Public Health England

CENTRE *for* SUSTAINABLE HEALTHCARE

Protecting and improving the nation's health

Carbon modelling within dentistry

Towards a sustainable future

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Foreword

Few people now question the imperative to make a radical reduction to our carbon footprint, a legal requirement since the Climate Change Act came into force in 2008[1].

In 2014, the Health and Social Care System agreed a strategy to achieve the ambitious goal that, by 2050, there will be an 80% reduction from the 2008 baseline[2]. The dental sector has a part to play in meeting the goal.

Many of us are deeply worried about the impact of climate change on the planet and how it will affect our families, friends and future generations. As a response, many of us are already adapting our home and working environments and making lifestyle and purchasing changes to limit our personal, family and work carbon use. Combatting climate change is urgent and unless each one of us takes action personally, the scale of change required across the world will not be achieved in time.

PHE commissioned this report from the Centre for Sustainable Healthcare to understand the carbon emissions associated with commonly performed dental procedures so that this knowledge can support the development of more sustainable patterns of care.

For patients, we must re-enforce our messages to encourage prevention of dental disease using Delivering Better Oral Health[3] guidance. Improved oral health will not only reduce dental treatments, but also the frequency of recall visits in line with the NICE recall guidance[4].

The report alerts dental teams to take immediate and sustained action to reduce travel. Dental practices can adopt, encourage and facilitate active travel such as cycling and walking, to and from work where possible. This in turn will not only reduce the carbon footprint of the business, but also improve cardiovascular, general health and wellbeing of the team.

PHE and NHS England will be continuing to work together promoting establishment of evidence for what works and facilitating wider and more systematic implementation of interventions to reduce carbon emissions.

We hope that this report will be of interest to all those involved in delivering and commissioning dental services.

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Executive summary

Public Health England (PHE) has acknowledged that to be able to protect and improve the nation's health and wellbeing now and for the future it is vital to improve sustainability and reduce carbon emissions.

To achieve the scale of carbon reductions the UK government and National Health Service (NHS) has committed to (ie 34% by 2020 and over 80% by 2050), the NHS has expanded its efforts from a focus on direct use of natural resources such as water, energy, fuel and waste to looking at the opportunities to reduce the social and environmental impacts from procurement and clinical pathways. This requires the development of a system which attaches carbon emissions as well as costs and outcomes to the assessment of interventions and includes all 3 in the evaluation of clinical pathways. Estimating the carbon emissions of different procedures is one step towards the development of this system.

The aim of this report is to calculate and analyse the carbon footprint[a] of 17 of the most common dental procedures, including both high volume and resource intensive treatments, and to identify types of service which are responsible for large amounts of greenhouse gas emissions.

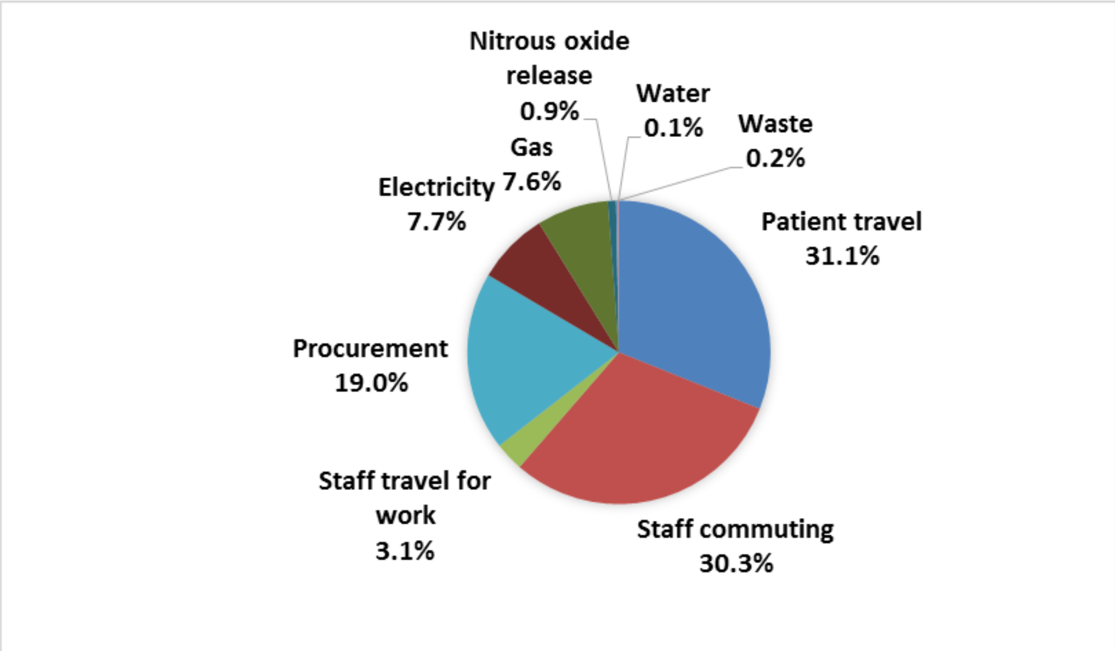
As a first step the carbon emissions of NHS dental services in England associated with patient travel, staff commuting, business travel, procurement, gas and electricity use, waste disposal, water use and nitrous oxide release were calculated. Once the total greenhouse gas emissions were estimated, emissions were allocated to the different procedures by standard denominators, ie time spent on procedure, number of visits per procedure or claim value of procedure. This does not constitute a full lifecycle assessment of each procedure, as the different levels of embodied carbon in the manufacture and supply of dental products is not covered in detail due to lack of consistent data at this granularity. However, it provides a way to identify the types of dental procedures which are responsible for large amounts of greenhouse gas emissions.

In 2013 to 2014, the total greenhouse gas emissions of NHS dental services in England measured in tonnes of carbon dioxide equivalents (tCO_2e) was 675,706. This is equivalent to flying 50,000 times from the UK to Hong Kong and makes up 3% of the overall carbon footprint of the NHS in England. The highest proportion of these emissions is caused by travel, followed by procurement, energy, nitrous oxide, waste and water

[a] The term 'carbon footprint' is used to describe the sum of greenhouse gas emissions (carbon emissions) released in relation to an organisation, product or service, expressed as 'carbon dioxide equivalents (CO_2e)'.

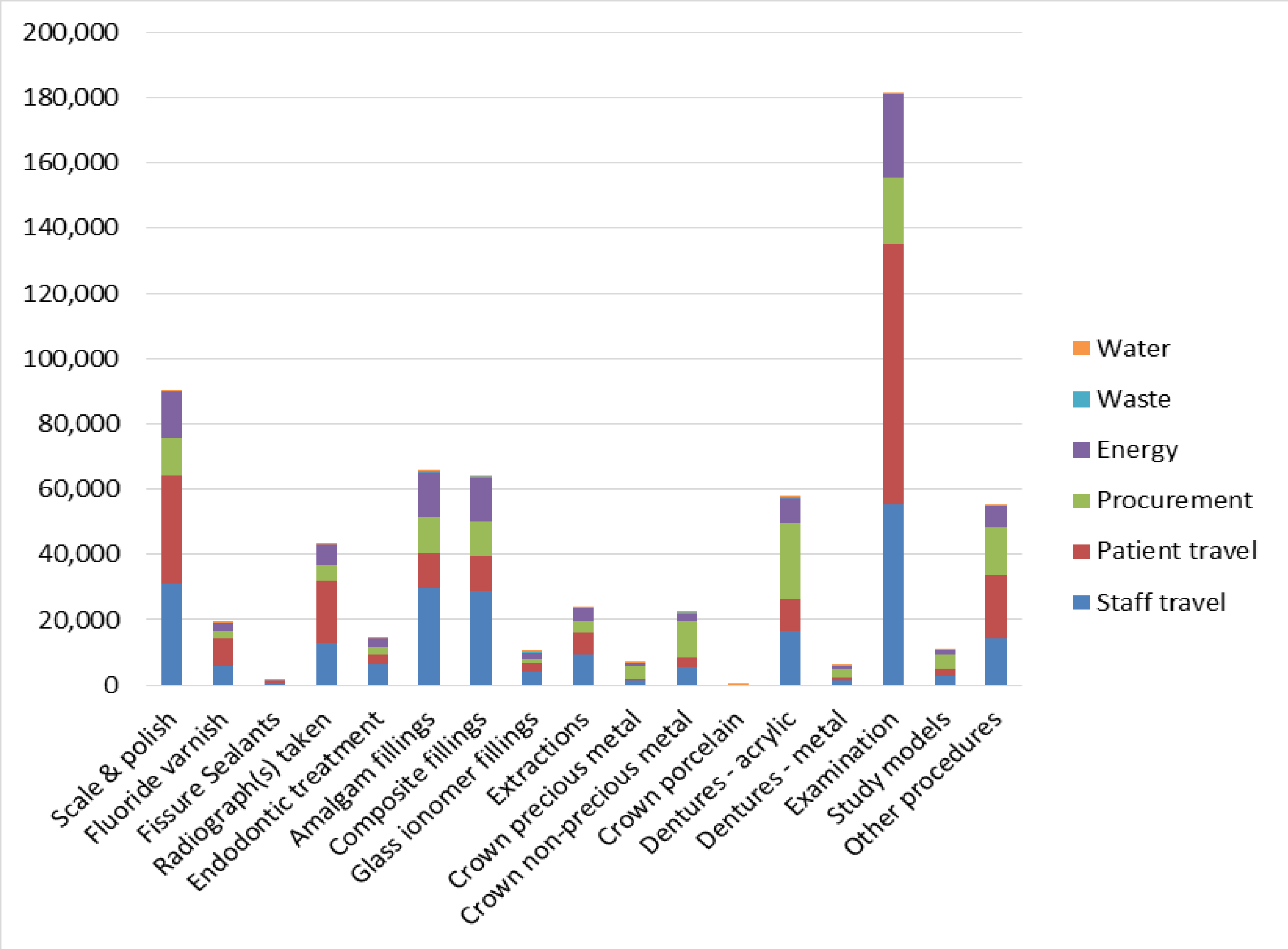
(see Figure 1). For 10 of the analysed procedures, travel makes up over 60% of the dental carbon footprint. Energy ranks second, contributing 14 to 21% of the greenhouse gas emissions, and procurement, third. For the more resource intensive procedures, travel contributes a lower proportion of the greenhouse gas emissions. Procurement is responsible for between 39 and 61%, and energy for 9 to 13%.

Figure 1: Total annual carbon footprint of dental services in England – 2013/14



Considering the carbon footprint of the 17 procedures, the dental examination contributes the highest proportion (27.1%) to the overall carbon footprint, followed by scale and polish with 13.4%, amalgam and composite fillings with 9.7% and 9.5% respectively. Acrylic dentures constitute 8.6% and radiographs 6.4%; extractions contribute 3.5%, non-precious metal crowns 3.3%, fluoride varnish 2.9% and endodontic treatment 2.1%. One point 6 percent of the greenhouse gas emissions are associated with study models and 1.5% with glass ionomer fillings. Precious metal crowns, metal dentures, fissure sealants and porcelain crowns contribute less than 1% to the carbon dioxide equivalents of dental procedures.

Figure 2: Carbon dioxide equivalents per carbon category and procedure (tCO2e)



However, looking at one course of treatment with a procedure, an examination, a radiograph and a fluoride varnish treatment have the lowest carbon footprint compared to the rest of the procedures, ie 5.5 kgCO2e per treatment. A scale and polish has the second lowest carbon footprint, 6.5 kgCO2e, followed by extractions, tooth restoration with glass ionomer fillings and fissure sealants, 8.6 kgCO2e. Study models use 12.1 kgCO2e and tooth restoration with amalgam and composite fillings 14.8 kgCO2e. Dentures have the largest greenhouse gas emissions, 58–71 kgCO2e each. The carbon footprint of crowns is between 35 and 44 kgCO2e depending on the type of crown. Endodontic treatment is responsible for 23.3 kgCO2e.

The analysis of the carbon footprint has identified travel – both patient and staff travel - as the main source of carbon emissions by NHS dental services as a whole and for the majority of dental procedures. For resource intensive treatments procurement is a major contributor to greenhouse gas emissions.

To improve the sustainability of NHS dental services and reduce the travel related carbon emissions, service configuration could be reviewed to try to reduce the amount of travelling by patients and staff.

Most dentists already plan treatment to reduce the number of visits needed and further implementation of NICE guidance on the interval between courses of treatment might help (while being considerate of patient choice.)

To be able to tackle dental procurement, which is the second highest contributor to the greenhouse gas emissions, detailed research into the carbon emissions of dental products is required.

To achieve long-term improvement in the sustainability of dental services, engagement with those working in policy, education and research (Health Education, Public Health England, research institutions), those working in delivering, or commissioning patient care (the dental team, Local Dental Networks and NHS England dental commissioners) and the dental industry is critical.

The collection and improvement of dental carbon footprinting data and the linking of carbon data to cost-benefit analysis of treatments would help with the identification of effective, patient centred treatment with reduced environmental impact. Dental services can become more sustainable on the ground by improving the sustainability of travel, procurement and the management of their dental practices

Aim of the report

The aim of this project is to calculate and analyse the carbon footprint of 17 different key dental procedures carried out by NHS England commissioned dental teams to identify the dental procedures within the service which produce the largest amounts of greenhouse gas emissions. These procedures include both high volume procedures and resource intensive items which were considered, at the project onset, to have a particularly high carbon footprint. The report includes findings from the analysis, a description of the methodology and details of the information used. It is hoped that this information will be of methodological interest to those working in sustainability or carbon footprinting in areas other than dentistry.

The following are the 17 procedures which have been included in this study. These procedures make up 93% of all dental procedures for adults and children in England[5]:

1. examinations
2. scale and polish
3. radiographs
4. fluoride varnish
5. extractions
6. fissure sealants
7. endodontic treatment
8. amalgam fillings
9. composite fillings
10. glass ionomer fillings
11. crowns; precious metal
12. crowns; non-precious metal
13. crowns; porcelain
14. dentures; acrylic
15. dentures; metal
16. study models
17. nitrous oxide

For a detailed description of the procedures please see Appendix 1.

Why is this work important?

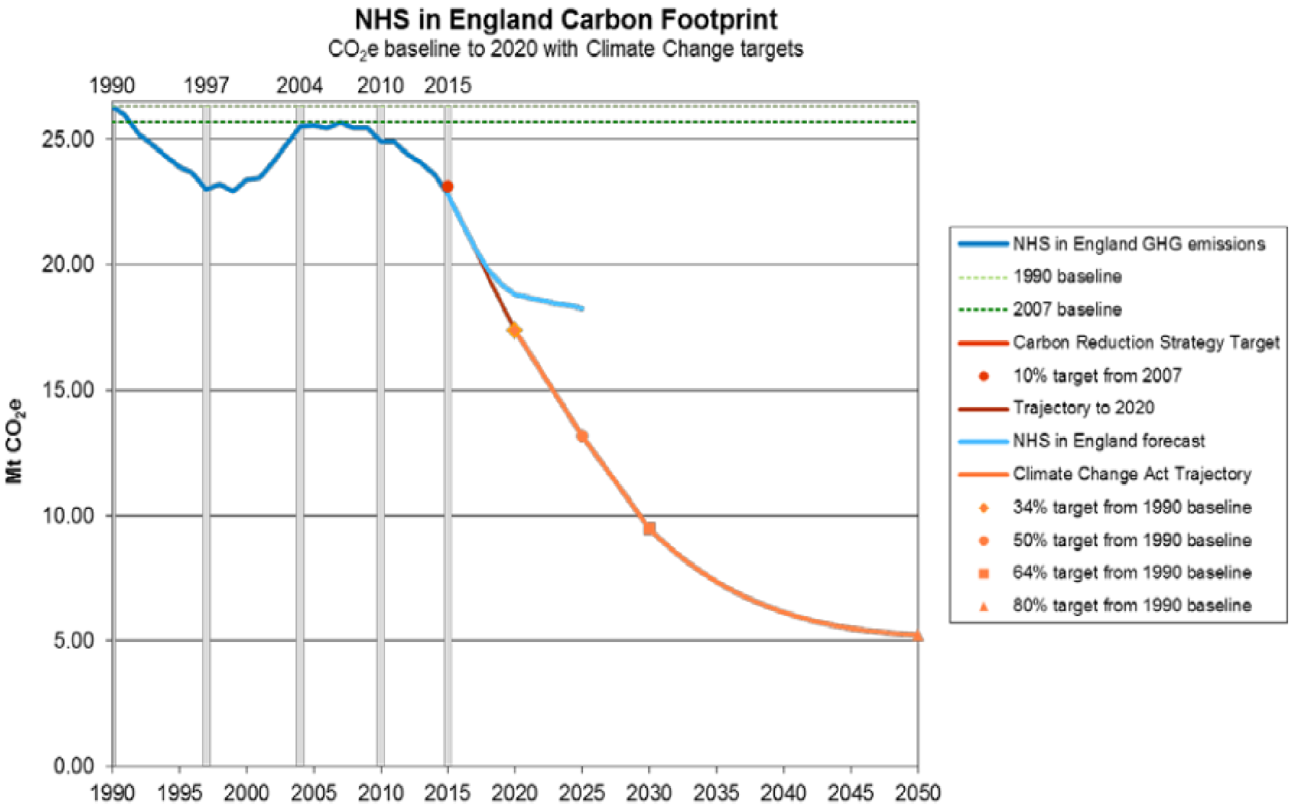
Dental services have an important opportunity to address the sustainability of services – from the design of clinical pathways to the organisation and delivery of care. As a result of the Climate Change Act (2008)[6], NHS England is legally required to reduce its greenhouse gas emissions.

Secondly, the Sustainable Development Unit has committed to reducing its environmental impacts in the Sustainable Development Strategy (SDS) for the Health and Social Care System. Launched in January 2014, the SDS describes the vision for a sustainable health and care system by reducing carbon emissions, protecting natural resources, preparing communities for extreme weather events and promoting healthy lifestyles and environments.

To achieve the above, we need to understand where and how we use finite resources within the system, including carbon and money, and reduce their use whilst still maintaining or improving quality of care. To ensure this is integrated from the bottom up it is important to understand the carbon consequences of a particular healthcare pathway.

The Climate Change Act (2008) was introduced to ensure the UK cuts its carbon emissions by 80% by the year 2050. As the largest public sector emitter of carbon emissions, the NHS has a duty to meet these legal targets. In order to achieve them, the NHS has already committed to and succeeded in reducing its carbon footprint by 10% by 2015, by 34% by 2020 and 50% by 2025. Indeed the SDU reported in January 2016 that the health and social care system had achieved a 13% cut in emission between 2007 and 2016. The following graph shows the necessary trajectory for reduction and what the NHS is actually achieving.

Figure 3: NHS England CO2E footprint 1990 to 2020 with Climate Change Act (2008)



Targets[7]

Figure 3 shows the carbon emissions in million tonnes associated with the NHS in England. The yellow curve demonstrates the scale of the changes needed to achieve the reduction in carbon by 80% by 2050 that the NHS, and the country as a whole, has signed up to under the Climate Change Act of 2008. The blue line demonstrates actual carbon emissions.

Figure 4: Carbon footprint of the Health and Social Care System in England, 2015[8]

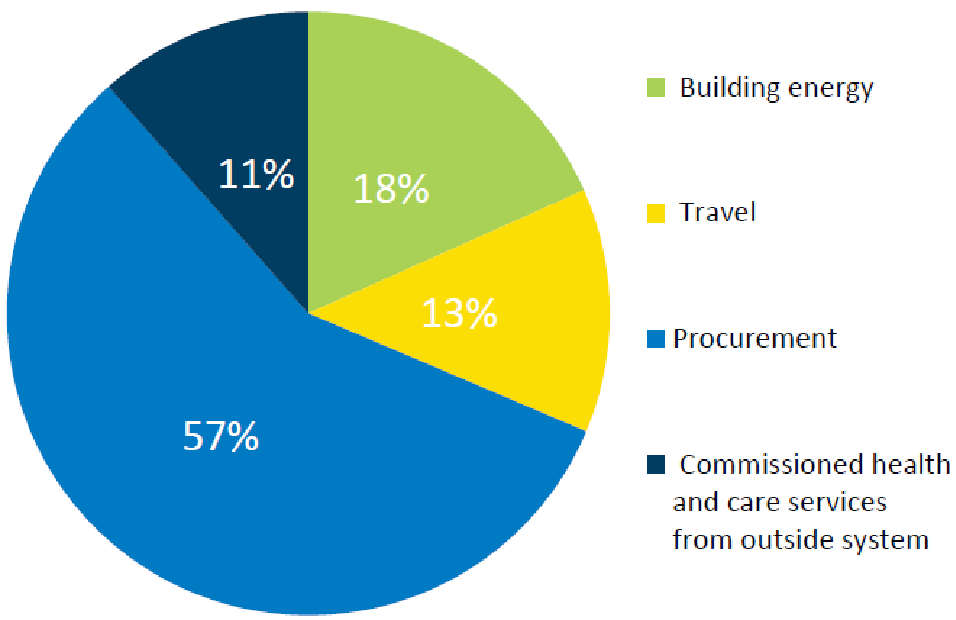


Figure 4 shows the main components of the carbon footprint of the Health and Social Care system in England. In 2015, travel emissions were 3.5 MtCO2e (13%); building energy use was 4.9 MtCO2e (18%); and procurement was 15.2 MtCO2e (57%)[8]. Since 2007 Carbon emissions in relation to procurement have reduced by 16% - this is mainly in relation to pharmaceuticals. Travel emissions have reduced by 5% - which also offers the ‘co-benefit’ for health in reducing air pollution, and energy emissions have reduced by 4% along with significant energy cost savings.

While the early focus for carbon reduction across the sector was the quick wins in estates energy, travel and waste over the last few years there has been an increasing move to address the emissions that sit in the supply chain and in particular looking more closely at pharmaceuticals, medical devices, care pathways and models of care.

The Sustainable Development Unit established the Coalition in Sustainable Pharmaceuticals and Medical Devices in 2012 to start work in this area and commissioned several pieces of work to advance knowledge in the area of footprinting care pathways[9], pharmaceuticals[10] and soon to be published detailed guidance on medical devices. The aim of this work has been to build a more detailed bottom up understanding of the carbon embedded in healthcare products and pathways. All SDU guidance has been based on the accepted national (DEFRA) and international carbon factor sets and the global Greenhouse Gas Protocol standards. With the increasing importance of water as a natural resource, the guidance has also included water footprint calculations.

While the SDU has been working on producing standard guidance for the sector and targeting the largest areas of emissions, to achieve the scale of carbon reduction needed to meet government targets, basic information on the environmental impacts of different care pathways is needed across the board, so that clinicians, commissioners and, in this case, dental professionals, can make informed decisions on service configuration based on cost effectiveness, quality and carbon impact.[11] For this reason, this report has chosen to link carbon emission factors to each dental procedure.

This report was produced before the SDU guidance on care pathway footprinting was published. The methodology in this report has been reviewed by the SDU team and agreed as useful and valid for prioritisation and targeting action.

The report proposes to model the carbon footprints of the most common procedures in dental practice. It is anticipated that providing the carbon footprint alongside the monetary costs will increase our knowledge and understanding of resource use and identify opportunities to improve value within care pathways. Ideally, dentistry will move towards granular (detailed) reporting, linked with existing information systems, which will provide information for decision-making based on comparisons between different approaches to service delivery. This approach is how the insurance-based systems, for example, in the US, manage their cost accounting. In the UK it is called Patient Level Information Costing Systems, (PLICS), which is the recommended method of accounting for health care organisations in the UK.[12] The relevance of this to accounting for carbon in health services was explored in the Occasional Paper 97 ‘Sustainability in Psychiatry’ of the Royal College of Psychiatrists.[13]

This work is hoped to be of interest to dental professionals, commissioners of dental services, all those involved in the provision of education, dental training and work in sustainability or carbon footprinting in areas other than dentistry.

Background on NHS dentistry in England

In England, NHS dentistry is delivered by NHS high street dentists, Community Dental Services (CDS) and, through secondary care, within the hospital setting. Dental activity is recorded differently in different sectors.

In primary care (high street and the CDS), dental activity is measured in courses of treatments (CoTs) and recorded on FP17 forms that are sent to the NHS Business Services Authority (NHS BSA). The level of detail within the FP17 forms includes the complexity of care given (Band 1, Band 2 or Band 3, Urgent) and determines the payment to the dentists (see Appendix 2).

- Band 1 - covers a check-up and simple treatment (such as examination, diagnosis (eg x-rays), advice on preventative measures and a scale and polish)
- Band 2 - includes mid-range treatments (such as fillings, extractions and root canal work) in addition to Band 1 work
- Band 3 - includes complex treatments (such as crowns, dentures and bridges) in addition to Band 1 and Band 2 work
- Urgent - a specified set of possible treatments provided to a patient in circumstances which require immediate therapeutic intervention

In addition, the NHS BSA collects information on various procedures such as number of fluoride varnish applications, extractions, restorations etc.

Information on Scottish NHS dentistry is similarly collected through GP17 forms. However, in Scotland, dentists are paid on an item by item basis, resulting in significant detail being recorded on all procedures. This report has used the published research which developed from exploiting the increased granularity of the Scottish data

In England secondary care dental activity is recorded using hospital codes which are less detailed and, as a result, make it more difficult to analyse exact care (procedure by procedure) across the country (though work has commenced in NHS England to develop new codes for hospital dental care across England). The authors, therefore, have not included activity in secondary care in this report.

In NHS England, 2013-2014, there were 28.7 million courses of treatment undertaken, involving 61.3 million dental procedures.[14]

Some of the dental procedures in Band 1 are for prevention and early intervention; for example, the application of fluoride varnish. From a prevention perspective, there is significant evidence to show that the application of fluoride varnish in both permanent and primary teeth is very beneficial.[15] It can be hypothesised that prevention has a lower carbon footprint and costs less, however, the detailed research to confirm or disprove such a hypothesis is not available. (see Conclusions and recommendations)

Public Health England is keen to understand this element of resource use in order to identify the best place within dentistry for improvements to be made in sustainability.

Methodology and data sources

The complexity of supply chains ensures that carbon footprints can never be measured precisely. Footprinting is an emerging field and while there are accepted international and national standards for organisational footprinting there are still gaps in the guidance on more detailed lifecycle assessment and sector specific methodologies. Part of the role of the carbon footprinting community is to not only measure carbon footprints but also to contribute to the development of sector specific methodology in this area. Transparency is important. In order to be rigorous and allow others to check and repeat or change the analysis, all of the data has been documented and referenced as thoroughly as possible.

There are also no standard sector benchmarks and national data in primary care, which can be easily drawn from by carbon methodologists to compile a carbon footprint for this part of the healthcare sector. The reader of this report will see both English and Scottish data used in an effort to quantify the carbon footprint of the dental service as they both provide information relevant to the calculation of the greenhouse gas emissions.

In this project the term carbon footprinting is used to describe the sum of direct and indirect greenhouse gas emissions which are produced throughout the supply chain of activities and products. For example, the emissions factors for patient travel cover the different greenhouse gases which are part of the tailpipe emissions – carbon dioxide, methane and nitrous oxide – plus the indirect emissions embedded in the production of fuel (for example, extraction, shipping, refining and distribution), with an additional component to take account of the carbon emissions embedded in the manufacture and maintenance of vehicles (see Appendix 3: Definitions and terminology).

The 2 core methodologies currently used for carbon footprinting are process based life cycle analysis and environmental input output analysis. Each methodology has advantages and disadvantages and the 2 approaches can be combined in various ways to produce a ‘hybrid’ approach with the aim of drawing upon the strengths and overcoming the weaknesses of each.

Process based life cycle analysis (PBLCA)

Process based life cycle analysis (sometimes referred to as a 'bottom-up' approach) is the most common type of carbon footprinting. It involves mapping out the pathways in the supply chain of a product and estimating the emissions attributable to each stage. It is a straightforward concept that can look in detail at specific supply chains. However, it also has serious weaknesses:

1. The number of processes involved in creating a product or activity is infinite whereas any analysis only has the resources to consider a finite number. The result is that boundaries have to be set defining the processes to be included in the carbon footprinting. This will lead to 'truncation errors'. The resulting systematic underestimation of the final carbon footprint is not simple to quantify and can be well over 50%, even in detailed studies, and varies greatly between products even when consistent inclusion criteria are established. Process based life cycle analysis, when used on its own, has a tendency to underestimate greenhouse gas footprints and is also unfit for overall comparisons between products.[16]
2. Whilst process based life cycle analysis has the potential to consider individual supply chains with great specificity, in reality, in order to achieve this, a great deal of resource is required to measure the emissions actually occurring at each stage in a process. Very often studies have to fall back on generic emissions factors derived from other studies and, when these 'secondary' sources are used, the advantage of specificity is lost.[16]

The weaknesses of process based life cycle analysis are often overlooked but are well articulated in a UK government-backed review of the draft methodology for PAS 2050[17] (a publicly available standard on carbon footprinting) which was carried out by the Stockholm Environment Institute and which consulted a range of leading academics from around the world.[16] This review concluded that the PAS 2050 draft was unfit for its core intended purposes. (Incidentally, the final version was not changed to take this criticism on board.)

Despite all the problems with this approach at present, process based lifecycle analysis is still an important source of detailed information which the authors hope will become more standardised, accurate and available over time.

Environmental input output analysis (EIO)

Environmental input output analysis (or 'top-down' carbon footprinting) is a robust alternative method using macroeconomic modelling.[18] Although the results from this method rely on average carbon emissions for each category of spend, this approach does not incur truncation error and is relatively easy to apply to yield broadly realistic and comparable results.

It also has disadvantages:

1. It makes generic assumptions about the supply chains of products within industry sectors.
2. There are problems with the comprehensiveness of data sets.[19] However, for a single regional model the UK has good data. The weakness is that it has to be assumed that the UK is representative of the whole world.
3. The data are often indirect and may be based on partial measurements of resource extractions, therefore statistical procedures have to be used to produce the data set.[20]

For the purposes of this report PBLCA and EIO have been combined to achieve the most reliable result possible with the resources available.

Determining specific methodology for the analysis

Process based life cycle analysis?

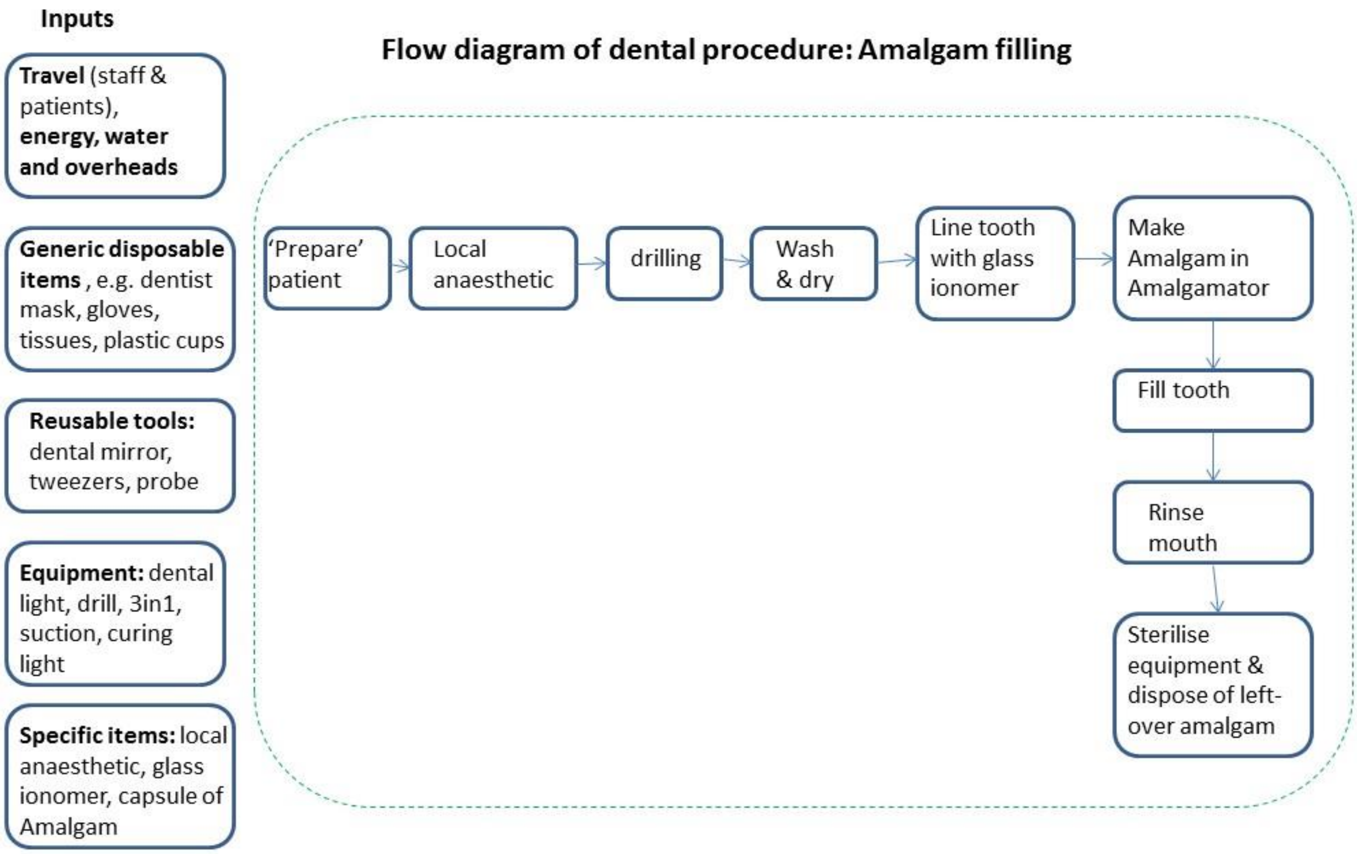
To start with, process based life cycle analysis (PBLCA) was considered to calculate the greenhouse gas emissions of each of the procedures. The individual steps which the dentists and their patients follow when carrying out/undergoing treatment and the resources used at each step were noted down. The resources used can be categorised as follows:

1. Staff travel: commuting and travel for work.
2. Patient travel: it was assumed that patients travel to the dental surgery from home.
3. Energy: gas and electricity as an overhead in the dental surgery (excluding use of electricity for dental machinery and equipment).
4. Water: used in the dental surgery.
5. Generic disposable materials which are used for all procedures, eg, dentist's and assistants face masks and gloves, disposable paper towels etc.
6. Reusable sterilisable tools, eg, dental probe and tweezers.
7. Electrical equipment and the duration of time they are used for a procedure and their energy consumption.
8. Bespoke materials specific to particular procedures, eg, amalgam used for a restoration, nitrous oxide used for conscious sedation.

For a detailed description of the resources used during each procedure see Appendix 4.

As an example of how carbon emissions using process based life cycle analysis would be calculated, the following flow diagram describes in detail the process of getting a tooth restored with an amalgam filling and the resources the process requires.

Figure 5: Flow diagram of a dental procedure - tooth restoration with amalgam



As demonstrated in the diagram, restoring a decayed tooth with amalgam involves a number of steps and uses different resources. For many of the resources used, it would be difficult to estimate the greenhouse gas emissions using PBLCA. In addition, to calculate the total carbon footprint based on PBLCA, patient travel for tooth restoration with amalgam would need to be collected with a sufficient sample size. This data would help to identify the contribution of patient travel to the greenhouse gas emissions embedded in this tooth restoration.

Carbon modelling consumable dental products

For a few very simple generic disposable items, which are used in almost every procedure, (eg, plastic cups used for the mouth wash), the embedded carbon emissions can be calculated by looking at the main material the item is made of, weighing the item and applying the correct carbon conversion factor for the material. However, for most items, the process would be complex and time consuming and the data simply may not exist.

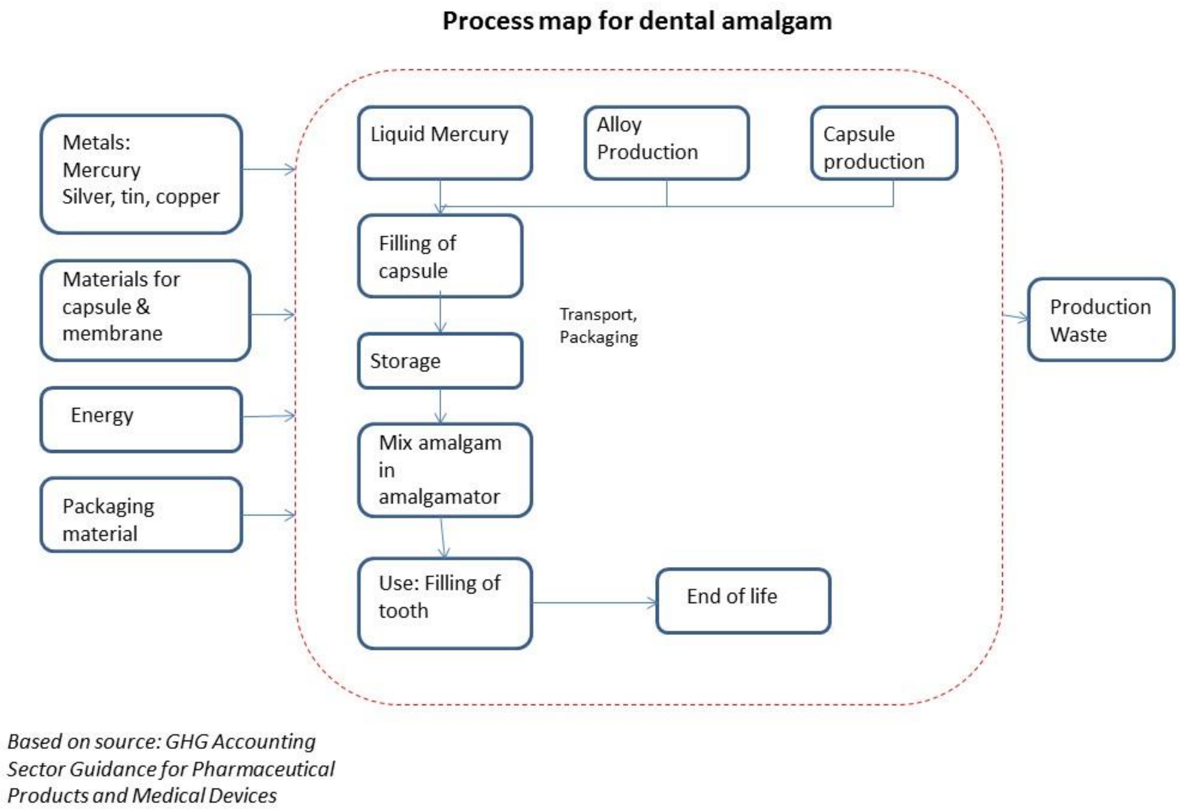
As an example of the lack of carbon footprinting data of dental materials, the information paucity on medical gloves will be highlighted. Dentists and their assistants use at least one pair of disposable gloves for each patient visit. This means at least 2 pairs of gloves for each appointment. Dental staff use either latex powder free, latex powdered, nitrile powder free or nitrile powdered gloves. Conversion factors for nitrile gloves, or ordinary gloves could not be found, only a carbon conversion factor for “rubber”. There were 2 academic papers that reported the carbon footprint of latex (gloves), however these reported 2 very different conversion factors.[21,22]

To calculate the carbon emissions embedded in bespoke dental products based on process based life cycle analysis all steps in the product’s supply chain would have to be considered. The unavailability of specific carbon conversion factors makes it very complex to try to carbon footprint bespoke dental materials unless that product happens to have been carbon footprinted by the manufacturer.

As an example, Figure 6[23] outlines the processes involved in the production, use and disposal of just one bespoke material used to restore a tooth with amalgam. This figure is a subset of Figure 5, and illustrates the steps in the commercial production of amalgam rather than the whole process of clinically treating a patient using amalgam. Amalgam fillings consist of a metal alloy and mercury. The raw filling material is supplied to the clinician in a capsule with metal alloy on one side separated by a membrane from the mercury. The metal alloy is a mixture of tin, silver and copper. Sometimes also zinc is added.

There are publically available generic carbon emissions factors for mercury, silver, tin and copper production. However, the generic carbon emissions factors do not provide information on what emissions are involved in turning the simple metals into a usable form to produce the alloy needed for the creation of the amalgam filling. Also, the exact steps in the alloy production or what material is used in the production of the capsule and its membrane and how much greenhouse gas emissions are produced during the process are not known.

Figure 6: Process map for dental amalgam



This is further complicated because amalgam fillings made by different manufacturers use different concentrations of materials. For example, looking at just one manufacturer 4 different amalgam fillings were identified, all of which have different concentrations of the metals[24], and they can be delivered in single dose, double dose or triple dose capsules. When comparing the carbon conversion factors of the different metals, there is a big variation - with copper having the smallest and tin having the highest emissions (kgCO2e/kg). A variation in the concentration of the metals in the alloy will, therefore, have an impact on the greenhouse gas emissions embedded in an amalgam filling.

It can also be assumed that there is variation in the manufacturing process between different manufacturers. To calculate accurate figures information on industry market share would be needed - or at least sufficient information to calculate an average.

Furthermore, amalgam cannot be disposed of as ‘normal’ waste. All amalgam has to be collected and recycled.[25] Though the greenhouse gas emissions for recycling amalgam are not known, it can be assumed that the carbon footprint is higher since it requires special treatment.

Carbon modelling reusable tools

There are dental hand instruments which are used during every dental appointment, such as the dental mirror, dental probe and dental tweezers. There are also hand tools which are used only for specific procedures. For example, if carrying out a tooth extraction, there are a number of different extraction forceps and elevators that could be used.

Reusable tools are often made out of stainless steel, but can also be made of ceramics or brass. Stainless steel has the highest carbon footprint (6.15kgCO2e/kg) compared with ceramics (1.14kgCO2e/kg)) and brass (2.42kgCO2e/kg). However, the carbon associated with turning each of these materials into hand instruments is not known. It is also worth considering that a dentist will have more than one set, since hand instruments have to be sterilised after each appointment. However, they will last for a long time, so do not have to be replaced frequently.

Use of hybrid methodology

Assuming that all dental procedures with specific materials, hand instruments and electrical equipment are similarly complex, conducting a process based life cycle analysis for each procedure would be time consuming and, with the lack of reliable detailed data, inaccurate. Furthermore, because this is the first carbon modelling work undertaken in dentistry in England, and since it is unclear at this stage which of the categories of resources contributes the most carbon emissions to dental procedures, the decision was taken that it would be a priority to have a robust overview of the carbon footprint of the whole service.

Consequently, as not all of the data to do a direct PBLCA was available, a hybrid methodology has been used, drawing on a variety of different methods and a range of publicly available data sources and personal investigations to carry out the study (see Data sources and data quality).

Boundaries

To measure the carbon footprint of 17 dental procedures the following greenhouse gas emissions have been calculated; emissions associated with:

- patient travel: from home postcode to practice postcode
- staff travel: commuting to work
- staff travel: travelling for direct work purposes (eg, a domiciliary visit, training)
- procurement: administrative items, materials and laboratory services
- energy: electricity and gas for heating
- water
- waste
- nitrous oxide

The following carbon emissions were excluded:

1. Carbon embedded in capital items which are part of the set-up of a dental practice (dental equipment and furniture). The data from the National Association of Specialist Dental Accountants (NASDA), which was used, included the average annual accounts costs of a provider performer dentist with at least 80% NHS activity. It was assumed that these also exclude initial set-up costs for the dental practice.

The estimation of the dental carbon footprint was based on the work of 8422 NHS' High Street' dental practices. Dentistry carried out at hospital level was excluded.

Greenhouse Gas Protocol

The project followed the reporting principles of the Greenhouse Gas Protocol (GGP) developed by World Resources Institute (WRI) and World Business Council on Sustainable Development (WBCSD).[26] The protocol covers 7 different greenhouse gases which, on the basis of their weight and global warming potential, are expressed in carbon dioxide equivalents (CO2e). For company reporting the GGP has grouped emissions into 3 categories: Scope 1, 2 and 3.

- Scope 1: all direct emissions, eg vehicle emissions and emissions from buildings
- Scope 2: indirect GHG emissions from consumption of purchased electricity, heat or steam
- Scope 3: emissions embedded in the supply chain

For this project, the following categories and their scope of emissions were included:

Table 1: Categories and scope of their emissions

	Scope 1 emissions	Scope 2 emissions	Scope 3 emissions
Nitrous oxide	√		
Travel/commuting	√		√
Energy	√	√	√
Procurement			√
Water			√
Waste	√		√

Data sources and data quality

To estimate the carbon footprint of the 17 dental procedures the overall carbon footprint of NHS dental services in England was calculated first. Once the total greenhouse gas emissions were estimated the different areas of emissions were allocated to the different procedures by agreed denominators.

Ideally, practice level information for a representative sample of NHS dental practices in England would have been available on travel, procurement, energy and water use, waste, nitrous oxide use and volume of activity for each dental procedure. However, as this was not the case, the following sources of data were used:

- staff commuting, energy, waste and water use: Duane B et al. Taking a bite out of Scotland's dental carbon emissions in the transition to a low carbon future[27]
- patient travel: Data Warehouse of the NHS Business Authority[28]
- CoTs of dental procedures: Health and Social Care Information Centre (HSCIC)[5]
- value/cost of dental procedures: Information Services Division Scotland General Dental Service (ISD Scotland)[29]
- procurement: National Association of Specialist Dental Accountants (NASDA) 2005/06[30]
- staff travel for work: National Association of Specialist Dental Accountants (NASDA) 2005/06[30]

For the conversion factors the following sources were consulted:

- Department for Environment, Food and Rural Affairs (Defra)[31],[32]
- Small World Consulting Ltd's carbon calculator[33]

Correspondence with individual dentists helped with cross checking data.

The calculations of the carbon footprint of dental staff travel, energy, water use and waste are mainly based on data collected for a carbon footprinting study of dental services in Fife, extrapolated to NHS dental services in England.[34] The estimations of greenhouse gas emissions of patient travel are based on the Data Warehouse of the NHS Business Authority.[28] For the carbon embedded in procurement, the most recently published average dental accounts from the NASDA[30] of 2005/06 have been used.

For the conversion factors to calculate the carbon emissions 2 sources were consulted – Defra[31,32] and Small World Consulting Ltd's carbon calculator.[33] The conversion factors from Small World Consulting Ltd's calculator are, in many cases, based on Defra's conversion factors. However, the factors are more comprehensive and inclusive. For example, the conversion factors for miles driven include direct tailpipe emissions, fuel supply chain emissions plus the carbon emissions which are embedded in the purchase and maintenance of the car, whilst Defra factors consider either the tailpipe emissions only[31] or tailpipe emissions and fuel supply chain emissions.[32]

As for most areas of dental greenhouse gas emission no practice level data for NHS dentists in England were found, for each area of emissions it will be described how the carbon footprint was calculated and which data sources were used.

Patient travel

Main sources of information

- NHS Business Authority: Location of dental practices, residency of patients and number of FP17s per practice[28]
- National Travel Survey 2013, Table NTS0308: Average number of trips by trip length and main mode[35]
- Small World Consulting Ltd (SWC) Environmental Input Output Model: Conversion factors for different modes of transport[33]

Comment

Though there was no dental travel survey data for England specifically measuring patient travel to dental appointments, there is very detailed information on the location of dental practices and the home addresses of their patients who have visited in the previous 12 months. By measuring the distance between the postcode of the main practice of the contract holder and the postcode of the patient's residence the distance travelled for each dental visit could be calculated. The calculations of the distances travelled and the carbon emissions produced have been carried out in collaboration with Public Health England.

Calculations

- the distance between the postcode of the main practice of the dental contract holder and the patient's residence are recorded in the NHS Business Authority's data warehouse. The data warehouse is able to allocate X and Y coordinates to the postcodes allowing a measurement of a straight line between the postcodes
- as the distance measured is a 'how the crow flies' distance, it was adjusted to the actual distance travelled. One mile of actual travel equals 1.6km, which equals 1.24km of 'how the crow flies'[28]
- all patients who visited their dentist in the previous 12 months were allocated to groups depending on how far they travelled to their dentist: ie less than 1 mile, 1 to less than 2 miles, 2 to less than 5 miles, 5 to less than 10 miles and 10 miles and more
- the National Travel Survey in England shows the combination of different modes of transport people use for different distances travelled, for example, if under 1 mile, 78% of people walk to their destination; whereas, if between 2 and 5 miles, only 4.7% walk. Taking into account the different mix of modes of transport for the different

categories of distances travelled and the carbon conversion factors for each mode of transport the average emissions per distance category was calculated

- it was assumed that patients in each category travel the distance of the mid-point of that category. For example, it was assumed that people travelling less than a mile travel 0.5 miles on average, and people travelling between 1 and 2 miles travel 1.5 miles etc. For patients who travel 10 miles and more, it was assumed that they travel, on average, 20 miles
- to calculate the overall carbon footprint of patient travel the number of times patients travel to their dentist annually has been taken into account. The number of dentists' claim forms (FP17s) submitted to the NHS is an indication of the number of treatments patients have received
- different treatments require different number of visits to the dentist. On average, patients who receive a treatment in Band 1 will visit the dentist once for treatment. Patients in Band 2, on average, have 2 and a half appointments, and treatments in Band 3 require 4 visits. Treatments in the category 'urgent' only require one visit. Taking into account the percentages of patients who receive treatments in Band 1, 2, 3 and Urgent, and factors for the different modes of transport developed by Small World Consulting Ltd, it can be estimated that on average patients have 1.58 appointments per treatment (see Appendix 5)
- the greenhouse gas emissions factors for the different modes of transport developed by Small World Consulting Ltd were used[33]
- for a detailed description of the calculations see the Overall carbon footprint of NHS dental services in England final, worksheet 'CO2e patient travel'.

Data quality

The patient travel data is accurate and the only practice level data available for NHS dental practices in England. The main shortcoming of this data set is that the distance a patient travels is measured between the residence of the patient and the postcode of the contract holder's main practice. If a contract holder has more than one practice, the practice address used for the calculation might not be the actual practice the patient visits, therefore, the distance travelled might have been over- or underestimated.

Furthermore, for patient travel, a combination of modes of transport was assumed depending on the distance travelled by the patient. As this is based on the national travel survey it can be assumed this is an accurate representation of travelling behaviour of the English population and therefore also of patients travelling to their dentists. However, it might be incorrect to assume that the midpoint of the distance categories is the on average actual distance travelled. This might have led to either an over- or an underestimation.

The carbon conversion factors for travel are generic, based on averages for each mode of transport. In this study the greenhouse gas emissions factors developed by Small World Consulting Ltd have been used as they include the direct emissions, tailpipe emissions and the indirect emissions, production and transport of fuel plus production and maintenance of vehicles.

Staff travel to work: Commuting

Main sources of information:

- Duane B et al. Taking a bite out of Scotland's dental carbon emissions in the transition to a low carbon future[27]
- General Dental Council[36]
- Health and Social Care Information Centre (HSCIC). NHS Dental Statistics 2013/145
- Health and Social Care Information Centre (HSCIC). Dental Working Hours 2012/13 and 2013/14 Initial Analysis[37]
- Small World Consulting Ltd (SWC) carbon calculator: Conversion factors for different modes of transport[33]

Comment

Since there was no travel data on NHS dental staff in England commuting to work, it was assumed that dental staff in England commute in the same way, the same distance and the same mode of transport as dental staff in Fife, Scotland, from where good travel survey data was available. Initially, it was assumed that the commuting distances in Scotland might be higher than that in England due to a lower population density (population density in England: 413/square km, Scotland 68/square km)[38], however, the average distance of dental patient journeys in Fife and England are very similar (7.26[27] vs 7.57miles/return journey[28]); therefore the assumption was made that this would be the same for the dental staff. The carbon footprint of staff commuting to and back from work includes the greenhouse gas emissions of dentists', dental nurses', hygienists', therapists' and receptionists' travel.

Calculation

- the different commuting distances of each dental staff group (dentists, dental nurses, hygienists, therapists and dental receptionists) in Fife, Scotland, were applied to the English dental population with NHS activity
- as all dental staff in the Fife study, apart from one, commute to work by car, it was assumed that dental staff in England also commute to work by car
- the General Dental Service (GDS) was consulted to find out the overall number of dental staff employed and the numbers of each designation of dental staff in England. However, the GDS registers all dental staff – both private and NHS. To estimate the number of dental staff in England working with NHS activity the number of NHS dentists recorded by the HSCIC and the ratio of dentists to other dental staff in the GDS data was considered. Assuming the ratio is the same for dental nurses, hygienists and therapists with NHS activity the number of dental nurses, hygienists

and therapists who work at least partly for the NHS could be estimated (see Overall carbon footprint of dental services in England final, worksheet 'No dental staff')

- to estimate the number of receptionists, the Association of Dental Administrators and Managers (ADAM)[39] was contacted. Though they do not have any record of dental administrative/office staff, they assume that each dental practice will have, on average, one receptionist/office manager
- it was assumed that the dental staff used an average sized car and did not do any car sharing
- to calculate the total carbon emissions for staff commuting to and back from work a carbon conversion factor was applied, which included not only the direct tailpipe emissions, but also the embedded carbon emissions of fuel production and car purchase and maintenance (see Overall carbon footprint of dental services in England final, worksheet 'staff travel')
- on average, NHS dentists have 71.4% NHS activity[37]. A factor of 0.714 was, therefore, applied to the carbon emissions to account for the embedded carbon which is due solely to NHS activity
- in Fife, dental staff work on average 0.82fte. It was assumed that dental staff in England work the same hours. To account for the 0.82fte a factor of 0.82 was applied

Data quality

Though the dataset on staff commuting from the Fife study is accurate, our assumption that NHS dental staff in England show similar commuting patterns might be questioned. England has a higher average number of urban areas than Fife and England's population density is also much higher. Taking the English population density into account reduces the total carbon footprint of NHS England dental services by 4.3% (see Overall carbon footprint of dental services in England final, worksheet 'staff travel').

The greenhouse gas emissions factor used for car travel is accurate, however generic, as the type of car used was not known. It was assumed that dentists travel in a medium-sized car with unknown fuel use (assuming 50/50 petrol/diesel).

Staff travel for work: Business travel

Main sources of information

- Health and Social Care Information Centre (HSCIC). The Dental Earnings and Expenses Report and the National Association of Specialist Dental Accountants (NASDA) clients' survey: a comparison of results and methodologies[30]
- Health and Social Care Information Centre (HSCIC). Dental Earnings and Expenses 2013/14 Initial Analysis[40]
- Health and Social Care Information Centre (HSCIC). Dental Working Hours 2012/13 and 2013/14 Initial Analysis[37]
- Defra conversion factors June 2015[31]

- Small World Consulting Ltd (SWC) Carbon Calculator: Conversion factors for different modes of transport[33]

Comment

Though there was no travel survey data on how many miles dental staff travel for work annually, annual accounts of an average principal dental contract holder (provider performer) with over 80% NHS activity could be accessed. This had been compiled by the National Association of Specialist Dental Accountants (NASDA) who had carried out a survey with their dental clients. The last year of the detailed breakdown of expenses published by NASDA is 2005 to 2006.[30]

For performer only dentists the travel expense data from the HSCIC 'Dental earnings and expenses 2013 to 2014' report was used.[40]

Calculation

- for provider performer dentists the data on motor expenses and travel expenses from the NASDA accounts was used
- for performer only dentists the travel expenses from the HSCIC 'Dental Earnings and Expenses 2013/14' report were split into motor expenses and travel expenses according to the same ratio as it is recorded by the NASDA accounts
- with data from the Automobile Association (AA)[41] and calculations undertaken by Small World Consulting Ltd (SWC), the costs of the motor expenses relating to the actual fuel consumption were calculated and therefore the amount of fuel could be estimated. This allowed the calculation of carbon emissions due to tailpipe emissions and the indirect carbon emissions related to fuel production on the basis of Defra's Scope 1 and 3 conversion factors
- the costs which were not allocated to fuel consumption were attributed to car purchase and maintenance and the conversion factor from the SWC carbon calculator used
- for travel expenses a conversion factor for 'Land transport service' from SWC carbon calculator was used
- on average, NHS dentists have 71.4% NHS activity.[37] A factor of 0.714 was, therefore, applied to the carbon emissions to account for the embedded carbon which is due solely to NHS activity
- for detailed calculations see Overall carbon footprint of dental services in England final, worksheet 'CO2e staff travel'

Data quality

It can be assumed that the NASDA accounts on 'motor running' and 'travelling expenses' are a fair representation of the actual claims as this is based on survey data. However, the data is based on an average provider performer dentist.

It can be also assumed that the ‘travel expenses’ data for the ‘Dental Earnings and Expenses report 2013 to 2014’ is an accurate reflection of the travel for work behaviour of performer only dentists as this data is based on anonymised tax data.

The greenhouse gas emissions factors for travel and transport are accurate, but generic (see ‘Patient travel – quality of data’). Any level of inaccuracy might be due to the assumption on the type of transport used. Though the NASDA accounts differentiate between car use, motor running and other transport, and travelling expenses, information on the type of car used and if travel expenses refer to, for example, bus, train or taxis was not known.

Procurement

Main sources of information

- Health and Social Care Information Centre. The Dental Earnings and Expenses Report and the National Association of Specialist Dental Accountants (NASDA) clients' survey: a comparison of results and methodologies[30]
- Health and Social Care Information Centre. Dental Earnings and Expenses 2013/14 Initial Analysis[40]
- Health and Social Care Information Centre (HSCIC). Dental Working Hours 2012/13 and 2013/14 Initial Analysis[37]

Comment

The greenhouse gas emissions embedded in dental procurement have been calculated on the basis of cost data and using the carbon calculator of Small World Consulting Ltd (SWC).

To estimate the carbon emissions embedded in dental procurement of provider performer dentists, expenditure data of an average dental account of a principal contract holder with more than 80% NHS activity was used.

These accounts have been compiled by the National Association of Specialist Dental Accountants (NASDA). The most recent detailed published cost figures are from 2005/06. More up to date figures are available as a percentage of gross income. However, the more up to date data is not broken down into as much detail as the 2005/06 data.

For performer only dentists the carbon emissions embedded in dental procurement have been calculated on the basis of the HSCIC ‘Dental earning and expenses 2013/14 initial analysis’ report. The expenses of performer only dentists are in general much less/smaller. In the ‘Dental earning and expenses reports’ the expenses are not broken down in as much detail as the NASDA accounts. Where appropriate costs have been allocated to the NASDA cost categories in the same proportion as the average costs of principal contract holders with over 80% NHS activity in the NASDA accounts.

Calculation

Provider performer dentists

- cost figures of an average principal contract holder with over 80% NHS activity in 2005 to 2006 were used
- to each cost category a carbon conversion factor of kgCO2e/£ was allocated from SWC carbon calculator
- a carbon footprint per principal contract holder was calculated
- the carbon footprint per principal contract holder is extrapolated to all 4,413 provider performer dentists in England
- on average, NHS dentists have 71.4% NHS activity.[37] A factor of 0.714 was, therefore, applied to the carbon emissions to account for the embedded carbon which is due solely to NHS activity

Performer only dentists

- the expenses from the ‘Dental Earnings and Expenses 2013/14’ were allocated to the NASDA cost categories
- in cases where the expense categories combined a few of the NASDA cost categories, the expenses were broken down in the same proportion as in the NASDA accounts.
- the conversion factors of SWC carbon calculator were applied
- the resulting ‘per practice’ footprint was extrapolated to the 19,310 performer only dentists
- as above, a factor of 0.714 was applied to account for the embedded carbon of dental procurement due solely to NHS activity
- for detailed calculations see Overall carbon footprint of dental services in England final, worksheet ’CO2e procurement’

The carbon emissions of provider performer and performer only dentists have been totalled to give a picture of the total dental carbon footprint for NHS England due to procurement.

Data quality

The main shortcomings of the 2 information sources for dental expenditure are the small number of expenditure categories. The advantage of the NASDA accountancy data is that they have separate cost categories for materials and laboratory fees, whereas, in the ‘Dental earnings and expenses reports’ by HSCIC, materials and laboratory fees are included in the ‘other costs’ expenditure category. In general, the fairly crude categorisation does not allow a very detailed differentiation of greenhouse gas emissions factors.

Nitrous oxide

Main sources of information

- Information Services Division Scotland General Dental Service (ISD Scotland)[29]
- conversations with dentists
- BOC Medical Nitrous Oxide Essential Safety Information[42]

Comment

Nitrous oxide (N2O) is a gas which is used by some dentists in addition to local anaesthetic for sedation and pain relief. It is brought to the dental practice in cylinders and administered in combination with oxygen. Not all dentists are trained to use it and, if they do, they are professionally responsible to demonstrate competency. Nitrous oxide is used mainly for patients who suffer from anxiety.

As no data on the total number of sedations with nitrous oxide undertaken by NHS dentists in England could be found, the number of sedations carried out on dental patients in Scotland were extrapolated to patient numbers in England, thus assuming that the same proportion of NHS dental patients receive sedation in Scotland as in England.

Concerning the average volume of nitrous oxide used during a sedation, figures for England or Scotland, either practice-based or for all of NHS dentistry could not be obtained. However, information from one community dental service in England, on the number of patient sedations provided per cylinder of N2O was provided and was used to calculate the amount per patient episode and, subsequently, for all NHS dentistry in England. See Table 2.

Table 2: Number of patients receiving sedation with nitrous oxide

	Dental NHS patients attended in last 24 mths[11,12]	No of patients receiving sedation 2014[11]	% receiving sedations
Scotland	3,400,000	7,249	0.21%
England	29,900,000	63,749	0.21%

Calculation

- the Scottish Dental Registry has detailed information on how many sedations were provided to adults and how many to children in 2014
- in the year 2014, 7,249 adults and children received N2O which is 0.21% of all dental patients (see Table 2)
- extrapolated to the number of dental NHS patients in England, 63,749 dental patients received N2O in 2014

- according to dentists, a 1800l cylinder of nitrous oxide lasts on average for 11 patients. That is around 163 litres of N2O per patient episode (see Table 3 and Overall carbon footprint of dental services in England final, 'CO2e N2O')
- according to the N2O provider BOC (one of the main dental suppliers) nitrous oxide gas contains 1.875 kgN2O/m3, which equals 3.375 kgN2O/cylinder and 0.3068kgN2O per patient episode
- the global warming potential of 1kgN2O is 298kgCO2e. Therefore, 0.3068kgN2O per patient episode equals 91.43kgCO2e

Table 3: Nitrous oxide supply - calculation of carbon emissions per patient

Supply of N2O	No of patients per cylinder	N2O/m3 (kg)	N2O/cylinder (kg)	N2O/patient episode (kg)	CO2e/ patient episode (kg)
1800l cylinders	11	1.875	3.37	0.3068	91.43

The carbon footprint of nitrous oxide emitted during treatment is 91.43kgCO2e per patient episode. This does not include the embedded carbon of N2O production or the embedded carbon of its cylinder (which is usually rented) as the indirect emissions are accounted for in dental procurement. The same applies to the oxygen which is mixed with nitrous oxide during the sedation.

N2O is not attributable to specific dental procedures, but tends to be used across procedures for people who suffer from anxiety. When calculating the carbon footprint per procedure, the individual procedure with and without sedation was considered.

Data quality

The number of sedations is well recorded in Scotland and therefore can be assumed to be accurate. In the absence of similar data for patients in England, it can only be assumed that they receive the same proportion of sedations as their counterparts in Scotland.

Nitrous oxide is a greenhouse gas and its global warming potential, and therefore its carbon dioxide equivalent, is well known.

Energy

Main sources of information

- Duane B et al. Taking a bite out of Scotland's dental carbon emissions in the transition to a low carbon future[27]
- General Dental Council[36]
- Health and Social Care Information Centre (HSCIC). NHS Dental Statistics 2013/145

Comment

During the carbon footprinting study of dental services in Fife, actual measurements of annual electricity consumption and gas use of 6 out of 22 dental practices were collected; 3 of these dental practices were in old buildings and 3 in new. The average annual energy consumption of the dental practices in Fife, Scotland, was extrapolated to the number of practices in England.

Additional data from a dental practice in England revealed differences in electricity and gas usage from the dental practices in Fife. As the English practice was only one of 8,422 practices it was decided to use the empirical data from Fife, which was felt to be more representative.

Calculation

- average electricity and gas consumption of dental practices in Fife had been calculated and analysed for old and new buildings. The sample of older buildings where energy use was available had been extrapolated to calculate energy use for all older dental practices in Fife taking into account the number of surgeries of the individual dental practices. The same was done with the actual measurement of electricity and gas consumption in new buildings
- the total electricity and gas consumption of dental practices in Fife was calculated by adding the electricity and gas use in old and new buildings together
- the average carbon footprint due to electricity and gas use in Fife was calculated using up to date carbon conversion factors from Defra[31]
- the carbon conversion factor used for electricity included Defra's Scope 2 emissions factor for electricity generation plus Defra's Scope 3 emissions for transmission and distribution and well-to-tank[31]
- the carbon conversion factor for gas included Defra's conversion factor for Scope 1 emissions plus Scope 3 emissions for well-to-tank
- the carbon footprint of electricity and gas use per surgery in Fife was extrapolated to all practices in England by assuming an average dental practice size of 2.82 chairs
- the average dental practice size was calculated by dividing the number of dentists by the number of practices. This is the best estimate though it is recognised that dentists (both provider performers and performer only) can, and often do, work at more than one practice
- to look at the calculations go to Overall carbon footprint of dental services in England final, worksheet 'CO2e energy'

Data quality

The actual energy data measured in dental practices in Fife is accurate. However, the sample size of practices who took the measurement is very small, ie 6 out of 22. Out of these 6 practices, 3 were located in old and 3 in new buildings. In general, the practices in the new buildings had more surgeries; 6 surgeries in the new practices and one or 2 in the old practices, and their energy consumption per surgery was higher.

The electricity consumption per surgery of the practice in England (which has 6 surgeries and an educational centre), was slightly lower than the average electricity consumption of the older dental practices in Fife. The gas use was only a third of Fife's consumption.

The greenhouse gas emissions factors for energy and electricity from Defra are considered reliable.

Water

Main sources of information

- Duane B et al. Taking a bite out of Scotland's dental carbon emissions in the transition to a low carbon future[27]
- one dental practice in England
- General Dental Council[36]
- Health and Social Care Information Centre. General dental practices in England, Wales and IoM[34]

Comment

The actual annual water consumption had been measured in only one dental practice in Fife; the practice is in a new building and has 3 surgeries. Additionally, data was available on one practice in England which had 6 surgeries plus an oral education centre who had measured their water usage. However, the age of this building was not known. The range of the water consumption between these 2 practices was large. However, the contribution of water consumption to the overall carbon footprint of NHS dental services in England is small; therefore the incompleteness of the data has only a minor impact on the overall dental greenhouse gas emissions. The average water consumption per surgery of the 2 practices was calculated and extrapolated to the practices in England, assuming each dental practice had an average of 2.82 surgeries.

Calculation

- the average water use in m^3 per surgery of the 2 practices was calculated
- the results were extrapolated to an average dental practice size of 2.82 surgeries in England
- the 2 Defra carbon conversion factors for water supply and water treatment were combined and applied to the average annual water use of a dental practice with 2.82 dental surgeries
- the carbon footprint due to water use of an average dental practice was extrapolated to all dental practices in England to get the total carbon footprint due to water use (see Overall carbon footprint of dental services in England final, worksheet 'CO2e water')

Data quality

As the sample size for water use was very small, there is uncertainty around the accuracy of the data.

The greenhouse gas emissions embedded in water supply and water treatment are both Scope 3 emissions.

Waste

Main sources of information

- Duane B et al. Taking a bite out of Scotland's dental carbon emissions in the transition to a low carbon future[27]
- General Dental Council[36]
- Health and Social Care Information Centre. General Dental Practices in England, Wales and IoM[34]
- Defra. UK Government conversion factors for company reporting[32]

Comment

For the carbon footprint of waste 4 types of waste and their most common disposal streams were considered:

1. Clinical waste: incinerated
2. Special waste (amalgam): recycled
3. Domestic waste: landfill
4. Cardboard: recycled

To estimate the amount of waste collected and disposed of annually per practice, a combination of 2 data sources were used; the Fife carbon footprinting study and waste data collected by one dental practice in England.

Calculation

- the amount of special waste per surgery from the Fife study was considered
- data on the amount of domestic, recycling and clinical waste from the dental practice in England was used
- to calculate the carbon footprint of the different waste streams 4 different conversion factors from Defra for waste were chosen:[31]
  - clinical waste: conversion factor for the incineration of municipal, industrial and commercial waste – 0.021kgCO2e/kg waste
  - domestic waste: conversion factor for municipal waste delivered to landfill – 0.459kgCO2e/kg waste
  - amalgam waste: conversion factor for open loop recycling of batteries as a proxy – 0.065kgCO2e/kg waste
  - cardboard waste: the amount of waste collected annually was measured in litres. To estimate its waste in kilograms WRAPS bulky materials density factor for mixed paper and card was used. The conversion factor for closed loop waste disposal was chosen to

calculate the greenhouse gas emissions of recycling of cardboard – 0.021kg CO2e/kg waste[43]

- for detailed calculations go to Overall carbon footprint of dental services in England final, worksheet 'CO2e waste'

Data quality

The data on the amount of domestic, clinical and recycling waste from one dental practice in England was collected by actual measurement. The data is accurate, but as it only represents one practice there is uncertainty that it is representative of all other dental practices. The data on amalgam waste from Fife is based on the measurement of the actual container in which amalgam is collected.

The greenhouse gas emissions factors used are based on Defra's conversion factors. The domestic waste conversion factor includes the greenhouse gas emissions which occur during collection, transport and landfill storage, 'cradle to grave'. The recycling and combustion conversion factors 'only' include the transport of the waste to an energy and/or materials reclamation facility. Subsequent emissions are attributed to electricity generation or recycled material production respectively.[31]

If the incineration of clinical waste is not used for electricity generation (as is probably often the case with on-site incineration at hospitals), the carbon conversion factor used will have underestimated the greenhouse gas emission attributed to its disposal.

Allocating carbon emissions to procedures

After the greenhouse gas emissions associated with staff and patient travel, procurement, energy, nitrous oxide, waste and water for all dental practices with NHS activity in England were calculated, the emissions were allocated to 16 out of the 17 procedures included in this study.[b]

The courses of treatments (CoTs) recorded by HSCIC had only one category for fillings and one for crowns. It can be assumed that different types of fillings and crowns are likely to have different carbon footprints. Information Service Division (ISD) Scotland collects data on the number of claims for the different types of fillings.[29,44] It was assumed that NHS dentists in England use amalgam, composite and glass ionomer fillings in the same proportion as Scottish NHS dentists, so the number of fillings and restorations recorded in England were split in the same proportion as recorded in Scotland. The same assumption was undertaken for precious metal, non-precious metal and porcelain crowns.

[b] 'Nitrous oxide' is not a separate dental procedure as such. Sedation with nitrous oxide can be used during any of the 16 treatments; therefore sedation was not treated as a procedure on its own.

Allocation per time spent on a procedure

Most carbon emissions categories were allocated on the basis of time spent on a procedure. The assumption is that the longer the patient spends at the dentist, the more resources are likely to be used – human resources, material resources and equipment.

Table 4: Allocation of carbon emissions to the 16 different dental procedures

Carbon emissions category	Allocated according to
Patient travel	Number of visits
Staff travel	Time spent on procedure
Administrative procurement	Time spent on procedure
Material procurement	Time spent on procedure
Laboratory fees	Value of procedure's claims
Energy	Time spent on procedure
Waste (clinical, domestic, recycling)	Time spent on procedure
Special waste	Amalgam fillings
Water	Time spent on procedure

Staff travel was allocated proportionally to time spent per treatment and number of treatments as it reflects the human resource use of the particular procedure.

In the case of *energy* and *water use*, the length of time spent on a patient and the number of treatments is the most important determining factor of the amount used. For example, the longer the patient spends in the dental chair, the longer the dental light is switched on and the more electricity is used for the light. Furthermore, procedures which require longer patient visits are characterised by more complex treatments which are likely to require additional dental equipment. For example, restoring a decayed tooth requires the removal of decay with a hand piece which is usually accompanied by suction equipment. Both types of equipment require electricity.

Allocating the carbon emissions embedded in *procurement* provided a bigger challenge. There are 3 main cost categories for dental procurement: administrative expenses, laboratory fees and material costs.

The carbon emissions for *administrative expenses* were allocated simply according to time spent on a procedure as it was assumed that the costs will be proportional to the total time spent on a particular treatment.

To reflect the additional carbon emissions in dental work which requires laboratory services, *laboratory fees* were allocated according to claim value to those procedures which require the service – see 'Allocation per claim value'.

However, *material costs* and their embedded carbon emissions were more difficult to allocate. Material costs cover 2 types of material; generic items - which are used for all procedures, such as face masks, mouthwash etc - and more specific items like local anaesthetic, different types of fillings etc. As with laboratory fees, allocating the carbon footprint due to material use on the basis of the claim value was considered. However, data from Scotland showed that different claim values do not accurately reflect difference in material use. For example, according to ISD Scotland 2014, the claim value for fluoride varnish for an adult is £38.10 and for a child is £6.08. Though it could be argued that more fluoride varnish is used for adult teeth, the big difference in claim value is most likely caused by other factors, for example fluoride varnish is routinely offered to children as a preventative measure and therefore costs are kept low. Looking at fillings as another example, there is little difference in claim value for amalgam fillings and composite fillings. Therefore, instead of using the claim values to allocate material costs, it was decided to allocate the carbon emissions embedded in material use according to time spent on the procedures.

Calculation

To be able to allocate carbon emissions on the basis of the proportion of time spent on a certain procedure a dentist was consulted to estimate the time spent on each treatment. This had to include all procedures; the ones which were selected for the study and the ones outside the remit of the project. The time spent per procedure was then multiplied with the number of CoTs which include this procedure. For each procedure the proportion of time spent could be calculated.

Allocation per number of visits for a procedure

Patient travel was allocated according to the number of visits per procedure. The number of return visits and the miles per return journey are the main determinants of the carbon footprint created by patient travel.

Calculation

With the help of a dentist the number of visits was allocated to each procedure; for the selected procedures and the procedures not in the remit of this study. The overall number of visits for each procedure and the proportion of all visits of a procedure could then be calculated. The proportion of carbon emission of the total patient travel carbon footprint for each treatment could be estimated.

Allocation per claim value

The cost of laboratory fees was spread across the procedures which involve laboratory services according to their claims value.

Not all of the procedures which have been included in the project require the services of a laboratory. For the ones which do, it was important to try to account for the difference in material used for the different procedures. As there were no actual claim figures for the individual procedures for England (as claims are organised according to bands and different crowns for example are in the same band), the data of ISD Scotland was considered. To have an estimation of the claim value of a procedure, the total claim value was divided by the number of procedures claimed. These values per claim were used for the procedures of fitting different crowns, dentures and study models. Figures for the claim values of procedures which require laboratory services but were not part of our study were also included as these procedures contribute to the overall laboratory costs, for example, veneers, inlays and bridges. Once the total claim value was calculated the proportion of a procedure's claim value could be estimated.

Special waste

Special waste is referring to the amalgam waste which is collected at the dentists. Therefore the carbon footprint associated with special waste was allocated solely to amalgam fillings.

Nitrous oxide

Nitrous oxide is given to patients who suffer, for various reasons, from dental anxiety when going to the dentist. Although in Scotland dentists can claim for sedations separately, sedations are given to patients who come for 'other' dental treatments; it is not a separate treatment which is given on its own. Therefore, it was thought to be incorrect to allocate a travel, procurement, energy, water and waste carbon footprint to nitrous oxide.

Furthermore, there was no information available on whether patients receive sedation equally often for examinations as, for example, for root canal (endodontic) treatments. Hence, there were no criteria to allocate the use of nitrous oxide proportionally to any of the procedures.

To gauge how much nitrous oxide contributes to the carbon footprint of a procedure, the greenhouse gas emissions of each individual procedure carried out with and without the use of N2O were examined.

Results

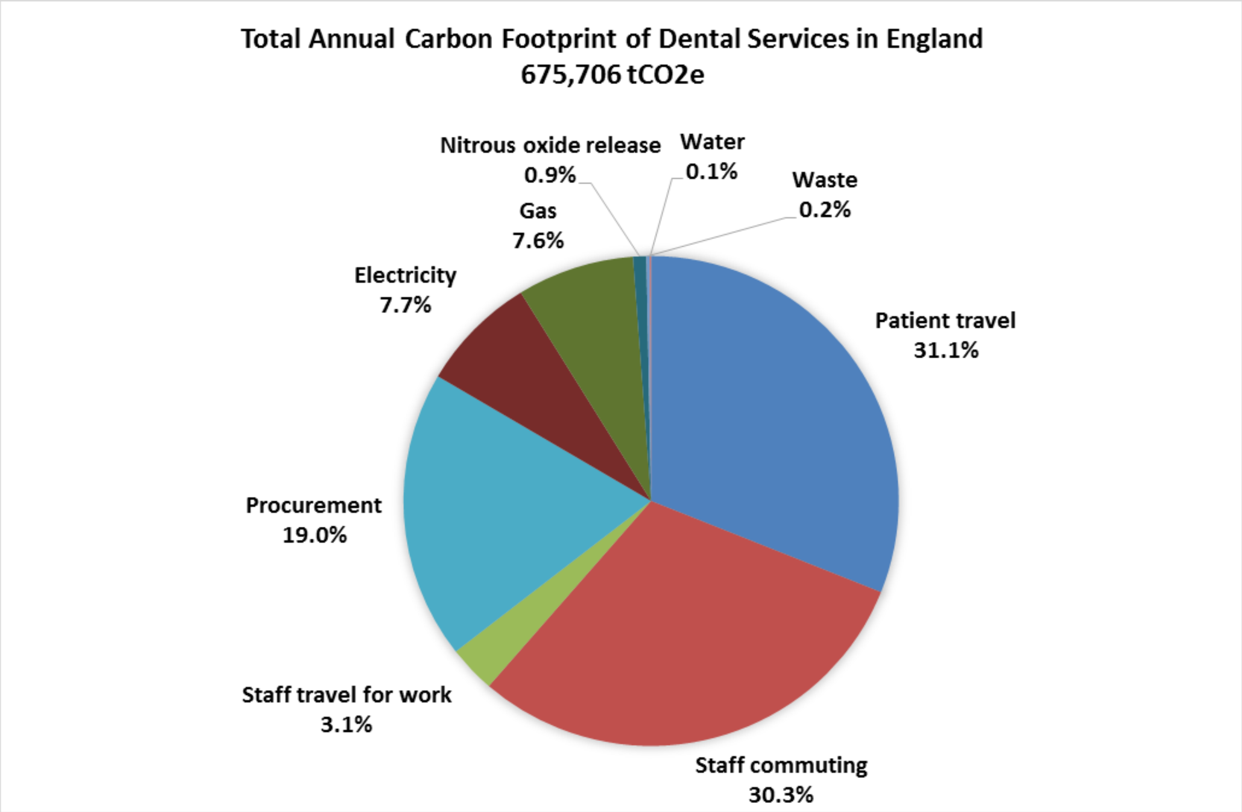
Table 5 shows the overall carbon footprint of NHS dental services in England in 2013/14. The total greenhouse gas emissions measured in tCO2e are 675,706. This is 3% of the overall carbon footprint of the NHS in England (22.8MtCO2e, published 2015)[45]. The highest proportion of these emissions is caused by travel, followed by procurement, energy, nitrous oxide use, waste and water.

Table 5: Total annual carbon footprint of dental services in England – 2013/14

	kg CO2e/yr	**t CO2e/yr**	**% of tCO2e**
Patient travel	209,937,971	209,938	31.07%
Staff travel commuting to and from work	204,709,438	204,709	30.30%
Staff travel for work	20,922,417	20,922	3.10%
Procurement	128,639,228	128,639	19.04%
Energy			
Electricity	51,939,330	51,939	7.69%
Gas	51,649,000	51,649	7.64%
Nitrous oxide release	5,828,647	5,829	0.86%
Waste	1,493,128	1,493	0.22%
Water	586,542	587	0.09%
Total	**675,705,701**	**675,706**	100%

NB. Given data limitations, although results are listed to 2 decimal points, caution is needed with interpretation.

Figure 7: Total annual carbon footprint of dental services in England – 2013/14



Carbon footprint per category

Patient travel

With approximately 209,938 tCO_2e, patient travel makes up the highest proportion (31.1%) of the total carbon emissions of NHS dental services in England.

In 2013/14, 25.89 million people in England visited NHS dentists and received 39.78 million CoTs. Each of the CoTs requires on average 1.58 visits/return journeys, (see Appendix 2) meaning patients in England made 62.95 million return journeys to their NHS dentists. On average, patients travel 7.57 miles to and from their dentist emitting 3.33$kgCO_2e$ per return journey. As a comparison, patients in Fife (Scotland) travel a very similar distance to and from their dental practice, ie an average of 7.26 miles.

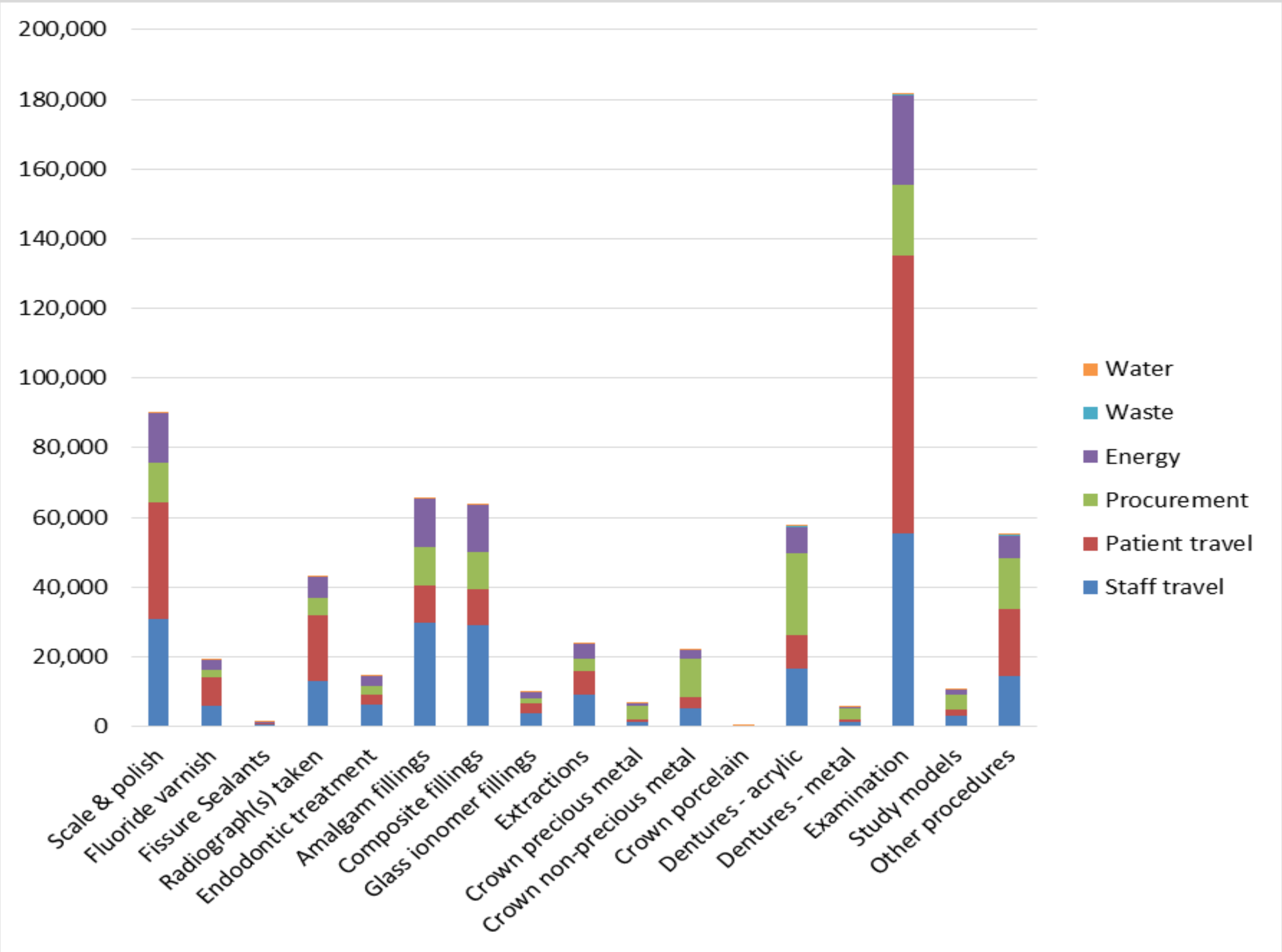
There is a slight caveat to the way the distance dental patient travel to their practice was measured. Both in this calculation and in the Fife study, the distance was calculated between the patients' home address and the dentist's contract location. If the dentist's contract location differed from the actual treatment location, or if the patient did not start their journey at their home, the distance measured will be inaccurate and could be slightly under- or overestimated.

The carbon footprint was based on the activity of NHS dentists. Although some consumer surveys report that it is difficult to register/see an NHS high street dentist[46] and could explain the relatively long distance travelled to see a dentist, there is contradictory evidence.

Looking at the nature of NHS high street dentistry it is unsurprising that patient travel is responsible for such a high proportion of the overall carbon footprint. According to HSCIC the majority of dental treatments consist of procedures which take very little time and have very few material costs. Band 1 procedures, for example, scale and polish, fluoride varnish, radiographs taken and examinations make up 73% of all procedures for adults and children. Forty one and a half percent of procedures for adults and children are examinations – and an examination takes around 15 minutes. It uses generic items such as disposable gloves and facemasks for the dentist and the dental nurse, plus hand instruments such as the dental mirror, probe and tweezers. However, there is no need for bespoke materials, such as in the case of fillings, and no laboratory services are required as in the case of crowns.

In the case of Band 2 and 3 treatments, patient travel accounts for a smaller, but still high proportion of the carbon footprint as the treatments usually require 2 to 4 return journeys to complete.

Figure 8: Carbon dioxide equivalents per carbon category and procedure (tCO2e)



Staff travel

The total carbon footprint of dental staff commuting to and from work is 204,709tCO2e. This constitutes 30.3% of the overall carbon footprint of NHS dental services in England, a very high proportion. On average dental staff produce 2.86 tCO2e per person per year while commuting based on the assumption that they work on average 0.82 full time equivalent (FTE) and 71.4% of their work volume is done for the NHS.

The average distance commuted to and from work by NHS dental staff in England was based on the travel survey data of the carbon footprinting study of dental services in Fife. The average one-way distance commuted by dentists in Fife is 27 miles, for dental nurses 17 miles, for hygienists and therapists 26 miles and for dental receptionists 14 miles.

It could be argued the population density is much lower in Scotland than in England and therefore the distance commuted should be adjusted. However, as the distance travelled by dental patients in Fife is similar to the one travelled by patients in England (7.26 vs 7.57 miles per return journey), the same comparison for England v Scotland dental staff travel was assumed.

Adjusting the distance commuted to and from work for the population density reduces the total carbon footprint of NHS dental services in England by 4.3%. However, proportionally, the carbon footprint due to staff commuting would be only 3% less, hence staff travel would still contribute 28% to the total carbon footprint of NHS dental services in England.

Another assumption made when calculating the carbon footprint of staff commuting to and from work concerned the mode of transport. In Fife, apart from one dental nurse, all staff travelled by car. It was assumed that Fife represented the commuting behaviour of dental professionals and therefore that the mode of transport for dental staff in England is also the car. Arguably this might be different for the whole of England. The study area of Fife covers 22 dental practices and its biggest town, Dunfermline, has a population of around 55,000. In England there are 8,422 dental practices, many in urban centres, where the commuting behaviour might differ and a proportion of professionals might opt to commute by walking, cycling, taking public transport or car sharing.

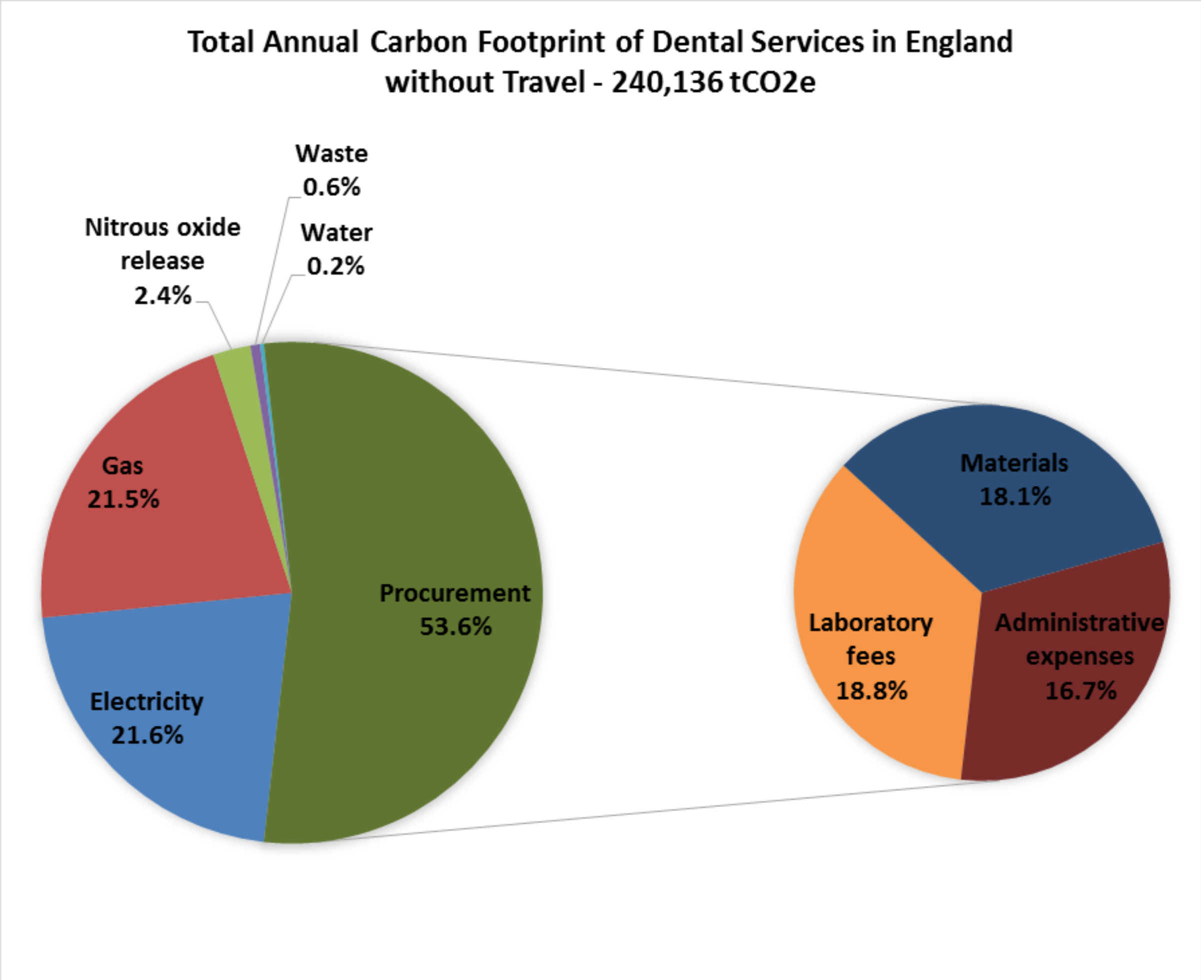
Dentists accept long commuting distances to find an NHS job for a variety of reasons which may impact on their chosen mode of transport.

Procurement

Procurement adds 128,639tCO2e to the carbon footprint of NHS England dental services. Procurement is the second highest contributor to the total greenhouse gas emissions of NHS dentistry, though, at 19%, the carbon footprint attributed to procurement is fairly low compared to the carbon footprint of procurement for the whole of the NHS in England, which is 58%[45]. Dental procurement costs can be split into 3 different costs, ie administrative, material and laboratory service costs. The carbon embedded in these categories makes up 31.2%, 33.8% and 35.1% respectively.

If patient or staff travel was omitted from the total carbon footprint of NHS dental services in England, the picture would change greatly. The greenhouse gas emissions attributed to procurement would contribute 55.1% to the total carbon footprint.

Figure 9: Total annual carbon footprint of dental services without travel



Energy

The annual carbon footprint of NHS dental electricity use is 51,939tCO2e and for gas 51,649tCO2e; 7.7% and 7.6% of the total carbon footprint of NHS dental services in England respectively. These results are based on average electricity and gas use per surgery in Fife extrapolated to all NHS dental surgeries in England.

Though the proportion of the carbon footprint due to electricity and gas consumption does not appear high when compared to the whole of the NHS (where energy use produces 20% of the total NHS greenhouse gas emissions), actual measurements of electricity and gas use obtained from one dental practice in England shows an even lower energy use. Though this practice has 6 surgeries and an oral health education suite, the use of electricity per surgery was slightly more than half of the average electricity used in Fife and a third of the average amount of gas.

If travel would be excluded from the total carbon footprint, electricity and gas would be responsible for 21.6% and 21.5% of the greenhouse gas emissions associated with NHS dental services in England.

Nitrous oxide

According to the number of sedations used in Scotland, 0.21% of patients received nitrous oxide in 2014. Assuming the same proportion receive sedation in England, 63,749 dental patients in England will have been given nitrous oxide in 2014. Each patient will have received on average 163 litres N2O per episode which is equivalent to 0.3068kgN2O and has the global warming potential of 91.43 kgCO2e.

This means that the nitrous oxide release during the sedation of 63,749 patients produced 5,829 tCO2e or 0.9% of the total carbon footprint of NHS dental services in England and 1.3% of the total nitrous oxide use of NHS England.[c]

Though the impact of nitrous oxide seems low, if it is considered that the anaesthetic gas use for the whole of the NHS in England contributes 2.5% to the total carbon footprint of the NHS, and 5% to the carbon footprint of acute organisations[47], the nitrous oxide release contribution of 0.9% to the dental carbon footprint looks more significant.

Furthermore, if nitrous oxide is added to any of the dental procedures it makes up a big part of the procedure's carbon footprint (see Nitrous oxide)

Waste

The carbon emissions embedded in the disposal of all waste streams is approximately 1,493tCO2e, which is 0.22% of the overall carbon footprint of NHS dental services in England. The waste stream with the highest contribution to the greenhouse gas emissions of dental waste disposal is domestic waste at 90.3%. This is due to the fact that the volume of domestic waste compared to the other waste streams is the biggest and the carbon conversion factor for domestic waste disposed of at landfill is also the highest. Clinical waste makes up 6.4%, amalgam waste 0.8% and recycling cardboard 2.5% of the carbon footprint of waste disposal.

The carbon impact of amalgam waste disposal might have been underestimated as there is no specific greenhouse gas emissions factor for this waste. The conversion factor for open loop recycling of batteries as a proxy was applied. However, the amount of amalgam waste compared to the other waste streams is very low and therefore the contribution to the greenhouse gas emissions embedded in waste disposal are expected to be low.

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[c]This figure does not include the embedded carbon of producing the nitrous oxide, the oxygen, which is also required during the sedation, nor the rental of the cylinders as this will be part of the greenhouse gas emissions embedded in procurement.

It is likely that the greatest environmental impact of amalgam is not its greenhouse gas emissions caused by its production and disposal, but its toxicity. There have been great concerns that amalgam fillings, because of their mercury content, can affect patients' health. Numerous studies have looked into the impact of amalgam fillings on, for example, Alzheimer's, Parkinson's and kidney diseases; to date, no causal link has been found.[48] However, the disposal of amalgam and its mercury content, if not done carefully, can have an impact on the environment. The United Nations Environmental Programme's (UNEP) Minamata Convention was formally signed in 2013 to regulate and reduce all man-made sources of mercury including amalgam. For dentists this could mean a gradual phasing out of amalgam fillings where appropriate.[49]

As far as could be ascertained, amalgam waste is currently collected from dentists by healthcare waste management companies. Information from one company was obtained that it sends the amalgam waste to Germany for recycling. The mercury can be separated from the rest of the amalgam through vacuothermal distillation. At the present time, there is insufficient information on whether this is the standard procedure of disposing and recycling of amalgam for all healthcare waste management companies.

There is also the possibility that the greenhouse gas emissions attributable to clinical dental waste have been underestimated. Defra's carbon conversion factor for combustion of municipal, industrial and commercial waste 'only' includes transport of the waste to the incineration facility. The carbon emissions produced by the incineration facility to generate electricity is attributed to the incineration/electricity generation plant.

In the Fife study higher conversion factors for clinical and special waste were used, 1.8kg/kg and 3.8 kg/kg respectively. If the carbon footprint based on the weight of waste streams collected for the Fife data of a) using Defra's conversion factor is compared with b) using the higher conversion factors, the carbon footprint due to waste would increase 3.7-fold. Yet, the greenhouse gas emissions caused by waste would still make up only 0.9% of the total carbon footprint of NHS dental services in England.

The origins of the higher conversion factors for clinical and amalgam waste could not be traced. It is assumed that the higher greenhouse gas emissions factor of clinical waste is based on the assumption that the incineration is not used for electricity generation, so the greenhouse gases released during the incineration process have been allocated to the waste disposal.

Water

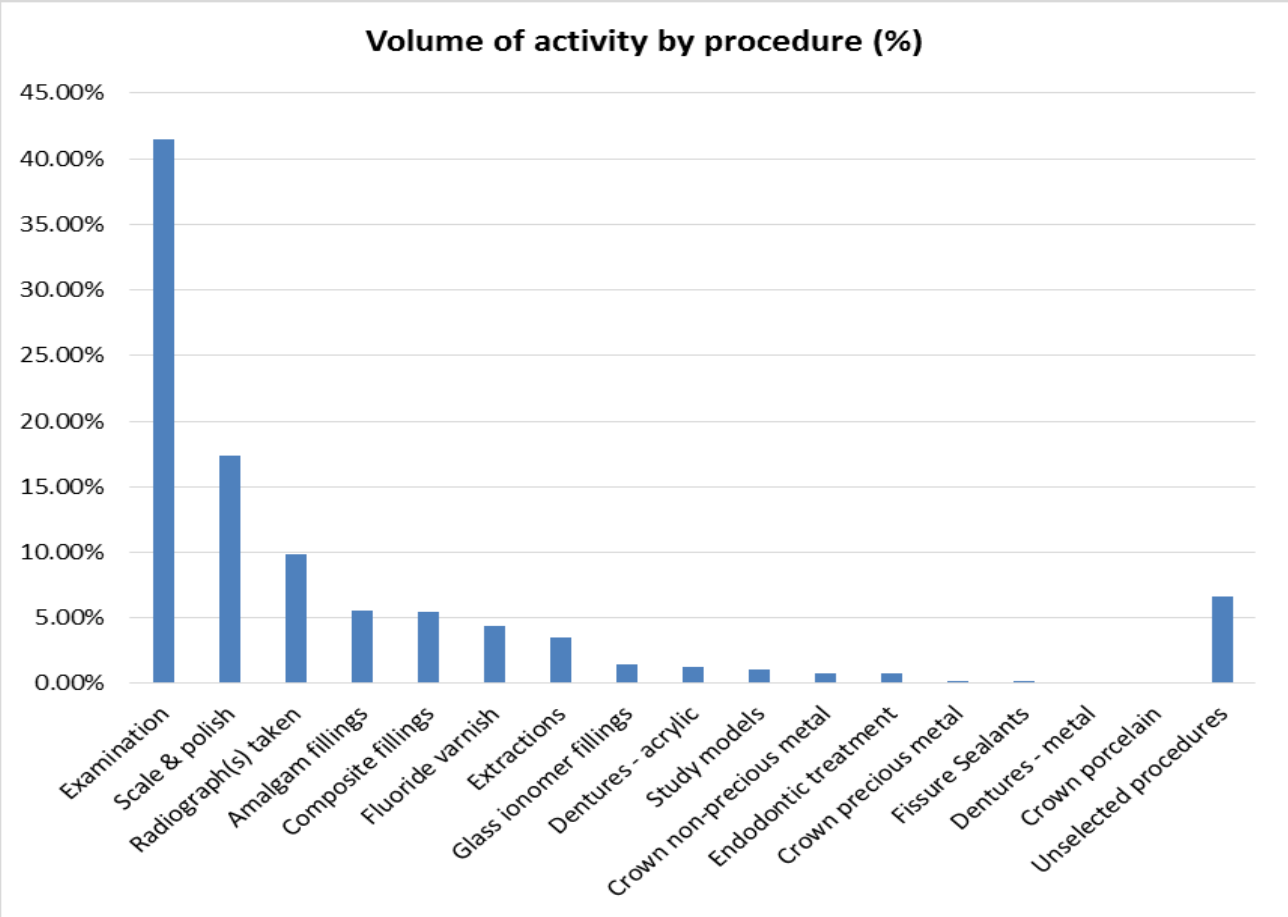
The carbon footprint due to water use is 587tCO2e. This is based on the annual water consumption of only 2 practices, one in Fife and one in England. Their water use per year is 41.50m^3/surgery and 24.33m^3/surgery respectively which gives an average of 32.92m^3/surgery per year. The proportion of the carbon footprint of water use is only 0.09% of the overall carbon footprint.

Carbon footprint per procedure

Volume of activity

The dental procedure with the highest volume of activity is the examination. Forty one percent of procedures are examinations. This is followed by scale and polish with an activity volume of 17.3%, 9.8% of procedures are radiographs and, approximately, 5.5% are amalgam and composite fillings. Four percent of procedures are fluoride varnish, 3% extractions, around 1% are glass ionomer fillings, acrylic dentures and study models. Fissure sealants, endodontic treatment, crowns and metal dentures make up less than 1% of procedures (see Figure 10 'Volume of activity' and Table 6).

Figure 10: Volume of activity by procedure (%)



Carbon footprint of 17 procedures of NHS dental services in England

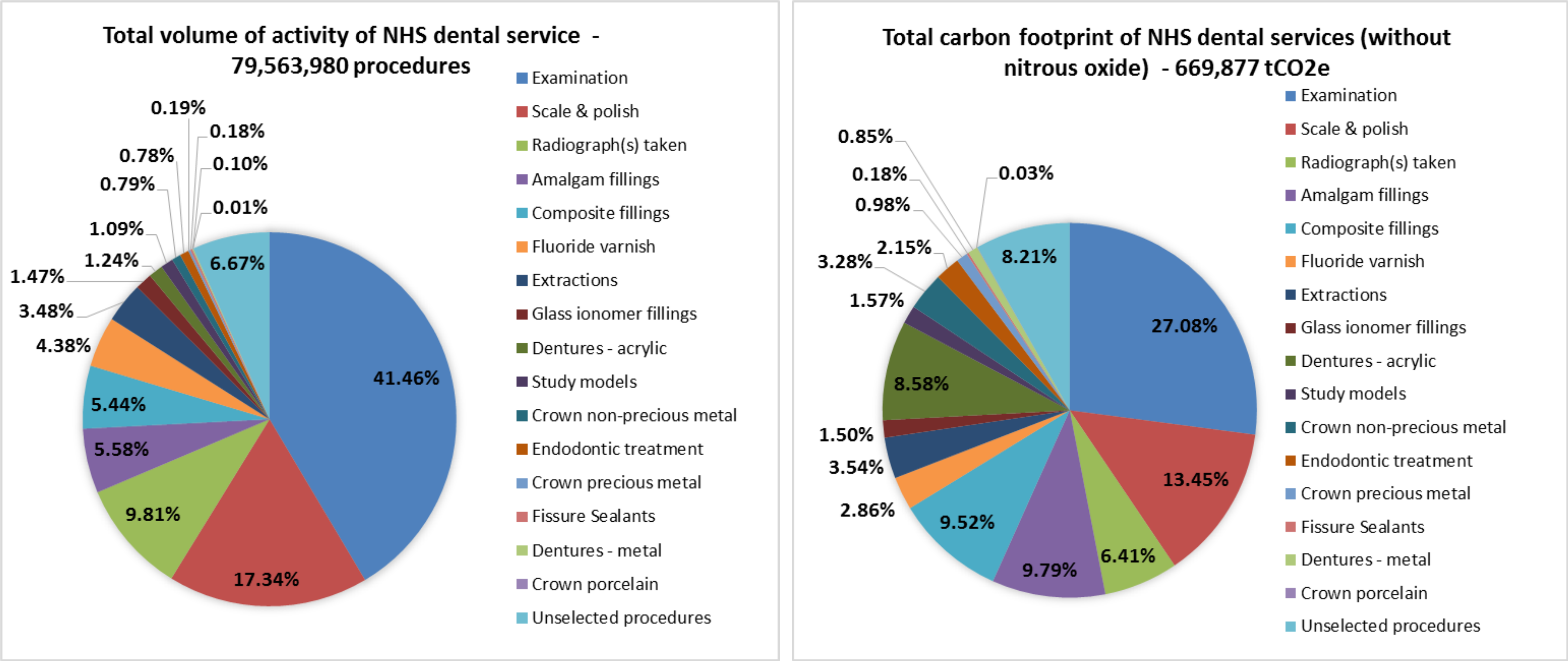
With 27.1% of the carbon footprint, examinations contribute the highest proportion to the overall carbon footprint of dental services in England, followed by scale and polish with 13.4%, amalgam and composite fillings with 9.7% and 9.5% respectively, dentures acrylic with 8.6% and radiographs taken with 6.4% (see Table 6). Extractions contribute 3.5%, crowns non-precious metal 3.3%, fluoride varnish 2.9% and endodontic treatment 2.1% to the total carbon footprint. 1.6% of the greenhouse gas emissions are associated with study models and 1.5% with glass ionomer fillings. Precious metal crowns, metal dentures, fissure sealants and porcelain crowns contribute less than 1% to the carbon dioxide equivalents of dental procedures.

Table 6: Volume of dental activity, total and individual carbon footprints per procedure

Procedure	No of courses of treatment (CoTs) with	Volume of activity (%)	Total carbon footprint (kgCO2e)	Proportion of total carbon footprint of dental services (%)	Carbon footprint per individual procedure (kgCO2e)	Carbon footprint per individual procedure with N2O (kgCO2e)
Examination	32,985,244	41.46%	181,432,761	27.08%	5.50	39.79
Scale and polish	13,798,989	17.34%	90,086,135	13.45%	6.53	52.24
Radiograph(s) taken	7,804,931	9.81%	42,930,414	6.41%	5.50	39.79
Amalgam fillings	4,443,128	5.58%	65,559,951	9.79%	14.76	151.90
Composite fillings	4,324,523	5.44%	63,798,628	9.52%	14.75	151.90
Fluoride varnish	3,481,699	4.38%	19,150,814	2.86%	5.50	39.79
Extractions	2,765,962	3.48%	23,744,493	3.54%	8.58	77.16
Glass ionomer fillings	1,169,608	1.47%	10,040,538	1.50%	8.58	77.16
Dentures - acrylic	988,458	1.24%	57,489,271	8.58%	58.16	401.03
Study models	871,032	1.09%	10,544,760	1.57%	12.11	80.68
Crown non-precious metal	625,399	0.79%	21,995,170	3.28%	35.17	206.60
Endodontic treatment	617,041	0.78%	14,400,064	2.15%	23.34	229.06
Crown precious metal	150,200	0.19%	6,580,747	0.98%	43.81	215.25
Fissure sealants	142,133	0.18%	1,220,145	0.18%	8.58	77.16
Dentures - metal	81,134	0.10%	5,721,890	0.85%	70.52	413.39
Crown porcelain	5,917	0.01%	216,836	0.03%	36.64	208.08
Nitrous oxide	63,749		5,828,647		119.00	
Unselected procedures	5,308,581	6.67%	54,964,438	8.21%		

NB. Given data limitations, although results are listed to 2 decimal points, caution is needed with interpretation.

Figure 11: Comparison of volume of activity and carbon footprint of 16 selected dental procedures



The 4 procedures which have the highest volume of activity are also among the 5 highest contributors to the carbon footprint of England's NHS dental services. Depending on the type of procedure, the contribution to the footprint might be less than the volume of activity – for example, examinations contribute 41% to the total volume of activity, but only 27% to the carbon footprint - or higher than the volume of activity such as in the case of fillings, crowns and dentures. The 2 pie diagrams in Figure 11 reflect the difference in proportions.

Carbon footprint of individual procedures

The picture changes again if the carbon footprint of individual treatments are compared. For example, comparing the carbon footprint of one examination, 5.5kgCO2e, to the carbon footprint of one tooth restoration with an amalgam filling, 14.8kgCO2e (see Table 6).

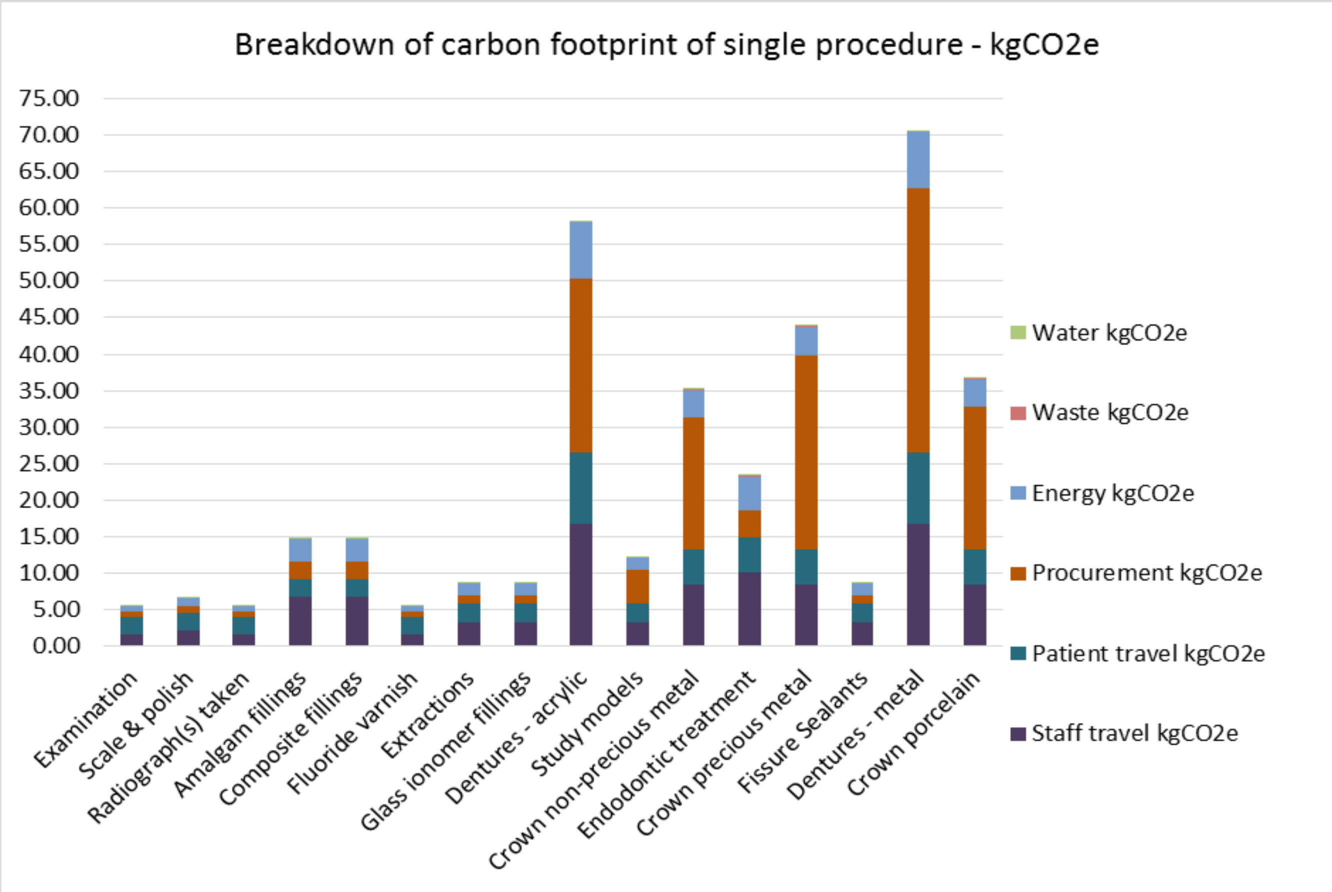
Whereas the total number of all examinations provided by NHS dental services in England contribute 27% to the overall carbon footprint of dental services in England, one examination - also one radiograph and one fluoride varnish treatment - has the lowest carbon footprint compared to the rest of the procedures, ie 5.5kgCO2e. A scale and polish has the second lowest carbon footprint with 6.5kgCO2e, followed by extractions, tooth restoration with glass ionomer fillings and fissure sealants with 8.6kgCO2e. Study models embed 12.1kgCO2e and tooth restoration with amalgam and composite fillings 14.8kgCO2e. Dentures have the largest greenhouse gas emissions embedded – 70.5kgCO2 for metal dentures and 58.2kgCO2e for acrylic dentures. The carbon footprint of crowns is between 35-44kgCO2e depending on the type of crown. Endodontic treatment is responsible for 23.3kgCO2e.

Examination

Thirty 3 million CoTs include examinations, ie 41.5% of all procedures. The carbon emissions embedded in dental examinations are 181,432tCO2e which is equivalent to 27.1% of the overall carbon emissions of dental services in England. A high proportion of the greenhouse gas emissions associated with dental examinations is due to patient and staff travel, ie 43.9% and 30.5% respectively. Energy use for examinations contributes 14% to the carbon footprint and 11.3% is embedded in procurement. Waste constitutes 0.2% and water 0.1% of the greenhouse gas emissions.

The carbon footprint per individual examination is 5.5kgCO2e, the smallest amongst the studied procedures. This is possibly due to the fact that only a small number of resources are used during an examination, mainly generic materials and reusable hand instruments and only few items of dental equipment, for example, dental light and autoclave.

Figure 12: Breakdown of carbon footprint of single procedures into categories



Scale and polish

In 2013/14 21% of all CoTs or 13.8mio CoTs included scale and polish; this made up 17.3% of all procedures. Thirteen percent of the total carbon footprint of NHS dental services can be attributed to scale and polish, which equals 90,086tCO2e.

Thirty 7 percent of the carbon footprint of scale and polish is due to patient travel and 34.3% to staff travel. Energy makes up 15.7% of the footprint and procurement 12.7%. Waste and water constitutes less than 1% of the greenhouse gas emissions of this procedure.

The carbon footprint per individual scale and polish is 6.53kgCO2e. This is slightly higher than the carbon footprint of examinations as the scale and polish procedure takes more time than an examination and involves more resources, eg an electric scaling tool and prophylactic paste.

Radiographs taken

In 2013/14, 7.8million CoTs included the taking of radiographs - which is 9.8% of the total volume of activity of NHS dental services. Altogether 14.1 million radiographs were taken. Radiographs contributed 42,930tCO2e to the carbon footprint of NHS dental services which equals 6.4% of the total greenhouse gas emissions.

Staff travel makes up 30.5%, patient travel 43.9%, energy 14%, procurement 11.3%, waste 0.2% and water 0.08% of the carbon footprint of dental radiographs. The carbon footprint of one dental visit during which radiographs are taken is 5.5kgCO2e.

Fillings

Amalgam fillings

Amalgam is still the most frequently used material for fillings. In 2013/14, 4.4million CoTs included the restoration of teeth with amalgam fillings, which is 5.6% of the total dental volume of activity.

Amalgam contributes 9.8% to the carbon footprint of NHS dental services, ie 65,560tCO2e. A restoration with amalgam (which on average covers 1.4 teeth), has a carbon footprint of 14.8kg CO2e. The carbon footprint is 45.5% due to staff travel, 16.4% to patient travel, 16.8% to procurement, 20.9% to energy, 0.3% to waste and 0.1% to water.

Composite fillings

With 4.3million CoTs including composite fillings, they are the second most frequently used type of fillings. Restoring teeth with composite fillings make up 5.4% of NHS dentists' volume of activity in England and 9.5% of the overall NHS dental carbon footprint, ie 63,799tCO2e.

On average, during CoTs with composite fillings, 1.6 teeth are restored. The individual carbon footprint of the procedure is 14.75kgCO2, the same as restoring teeth with an amalgam filling. 45.5% greenhouse gas emissions are associated with staff travel, 16.4% with patient travel, 16.8% with procurement, 20.9% with energy, 0.3% with waste and 0.1% with water.

Our hybrid carbon footprint methodology does not allow us to differentiate between the 2 fillings sufficiently to pick up different carbon impacts of different dental materials used and any differences in use of dental equipment.

It is likely that the carbon footprint due to procurement is slightly higher for amalgam fillings than that of composite fillings as there are more greenhouse gas emissions embedded in the components of an amalgam filling per pound spent than of a composite filling (though this might be balanced out by the fact that there are more bespoke dental materials needed when restoring a tooth with a composite filling than an amalgam filling - see Table 7).

Table 7: Dental materials used for tooth restoration with amalgam and composites

Dental materials	Amalgam fillings	Composite fillings
Dental materials	Lignocaine, glass ionomer, capsule of amalgam, amalgam carrier	Lignocaine, glass ionomer, phosphoric acid, microbrush, adhesive hema, adhesive, capsule of composite

Looking at waste, it can be assumed that the carbon footprint due to waste will be higher for amalgam as amalgam, owing to its mercury content, needs to be disposed of as special waste.

Amalgam waste occurs in 3 areas during the restoration of a tooth.[50] A surplus of amalgam in the capsule and a carved surplus creates major amalgam particles which are collected for recycling. Minor amalgam particles, which occur during carving, burnishing and polishing, are sucked up and transported by a vacuum system. An amalgam separation unit collects the sediment which is sent off for special waste recycling.[51] Major amalgam particles also occur when removing an old amalgam filling and are absorbed by the vacuum system.

Though the carbon footprint of amalgam waste was estimated and solely attributed to the procedure of restoring teeth with amalgam fillings, the carbon footprint of amalgam disposal was very small compared to the other greenhouse gas emissions associated with the procedure. Hence, its influence on the total carbon footprint is very small.

However, as there is no carbon conversion factor for amalgam currently available, the carbon conversion factor for the recycling of batteries was applied based on the assumption that the greenhouse gas emissions factor for recycling batteries is similar to the greenhouse gas emissions factor of recycling amalgam. As the recycling process for batteries varies depending on the battery's materials and is different to the recycling process of amalgam, the carbon footprint of amalgam disposal may have been underestimated.

As mentioned above, the carbon footprint is not the only consideration when using amalgam. Its environmental toxicity is of greater concern.

Glass ionomer fillings

There are only 1.2million CoTs which include glass ionomer fillings. This makes up 1.5% of NHS dentists' volume of activity in England.

The total carbon footprint of glass ionomer fillings is 10,040tCO_2e, contributing 1.5% to the total carbon footprint of NHS dental service in England.

A restoration with a glass ionomer filling (which on average, includes the restoration of 1.7 teeth), has a carbon footprint of 8.6kg CO_2e. The greenhouse gas emissions are due

39.1% to staff travel, 28.2% to patients travel,14.5% to procurement, 17.9% to energy, 0.3 % to waste and 0.1 % to water.

Fluoride varnish

There are 3.5 million CoTs which include fluoride varnish, of which 78% are given to children. Applying the varnish takes up 4.4% volume of activity of NHS dental services in England – 15.1% of children’s treatments and 1.2% of adult procedures. The procedure contributes 2.9% to its total carbon footprint, 19,150tCO2e.

Staff travel contribute 30.5%, patient travel 43.9%, procurement 11.3%, energy 14%, waste 0.2% and water 0.1% to the procedure’s greenhouse gas emissions.

Protecting one patient’s teeth with fluoride varnish is estimated to have a carbon footprint of 5.5kgCO2e.

Fissure sealants

Only 142,133 CoTs include fissure sealants, which is around 0.2% volume of activity of NHS dental services in England. The carbon footprint of fissure sealants is 1,220tCO2e, 0.2% of the total NHS dental greenhouse gas emissions.

Staff travel contributes 39.1%, patient travel 28.2%, procurement 14.5%, energy 17.9%, waste 0.3% and water 0.1% to the greenhouse gas emission of the procedure.

When teeth are protected with fissure sealants on average 2.3 teeth are treated. The carbon footprint of the treatment is 8.6kgCO2e.

Extractions

Only 3.5% of dental procedures are tooth extractions; 2.8 million CoTs include the procedure. The carbon footprint due to tooth removal is 23,744tCO2e which is 3.5% of the overall carbon footprint.

39.1% of the carbon footprint of extractions is due to staff travel, 28.2% is patient travel; procurement contributes 14.5% and energy 17.9% to the carbon emissions. Waste and water make up 0.3% and 0.1% of the carbon footprint of extractions respectively.

The carbon footprint of a tooth extraction is 8.6kgCO2e. This is higher than for examinations and scale and polish due to the longer duration of the procedure.

Crowns

Crowns - non-precious

Though non-precious metal crowns are the most frequently used crowns, only 625,399 CoTs include them, making up 0.8% volume of activity of NHS dentists in England. The total carbon footprint of non-precious crowns is 21,995tCO2e, which is 3.3% of the total NHS dental carbon footprint in England.

Of the greenhouse gas emissions for this procedure, 23.9% is due to staff travel, 13.7% to patient travel, 51.2% to procurement, 11% to energy, 0.2% to waste and 0.1% to water.

The individual carbon footprint of fitting a non-precious metal crown is 35.2kgCO2e.

Crowns - precious metal

There are only 150,200 CoTs which include crowns made of precious metal. This covers 0.2% volume of activity of NHS dentists in England and contributes a carbon footprint of 6,581tCO2e which is 1% of the total greenhouse gas emissions of NHS dental services in England.

Staff travel contributes 19.1%, patient travel 11%, procurement 60.9%, energy 8.8%, waste 0.1% and water 0.1% to the carbon footprint of fitting a precious metal crown.

The individual carbon footprint of fitting a precious metal crown is 43.81kgCO2e.

Crowns - porcelain

Porcelain crowns are very rarely fitted. Only 5,917 CoTs include porcelain crowns. This is equivalent to 0.01% volume of activity. The total carbon footprint of fitting porcelain crowns is 217tCO2e, which adds 0.03% to the total carbon footprint of NHS dental services.

Staff travel makes up 22.9%, patient travel 13.2%, procurement 53.2%, energy 10.5%, waste 0.2% and water 0.1%.

The greenhouse gas emissions associated with fitting a porcelain crown are 36.64kgCO2e.

According to Scottish data 2013/14 different crowns have different claim values. As expected, precious metal crowns have the highest claim value at £125, followed by porcelain crowns at £85 and non-precious metal crowns £84. The carbon footprint associated with laboratory services was allocated according to the claim value of the procedure since this best reflected the embedded greenhouse gas emissions of the laboratory services. As a result, the carbon footprint of fitting a precious metal crown is highest, followed by porcelain crowns then non-precious metal crowns.

In England, NHS dentists claim for their dental service in Bands. Fitting a crown falls into Band 3 irrespective of what type of material the crown is made out of. It appears there may, therefore, be very little incentive for the dentist to fit a more costly crown as he/she will not be able to claim a higher fee.

It seems fitting non-precious metal crowns is also better for the environment as they have a lower carbon footprint. However, it has to be balanced with the lifetime of a crown which can be assumed higher when it is made out of precious metal as the material is stronger.

Study models

There are 871,032 CoTs which include study models. This equals 1.1% of the NHS dental volume of activity. The carbon footprint associated with study models is 10,545tCO_2e. This constitutes 1.6% of the total greenhouse gas emissions of NHS dental services in England.

Staff travel is associated with 27.7% of a study model's carbon footprint, patient travel with 20%, procurement with 39.4%, energy with 12.7%, waste with 0.2% and water with 0.1%. Using a study model has a carbon footprint of 12.1kg CO_2e.

Endodontic treatment (root canal)

617,041 CoTs include endodontic treatment, 0.8% of volume of activity. The greenhouse gas emissions embedded in root canal treatment are 14,400tCO_2e which is 2.2% of the total carbon footprint of NHS dental services.

Staff travel constitutes 43.1%, patient travel 20.7%, procurement 16%, energy 19.8%, waste 0.3% and water 0.1% of the greenhouse gas emissions.

The carbon footprint of an endodontic treatment is 23.34kgCO_2e.

Endodontic treatment is a secondary preventative procedure to avoid tooth extraction. It is interesting to note that there are 4.5 times more CoTs with extractions than with root canal treatments, 2.8 million extractions compared to 617,041 root canal treatments. At first glance this would look favourable for the dental carbon footprint as an extraction is only associated with 8.4kgCO_2e whereas a root canal involves 22.8kgCO_2e. However, as 80% of extractions are carried out on adults, it is likely that the procedure will be finished with a denture or an implant. The carbon footprint of an implant was not available, but an acrylic denture (the most common) is estimated to produce 58.2kgCO_2e which is more than double the amount of conducting an endodontic treatment.

Dentures

Dentures: acrylic

Acrylic dentures are the most common dentures. 988,458 CoTs in England include acrylic dentures. These make up 1.2% of all NHS dental procedures and have a footprint of 57,489tCO_2e. This equals 8.6% of the total greenhouse gas emissions of NHS dental service in England.

28.8% of the greenhouse gas emissions are caused by staff travel, 16.6% by patient travel, 41% by procurement, 13% by energy, 0.2% by waste and 0.1% by water.

The procedure of fitting a patient with acrylic dentures has a carbon footprint of 58.16kg CO_2e. Of the 16 procedures considered in the study, this has the second highest carbon footprint.

Dentures: metal

Metal dentures are included in 81,134 CoTs; 0.1% of the volume of activity of NHS dental services in England. They make up 8% of all dentures. The total carbon footprint of metal dentures is 5,722tCO2e which equals 0.9% of the total dental greenhouse gas emissions of NHS England.

Of the carbon emissions embedded in metal dentures, 23.8% are due to staff travel, 13.7% patient travel, 51.4% procurement, 10.9% energy, 0.2% to waste and 0.1% to water.

Fitting metal dentures for a patient has an individual carbon footprint of 70.52kgCO2e. This is the highest carbon footprint of all 16 dental procedures considered.

Acrylic and metal dentures have a high carbon footprint due to the fact that fitting dentures require 4 patient visits and one of the highest amounts of dental materials. Metal dentures are more expensive than acrylic ones. As the greenhouse gas emissions embedded in procurement are measured per pound spent and a generic carbon conversion factor was used for laboratory services, the carbon footprint of metal dentures is higher than that of acrylic dentures.

Nitrous oxide

As explained earlier, nitrous oxide is a gas which is used in sedation and pain relief by some dentists in addition to local anaesthetics. It is not a procedure in its own right as it is only applied to patients who attend for ‘other’ dental treatments.

Table 8 lays out the impact of ‘adding’ nitrous oxide to a procedure.

Although the carbon footprint of nitrous oxide release for the whole of NHS dental services in England is under 1% of the total carbon footprint, using N2O for a procedure can make up 80 to 90% of that procedure’s carbon footprint and add between 34.3kgCO2e, at the lowest end, and up to 342.9kgCO2e at the highest end to a procedure’s carbon footprint. Through the use of nitrous oxide the carbon footprint of a procedure increases between 4.7- and 9.5-fold. This is a very significant rise for one individual treatment.

Table 8: Impact of nitrous oxide on the carbon footprint of a treatment

	Carbon footprint for single procedure without nitrous oxide (kgCO2e)	CO2e of nitrous oxide for a single procedure - 2.2858kgCO2e/min	Carbon footprint for single procedure with nitrous oxide (kgCO2e)	Proportion of carbon footprint which is nitrous oxide
Examination	5.50	34.29	39.79	86.18%
Scale and polish	6.53	45.72	52.24	87.50%
Radiograph(s) taken	5.50	34.29	39.79	86.18%
Amalgam fillings	14.76	137.15	151.90	90.29%
Composite fillings	14.75	137.15	151.90	90.29%

Fluoride varnish	5.50	34.29	39.79	86.18%
Extractions	8.58	68.57	77.16	88.87%
Glass ionomer fillings	8.58	68.57	77.16	88.87%
Dentures - acrylic	58.16	342.87	401.03	85.50%
Study models	12.11	68.57	80.68	84.99%
Crown non-precious metal	35.17	171.43	206.60	82.98%
Endodontic treatment	23.34	205.72	229.06	89.81%
Crown precious metal	43.81	171.43	215.25	79.65%
Fissure sealants	8.58	68.57	77.16	88.87%
Dentures - metal	70.52	342.87	413.39	82.94%
Crown porcelain	36.64	171.43	208.08	82.39%

NB. Given data limitations, although results are listed to 2 decimal points, caution is needed with interpretation.

Alternatives to nitrous oxide

Alternatives in current use are local anaesthetic alone, intravenous sedation or general anaesthetic. However, both intravenous sedation and general anaesthetic are seen as more risky and intravenous sedation can only be given to patients aged 12 years and older.

An alternative to releasing the gas into the air is to capture it and neutralise it. There are several technologies which can be used to extract gases from released air, such as ‘scrubbing’ which is widely used at an industrial scale, but is implemented also in hospitals.[52]

Conclusions and suggestions for improvements

Sustainability is not just about carbon reduction, but about delivering high quality care within economic, social and environmental limits.

The historic “curative” paradigm of dental care delivery illustrated by the “drill and fill” concept is now being replaced by an upstream and preventative approach to promote oral health. The former reinforces the medical model and diminishes individual responsibility for health; the latter is believed to be a much more sustainable health model.

According to the Lancet, climate change is the biggest global health threat of the 21st century.[53] The General Dental Council “Standards for the Dental Team” does not mention sustainability specifically, but it does state that all members of the dental team should act with integrity, take a holistic approach to patient care and work with colleagues in a way that is in a patient's best interests.[54] As a dental team, our core business is oral health but it could also be argued that like our medical colleagues "*we have a moral duty to act on health threats, to manage long term strategic risk and to mitigate future demand on the health services*."[55]

The analysis of the carbon footprint of dental services as a whole and of individual dental procedures has helped to identify what produces the largest amounts of greenhouse gas emissions. At this stage of the research the overall carbon footprint is probably more informative than looking at individual procedures for 2 main reasons:

1. The analysis showed that procurement is only 20% of the whole footprint – it is therefore less of a focal point than for the rest of healthcare.
2. For comparison of procedures the detail of carbon is simply not available. A long term strand of work would be required to encourage each industry to measure the footprint of their products using the SDU published guidance on foot printing pharmaceuticals and medical devices.

Dentistry can become more sustainable with a whole system approach. In order, however, to simplify this approach, recommendations under each main element of the carbon footprint (travel, procurement, energy/waste/water) have been further divided into dental professional recommendations, commissioner recommendations (ie NHS England), and those for providers of education, policy and research (HEE England and Public Health).

Dental professionals

General

To start engaging with and improve the sustainability in their practice, dental health professionals can:

1. Ensure their practice is prevention focused and following Delivering Better Oral Health guidance for their patients. Dental teams should ensure advice on sugar and fluorides are given to patients to reduce the need for treatment. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/605266/Delivering_better_oral_health.pdf. Reducing the amount of treatment needed will reduce the quantity of resources needed to treat.
2. Dental practices can integrate sustainability in to business ethos, management and governance. For larger practices and chains this could be through an organisational Sustainable Development Management Plan (following SDU guidance http://www.sduhealth.org.uk/documents/SDMP/SDMP_Guidance_-_March_2014.pdf). For smaller practices this could be by implementing a small business environmental management system, such as Investors in the Environment (http://www.iie.uk.com/) or BS8555. These can be used as evidence in bidding for contracts and be good for CSR.
3. Join the network 'Dental Susnet', hosted by the Centre for Sustainable Healthcare, for blogs, discussions and resources around sustainability in dentistry; available at: http://networks.sustainablehealthcare.org.uk/network/dental-susnet3.
4. Implement the Green Impact Programme of the National Student Union (NSU), an engagement tool for dentists on how to include sustainability in their work; see http://www.green-impact.org.uk/green-impact-students%E2%80%99-unions.
5. Join a local small business low carbon, innovation or resource efficiency network to become more sustainable.
6. Increase understanding of sustainability through accessing training such as the online module on sustainability for the wider dental team; see https://portal.e-lfh.org.uk/Component/Details/424027

Travel

Travel makes up almost two thirds (64%) of the total carbon footprint of dental services in England. Within procedures this contributes to between 30% and 74% greenhouse gas emissions. There are several recommendations to reduce the carbon footprint due to patient and staff travel:

1. Service re-configuration at practice level can be considered:
    a. A review of the way dental appointments are allocated might identify dental visits where procedures can be combined, so for example having all the restorations in one quadrant carried out in one visit where this is possible..

   b. The usefulness of telemedicine within dentistry can be assessed. It may be also possible in some instances for the dental team to offer advice/reassurance over the telephone and reduce unnecessary patient travel. This type of care is currently operating within Dublin in the Oral Medicine Unit. For further details see http://networks.sustainablehealthcare.org.uk/network/dental-susnet

2. Patients and staff of all healthcare services including dental services can be encouraged to switch to active travel, public transport or car sharing:
   a. Cycle friendly policies at work can be adopted, including the provision of secure cycle facilities, showers for employees, the sign up to a bike to work scheme.
   b. Patients usually have to wait at the dentist until they are called in for their appointment. The dental team might consider using waiting rooms and time as an opportunity for the dental practice to inform and engage patients about active travel and the positive impact using exercise to travel can have on people's health and on climate change mitigation.
   c. A travel survey can be carried out with staff and patients. The process in itself offers a good opportunity to engage patients and staff to think about their way of travel and the survey will provide insight into their travel behaviour.
   d. Information can be provided to your patients and staff on how to travel to your practice by active travel or public transport. If possible information on safe cycling and walking routes can be supplied.

Procurement

After travel, procurement is the second highest contributor to the total greenhouse gas emissions of NHS dentistry, adding approximately 130 thousand tonnes CO2e. It makes up 19% of the total carbon footprint of NHS dental services. Dental procurement costs can be split into 3 different costs: administrative costs, material costs and costs of laboratory services. The carbon embedded in these categories makes up 31.2%, 33.8% and 35.1% respectively.

To reduce the greenhouse gas emissions associated with procurement dental practices can:

1. Further review stock control and ordering, to avoid waste due to materials' expiry dates.
2. Research whether there are items for which more sustainable alternatives can be bought, eg recycled paper instead of virgin paper for the office?
3. Include statements on carbon reduction and sustainability in tendering processes with suppliers, especially if they are larger corporates. SDU's 'Procuring for carbon reduction (P4CR)' tool[56] and the European Commission's sustainable procurement guidelines[57] could offer help with the development.

Energy, waste and water

Though energy use, waste disposal and water use make up ‘only’ 15% of the greenhouse gas emissions of dental services in England, it still offers scope for reduction. The variation of energy use of the different practices across the UK demonstrates that energy reduction is possible. Amongst the procedures, energy contributes between 9% and 21% to the total greenhouse gas emissions.

Furthermore, looking at waste disposal, the small sample of dental practices in Fife shows that recycling was still not widely carried out. Likewise, assuming that the waste audit at one English dental practice is representative, some of the domestic waste might unnecessarily be disposed of as clinical waste.

The contribution of water use and treatment to the carbon footprint of dental services is the smallest. However, water is a scarce resource and should be used efficiently.

To reduce the greenhouse gas emissions produced by energy, water use and waste disposal, dental practices can:

1. Review if their practice could use renewable energy, for example, install solar panels, or choose electricity providers who, at least in part, offer electricity produced by renewable sources.
2. Audit the electrical equipment and their use: Is equipment running though not in use? Can this equipment be put on a timer to avoid unnecessary usage?
3. Work with industry to reduce the energy use of dental equipment.
4. Audit heating infrastructure: Is the boiler efficient? Are the radiators heating the rooms optimally?
5. Ensure their practice is well insulated.
6. Develop and implement a waste disposal policy of ‘reduce, reuse, recycle’, making correct waste disposal as easy as possible by, for example, colour coding the different bins and by training all staff, including cleaning staff, in correct waste disposal.
7. Carry out a waste audit to identify the scale of incorrect waste disposal.
8. Ensure all practice products and equipment use water efficiently.
9. Ensure there are no water leaks in the practices.

NHS England: Commissioners of dental services

Travel

To reduce greenhouse gas emissions associated with travel, commissioners of dental services can:

1. Consider travel optimisation when commissioning new dental contracts, trying to ensure services are commissioned as close to patient’s usual travel patterns, ideally working with consultants in dental public health and geographic information system analysts to consider patient travel patterns.

2. Ensure that services are easily accessible via public transport. NHS England should work with Local Authorities and/or local travel providers to support services. Commissioners can also consider the sustainability benefits of co-locating health services.
3. Encourage providers to develop and implement a travel plan promoting active travel, public transport and lift-sharing among staff and patients as part of an overall NHS England sustainability carbon management plan.

Procurement

To reduce the environmental impact of procurement commissioners can:

1. In partnership with dental professionals, encourage industry to work on measuring the carbon emissions of their products.
2. In line with delivering better oral health, ensure that the use of resources are allocated and used most effectively, with dentistry continually moving to a preventative approach.
3. Ensure that dentistry is included in any health system wide plans to agree standards around shadow carbon accounting. Shadow carbon accounting refers to the inclusion of carbon in accounting systems and is to enable granular and easy measurement of carbon with healthcare, or any other, organisations. Once carbon is included in the reporting alongside money, carbon will become much more familiar and valued as a resource, and specific carbon modelling work as a separate exercise will not be required.

Energy, waste and water

To reduce greenhouse gas emissions associated with energy, waste and water, commissioners of dental services can:

1. Encourage practices to follow the principle of reduce, reuse, recycle in respect to waste.

Providers of education, policy and research (ie Health Education England, Public Health England, academic institutions)

General

To improve the sustainability of dental services Health Education England can:

1. As the national body providing expert advice to the government, improve the understanding of health care providers (eg the dental team) in sustainability. This could include further work in understanding change management processes within this sector (ie how can we motivate the dental team to understand, and change their systems).

2. Work with universities to include sustainable healthcare in the training of dental health professionals.
3. Support the development of an e-learning module in sustainable dentistry.
4. Support a scholar/fellowship programme in sustainable dentistry.

Public Health England

To improve the sustainability of dental services Public Health England can:

1. Further and support understanding of how preventative practice in dentistry (eg the use of fluoride varnish, fluoride toothbrushing) influences the carbon footprint of the service.
2. Consider sustainability alongside other metrics when analysing cost-benefit analysis of dental care.
3. Work with its partner organisation NHS England to repeat a national modelling calculation of dental services, in line with the national carbon calculation run by the Sustainable Development Unit.
4. Support NHS England in commissioning sustainable dental services.
5. Support Health Education England to develop tools and resources.
6. Encourage regulators to take account of sustainability eg considerations of including sustainability in “Standards for the Dental Team” (General Dental Council) consideration of including sustainability issues in key lines of enquiry (Care Quality Commission).

Research institutions

To improve the sustainability of dental services research institutions can increase the evidence base by:

1. Carrying out research into standardising carbon modelling methodologies.
2. Carrying out research into how to include carbon emissions into cost benefit analysis of health interventions.
3. Carrying out research in how dental practices can practice dentistry in the most sustainable way.

Dental Industry

To reduce the greenhouse gas emissions associated with procurement dental industry can:

1. Work with academic institutions on a standardised methodology of carbon footprinting dental products.
2. Carry out a comprehensive carbon footprint of all dental products.

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Appendices

Appendix 1: Description of 16 dental procedures

Examination

An examination is a Band 1 treatment. During an examination the dentist carries out a visual check-up of the teeth, gums and skin inside the mouth with the help of the dental light. Dental charting is done which includes the counting of teeth and any restoration work, checking the teeth surface for decay with the help of a dental probe and also examining the gums with a ball ended probe.[58]

Scale and polish

Scale and polish is also a Band 1 treatment. It involves removing plaque and tartar deposits that have built up on the teeth over time. The dental hygienist or dentist uses specialised instruments, an ultrasonic instrument and fine hand tools, to gently remove these deposits without harming the teeth. This is followed by a polish using a slow speed hand piece with a soft rubber cup covered with prophylaxis paste.[59]

Radiographs taken

X-rays are important for diagnosing problems under the tooth surface, around the foundation and in the root canal of the tooth. The x-rays are usually taken by getting the patient to bite on a small tab to steady the x-ray film (which is made of soft plastic) in the mouth. The dentist then focuses the x-ray beam on the outside of the patient’s cheek close to the area where the relevant tooth is. The films of newer digital x-rays are slightly bulkier, however, the dose of radiation is smaller and the x-ray pictures will appear much more quickly on the computer screen.

Fluoride varnish

Applying fluoride varnish twice yearly to children’s teeth is proving to be highly effective in preventing tooth decay in combination with brushing teeth twice daily. Fluoride varnish is a pale yellow fluid which is applied with a soft microbrush to the teeth. The varnish dries very quickly following application.[60]

Extractions

Before extracting a tooth the dentist administers a local anaesthetic to numb the area where the tooth is to be removed. When the local anaesthetic has taken effect the dentist removes the tooth with the help of dental forceps rocking the tooth to and fro. Once the tooth is removed a blood clot starts to form in the tooth socket. The dentist will put a gauze pad into the wound until the blood clot has formed.[61]

Fissure sealants

Fissure sealants can be applied to teeth to seal off pits, grooves and fissures from the rest of the oral environment. As fissures are not easy to clean, sealing the tooth surface protects fissures from bacteria and fermentable foods thus helping prevent decay. Though any tooth with pits and fissures can be treated, the most commonly sealed teeth are molars and premolars. As part of the procedure the tooth is properly cleaned, etched with phosphoric acid, dried, and the sealant (which is a resin-based coating) applied. It then hardens to form a protective coating over the tooth. If looked after well, fissure sealants can last as long as amalgam fillings.[62,63]

Endodontic treatment

Endodontic treatment or root canal treatment eliminates the infection of the pulp of a tooth and protects the decontaminated tooth from future microbial invasion.

Fillings

Bacteria in our mouths produce acid which dissolves the enamel on our teeth and causes holes. These holes have to be filled to prevent further damage to our teeth. The 2 most common filling materials are amalgam and composite resin.

Amalgam fillings

Amalgam fillings are more commonly known as silver or mercury fillings. They are made up of silver, tin, copper, zinc and mercury. When the metals in amalgam are mixed together they form a soft material that can be used to build a tooth back to its original form. After a few minutes, the amalgam begins to harden. Although pure mercury is toxic, the mercury found in amalgam fillings is locked inside when the filling hardens and is therefore not harmful.

Composite fillings

Composite resin fillings are more commonly known as white fillings, tooth-coloured fillings or direct veneers. They are made of tiny pieces of silica surrounded by a plastic resin usually composed of bis-GMA. The composite resin has the consistency of modelling clay. In order for the composite to harden, the dentist shines a bright blue light on it, then, through a series of chemical reactions, the composite resin hardens into a very strong material that looks very much like a natural tooth.

Glass ionomer fillings

Glass ionomer fillings are made of silicate glass powder and polyalcenoic acid. They form a chemical link with the tooth while at the same time releasing fluoride, which helps to prevent further tooth decay.[64] As this type of filling is fairly weak[65], it is not recommended for use on molars unless as a base to an amalgam or composite filling.

Crowns

A crown is a type of cap that completely covers a real tooth. The crown is like a special sleeve made of metal and/or porcelain which is placed over a damaged or weak tooth. The dentist will match it to the shape and, in the case of porcelain crowns, colour of other teeth so it will look natural. The crown will probably last for many years, depending on the health of the tooth underneath and good oral hygiene.

The dentist will shape the tooth so that, with the artificial crown, it will be the same size as a natural tooth. Preparation time will depend on how damaged the tooth is and whether it needs to be built up with a filling. The tooth might have to be root-filled first; this is sometimes called 'removing the nerve'. The crown may need to be held in place by a peg in the root canal if a lot of the natural tooth is missing.

The dentist will use a soft mouldable material to make an exact 'impression' of the tooth to be crowned and the nearby teeth. A dental technician uses this impression to make the crown the exact size needed. A thin cord may be used to hold the gum away from the tooth so that the impression is accurate round the edges.

A temporary crown (made of plastic or metal) is put over the tooth until the permanent crown is made. When the crown is fitted, the dentist will make adjustments to ensure the patient can bite comfortably. The crown is tried on first then glued permanently into place.

Dentures

Dentures are replacements for missing teeth which can be removed. They can be made either of plastic (acrylic dentures) or metal. If all of the patient’s teeth are missing, a complete denture is made. If the patient has some natural teeth remaining a partial denture will be made.

The process of making and fitting dentures takes around 3 to 6 weeks and several appointments. The general steps are:

- The dentist takes several impressions of the patient’s jaw and measurements of how the jaws relate to one another.
- Models and wax forms are created in the exact shape and position of the denture to be made. The patient will "try in" this model several times and the denture will be assessed for colour, shape and fit before the final denture is cast.
- After casting the final dentures, adjustments are made as necessary.

Study models

Study models are used for many reasons, including providing a permanent record of the occlusion of a patient, providing a record of wear patterns, missing teeth, drifting teeth, tooth size, and shape. They are constructed by taking an impression of the patient's teeth in the clinic, then pouring either stone or plaster into the impression to create a solid replica of a patient's mouth.

Nitrous Oxide

Nitrous oxide is used mainly for patients who suffer from dental anxiety. Nitrous oxide (N2O) is a gas which is used by some dentists in addition to local anaesthetic for sedation and pain relief. It is brought to the dental practice in cylinders and administered in combination with oxygen. The nitrous oxide – oxygen mix is given to the patient via a nasal hood or cannula which is put over the patient's nose. For the gas to take effect the patient just has to breathe normally[66].

Appendix 2: How activity is measured and reported in dentistry: courses of treatment

1. In England dental activity is measured by the number of courses of treatment (CoT) delivered and the number of units of dental activity (UDA) this represents. When a patient first goes to the dentist, the dentist determines the amount of preventative/restorative work required. The patient then starts what is known as a CoT. Each CoT, dependent on the complexity of the treatment, represents a given number of units of dental activity. Area teams monitor these units throughout the year to ensure that the activity the local NHS has contracted for is delivered.
2. Information on CoTs completed by an NHS dentist is submitted to the NHS Dental Services on an FP17 form, the majority of which are submitted electronically. It is the information recorded on these forms that can be used to report the NHS activity of NHS dentists.
3. A CoT is defined as: a) an examination of a patient, an assessment of their oral health, and the planning of any treatment to be provided to that patient as a result of that examination and assessment and, b), the provision of any planned treatment (including any treatment planned at a time other than the time of the initial examination) to that patient.
4. Each CoT is associated with a single form (the FP17 form) which is submitted by dental providers to the NHS Dental Services for monitoring and payment purposes. Under previous contractual arrangements each treatment activity was recorded. As of 1 April 2006, a course of treatment is banded according to the most complex treatment within the course. This restricts the comparisons that can be made between contracts.

Appendix 3: Definitions and terminology

In this report the following terminology is used, and is explained here for clarity.

Carbon footprint and carbon dioxide equivalents

The term ‘carbon footprint’ is used to describe the sum of greenhouse gas emissions released in relation to an organisation, product or service, expressed as ‘carbon dioxide equivalents (CO2e)’.

Greenhouse gas emissions and carbon emissions

The term ‘greenhouse gas emissions’ and the term ‘carbon emissions’ have been used interchangeably.

Courses of treatments (CoTs)

Dental activity is measured by the number of courses of treatment (CoT) delivered. When a patient first goes to the dentist, the dentist determines the amount of preventative/restorative work required.[67] A CoT could be a single procedure, eg an examination, or a series of procedures, for example, an examination and a set of fillings. Depending on the procedures planned, a CoT can require more than one patient visit.

Dental practice

The building housing any number of dental surgeries.

Dental procedure and dental treatment

The term ‘dental procedure’ and ‘dental treatment’ was used interchangeably.

Dental staff

The term ‘dental staff’ encompasses dentists, dental nurses, dental technicians, hygienists, therapists and receptionists/secretaries/practice managers.

Dental surgery

The actual workspace of a dental professional, involving one dental chair, light etc. A dental practice with 6 dental chairs, for example, is a practice with 6 dental surgeries.

FTE

Full time equivalent.

Greenhouse gas emissions factors and carbon conversion factors

The factor expresses the greenhouse gas emissions of a product or service in kgCO2e/kg, kgCO2e/kwh or kgCO2e/£. It can include Scope 1, Scope 2 and/or Scope 3 emissions.

The term 'greenhouse gas emissions factor' and 'carbon conversion factor' was used interchangeably encompassing all the different greenhouse gases contributing to global warming.

Performers only

'Performers only' are dentists who work with a provider either as an associate or self-employed.

Provider performer and contract holder

Provider performers are dentists who have a direct contractual relationship with NHS Area Teams. The term 'provider performer' and 'contract holder' was used interchangeably. (In 2013/2014, they made up 18.6% of all dentists.)

Restoration

Filling used to restore the tooth.

Appendix 4: Resource use of 16 dental procedures

Generic materials:	Face mask, disposable gloves, plastic cup, mouth wash, tissue for patients, patient records		
Reusable tools:	Patient glasses, dental mirror, assorted dental probes, dental tweezers		
Procedure	**Human resources**	**Dental equipment**	**Dental bespoke material**
Examination	Staff time: 1 visit, 15 mins	Dental light, steriliser/autoclave	None
Scale and polish	Staff time: 1 visit, 20 mins	Dental light, electric scaling tool, electric suction tool, sterilizer/autoclave	Prophylactic paste
Radiographs taken	Staff time: 1 visit, 5 mins	x-ray machine	Small plastic plate, x-ray film, x-ray developer, x-ray film fixer
Fillings (amalgam and composites)	Staff time: 1 visit, 60 mins	Both fillings: dental light, sterilizer, drill, 3-in-1, suction tool, curing light Amalgam: amalgamator	Both fillings: lignocaine, glass ionomer, cotton wool Amalgam: capsule of amalgam, amalgam carrier Composite: phosphoric acid, microbrush, adhesive hema, adhesive, capsule of composite
Glass ionomer fillings	Staff time: 1 visit, 30 mins	Dental light, drill, 3-in-1 suction tool, sterilizer/autoclave	Polyacrylic acid, microbrush, adhesive, glass ionomer, cotton wool
Fluoride varnish	Staff time: 1 visit, 15 mins	Dental light, suction tool, sterilizer	Fluoride varnish, microbrush, cotton wool
Extractions	Staff time: 1 visit, 30 mins	Dental light, suction, sterilizer/autoclave	Dental forceps, dental elevators, dental chisels, cotton gauze
Dentures (acrylic, metal)	Staff time: 5 visits, 150 mins	Dental light, suction, 3-in-1 washer/dryer, carving, melting wax, curing teeth in hot water, sterilizer/autoclave	Steel or disposable tray, wax, alginate, stone, acrylic tray
Study models	Staff time: 30 mins	Dental light, sterilizer/autoclave	Steel or disposable tray, alginate, stone

Procedure	**Human resources**	**Dental equipment**	**Dental bespoke material**
Crowns (non-precious metals, precious metals and porcelain)	Staff: 2 visits, 75 mins (1 x 60 mins and 1 x 15 mins)	Dental light, drill, suction, 3-in-1 washer and dryer, curing light, sterilizer/ autoclave	All 3 crowns: local anaesthetic, plastic or metal tray, silicone, temporary cement (zinc eugenol), temporary crown acrylic, stone, luting cement Crown: non-precious metal Crown: precious metal Crown: porcelain
Endodontic treatment	Staff time: 2-3 visits, 90mins	Dental light, drill, 3-in-1 washer and dryer, suction, steriliser/autoclave	Local anaesthetic, nickel titanium or steel file, calcium hydroxide cleaning (ledermix), paper points, glue AH26, gutta percha
Fissure sealants	Staff time: 1 visit, 30mins	Dental light, 3-in-1 washer and dryer, curing light, steriliser/autoclave	Pumice for cleaning, phosphoric acid, unfilled resin
Nitrous oxide	Dependent on what procedure it is used for, on average 40mins	Dental light	Oxygen cylinder, nitrous oxide cylinder, mixer tap, monitor

Appendix 5: Average number of dental visits per course of treatment

Dental treatment band	Number of appointments per band	Proportion of care (%)
Band 1	1	56
Band 2	2.5	28.5
Band 3	4	5.3
Urgent	1	9.8
Total		100
Average	**1.5825**	

CoTs in Band 1 require an average of one appointment/patient visit. 56% of all treatments are Band 1 treatments. CoTs in Band 2 require an average of 2.5 appointments. 28.5% of all treatments are Band 2 treatments. In Band 3 a CoT requires an average of 4 patient visits and 5.3% of all treatments are Band 3 treatments. Urgent treatments are carried out in one visit and 9.8% of all treatments fall into the ‘urgent’ category. If the average number of appointments is weighted by the proportion of care, the average number of visits per treatment is 1.5825.

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