland contribute almost £1bn per year to economic output and support 25,000 jobs⁴¹. Numerous other social benefits also exist, such as better air quality, improved biodiversity, water quality and flood management, reduced noise pollution and savings on heating costs when used as shelterbelts. These benefits, among others, were beyond the scope of this report and are not included in the estimates shown above.

7.1 Methodology

The CSGN costing study laid out an ambition to increase the area of woodland in the CSGN by 50%, which is an effective increase of 85,500 hectares. To estimate the carbon sequestration which can be achieved through this, we employed carbon lookup tables provided by the Forestry Commission⁴². These tables estimate the carbon sequestered by a hectare of trees per year, an amount which varies depending on the species planted, the spacing of trees, their age and growth rate.

Section 3.2 of the Carbon lookup table guide⁴³ suggests that when planting mixed woodland containing different native tree species, it is recommended to use the settings for Sycamore,

⁴¹ The Economic Contribution of the Forestry Sector in Scotland. Forestry Commission, 2015: <http://scotland.forestry.gov.uk/images/corporate/pdf/economic-contribution-forestry-2015.pdf>

⁴² Project Carbon Sequestration. Forestry Commission, 2012: <http://www.forestry.gov.uk/forestry/infd-8jue9t>

⁴³ Estimating Woodland Carbon Sequestration from the Carbon Lookup Tables. Forestry Commission, 2012:

Ash and Birch contained in the model. The costing study did not specify the tree species to be introduced, therefore this setting which is generally representative of a variety of native species of trees was selected for the valuation.

The rate of growth for trees, or 'yield class' is a crucial variable in determining sequestration. Colleagues at the Forestry Commission Scotland advised that the average 'yield class' for broadleaves in Scotland was 5.3, lower than the UK average of 6 due to the lesser fertility of the land. We used the lowest available yield class of 4, again to be conservative while also accounting for the potential need to employ less fertile than average land in order to find the space for new forests. We used the widest available spacing between trees, which reduces the carbon sequestration, in order to be conservative in our estimate.

We assume that all forests are planted in 2016, which is a simplification to make the benefit comparable to the costs presented by the CSGN costing study. Both costs and benefits therefore align so that the cost is incurred at the same time as the stream of benefits begins.

To value the carbon sequestered we used the same carbon prices used to value peatland sequestration, those published by the Department of Energy and Climate Change (DECC). These provide estimates of future values for both tradeable and non-tradeable carbon. We inflated these values to 2016 prices and these are replicated below in Table 19.

Table 19: Carbon price estimates published by DECC

Carbon price estimate	2016 Carbon price per tCO2e
Traded carbon price, low estimate	£15.19
Traded carbon price, medium estimate	£22.79
Traded carbon price, high estimate	£29.30
Non- traded carbon price, low estimate	£32.56
Non -traded carbon price, medium estimate	£65.11
Non- traded carbon price, high estimate	£97.67

The sequestration benefit was valued for each of this range of carbon prices. Our central estimate is based on the medium estimate of non-traded carbon prices. The calculations are highly sensitive to the values estimated by DECC, which vary according to different climate change scenarios.

Even if DECC's low estimates of carbon price were used it is clear to see that the carbon sequestration benefit of planting so much new woodland is substantial. This hints at the most problematic variable in the calculation - 85,500 hectares of new woodland is extremely ambitious. Colleagues at Forestry Commission Scotland were unable to say whether so much viable land is realistically available for forest planting. If there were not sufficient unused land

[http://www.forestry.gov.uk/pdf/WCC_Lookup_guidance_v1.4_27Jul2012.pdf/\\$file/WCC_Lookup_guidance_v1.4_27Jul2012.pdf](http://www.forestry.gov.uk/pdf/WCC_Lookup_guidance_v1.4_27Jul2012.pdf/$file/WCC_Lookup_guidance_v1.4_27Jul2012.pdf)

it is worth considering whether this means land would have to be transferred from some other use for forestry. This option may be justifiable provided the range of benefits could be demonstrated to be more valuable than the opportunity cost of leaving the land to its existing use.

8 Valuing the flood damage avoided through sustainable flood protection

We estimated the value of the flood damage it is possible to avoid through incorporating green infrastructure into new residential, commercial and industrial developments, as well as retrofitting green infrastructure into existing urban areas. Our approach estimates a total annual benefit of £43m in 2016, which translates into a total net present value of benefits of £1,206m to 2050. The breakdown of these components is shown in Table 20.

Table 20: The value of avoided flood damage

Benefit	Peak annual costs avoided	Total net present value of benefits to 2050 (£2016)
Costs avoided for existing property	£43m in 2016	£1,092m
Costs avoided for new property	£5m in 2050	£114m
Total	£48m	£1,206m

These calculations are based on recent SEPA data, which is being used to inform Scotland's approach to flood protection. SEPA's dataset predicts average annual damage costs for the 19 local authorities in the CSGN area: - total 2016 levels average around £130m of damages per year. Furthermore, based on SEPA's estimates, the severity of flooding is likely to increase significantly over the forthcoming decades. Our valuation represents a conservative estimate of the flooding damage avoidable through sustainable flood management in the years to 2050.

Other financial benefits of sustainable flood management are not included in this figure. It is well-recognised⁴⁴ that use of SUDS can ease the flow and improve the quality of water going into the sewerage network better than traditional drainage. This reduces the required capacity of water infrastructure and helps deliver water services more cost-effectively.

There is also generally consensus that SUDS systems are typically cheaper to create and maintain than traditional drainage systems. If it is taken as given that the government has an obligation to manage flood risk, these cost savings relative to traditional drainage systems could be considered a benefit of SUDS. In collating evidence for their 2011 Impact Assessment⁴⁵ on sustainable drainage policy, DEFRA⁴⁶ find that sustainable drainage ranges

⁴⁴ Sustainable Drainage Schemes. Thames Water, 2015:

<http://www.thameswater.co.uk/cr/SustainableDrainage/SustainableUrbanDrainageSystems/index.html>

⁴⁵ Commencement of the Flood and Water Management Act 2010, Schedule 3 for Sustainable Drainage. Department for Environment, Food and Rural Affairs, 2011:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/82428/suds-consult-annexf-ia-111220.pdf

⁴⁶ Annex 1: Additional Evidence for SUDS. Department for Environment, Food and Rural Affairs, 2011:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/82429/suds-consult-annexf-ia-annex1-111220.pdf

from 5% more expensive (in “worst case scenarios”) to 30% cheaper than traditional drainage. If we applied this difference to the estimates in the costing study, which anticipated a cost of £878m in 2014, we would anticipate the investments to cost between £44m less and £263m more if traditional drainage were used. If we used the midpoint of these, this would mean we would save £110m in 2014 values by using sustainable drainage. Due to uncertainty over where a true broadly applicable figure might lie, this likely cost saving has been excluded from the headline calculation.

Apart from these financial benefits, existing evidence shows that sustainable flood management can also provide a range of other benefits. Green walls and roofs can reduce air and noise pollution as well as energy bills and the urban heat island effect. The natural environments which can be used for SUDS are proven to alleviate stress and improve mental health, while providing habitats for flora and fauna and recreational space for people. There can also be modest carbon sequestration benefits, in addition to avoiding the carbon emission impact of hard engineering solutions.

8.1 Methodology

We used a dataset put together by SEPA in preparation for publication of Scotland’s Flood Risk Management Strategies⁴⁷. This data was broken down by local authority, the type of damage and the type of flooding. For the purposes of this calculation, we referred primarily to the average annual damage costs predicted for each

Our calculation includes the damages from three types of flooding (fluvial, pluvial and coastal flooding). Due to the urban focus of the investments, we excluded one type of damage (agricultural). This meant our estimate comprised of damage to domestic property, damage to non-residential property, damage to vehicles, damage to roads and the cost to emergency services.

Flood damages are estimated in sets of ‘return periods’. This means the damage we might expect from a flood which is predicted to occur once in every set number of years. For example, damage from a flood with a return period of 25 years would be expected to be less than the damage from a flood with a return period of 200 years. Luckily, this 200-year flood is eight times less likely to occur in a given year than the 25-year flood. SEPA’s data included not only return periods for the present day, but also the return periods forecast for 2080. Future forecasts^{48,49} suggest climate change will cause overall average rainfall per year to increase, and more importantly in a flooding context, the frequency of extremely high rainfall events will increase too.

The dataset available did not contain estimates of average costs in 2080. To capture increased flood risks over the years to 2050, I considered the difference between the damages estimated for current return periods and those in 2080 by local authority, damage type and flood type,

⁴⁷ Flood Risk Management Strategies. Scottish Environment Protection Agency, 2015:

<http://apps.sepa.org.uk/FRMStrategies/>

⁴⁸ UK Climate Projections: Maps and Key Findings. Met Office, 2014:

<http://ukclimateprojections.metoffice.gov.uk/21708>

⁴⁹ Climate Change is a Reality, Chapter 3: What will Climate Change look like? Forestry Commission, 2012:

[http://www.forestry.gov.uk/pdf/3_what_will_climate_change_look_like.pdf/\\$FILE/3_what_will_climate_change_look_like.pdf](http://www.forestry.gov.uk/pdf/3_what_will_climate_change_look_like.pdf/$FILE/3_what_will_climate_change_look_like.pdf)

dividing the difference by the number of intervening years. I assumed that average costs would increase at the average rate the return period costs increased between 2016 and 2050, representing a year-on-year increase in expected average flood damages.

There is a notable area of uncertainty with this approach. The first is that it is by no means certain the increase in average damages will occur in a linear fashion, where the average damage increases by a fixed amount each year. If climate change and extreme weather increases more rapidly towards the end of the period, then an exponential increase in damage would be expected. A chain of thought to support this may be that given damages are reduced by fixed flood defences, and more extreme weather will render these defences increasingly ineffectual. Therefore increasingly extreme weather at the end of the period is likely to overcome defences to a greater and greater extent. This would mean flood defences become increasingly inadequate towards the end of the period, and more of the damage increase would occur after 2050.

A counter argument may be that co-ordinated international action is likely to bear fruit over the next few decades, resulting in a slower increase in greenhouse gas concentrations in the atmosphere. In this case a logarithmic function would be more likely, as the rate of flood risk increase would be front-loaded to the start of the period. For simplicity and transparency, the straightforward middle-road of a linear increase was selected. But it does seem quite possible that this means of estimating increasing flood risk would result in some degree overestimate for the period to 2050. The impact of this should be reduced by the discounting of benefits occurring in later years, and counterbalanced by other conservative assumptions, discussed later.

SEPA's figures do not account for the expansion of settlements. Mainstreaming SUDS into new developments was a key consideration of the costing study, and accounted for the majority of green infrastructure costs. To account for the damage prevented to homes which are built after 2016 I used the figure of 378,066 new dwellings and compared this to the existing housing stock in the CSGN area, available in the official Housing Statistics for Scotland⁵⁰. This showed the costing study predicted a 0.6% year-on-year increase in the housing stock, and so a further adjustment was made to increase flooding costs by this amount each year. This area of the estimate is likely to be conservative, given that it assumes the same level of flood risk for current and additional housing. It is inevitable that as developers seek new land parcels they must compromise more and more to find sites in a desirable location. This means these new developments are more likely to be contained in areas of greater flood risk and the potential damage in additional housing is likely to be underestimated.

The costing study also included the cost of incorporating SUDS into new commercial developments. Data on the extent of current commercial property, which would allow us to estimate the relative increase predicted by the costing study's assumptions, proved difficult to find. Because of this the 0.6% uplift found for residential was considered the best available fit for how much land footprint expansion we would expect in the commercial sector. This meant that the 0.6% year-on-year increase was applied to all flooding costs in the calculation from 2016 to 2050.

⁵⁰ Housing Statistics for Scotland. The Scottish Government, 2016:
<http://www.gov.scot/Topics/Statistics/Browse/Housing-Regeneration/HSfS/KeyInfoTables>

The CSGN's SUDS cost components focus primarily on urban developments, particularly the aim to retrofit green infrastructure into urban areas. This retrofit into existing urban areas accounts for the majority of benefits and in the interest of remaining conservative, we adjusted the damages using the 2013/14 urban/ rural classification data published by the Scottish Government⁵¹. We used this to estimate that 88% of damage in the CSGN's local authorities would occur in urban areas, and assumed that only this damage would be affected by our intervention.

It proved difficult to find a broadly applicable estimate of the level flood damage which can be realistically avoided by SUDS. In their 2011 impact assessment DEFRA considered the impact of all new housing developments utilising sustainable drainage. Their evidence review arrived at a central figure of 30% as an estimate of the share of total flood damage which could be avoided by SUDS. Our calculation used the higher share of 35% which DEFRA selected in policy option 3. DEFRA stated that higher levels of flood protection were made possible because this option led to 'infill' of urban areas, as smaller developments built within existing urban areas would improve the local drainage systems.

This was more representative of the programme envisioned by the CSGN. It is in fact still likely to be very conservative, given that the incidental infill imagined by DEFRA is actively pursued by retrofitting green infrastructure into existing urban areas. The evidence review states that early Foresight research suggested damage could be reduced by as much as 40%. However due to a lack of references we were unable to find the source of this statement. In the interests of maintaining a conservative estimate the figure of 35% was selected as the most appropriate and defensible.

Using this set of assumptions we arrived at a figure of £1,206m for the 35 years to 2050. Due to the influence of climate change and settlement expansion, much of the benefits are future-loaded, and had they not been discounted, annual benefits would almost double in the time between 2016 and 2050.

⁵¹ Scottish Government Urban Rural Classification 2013-2014. The Scottish Government, 2014: <http://www.gov.scot/Publications/2014/11/2763>

The Central Scotland Green Network (CSGN) vision:

By 2050, central Scotland has been transformed into a place where the environment adds value to the economy and where people's lives are enriched by its quality.

With greater public, private and third sector support we can do more. We need your help.

If you are interested in doing more, please contact:

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