Royal College of Obstetricians & Gynaecologists

Green Maternity Report

Detailed methodology and evidence for recommendations

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Within this document we use the terms woman and women's health. However, it is important to acknowledge that it is not only women for whom it is necessary to access maternity care.

Maternity services and delivery of care must therefore be appropriate, inclusive and sensitive to the needs of those individuals whose gender identity does not align with the sex they were assigned at birth.

Funding

This work was commissioned and funded by SBRI Healthcare and NHS England. SBRI Healthcare is an Accelerated Access Collaborative (AAC) initiative, in partnership with the Health Innovation Network. The views expressed in the publication are those of the author(s) and not necessarily those of SBRI Healthcare or its stakeholders.

Acknowledgements

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Green Maternity Challenge teams

We would like to extend a big thank you to all applicants and participants in the Green Maternity Challenge, without whom this project would not have been possible.

Including but not limited to: Menelaos Tzafetas, Emily Barrow, Patrizia Conidi, Shahanaz Rahman, Marisa Taylor-Clarke, Thomas Liney, Hannah Browne, Kerry Munro, Beth Laverick, Laura Allen, Sophie Holland, Lauren Flett, Michelle Mackie, Monique Sterrenburg, Georgina Clark, Kate Croissant, Perrine Dhaisne, Melissa Fox-Blach, Frances Rivers, Jennifer Prescot, Kathin Gray, Posy Bidwell, Meg Wilson, Ilana Pizer-mason, Gillian Delamotte, Caitlin Daly, Zoe Daggatt-Powrie, Angie Willis, Charlie Peters, Rosalind Freestone and Kath Townsend

Introduction

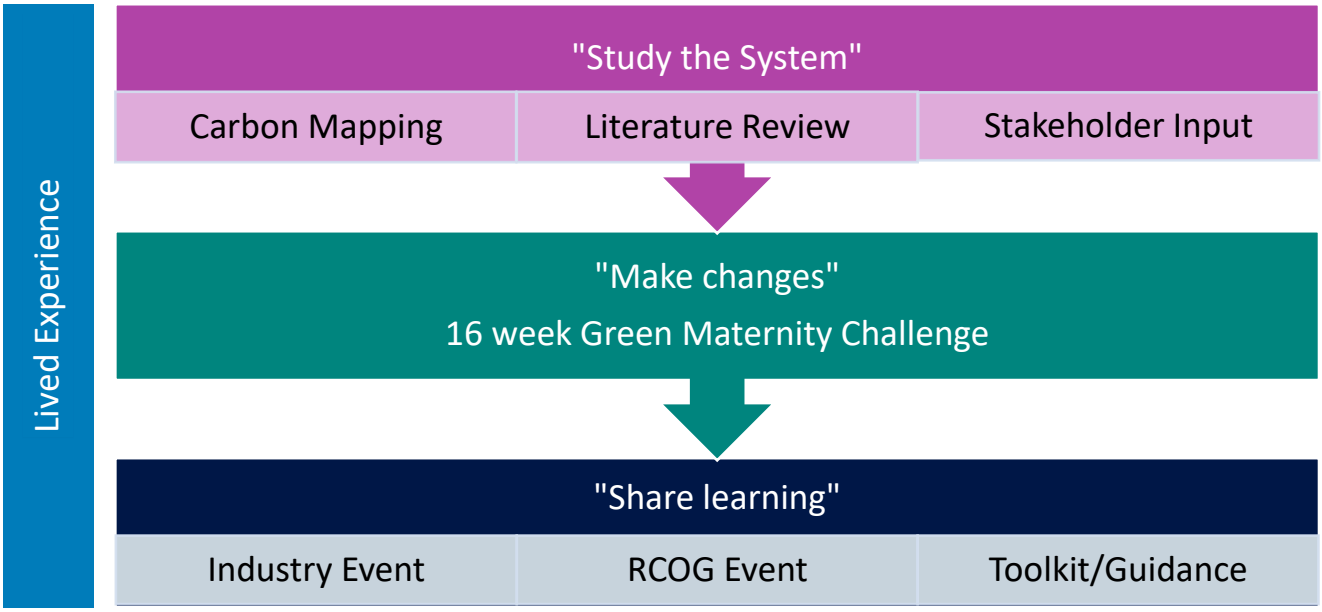
The Green Maternity Report brings together lived experience, high quality case studies, carbon modelling and evidence synthesis to agree eight initial priority areas, and evidence-based recommendations for carbon reduction in maternity services.

This document describes the methodology and evidence used to agree on these recommendations as part of a yearlong collaboration between the Royal College of Obstetricians and Gynaecologists (RCOG), Royal College of Midwives (RCM), the Centre for Sustainable Healthcare (CSH) and the Sustainable Healthcare Coalition (SHC).

Aims

- To bring the multi-disciplinary maternity community together to target high-value areas in the care pathway where carbon hotspots, maternal and perinatal outcomes, health inequalities and national priorities overlap.
- To demonstrate how these target areas can be tackled through on-the-ground projects and their robustly analysed impacts on carbon, care and equity.
- To activate the maternity community, build cohesion, increase understanding of net zero challenges and opportunities, and create networks of support to enable action.
- To make changes that avoid increasing inequalities.

Figure 1: Graphical representation of the green maternity project plan



Phase 1: "Study the system'

At the outset of the project, we established lived experience and expert advisory groups to guide ongoing work. To establish target areas for intervention, we performed a mixed-methods scoping exercise that combined a literature search, stakeholder engagement workshops, clinical pathway mapping, and carbon foot printing.

Lived experience group: Insights and priorities for maternity service improvement

All project work has been co-created and reviewed by a purposefully selected and inclusive group of 10 women with lived experience of maternity care. This group was recruited as one of the earliest actions in the project. As well as sharing their personal experience, several group members are already active in women's health and/or sustainability charities and advocacy groups, or hold professional roles in relevant industries. These women have really been at the centre of the project contributing to all important decisions, assisting in shortlisting and judging groups, speaking at all of our events and reviewing all published materials. This ensures that any changes we recommend on the basis of this work will truly serve everyone accessing maternity services. With their valuable insights we have carefully reflected on the impacts of any proposed changes on women and their families including those who face particular disadvantages and are seldom heard.

The following summary of the lived experience group's insights and priorities for maternity service improvement was provided by group member Tahnee Brathwaite in her own words:

The Lived Experience Group (LEG) on sustainable maternity care explored key challenges and opportunities for making maternity services more environmentally responsible and equitable. Although there is a strong desire among healthcare providers to adopt sustainable practices, progress has been limited by fragmented systems, inconsistent approaches between hospitals, and poor coordination between industry, procurement, and frontline services.

A major concern raised by the team is the lack of a cohesive digital system for maternity care. Inefficient information-sharing processes leads to duplication, errors, and resource wastage. Developing a unified system would improve care delivery, enhance communication, and reduce the environmental footprint of healthcare administration.

Education emerged as a critical gap in care. Early awareness of pelvic floor health, ideally starting in schools, was highlighted as essential for preventing long-term health issues. However, women's health education continues to be deprioritised. Postnatally, better access to contraception was identified as a key strategy to promote longer intervals between pregnancies, reducing the demand on antenatal services.

The "non-compliant" label, frequently applied to women who miss appointments, was criticised for ignoring socio-economic barriers such as travel difficulties, caregiving responsibilities, and insecure work contracts*, which disproportionately affect marginalised groups.*

Wasteful practices were a recurring theme in discussions. For example, neonatal wards often rely on single-use plastic bottles for sterilisation despite the availability of potentially more sustainable options. Similarly, barriers to the reuse of breast pumps, including sterilisation concerns, restrict access and contribute to waste. Positive innovations were noted, such as trusts adopting washable fabric curtains instead *of disposable ones, though scaling these efforts remains a challenge.*

The group emphasised the importance of systemic reforms, not just isolated projects, to create a sustainable and equitable maternity care system. Pockets of innovation and enthusiasm exist, but without coordinated action and investment, progress will remain limited.

This work is deeply important to me and to all women because maternity care impacts not only the health and well-being of mothers and babies but also the future of our planet. As women, we often carry the burden of navigating healthcare systems that are not always designed with our needs or the environment in mind. Ensuring maternity care is both sustainable and equitable is about more than reducing carbon footprints, it's about creating a system where every woman, regardless of race, background, or socio-economic status, feels supported, respected, and empowered during one of the most vulnerable times in her life. By addressing environmental waste, systemic inefficiencies, and health disparities, we can lay the groundwork for healthier families, stronger communities, and a better future for generations *to come.*

Literature review: Carbon reduction in maternity

Objectives

- To describe actions already taken by healthcare professionals in maternity to reduce carbon emissions.
- To identify areas where there is opportunity to reduce carbon emissions ('carbon hotspots within the maternity care pathway').
- To draw out areas where health inequities intersect or are impacted/influenced by identified carbon hotspots.

Methods

Search strategy

On the 10 April 2024, a search of MEDLINE (Ovid), Embase (Ovid) and Maternity & Infant Care (MIDIRS) databases was performed. Our search strategy was developed with the support of library staff at the RCOG. Search terms combined 1) carbon footprint/carbon emissions/greenhouse gas emissions with 2) the field of obstetrics/maternity. The search strategy is included in Appendix 1.

Study selection

In order to capture the greatest breadth of information, inclusion and exclusion criteria were kept to a minimum and are presented in Box 1. Any study design reporting on the carbon footprint (CFP) of any aspect of maternity services was deemed suitable for inclusion and only letters and conference extracts were excluded.

Due to time constraints of the wider project, titles and abstracts were screened by only one author. Irrelevant titles and duplicates were discarded. Full texts were obtained for the remaining articles and screened to confirm relevance. The references of included studies were scrutinized for additional papers not identified through the original search.

Box 1: Inclusion and exclusion criteria

Inclusion criteria

1. Reports on carbon footprinting or reduction of carbon emissions in the fields of obstetrics/maternity
2. Human population
3. English language

Exclusion criteria

1. No full text available
2. Letters and conference abstracts
3. Exclusively addresses impact of climate change on health

Data extraction

Data were extracted from each relevant study using a Microsoft Excel template (1). Gathered data for all study types covered the first author, year, country, design, main findings and suggested mitigation strategies. In addition for any lifecycle analyses (LCAs) data were extracted on the functional unit, CFP methodology used, sources of emissions factors (EF) and global warming

potentials (GWP), greenhouse gasses (GHG) included, other environmental impact categories, inventory boundary classified according to GHG protocol, and data type (2).

LCA is the gold standard study design in sustainability fields but its application to healthcare settings is relatively new. For an explanation of common terms used in LCA please see Box 2. Formal tools for assessment of bias were not applied but subjective assessment of strengths and weaknesses of each study was performed, and common themes were drawn out for discussion.

Results

Search results

The systematic search returned a total of 337 results. 204 studies were excluded based on title and abstract and 62 were selected for full-text screening. 37 of the original search results were included in the final review and an additional 10 papers were identified through screening of references (in total 47 records). See PRISMA diagram, Figure 3 (3).

The earliest paper included was published in 2006 with the majority being published from 2020 onwards (36/47) consistent with the rapid recent increase in interest in this field. The largest numbers of papers were published in the US (n=18), UK (n=13), and Australia (n=8), with 3 titles each from the Netherlands, India and Ireland.

Study design

The vast majority of results were secondary research publications, predominantly narrative reviews, editorials and opinion pieces (n=20). There has to date been one systematic review of environmental sustainability in obstetrics and gynaecology by Cohen 2023 (4),
Primary studies included 11 life cycle assessments, 4 quality improvement projects (QIP) or audits, 5 cross-sectional studies and 3 case reports/series.

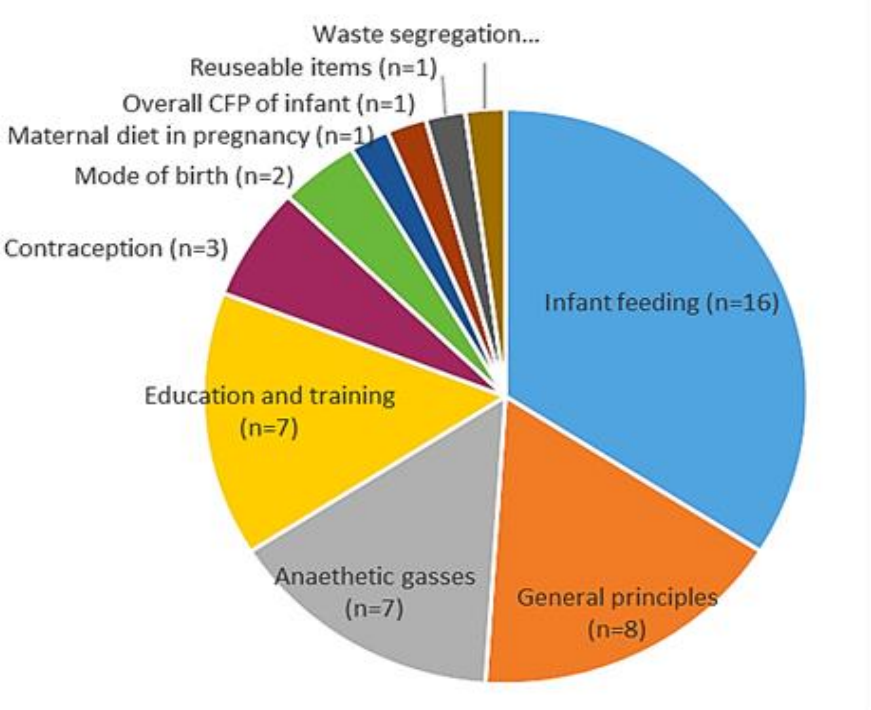


Figure 2: Breakdown of studies by topic

Box 2: Terms used in LCAs

Greenhouse gasses (GHGs) – Carbon dioxide (CO2) is the most well-known but other important GHGs include methane (CH4) nitrous oxide (N2O) Hydrofluorocarbons (HFCs) Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF6) (2).

Global warming potential (GWP) – A way to compare the heating effects of different GHGs. Expressed as a multiple of the effect of the same mass of CO2 over a given time.
The GWP100 of N20 is 265, i.e. it absorbs 265 times the thermal radiation of CO2 over 100 years.

Impact categories – GWP is one impact category but many LCAs will report on additional environmental impact drivers. Common examples are particulate matter (PM), terrestrial acidification (TA), eutrophication (EP), human toxicity (HTox), ecotoxicity (ETox), water use (WU), land use (LU), fossil fuel depletion (FD), and photochemical ozone creation (POCP).

Functional unit – The process, product or procedure studied e.g. four hours of labour analgesia.

Emission factor (EF) – A coefficient that describes the rate at which a given process releases GHGs into the atmosphere.

Carbon footprinting methodology
'Top down' – Uses the monetary value of a unit as a proxy for greenhouse gas emissions (GHGE). Assumes that a greater cost indicates greater resource intensity. Useful as a quick scoping exercise to identify likely carbon hotspots for investigation but lacks specificity and detail.

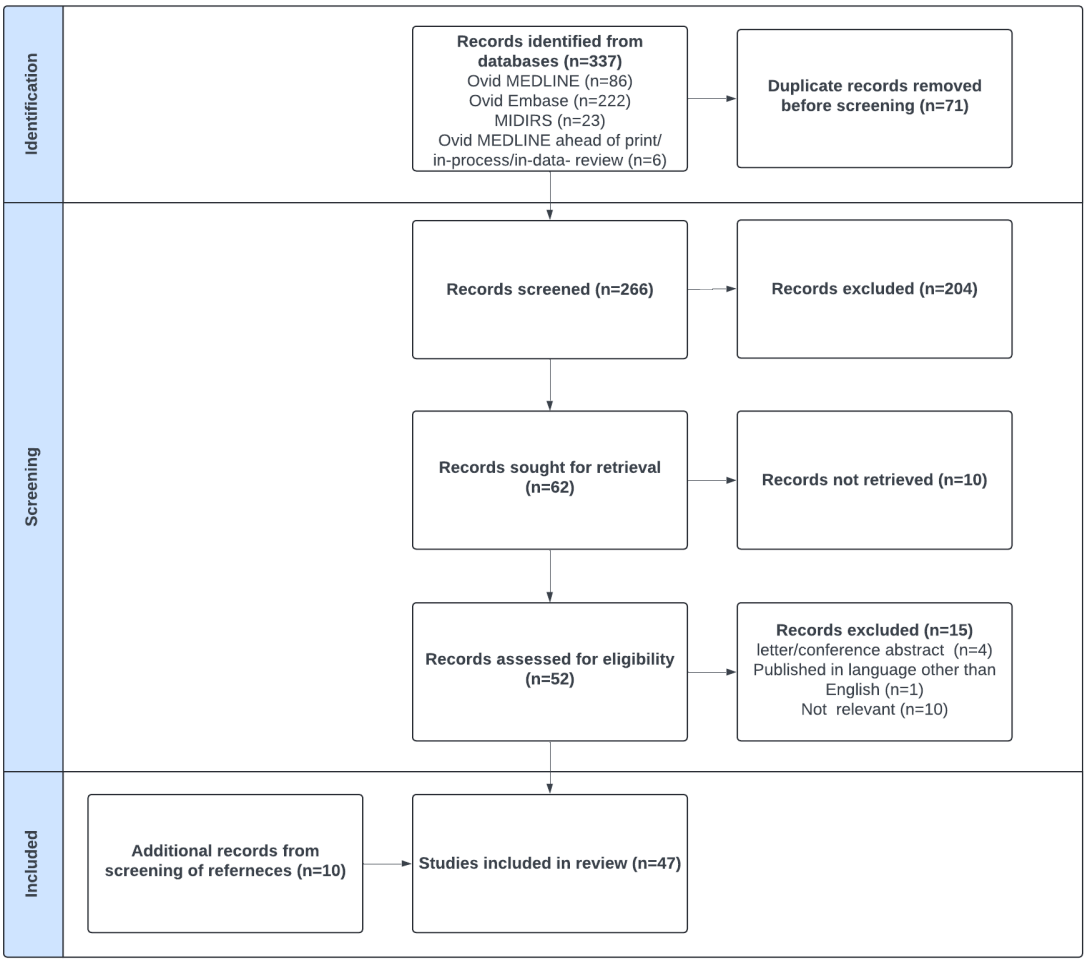
'Bottom up' – Emissions from all processes attributable to a functional unit are either measured or calculated from known averages. The inventory boundary must be clearly stated (see below). More detailed and resource intensive than a top down approach and vulnerable to error through omission of 'hidden sectors' e.g. marketing and development.

Inventory boundary – The inventory boundary refers to the limits of the processes included in the carbon footprinting calculation. This is classified according to greenhouse gas (GHG) protocol (2).
Scope one – direct emissions from the organisation (e.g. nitrous oxide directly emitted).
Scope two – indirect emissions from electricity use by the organisation.
Scope three – all other indirect emissions (e.g. supply chain, travel, and waste disposal).

Data type
Direct emissions data – GHG emissions are measured at the point of emission e.g. volume of nitrous oxide released.
Process activity data – Emissions are calculated from processes known to contribute GHG, but direct measurement is not possible.
Primary process activity data is derived from processes specific to the functional unit e.g. actual transport route used in hospital supply chain.
Secondary process activity data uses average process data which are not specific to the functional unit e.g. typical route of transport for similar items.
Secondary financial activity data GHG emissions are estimated based upon the monetary cost of items.

Based on GHG protocol and prior work of Rizan et al. (2,5)

Figure 3: PRISMA diagram



Topics

The breakdown of studies by topic is represented in figure 2. The greatest number of papers focussed on infant feeding (n=16), followed by general principles of sustainability (n=8), anaesthetic gasses (n=7) and education and training (n=7).

Many areas of maternity care were not represented at all in the literature (e.g. routine antenatal and postnatal care, maternal and fetal medicine, perinatal mental health, labour care).

Findings and mitigation strategies

The main findings from each study relevant to the project development are summarised in the following pages along with suggested mitigation strategies. More detailed information and results can be viewed in the supplementary material.

Antenatal care key findings

- No studies were identified focussing on the care of women and birthing people with pre-existing or pregnancy-related medical conditions (hypertensive disorders, gestational diabetes etc.), mental health conditions or from disadvantaged groups.
- Bossek et al. modelled the total CFP of an infant living in Germany from conception to three years post birth. In the pre-natal phase an additional 583kg CO2e were attributable to the developing pregnancy. **The highest contributors were transport (e.g. trips to antenatal clinics) and the increased food requirements of the mother** (6)**.**
- Wang et al. addressed the question of whether a sustainable diet (reduced red meat consumption) could meet the nutritional needs of a pregnant woman. **They found a reduction in of 372.2 kgCO2e per person if a woman replaced one serving of beef with one isoenergetic serving of firm tofu each week throughout the duration of their pregnancy** (equivalent to driving a typical passenger vehicle for 1498 km) (7).

Suggested mitigation

- **Encourage and support active or low-carbon transport to antenatal appointments.** Hospitals are often located on the peripheries of towns and cities with poor and infrequent public transport links and unsafe cycle routes. Systemic change is needed to support efficient, safe low-carbon travel.
- **Streamline antenatal appointments.** In the UK it is common to have separate midwifery, obstetrician and ultrasound appointments all within days of each other. Multiple visits increase travel-related carbon emissions and are a significant barrier to access for parents with insecure or unsupportive work environments, and those on lower incomes.
- **Reduce healthcare-associated travel by taking antenatal care out into community hubs and providing an option for virtual appointments where appropriate.** Virtual appointments must be carefully implemented as digital access and literacy unequally affected pregnant individuals' abilities to engage with virtual antenatal appointments during the coronavirus pandemic. Those lacking in socio-economic capital may be alienated or put at risk by the degree of self-responsibility in digital health care models (8).
- **Reduce intake of red meats (particularly beef) during pregnancy and breastfeeding and swap for plant-based foods.** Clinicians can be confident to encourage a seasonal, nutritious diet rich in plant-based foods during pregnancy without risking nutritional deficiency. Systematic barriers exist preventing equal access to nutritious, low carbon food. The Food Foundation calculated that the poorest fifth of UK households would need to spend 50% of their disposable income to eat the government-recommended healthy diet (9). When proposing dietary change we need to holistically address these barriers with a whole systems approach to maximise health and sustainability benefits.

Induction of labour key findings

- No study to date has modelled the CFP of induction of labour nor commented on the relative sustainability of the various methods of induction in practice today. This could be a valuable area of future research given that at current rates one in three labours are induced in England (10).

Suggested research questions

- What are the most significant contributory processes to the carbon footprint of induction of labour (e.g. pharmaceuticals/devices, hospital stay, travel)?
- Are there significant differences between units in the carbon footprint of induction of labour due to pathway efficiency and method used?
- How does the carbon footprint of induction differ between the various methods of induction in practice today?
- How does the carbon footprint of induction differ between inpatient versus outpatient induction of labour?

Labour and birth key findings

- **Excluding pain relief, caesarean birth has a higher carbon footprint compared with vaginal birth in hospital**. **Vaginal birth at home had the lowest CFP.** The major contributors were disposable packs and the energy consumption from machines, lighting, and HVAC (heating, ventilation and air conditioning systems (11,12).
- **The use of 'gas and air' (Entonox® , N2O/O2) in any birth setting increases the CFP 25-fold, meaning a vaginal birth with N2O/O2 exceeded the emissions of a caesarean by 227.49 kgCO2e (See box 3)**. Spil et al found a vaginal birth in the Netherlands had a lower CFP than in the UK predominantly due to a lower use of N2O/O2 but additionally due to less consumption of PPE and disposables (sterile gloves are not routinely used for vaginal examinations unless indicated) (11).
- **From previous work on pure N2O emissions reduction we can assume there is likely high systems wastage of N2O/O2 in maternity.** At three units studied as part of The Nitrous Oxide Project estimated systems losses were over 97% (meaning less than 3% of purchased N2O reached the patient) (13). Similar findings were demonstrated by Keady et al. in Ireland where two hospitals were responsible for over 15,000 tCO2e each annually in their 2019 audit. Significant leaks were later found to explain these results (14).
- Careful stock management is key as EU guidance states that unused or out of date medical N2O must be vented into the atmosphere (14). One medical gas supplier documented 6000 medical cylinders lost due to theft in a single year (13).

Box 3: Nitrous oxide

Nitrous oxide (N2O) has a GWP100 265 times that of CO2 and remains in the atmosphere far longer. It accounts for 6% of anthropogenic global warming and is responsible for most of the ongoing ozone depletion today (15). Additionally prolonged high level N2O exposure risks the health of maternity staff (16).

- **Epidurals and remifentanil patient controlled analgesia (PCAs) have a much lower carbon footprint than N2O/O2,** but can only be delivered in an obstetric-led birth unit with careful monitoring and one to one midwifery care. Pearson compared the emissions of N2O/O2 with different modes of labour analgesia. N2O/O2 had 200 times the carbon emissions of epidural or remifentanil PCA and 3111 times that of intramuscular morphine (17).
- **Ethyl chloride spray routinely used for testing spinal/epidural blocks has a high carbon footprint from travel and disposal, is costly and is directly harmful to the environment.** Alternatives including 'cool sticks' Theophany Ltd have been shown to have similar efficacy with a much lower carbon footprint (18).
- **From the Green Surgery Report and studies in maternity and other specialities we can be confident that reusable items will almost always outperform disposables on carbon emissions and other environmental impact categories (4,5,11,12,19–21)**. We can anticipate average carbon emissions reductions of 38-56% through switching to reusable products provided local sterilization facilities are available (19).

Suggested mitigation

Any improvements to labour care must be designed with women and birthing people and expand rather than limit choice. Care decisions should always be made by women and birthing people in discussion with their healthcare professionals and prioritise safety and experience.

- **Improve staff education on the environmental impacts of labour and birth.**
- **Support access to home birth where safe, clinically appropriate and desired (11,12).** Systemic barriers to access exist where homebirth is felt clinically appropriate e.g. due to poor staffing.
- **Ensure equity of access to low-carbon, effective pain relief and provide high quality antenatal patient information on all options (including the environmental impacts where this is desired by the birthing person).** A recent Scottish population-based study found a lower uptake of epidural anaesthesia amongst women from areas of greater socio-economic disadvantage. A correlation that persisted even when epidural was indicated for medical reasons and was more marked in Black and Asian groups (22). We must address implicit biases in access to epidural anaesthesia and ensure appropriate patient information is appropriate for all cultures and health literacy levels.
- **Explore the feasibility of expanding access to remifentanil PCAs.** Adoption of remifentanil as a labour analgesic has been slow in the UK due to concerns regarding sedation and respiratory depression (23,24). Despite the Royal College of Anaesthetists supporting its use for pain relief in labour few units currently offer remifentanil as a first-line option; or if offered publicise its availability to birthing people. We should work with our anaesthetic colleagues to assess if safe roll out can be achieved.
- **Swap ethyl chloride sprays for cool sticks® or simply ice cubes when testing epidural and spinal blocks (17).**
- **Systematically measure and reduce N2O/O2 wastage without affecting patient choice**. Successful strategies from the nitrous oxide project include decommissioning unnecessary manifolds and moving to point of use cylinders, routine leak testing and pipework inspection, closer stock management and better surveillance against theft (13).
- **Explore novel alternatives to gas and air.** Methoxyflurane (Penthrox®) has been suggested as a possible future alternative to N2O/O2 given its lower GWP100 and a short half-life. However, the drug

is not currently licenced in obstetric populations and its maximum recommended dose would limit use to two hours. It could be introduced as a bridging analgesia or for shorter procedures (e.g. perineal repairs) (17). Despite many years of use in labour there is only limited evidence of Entonox's efficacy over placebo and it is not without side effects (25). Further research into non-pharmacological methods of pain relief (immersion in water, relaxation, acupuncture, massage, hypnobirthing) could expand the choice of preferable, lower carbon options for women and birthing people.

- **Expand the use of existing technologies, and work closely with industry to develop new ways to reduce the environmental harms of N2O/O2.** A promising target in maternity is catalytic destruction or 'cracking', whereby exhaled N2O is broken down into harmless nitrogen and oxygen. (26, 27) Cracking not only reduces the environmental harms of N2O but prevents harm to staff from prolonged occupational exposure. Several units in the UK have already implemented this technology and have found it to be acceptable to staff and patients (26). Mandated cracking of surplus N2O returned to the supplier (rather than discharge to the atmosphere) should also be explored.
- **Limit the use of single use disposables (i.e. gloves, incontinence bed pads etc.) where unnecessary.** Further research should be carried out into whether a change to the use of non-sterile gloves in labour would be safe and feasible in the UK. (11)
- **Rationalise surgical packs, remove unnecessary items and arrange to maximise the efficiency of sterilisation.** The Green Surgery Report clearly outlines how to go about this and can be downloaded here Green Surgery Report | UK Health Alliance on Climate Change (19).
- **Swap disposable items, instruments and drapes for those which can be reused and sterilised.** Particular targets are single use surgical gowns and drapes due to their frequent use and high carbon footprint. A Cochrane review found no evidence of difference in surgical site infection rates between single-use versus reusable drapes (28).
- **Improve the energy efficiency of birthing environments. Optimize the HVAC system, utilize shut down checklists, install occupancy sensors and low energy lighting.** Again, the green Surgery report and intercollegiate green theatre checklist provide practical advice (19,29). Further work should be done to adapt these recommendations for maternity ensuring maximum energy efficiency while preserving safety in the unpredictable environment we operate in. **Transition to 100% renewable energy.**
- **Increase remanufacture, repurposing and recycling of products at their end of life. Work with suppliers to improve waste segregation (20).**

Postnatal care key findings

- Aside from infant feeding (discussed separately), routine postnatal care was notably absent from the current literature base and remains an untapped source for future work.

Suggested research questions

- Where are the carbon hotpots in routine postnatal care?
- What is the additional carbon footprint of care associated with common postnatal conditions (infections, hypertensive disease, perineal tear care, postnatal depression etc.) and can these be prevented or better managed?

- Can the early identification and active management of long-term health conditions in the post-natal period prevent more resource intense treatment in future pregnancies and later life (e.g. hypertension, diabetes and pelvic floor dysfunction)?

Infant feeding key findings

- **Consensus from the majority of studies was that formula milk has a larger carbon footprint than breastfeeding (30–33). Breastfeeding one infant for six months reduced carbon emissions by 95-153kg CO2e (34)**. A single LCA by Amonkar et al. found the converse but based their scenario on a US population where maternity leave is not protected and assumed that all breastfeeding mothers pump for every feed during work hours (35). No other study factored breast pump use into their breastfeeding scenario. Several unlikely assumptions in the Amonkar study limit its validity (e.g. that breastfeeding women travel to the supermarket more frequently to meet the increased energy requirements). We feel that on balance it is likely that breastfeeding is the more environmentally sustainable option but probably not to the degree that other studies have stated once pumping, storage and preparation of stored milk are taken into account.
- **LCAs indicate that manufacturing 1kg of formula milk produces between 2.02kg CO2e (31) to 11kg CO2e (32). Dairy milk production contributes 68-82% of this total.** Differences in farming practices and electricity mix (renewable/nuclear/fossil fuel) mean the CFP is significantly different across producer nations (32). Follow-on (FUF) and growing-up formulas (GUF) have a higher carbon footprint than standard preparations due to higher milk powder content and are forming an increasingly large part of the global market despite no evidence of their benefit (30,33,36).
- **"At-home" consumption processes can count for a further 11-14kg CO2e (32).** Bottle sterilisation was the greatest contributor post-production (32).
- **For breastfeeding the major source of carbon emissions was the mother's incremental food consumption which varied based on diet, largely the proportion of animal products (32,35).**
- Long et al. explored the emissions saved from the theoretical decarbonising of formula milk production using renewable gas. **Overall, while decarbonising the process would be useful, achieving the minimum target of 50% breastfeeding would be more effective (37).** Care must be taken to ensure that decarbonising formula production should not hinder efforts to increase breastfeeding uptake.
- **Though over 85% of women in the UK when surveyed wanted to breastfeed their child (38), by 6-8 weeks only 43% are still doing so** (39)**.** Breastfeeding rates are lower amongst young parents and those with lower levels of education (40). These groups may be in need of additional support and targeted interventions.
- **Breastfeeding has wide-ranging positive health effects for parent and child. Improving uptake would not only prevent immediate GHG emissions but would likely reduce healthcare-associated resource use across a lifetime.** Breastmilk is reactive to the nutritional needs of a child and confers passive immunity (41,42). Breast-fed babies have lower rates of respiratory and gastric conditions in the first weeks of life and a reduced risk of sudden infant death syndrome (SIDS)(39). Long-term breastfeeding has a protective effect on the development of diabetes and obesity, and is associated with improved developmental performance and educational achievement (39,41,42). In addition breastfeeding has been shown to reduce the risk of maternal breast and ovarian cancer, osteoporosis and diabetes (39).

Suggested mitigation

Improving services for those who struggle to breastfeed due to a lack of meaningful support should be a priority for women and birthing people, babies and the planet. At the same time we must strive to better support the physical and emotional needs of all women and birthing people (regardless of feeding method used).

- **Improve support for breastfeeding mothers including improved access to counselling and lactation specialists.** Further research is necessary to determine the carbon benefit of improving access to breast pumps and milk banks, however all efforts to support breastfeeding are desirable from a health perspective (34).
- **Improve patient information on environmental impacts of infant feeding choices and food system sustainability.** Including the impact of a more plant-based diet if choosing to breastfeed (31,43).
- **Adhere to the UNICEF UK Baby Friendly Initiative (44).**
- **Call for tighter regulation of the marketing of formula milk.** The UK has incorporated some of the WHO International Code of Marketing of Breastmilk Substitutes into domestic legislation, however at present there are no limits on the marketing of products for babies older than six months (46). By using similar branding for all their products, in effect companies are able to market products for younger infants while still remaining within UK law (36). Full adherence to the WHO code including the marketing of FUF/GUF should be a priority for the UK Government.
- **Expand workplace protections and facilities for breastfeeding mothers** including improving maternity/paternity leave policy, creating breastfeeding friendly environments, locating day-care centres and nurseries close to workplaces for easy access, and allowing infant visits in the workplace (43).
- **Increase the use of renewable energy sources in formula production and sustainable practice in dairy farming.** We must be cautious that decarbonising the formula industry doesn't hamper efforts to achieve breastfeeding targets (37).

Strengths and limitations

As far as we are aware, this is the first review of its kind to specifically address carbon reduction in maternity services. The broad inclusion and exclusion criteria meant we were able to give a thorough overview of the work completed in this field to date, but resulted in the return of many low quality reviews and commentary pieces from which we must be cautious to draw conclusions. This paucity of primary subject data was the main limitation of our review. Identifying where research is currently lacking is valuable in and of itself to guide our own project and wider work in the field.

An additional limitation was that due to time constraints of the wider project, titles and abstracts were only screened by one author. It is possible that relevant papers may have been missed due to this approach. Assessment of methodological rigour and risk of bias was surface level due to the breadth of subject material. This was appropriate to the aims of our review but limits its credibility overall. We hope to go on to author a full systematic review addressing some of these limitations and taking a deeper dive into the higher quality papers identified by this review.

Carbon footprint analysis of highlighted maternity care pathways

Aim

The aim of this report is to analyse the carbon footprint of the maternity care pathways highlighted by the project and to identify their carbon hotspots. It will look at the GHG emissions impact of the highlighted maternity care pathways across NHS England in 2022-23 and at an individual level.

Approach

The following maternity care pathways were highlighted and based on the respective NICE Guidance, mapped(46–50). (To see the detailed maternity care pathway maps, please go to Appendix 2):

- Antenatal care
- Hypertension care
- Induction
- Intrapartum care pathway: midwife-led, obstetric unit
- Pelvic floor care
- Postnatal care
- Infant feeding

With input from the project's stakeholders including midwives and obstetricians and people with lived experience the maternity care pathway maps were modified to reflect the experience of health professionals on the ground and those experiencing the pathways.

Following the pathway mapping, resources used on each pathway, also called activity data, were identified. Table 1 shows the activity data which were included for each pathway.

Based on the pathway maps and the activity data, SHC developed a carbon calculator for maternity care pathways which estimates the carbon footprint of each highlighted pathway, allowing the identification of variation between sites. However, only four partially completed pathway calculators were returned, as it was difficult for health professionals to pilot the calculator in the given time of the project. Instead, a different approach to estimate the carbon footprint of each pathway was chosen.

First, the total annual carbon footprint of each pathway was estimated taking the volume of service in 2022-23 into account. The average carbon footprint per person of each pathway was derived by dividing the total annual carbon footprint by the number of women and birthing people on the particular pathway. For example, the Carbon footprint per person of the intrapartum pathway reflects the proportion of home, spontaneous vaginal, assisted vaginal (forceps and ventouse) and caesarean births.

Table 1: Inclusion of activity data per pathway

Activity data	Ante-natal	Hyper-tension	Induction	Intrapartum	Pelvic floor	Postnatal	Infant feeding
Referral							
Women's travel**							
Staff travel							
Setting (visits/ classes/ inpatient bed days)***							
Blood tests							
Scans							
Pharmaceuticals							
Entonox							
Epidural/Caudal/Spinal /General Anaesthetic							
Birth							
Perineal tear							
Surgery							
Breast feeding****							
Formula feeding							

* *The blue fields indicate the activity data which has been included for the respective pathways*

** *Women's travel includes travel to antenatal and postnatal appointments, antenatal classes and to give birth*

*** *The term 'setting' is used to describe the resources used during antenatal visits, antenatal classes and postnatal visits at home, GP practices, midwife-led units and obstetric units, and inpatient bed days*

**** *We could not differentiate between direct breastfeeding or breastmilk via a bottle or donor milk due to lack of data.*

Boundaries and assumptions

Care provided along the highlighted pathways from the time of the referral to antenatal care to eight weeks post birth was included in the carbon footprint analysis.

A range of assumptions were made around the pathways, activity data and the carbon footprints and emission factors used. Some of the main assumptions are described below, with more detail on the assumptions provided in Appendix 3.

General

According to NHS Digital Maternity Statistics 2022-23, there were 547,244 births facilitated by NHS England in 2022-23 (51). It was assumed that all 547,244 would have been preceded by antenatal care and followed by postnatal care. Due to lack of data on the amount of antenatal care they received, women who experienced a miscarriage or ectopic pregnancy were not included. There were 545,251 live births, which were assumed to lead to either babies being breastfed or formula fed. Any care beyond eight weeks post birth was excluded as this was outside the study boundaries.

Induction care pathway

Surgical induction (induction by amniotomy), medical induction (includes the administration of agents either orally, intravenously or intravaginally) and combined induction (surgical and medical) were included in this pathway (48). As there were no separate statistics, it was assumed that augmentation is included in the induction statistics. It was assumed that all inductions were conducted as an inpatient, with the carbon footprint of induction being solely based on the additional antenatal inpatient bed days needed for the duration of the induction process. The methods of induction were not included in the carbon footprint analysis due to the unavailability of data on the volume of the different pharmaceuticals and devices used for induction.

Antenatal care pathway

It was assumed that women and birthing people with no previous pregnancies will have ten antenatal visits, the others seven as recommended by NICE and that all women have two antenatal appointments at hospital for their ultrasound scans (47).

Hypertension care pathway

Women and birthing people with pre-existing hypertension and gestational hypertension were included on this pathway. Pre-eclampsia has been excluded. It was assumed that all took up the offer of daily aspirin from 12 weeks onwards.

Based on NICE guidance, for gestational hypertension five additional scans, weekly blood tests and antenatal visits plus daily blood pressure medication was assumed (47).

Intrapartum care pathway

Home births, spontaneous vaginal births, assisted vaginal (forceps or ventouse) births and caesarean births (50), planned and unplanned, were included in this analysis. It has not been taken into account that women and birthing people who undergo an unplanned caesarean birth are likely to have started on a spontaneous vaginal or assisted vaginal birth pathway and therefore Entonox® and other consumables might have been used.

The carbon footprint of the intrapartum pathway at a midwife led unit and an obstetric unit could not be differentiated due to insufficient detail in the data.

Pelvic floor care pathway

The pelvic floor care pathway was solely based on the surgical repair of 3rd and 4th degree tears and the post-surgery drug prescriptions and follow-up review appointment based on information from the RCOG (52). Any additional care around incontinence and pelvic organ prolapse is likely to be required at the earliest post eight weeks from birth and therefore was excluded from this analysis.Postnatal care pathway

It was assumed that women and birthing people have 2-3 postnatal visits with the midwife, either at home or at the hospital, one visit by the health visitor and a visit to the GP within the first eight weeks after birth (49).

Infant feeding

For this analysis it was assumed that in the first two weeks of life 74% of women exclusively breastfed, and in weeks three to eight the figure dropped to 49%. This was based on the UK Government official statistics for 2022-23 (53). The carbon footprint of breastfeeding is solely based on the additional nutritional needs of women, excluding any use of breast pump, milk storage and preparation of stored milk. The carbon footprint of formula includes the cradle-to-grave GHG emissions of the formula (31).

Results

Annual carbon footprint of highlighted maternity care pathways

In 2022-23, the total annual carbon footprint of the highlighted maternity care pathways combined was 204,950 tonnes of carbon dioxide equivalents (tCO2e). With 117,190 tCO2e the intrapartum care pathway including home births, spontaneous vaginal and assisted vaginal (forceps and ventouse) births and planned and unplanned caesarean births, was the biggest greenhouse gas (GHG) emissions contributor (57%). Infant feeding contributed 46,229 tCO2e (23%), antenatal care 21,418 tCO2e (10%) and postnatal care 11,037 tCO2e (5%). The induction care pathway was responsible for 6,225 tCO2e (3%), hypertension care for 2,558 tCO2e (1%) and the pelvic floor care pathway for 294 tCO2e (0.14%) – see Figure 4.

Breaking down the 2022-23 carbon footprint of the highlighted maternity care pathways into its activity data shows that the use of Entonox® during birth, with 59,190 tCO2e, is the biggest GHG emissions contributor (29%). This is followed by the healthcare 'setting' (antenatal and postnatal visits or classes at the GP/midwife led hub/hospital and inpatient bed days) which is responsible for 58,087 tCO2e (28%) – see Table 2. Formula feeding accounts for 24,359 tCO2e (12%) and travel by women to appointments/classes/births for 22,331 tCO2e (10.9%). Breastfeeding, based on additional nutritional needs of women, contributes 21,870 tCO2e (10.7%) and birth, which includes energy, laundry, PPE, disposables, and reusable instruments is responsible for 10,001 tCO2e (5%). Staff travel for home visits make up 5,697 tCO2e (3%).

Carbon footprint per person of highlighted maternity care pathways

Based on the proportion of different modes of birth, taken from national data, the intrapartum care pathway has the highest average carbon footprint per person, 214.2 kgCO2e – see Figure 5. Entonox® contributes the most (51%) to the pathway's carbon footprint, followed by the GHG emissions embedded in inpatient bed days on an antenatal and postnatal ward (37%). However, the carbon hotspots vary between the different modes of birth – see below for a more detailed analysis under 'Modes of birth'.

Figure 4: 2022-23 carbon footprint of selected maternity care pathways in England

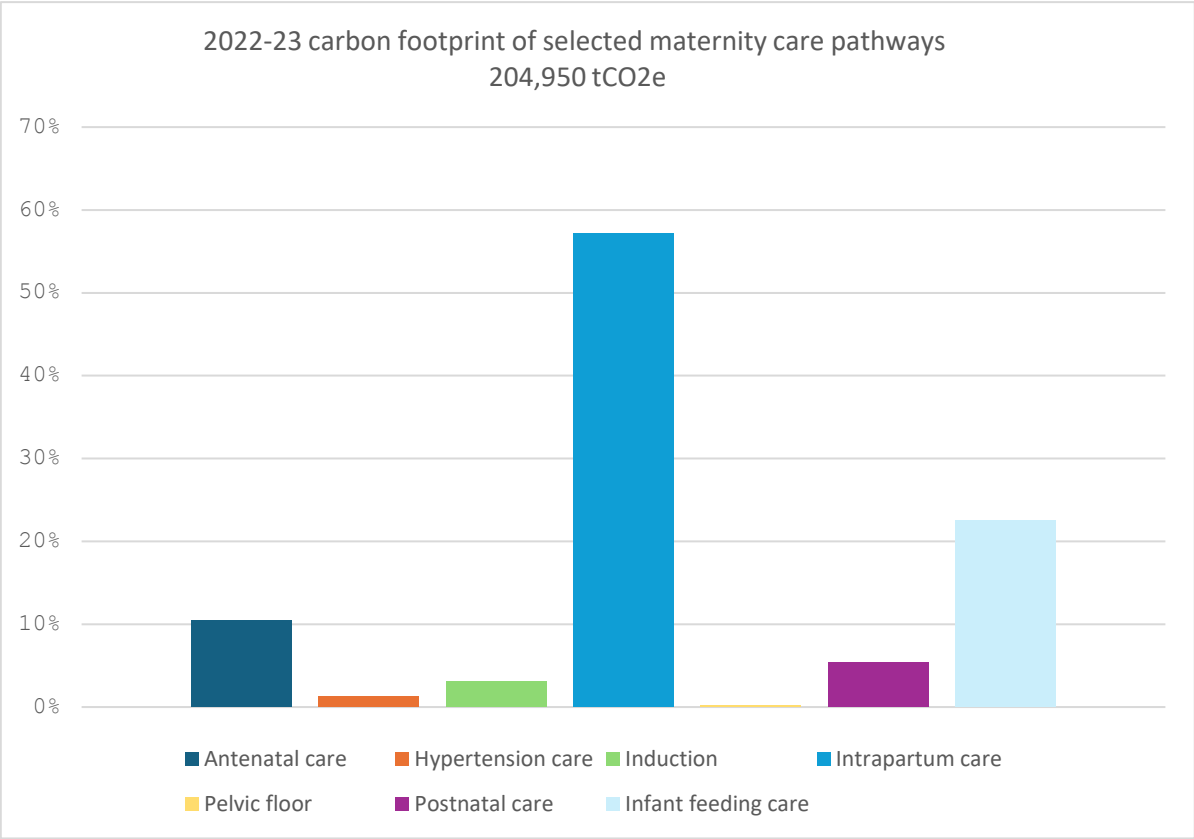
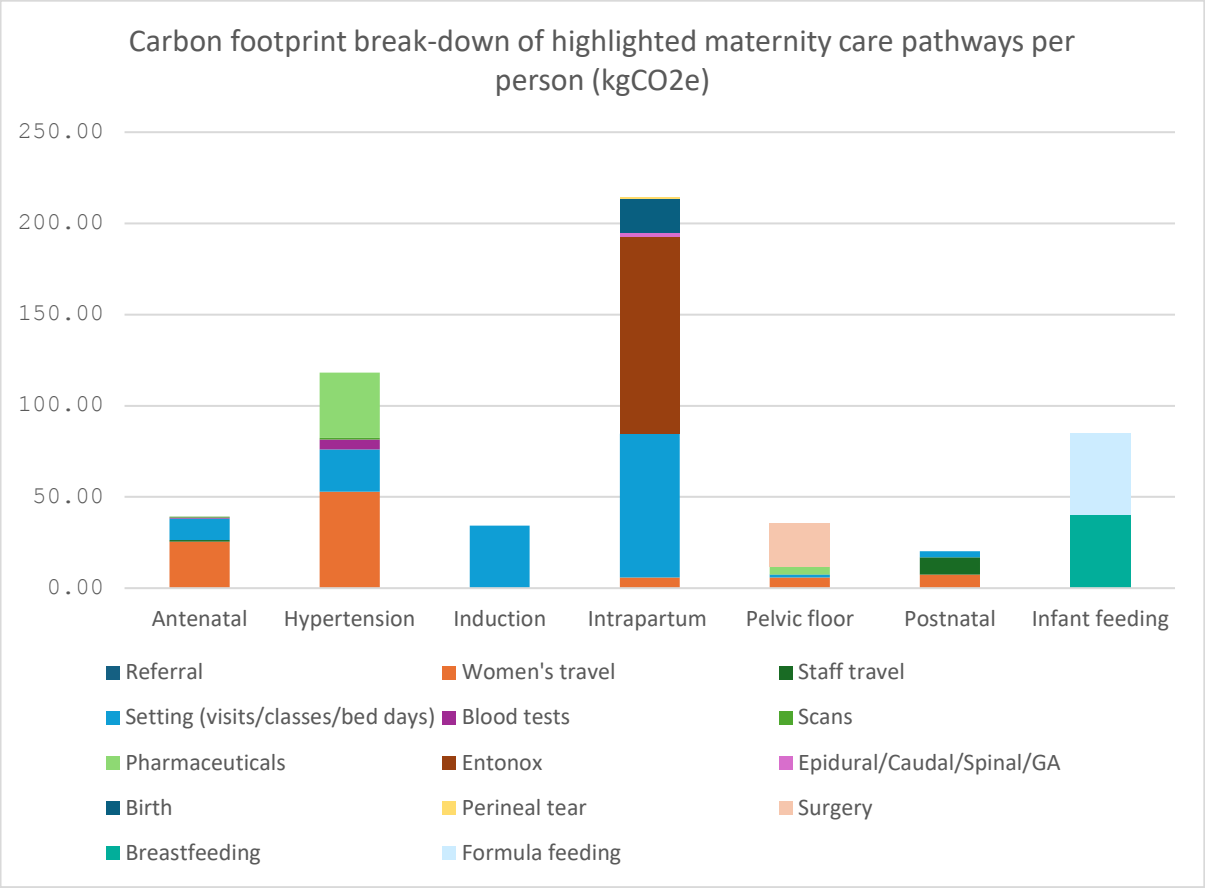


Table 2: Breakdown of annual carbon footprint of selected maternity care pathways into activity data

Care pathway and activity	Total (tCO2e)	% of total
Entonox	59,190	28.9
Setting (visits/classes/bed days)	58,087	28.3
Formula feeding	24,359	11.9
Women's travel	22,331	10.9
Breast feeding	21,870	10.7
Birth	10,003	4.9
Staff travel	5,697	2.8
Epidural/Caudal/Spinal/GA	1,228	0.60
Pharmaceuticals	811	0.40
Perineal tear	451	0.22
Blood tests	430	0.21
Scans	226	0.11
Surgery	198	0.10
Referral	73	0.04
Total across pathways	**204,950**	

Figure 5: Per person carbon footprint breakdown of selected maternity care pathways (kgCO2e)



Although amongst the highlighted maternity care pathways the hypertension pathway contributes the least GHG emissions at national level due to the relatively small number of women and birthing people who have either pre-existing hypertension (4,731) or gestational hypertension (22,194) (47), its per person carbon footprint is the second highest contributor, 118.2 kgCO2e. Women on the hypertension care pathway attend more antenatal visits for monitoring purposes. Depending on the severity of their hypertension and if the hypertension was pre-existing or gestational, attendance can vary between weekly and 4-weekly, making travel with 45% its biggest carbon hotspot and antenatal visits (healthcare 'setting') related GHG emissions its third biggest (20%) carbon hotspot. The carbon footprint contribution of pharmaceuticals, the hypertension care pathway's second biggest hotspot (30%), is due to pregnant women with high blood pressure often being prescribed aspirin and hypertension drugs to lower their blood pressure and prevent pre-eclampsia.

Infant feeding contributes on average 84.8 kgCO2e per person. Based on the assumption that 74% of women breastfed in the first two weeks after birth and 49% exclusively breastfed week three to eight (53), 53% of the carbon footprint is due to formula feeding and 47% due to breastfeeding. While the GHG emissions attributed to breastfeeding are based on additional nutritional needs of women, excluding any use of breast pump, milk storage and preparation of stored milk, the carbon footprint of formula milk includes the cradle to grave GHG emissions of feeding with formula milk.

At an individual level, the antenatal care pathway is the highlighted maternity care pathway with the fourth highest carbon footprint, contributing 39.1 kgCO2e. Travel contributes the most GHG emissions (65%), with the antenatal visits and classes (the 'setting') making up 30%.

The pelvic floor pathway, solely based on the surgical repair of 3rd and 4th degree tears and post-surgery care, adds on average 35.6 kgCO2e per person in addition to the carbon footprint of suturing as estimated by Spil et al. (3.07 kgCO2e). The surgery itself including a catheter contributes the most to the carbon footprint (67%), followed by women's travel to its outpatient follow-up appointment (16%) and the pharmaceuticals, antibiotics, painkillers and laxatives used after surgery (11.5%).

On average, induction is responsible for 34.3 kgCO2e per person based on the additional inpatient days to account for the duration of the induction process. Surgical induction adds on average 0.71 antenatal inpatient days, medical induction 0.87 and combined induction 1.16. Due to the unavailability of data on the number of pharmaceuticals, devices and volume of Entonox® used for and during the induction process, these could not be considered in the average carbon footprint per person of the induction process.

The postnatal pathway is on average responsible for 20.2 kgCO2e. It is characterised by staff travel being the highest contributor with 47%, followed by women's travel with 37%. The visits themselves, the 'setting', do not contribute much as many visits are carried out at new parents' homes, with the GHG emissions at home being excluded. The home visits are also the reason for the high GHG emissions contribution from staff travel.

Modes of births

Looking at the different modes of births in more detail shows that the assisted vaginal birth pathway using forceps or ventouse has the highest carbon footprint per person – 293.6 kgCO2e – see Figure 6. The majority of the carbon footprint (61%) is due to the use of Entonox. Ante-and postnatal inpatient bed days make up 31% of the GHG emissions and the birth itself, which includes energy use, laundry, PPE, disposables, and reusable instruments, is responsible for 4% of kgCO2e.

The spontaneous vaginal birth pathway at a hospital has a carbon footprint of 259.5 kgCO2e. Again, Entonox® contributes the largest proportion of GHG emissions, 69%. The contribution of inpatient bed days to the pathway's carbon footprint is slightly lower than for the assisted vaginal birth pathway as on average women's stay in hospital is three quarters of a day shorter. The GHG emissions contribution of the birth itself is, with 4%, nearly the same as for assisted vaginal birth. However, looking at the absolute numbers, spontaneous vaginal birth contributes 3.3 kgCO2e less to the carbon footprint as neither forceps nor a ventouse are used.

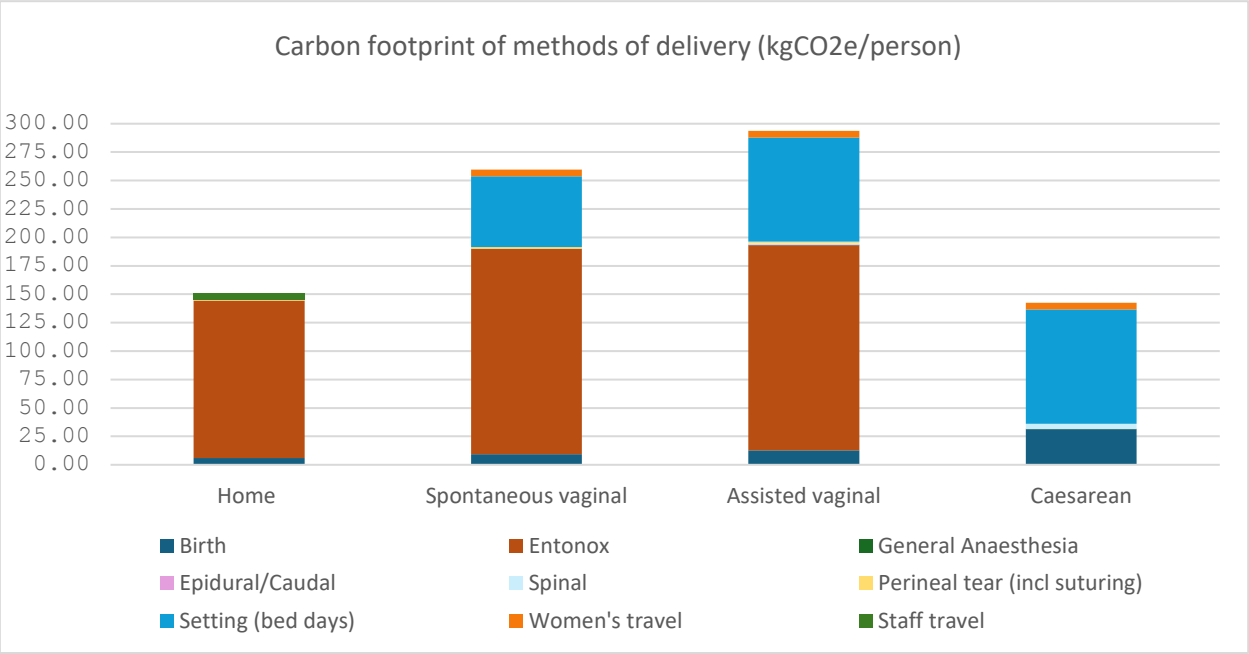
The home birth pathway is responsible for 151 kgCO2e. It is the mode of birth with the 2nd smallest carbon footprint. However, this could be due to women who have experienced complications during pregnancy or who were at a higher chance of complications during birth, not giving birth at home. Entonox® is the home births' biggest GHG emissions contributor – 92%.

The average carbon footprint per person of the caesarean birth pathway, planned and unplanned combined, is 142.4 kgCO2e, smaller than the spontaneous vaginal and assisted vaginal birth and home birth pathway as there is no use of Entonox. However, this is not taking into account that before an

unplanned caesarean birth women and birthing people are likely to have started to go through the spontaneous vaginal or assisted vaginal birth process and therefore might have used Entonox® and other consumables. The majority of GHG emissions (71%) of a caesarean are caused by the number of antenatal and postnatal inpatient bed days which is only a quarter higher than for assisted vaginal births.

The second highest contributor (22%) is the birth itself, as it is conducted in theatre, requiring more medical items to carry out the procedure than in the case of a home birth, spontaneous vaginal birth and assisted vaginal birth, e.g. a reusable tray with instruments, a disposable pack with consumables, separately packed consumables such as a urinary catheter and PPE.

Figure 6: Carbon footprint of modes of birth per person (kgCO2e)



Entonox®

Using 'cracking' technology, converting Entonox® into nitrogen and oxygen, can reduce the carbon footprint of Entonox® by 71-81% (26). If 'cracking' technology were used for the 76% of women who are assumed to have received Entonox, the average carbon footprint of the spontaneous vaginal birth pathway, for example, would have been reduced to 131.47 kgCO2e, lower than the average carbon footprint of a caesarean birth – see Figure 7. In units where there are high levels of Entonox® waste cracking will not be an appropriate solution and waste should be addressed first.

Induction of labour

According to NHS England Digital Maternity Statistics in 2022-23, the method of onset for 38% of spontaneous vaginal birth was induction (54). In the event of assisted vaginal births, induction precedes 47% of cases, and for caesarean births 22% follow inductions. The rate for caesarean births is smaller as caesarean births cover both planned and unplanned caesareans, but induction is likely to precede unplanned caesareans only.

If induction is required, it adds on average 13% to a spontaneous vaginal birth, 12% to an instrumental birth and 25% to a caesarean birth.

Figure 7: Average per person carbon footprint (kgCO2e) of spontaneous vaginal birth with and without Entonox® 'cracking'

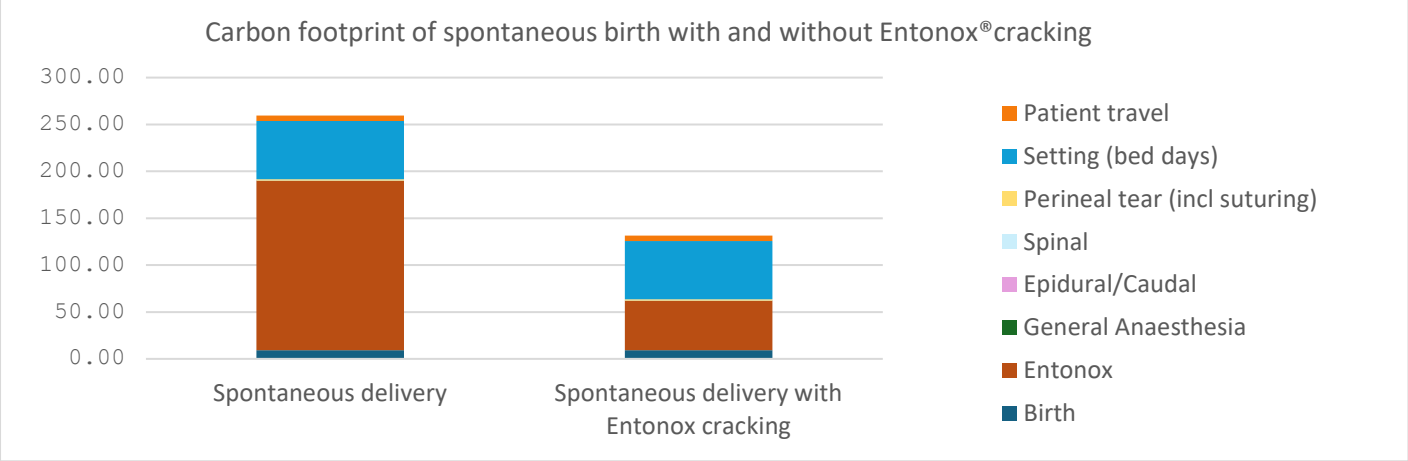
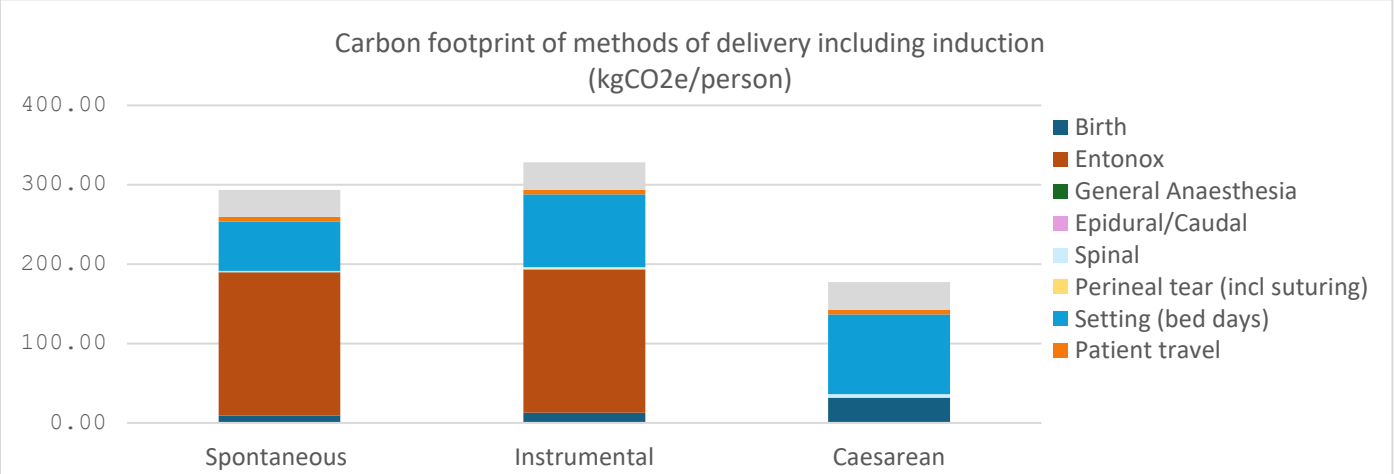


Figure 8: Average per person carbon footprint (kgCO2e) of spontaneous vaginal, assisted vaginal and caesarean birth, accounting for rate of induction



Pilot sites

Four pilot sites partially filled in the Maternity Care Pathway Calculator. All four pilot sites recorded data for the intrapartum care pathway, two pilot sites shared data on their antenatal care pathway and one pilot site filled in data for all pathways. Comparing the carbon footprint of the pilot sites' pathways with the most comprehensive activity data with our analysis shows the following.

Antenatal care pathway

Comparing the two pilot sites with our analysis shows that the carbon footprint per person at pilot site 1 is the smallest – see Table 3. This is due to the fact that the data was collected for one month only and therefore does not show the complete 6-9 months antenatal care pathway per person. Pilot site 2 has the

highest carbon footprint despite not recording data on regular antenatal visits, but on antenatal visits for ultrasound scans and blood testing only. Based on 7.3 ultrasounds scans and one set of blood testing per person, including the return travel to the appointments, pilot site 2's antenatal care pathway carbon footprint per person is 1.5 times or 20 kgCO2e higher than in our analysis. Women's travel and scans contribute more to pilot site 2's carbon footprint than at pilot site 1 and our analysis.

Table 3: Comparison of antenatal care pathway carbon footprint per person

	Carbon footprint per person (kg CO2e)					
	Pilot 2		Pilot 3		Analysis	
Referral	0.003	0.03%	0.00	0.00%	0.13	0.35%
Women's travel	7.94	69.3%	48.41	81.4%	25.35	65.7%
Staff travel (excl. commuting)	0.05	0.4%	0.00	0.0%	0.95	2.5%
Setting	3.42	29.9%	7.40	12.4%	11.76	30.5%
Ultrasound scans	0.07	0.6%	3.67	6.2%	0.38	1.0%
Total	**11.46**		**59.48**		**38.57**	

Intrapartum care pathway

Results of the intrapartum pathway of our four pilot sites showed a large variation of the carbon footprint per person – see Table 4. This is partly due to the difference in healthcare settings which have been included in the results. Whereas pilot 1 only included data around births at their obstetric units, pilot 2 and 3 also included data from a midwife attached unit and home births, and pilot 4 from an obstetric unit and home births. The different sample sizes and duration of time periods for which data was collected will also contribute to the difference in results. Whereas pilot site 1 looked at five births, pilot 2 considered their data recorded for one month in 2024 and pilot 3 and 4 both looked at data recorded in the last year.

The biggest variation can be seen in the GHG emissions associated with antenatal and postnatal inpatient bed days. While pilot site 1 recorded 5 days per patient, pilot site 3 recorded none at all and pilot site 2 recorded seven inpatient bed days at their midwife led unit, but only one inpatient bed day in their obstetric unit.

The second biggest difference is in the carbon footprint of Entonox® per birth. Whereas pilot site 4 hardly uses any Entonox, pilot site 2 seems to use the most.

Postnatal care pathway

Pilot site 2 submitted results for the postnatal care pathway. Their average carbon footprint per person is very similar to our analysis. However, the carbon footprint breakdown differs – see Table 5. While patient travel contributes 58% to the pilot site's postnatal care pathway, followed by staff travel with 23%, in our analysis staff travel contributes 47% and patient travel 37%. The higher contribution of women's travel to the pilot's site postnatal care pathway is due to a higher proportion of postnatal visits being conducted at an outpatient setting instead of at home.

Table 4: Comparison of intrapartum care pathway carbon footprint per person

	Carbon footprint per person (kgCO2e)				
	Pilot 1	**Pilot 2**	**Pilot 3**	**Pilot 4**	**Analysis**
Travel	5.80	6.02	6.02	5.80	5.80
Birth	27.54	11.87	12.41	21.24	18.28
Inpatient stay	190.0	70.9	0.00	113.54	78.84
Ultrasound scans	0.30	0.11	0.00	0.00	0.00
Pharmaceuticals (incl. Entonox)	147.84	182.1	106.47	4.97	110.41
Total	**371.5**	**270.9**	**124.9**	**145.5**	**213.3**
	Detail of units				
Total number of births	5	734	1,686	15,474	547,244
Setting included	Obstetric only	Home Midwife attach Obstetric	Home Midwife attach Obstetric	Home Obstetric	Home Midwife led Obstetric

Table 5: Comparison of postnatal care pathway carbon footprint per person

	Carbon footprint per patient (kg CO2e)			
	Pilot 2		**Analysis**	
Women's travel	14.21	57.6%	7.48	37.1%
Staff travel (excl. commuting)	5.80	23.5%	9.46	46.9%
Setting	4.68	18.9%	3.23	16.0%
Ultrasound scans	0.00	0.00%	0.00	0.00%
Pharmaceuticals	0.00	0.00%	0.00	0.00%
Total	**24.69**		**20.17**	

Infant feeding

The per person carbon footprint of pilot site 2's infant feeding pathway provides an interesting snapshot. Apart from looking at formula feeding (breastfeeding is excluded), the calculator also collects data on the number of inpatient days and referrals to outpatient clinics due to physiological concerns which might affect the feeding ability of the baby – see Table 6. The data shows that 64% of women initiated breastfeeding. There are 1.4 inpatient bed days and 25% referrals to outpatient appointments due to physiological concerns. As a result, the GHG emissions associated with the setting contribute 55% to the infant feeding care pathway, followed by infant formula with 44%.

Table 6: Infant feeding care pathway carbon footprint per person – pilot site 2

	Pilot 2	
	Carbon footprint per person(kg CO2e)	**Proportion (%)**
Women's travel	1.01	1.0%
Setting	54.09	55.3%
Infant formula	42.66	43.6%
Total	**97.76**	

Discussion

Based on NHS Digital's Maternity Statistic 2022-23 (54) data, the total annual carbon footprint of the project's highlighted maternity pathways was estimated to be 204,950 tCO2e, nearly 1% of the overall carbon footprint of NHS England. This will be an underestimation of the total GHG emissions impact of all NHS maternity services as several pathways and any activity data beyond eight weeks postnatal have been excluded, for example, care pathways for miscarriages, ectopic pregnancies, gestational diabetes, antenatal mental health, thromboembolism, vaginal bleeding, preeclampsia and the gynaecological care pathway beyond eight weeks postnatal to support women and birthing people with urinary incontinence and pelvic organ prolapse.

Strengths and limitations

The strength of this carbon footprint analysis is the range of maternity care pathways which were included. Though it does not cover all NHS maternity services, seven of the maternity care pathways have been incorporated.

The limitations are in the approach taken to carry out the carbon footprint analysis. The lack of site-specific data meant that the carbon footprint estimation relied on the most recent NHS Digital Maternity Statistics of 2022-23 and NICE Guidance. NICE Guidance offers a gold standard version of each maternity pathway. Though the pathway maps were modified incorporating expert opinion from the stakeholder group and input from the lived experience group, the extent of variation of service delivery on the ground could not be sufficiently explored. Preliminary results from our four pilot sites have shown considerable differences in the carbon footprints per birth mainly due to variation in the duration of delivery episodes, including antenatal and postnatal inpatient bed days, and due to the difference in the use of Entonox.

The carbon footprint analysis of the antenatal care pathway is likely to be an underestimation of the pathway's GHG emissions as it was based on seven to ten antenatal appointments including two scans per woman. According to expert opinion, most women have more appointments, some as part of the routine antenatal care pathway, others attend maternity triage or the maternity assessment units. Moreover, they are likely to receive more than two scans. One of the pilot sites reported more than seven scans per woman. Though the carbon footprint of an ultrasound scan is small the accompanying GHG emissions due to women's travel and the healthcare setting for an outpatient appointment would increase the emissions by 7.6 kgCO2e per scan appointment. Likewise, the inclusion of common pharmaceuticals, e.g. iron

supplements, omeprazole and Peptac/Gaviscon would have further increased the carbon footprint of the antenatal care pathway.

The reduction of the carbon footprint of induction to additional inpatient bed days on the antenatal ward will have resulted in an underestimation by not including the method on induction. However, estimating the carbon footprint of Oxytocin on the basis of cost, for example, shows that this would add only a small amount of GHG emissions. Including the use of Entonox® during the induction process though, might have increased the induction pathway's carbon footprint substantially.

The carbon footprint analysis of the induction pathway assumed that all inductions take place as an inpatient. However, an increasing number of inductions are now conducted as an outpatient appointment. This would reduce the GHG emissions embedded in inpatient bed days on an antenatal ward, but likely increase emissions associated with women's travel.

The carbon footprint analysis of the intrapartum care pathway was heavily reliant on Spil et al's study on 'The carbon footprint of different modes of birth in the UK and the Netherlands […]' (11) applying its analysis to data on onset and method of birth of NHS Digital Maternity Statistics 2022-23 (54). Though a very detailed study, the authors acknowledge the limitation of only studying uncomplicated births in low-risk pregnancies ending by the route planned. We understand that this idealised scenario is not reflective of real life. The use of the maternity care pathway calculator at the four pilot sites has given us a glimpse of the intrapartum care pathways on the ground, providing, for example, insight on the rate of transfers from home births to obstetric units and midwife attached units to obstetric units. The results of the pilot sites also highlighted the variation in practice with one pilot hardly using any Entonox.

The carbon footprints of units of healthcare activity as estimated by the Sustainable Development Unit (SDU) in collaboration with SHC in 2015(55–57), were based on a very small sample size. Our analysis' reliance on these carbon footprints might raise questions on the accuracy when applied to inpatient bed days on antenatal wards for the induction process, postnatal inpatient bed days, antenatal visits and antenatal classes and women's travel. Moreover, as the year of publication was 2015, the carbon footprints per unit of activity are likely to be higher than if they had been estimated with this year's (2024) emission factors, due to the lower carbon intensity of the current electricity grid and higher transport fuel efficiency.

Limiting the carbon footprint of the pelvic floor pathway to the repair of 3rd and 4th degrees tears is neglecting the long-lasting impact of a damaged pelvic floor. Preliminary data from one of the pilot sites has shown that around 13% enter the postnatal pathway, with 47% of those being referred to an outpatient appointment for assessment and 5% being referred to gynaecology. The environmental impact of potential pelvic floor care provided by multidisciplinary teams and long-term use of incontinence products is likely to outstrip the original carbon footprint of the repair of 3rd and 4th degree of tears. We have estimated, for example, that a lifetime supply of incontinence pads could contribute 8 tCO2e per person.

The carbon footprint estimations of breastfeeding and infant formula feeding are solely based on the study by Andresen et al. 'Environmental Impact of Feeding with Infant Formula in Comparison with Breastfeeding'(31). It compares the carbon footprint of formula feeding, including the production of the formula and five bottles and the preparation of the formula including the sterilisation of the bottles, with the additional nutritional requirements of a breastfeeding woman. Any potential use of breast pumps and

feeding bottles for expressed breastmilk has not been taken into account. One of the pilot site's data provided additional information on the GHG emissions impact additional inpatient days and outpatient referrals due to potential physiological concerns

Despite its limitations, the study was able to identify the main carbon hotspots of different maternity care pathways, and the highlighted pathways combined and to explore areas where the largest carbon reductions could be achieved.

Interpretation

Reviewing the highlighted pathways' hotspots, healthcare settings and travel come out top for several pathways. Inpatient bed days are GHG emissions hotspots of the induction and intrapartum care pathway. Though the induction care pathway has the second lowest carbon footprint per person and the third lowest when comparing the pathways across England, streamlining the induction process by avoiding any delays for women and birthing people progressing through the different stages of induction will reduce the number of inpatient bed days on the antenatal ward and mitigate the associated GHG emissions. Similarly, in the case of the intrapartum care pathway, working towards a timely postnatal discharge to reduce clinically unnecessary inpatient bed days will mitigate the carbon footprint of postnatal hospital stays.

The carbon footprint of antenatal visits at healthcare settings/midwife-led hubs and women's travel are carbon hotspots of the antenatal and hypertension care pathway. Streamlining of appointments might offer an opportunity to reduce the accompanying emissions and is more convenient for pregnant women and their carers. By considering and evaluating equitable locations of antenatal care provision, offering women a choice of where to receive their antenatal care based on access to active travel and local public transport systems, GHG emissions could be reduced further. This might also have a positive impact on women's healthcare associated travel costs and improve access especially for disadvantaged groups with low car ownership (58).

The use of Entonox® is the biggest carbon hotspot of the intrapartum care pathway, and of all highlighted maternity care pathways combined. As it is one of the main methods of pain relief during vaginal birth in England, and to ensure women have a choice of pain relief, Entonox® cannot be simply phased out similar to Desflurane. Currently, there are significant systems' losses of piped Entonox® which should be urgently addressed through systematic monitoring and feedback (13). In parallel, midwife-led and obstetric units need to ensure that there is capacity to administer all methods of pain relief, including epidurals and remifentanil PCAs (patient-controlled analgesia). Anecdotal evidence indicates that the limited availability of anaesthetists to administer epidurals contributes to the high use of Entonox® in England. Moreover, access to epidurals has been shown to be lower in Black and Asian ethnic groups (22). Information on the benefits and risks, including the environmental impacts, of all pain relief options should be freely available to all pregnant women and birthing people. Guaranteeing equity of access to all methods of pain relief offers another opportunity for carbon reduction.

Addressing Entonox® wastage and investing in 'cracking' technology will mitigate the GHG emissions of Entonox® when in use, reducing it by 71%-81% (26). As we have shown above, if cracking were used in the case of the 76% who on average receive Entonox, the average carbon footprint of the spontaneous vaginal birth care pathway would have been reduced to less than the average carbon footprint of a caesarean birth.

The lower carbon footprint of breastfeeding is adding to the other benefits of breastfeeding, namely the positive impact on the health of the baby and woman. Adequate information on breast/chestfeeding (for all cultures and literacy levels) and the provision of equitable access to breastfeeding support will help women and birthing people to make an informed choice on the type of infant feeding they would like to provide. Information campaigns on breastfeeding and provision of breastfeeding support might be particularly targeted at young parents and parents with lower levels of education as they show lower breastfeeding rates (40). This might also help to address the carbon hotspot of inpatient days and outpatient referrals from pilot site 2's infant feeding pathway, particularly those arising from physiological concerns.

Conclusion

Despite limited site-specific data, the carbon footprint analysis of highlighted maternity care pathways provided insight into the pathways' carbon hotspots and explored the areas where GHG emissions mitigation will have the biggest impact.

Glossary

Terms used in report	**Definitions/alternative terms used by NHS Maternity Statistics and other publications**
Surgical induction	Induction by amniotomy
Medical induction	Medical induction includes the administration of agents either orally, intravenously or intravaginally
Combined induction	Surgical and medical induction combined
Assisted vaginal birth, refers to birth assisted by either forceps or ventouse	Instrumental delivery, includes low forceps cephalic delivery, other forceps delivery, ventouse (vacuum) delivery, breech extraction delivery
Spontaneous vaginal birth	Spontaneous delivery, includes normal delivery (spontaneous vertex), spontaneous other delivery , other breech delivery
Caesarean birth, includes planned and unplanned caesarean births	Caesarean delivery, includes elective caesarean delivery, other/emergency caesarean delivery
Planned care	Elective care
Modes of birth	Method of delivery
Intrapartum care pathway/birth pathway	Method of delivery

Selection of target areas

Based on the scoping work described, and with the input of the project group, lived experience and expert stakeholders, seven targets areas were selected for the green maternity challenge:

1. Valuing people's time

Streamlining services and systems to avoid waste

Examples: Tackling delayed discharge, scheduling of appointments, decreasing travel to appointments

2. Supporting informed choices

Providing relevant information and support so that people can successfully access/implement the choices that are best for them

Examples: Linking into local voluntary provision, access to pain relief, better access to translation services, culturally relevant support, being explicit about sustainability choices e.g. bounty packs

3. Pelvic health and continence

Tackling the long-lasting effects of poor continence following childbirth

Examples: Promotion of ante-natal pelvic health guidance, access to specialist services, improvement to perineal tear care

4. Infant feeding

Meeting the unmet need of those who want to breastfeed but lack appropriate support

Examples: improved systems for supporting people in their feeding choices including peer support, culturally relevant nutritional support

5. Complex pregnancies

Improved systems for those with additional care needs or complications

Examples: hypertension pathway improvements, new ways of monitoring, reducing travel to appointments

6. Access and experience for people who experience worse maternity outcomes

Focusing resource and/or re-designing systems to cater for those that the system has underserved before

Examples: Improvement of services for people living in deprived communities, Black and Asian people, and young mothers and birthing people

7. Listening to women and birthing people

Reducing waste and improving outcomes by involving people in their own care, co-designing services, and utilising third sector support

Examples: More say for people in how and where they access care, processes that value their voices

Notable omissions

The following were identified as key targets for carbon reduction in maternity services that we consciously chose not to take forward to the challenge.

We acknowledge that these must be considered in future work to decarbonise maternity services but we felt that either existing work has already established best practice in these areas (e.g. The Green Surgery Report and Intercollegiate Green Theatre Checklist (19,29)) or that projects tackling these issues were not suited to the constraints of a 16 week quality improvement project:

Limiting N2O/O2 (Entonox® , Gas and air) wastage and improving access to all forms of pain relief in labour

Mitigating the adverse effects of N2O/O2 while maintaining patient choice and experience. Improving access to pharmacological and non-pharmacological pain management in labour.

Disposables

Reducing reliance on disposable birth packs, instruments, drapes, gowns.

Birth place energy consumption

Improving buildings, HVAC systems, low-energy lighting, and transitioning to renewable energy.

Digitisation

Development of a cohesive digital maternity system to improve care delivery, enhance communication, and reduce the environmental footprint of healthcare administration.

Improving access to nutritious, sustainable diet

Improving access to low-carbon, nutritional and affordable diets.

Phase 2: "Make changes"

The Green Maternity Challenge

The Green Maternity Challenge was launched in July to select and support multi-professional teams from across the UK to develop and implement sustainable quality improvement (SusQI) projects. The programme is a national adaptation of the Centre for Sustainable healthcare's

Green Team Competition – an award-winning, tried & tested programme to transform healthcare by cutting carbon, improving patient care and staff experience, and saving money.

GREEN MATERNITY CHALLENGE

Figure 9: Green Maternity Challenge timeline

Teams were guided to focus on identified target areas as part of the application process. A fully developed project was not required at the application stage, rather a thorough understanding of the problem and some suggested solutions. In total 30 applications were submitted, these were reviewed and scored based on the following:

Score for each metric: 1 = Inadequate, 2 = Insufficient, 3 = Acceptable, 4 = Good, 5 = Excellent

- *Why would you like to participate*
- *Problem identification and relevance to local service users and the identified priority target areas*
- *Proposed solutions and feasibility*
- *Organisational commitment and support*
- *Overall application*

Initial plans were to select six multidisciplinary clinical teams across the UK. Due to unprecedented enthusiasm from the maternity community, this was later expanded to nine teams. These teams have received expert mentoring and support from CSH to demonstrate how their initiatives will ensure impactful, practical, and achievable changes. They then had 16 weeks to deliver measurable carbon reduction in their local service before coming together to showcase their work at an online event on the 5th March 2025 (figure 9).

Challenge teams and projects

The nine successful teams are listed below with links to their project reports on the CSH's resource library: Recordings of all team presentations at the showcase event are also available here.

Reducing the impact of nausea and vomiting in pregnancy - an ambulatory approach

Norfolk and Norwich University NHS Hospital Trust (winning team)

NHS Norfolk and Norwich is introducing a virtual ward for women with hyperemesis gravidarum, allowing them to receive timely care at home. This will improve patient experience, reduce hospital visits, and lessen the environmental and financial strain on healthcare services.

Postnatal hypertension made simple and sustainable

Imperial College Healthcare NHS Trust (highly commended)

NHS Queen Charlotte and Chelsea is improving hypertension management in pregnancy by refining clinical guidelines and boosting staff confidence in treatment. This will enhance patient care, reduce hospital stays, and improve long-term health outcomes while minimising costs and resource use.

Improving access to care in a remote and rural area; local introduction of screening for newborn developmental hip dysplasia

NHS Orkney (highly commended)

NHS Orkney is developing a local newborn hip dysplasia screening service to reduce the need for stressful and costly travel to Aberdeen. Currently, 47% of families find the journey challenging, and 98% support local screening. By upskilling sonography-trained midwives in partnership with Aberdeen, the change will improve patient experience, job satisfaction, and sustainability while easing financial and environmental burdens.

Streamlining the multiple pregnancy pathway

West Suffolk NHS Foundation Trust

NHS West Suffolk is improving care for women with multiple pregnancies by enhancing appointment efficiency, reducing unnecessary tests, and offering virtual consultations to save time and improve patient experience. The changes aim to streamline care, improve satisfaction, and reduce the burden on both women and staff, with potential benefits for the wider antenatal population.

The Olive Clinic - Reducing health inequalities for Albanian-speaking women

Kingston Hospital NHS Foundation Trust

NHS Kingston is improving care for Albanian women by establishing a dedicated clinic with a safeguarding midwife and an Albanian-speaking Doula. This will enhance continuity, cultural sensitivity, and communication while reducing unnecessary interventions, improving maternal wellbeing, and supporting better birth outcomes.

Enhancing sustainable value of the first obstetric antenatal appointment

Imperial College Healthcare NHS Trust

NHS Imperial is optimising antenatal referrals by shifting unnecessary face-to-face appointments to virtual consultations. This will reduce travel, waiting times, and clinic overcrowding while ensuring in-person slots are reserved for women who need them most, improving efficiency and care quality.

Improving outcomes with perineal massage

South Warwickshire University NHS Foundation Trust

NHS South Warwickshire is promoting antenatal perineal massage to reduce birth-related trauma and improve pelvic health. By training staff to counsel women on this practice, the initiative aims to lower perineal tears, enhance recovery, and reduce long-term health complications, benefiting both patients and healthcare resources.

Implementation of Joint Antenatal Care Appointments

Whittington NHS Hospital Trust

NHS Whittington is improving antenatal care by combining midwifery and virtual obstetric appointments to prevent unnecessary hospital visits and duplicate tests. This change will enhance continuity, trust, and convenience while lowering environmental and financial costs.

Improving breastfeeding support

Great Western Hospital NHS Trust

NHS Great Western is enhancing breastfeeding support by introducing daily antenatal and postnatal group sessions led by maternity support workers. Reusable baby bottles will replace single-use alternatives to reduce waste and improve feeding consistency, benefiting families and the environment.

While these projects are a good first step, we recognise that our work so far has not represented many vital areas for service improvement.

"Health inequalities, particularly racial disparities, were a central focus [of the lived experience group's priorities for improvement]. The MBRRACE-UK report revealed that Black women are three times more likely to die during childbirth than white women (59). *Despite this alarming*

statistic and the significant strain this puts on NHS services, no green challenge team attempted to implement initiatives specifically addressing the needs of Black and global majority women."

Tahnee Brathwaite, lived experience group member

Figure 10: Combined carbon and cost savings of all nine teams

Clinical, social, financial and environmental impacts

The nine projects combined are projected to save 101,263 kgCO2e and £860,669 in the first year equivalent to driving 298,367 miles in an average car, a huge achievement in a short space of time (figure 10).

Table 7 on the following pages summarises the outcomes of the green maternity challenge considering clinical, social, financial and environmental impacts as represented by the triple bottom line equation below.

$$\text{Sustainable Value} = \frac{\text{Outcomes and experience for women and families}}{\text{Environmental + financial + social costs}}$$

Table 7: Summary of outcomes for the Green Maternity Challenge group projects

Environmental and financial savings reported are the predicted **annual** savings from the 2024-25 Green Maternity Challenge. **Black text** represents savings based on post-change data scaled over a year. **Blue text** indicates projected savings based on patient data, evidence, informed assumptions and/or expected outcomes.

Project	Financial savings	Environmental (CO_2e) savings	Social outcomes	Clinical outcomes
Streamlining the multiple birth pathway, **West Suffolk NHS Foundation Trust**	1,831	576	• Average saving of £20.22 per patient per pregnancy. • Patient waiting times are expected to decrease. • Patient satisfaction is expected to increase . • Positive impact on staff confidence and wellbeing, with reduced time spent preparing for consultations and more efficient running of our antenatal clinics.	• Care updated to the 2024 NICE guidance (endorsed Twins Trust pathway). • Care will become more collaborative, efficient and patient centred. • DNA rates expected to decrease • Timelier access to care.
Improving breastfeeding support, **Great Western Hospital NHS Trust**	4,641	1,585	• Positive feeding: "Great breastfeeding support from lovely knowledgeable staff". • Empowers birthing people to get the support they need and be welcomed into a group setting. • Staff feel more confident in offering support in a group setting and developing their skills. • Supports staff job satisfaction and efficient use of time.	• Improving effectiveness and person-centred care. • Improving breastfeeding can reduce readmissions for weight loss, feeding support and jaundice. • Supportive for maternal mental health
Upskilling staff to provide local hip dysplasia screening, **NHS Orkney**	15,915 in first year, 17,000 in subsequent years.	7,073 in first year, increasing to 7,615 in subsequent years.	• 98% families support local screening service which will reduce stress, travel & weather delays, time off work & financial pressures. • 88% families value NHS reducing their environmental impact. • Programme creates new opportunity for local staff, supporting job satisfaction.	• Reduced risk of delays to scanning & treatment if required. • Removes barriers families may face to travel to Aberdeen, ensuring equitable access • More appointment slots available at tertiary hospital for other patients.

Project	Financial Savings	Environmental (CO2e) Savings	Social outcomes	Clinical outcomes
Improving access for Albanian women, **Kingston Hospital NHS Foundation Trust**	Additional annual cost of £6,049. Once off cost of £1,326 to translate key documents.	Baseline carbon emissions have been calculated. At least 1 year is required to evaluate impact on carbon emissions.	• Having the same midwife and same female interpreter at each appointment had a very positive impact on experience, with one woman commenting *"It's my second time here and I feel very comfortable".* • Project accepted by staff with a positive impact on overall workload and time management. • Staff satisfaction improved knowing that Albanian women will have better access to care and information.	• Care more patient-centred, timely and efficient. • Continuity of care and continuity in interpreting services improve the standard of the care that women receive. • Improved education and support for informed choices, enhanced trust and engagement in healthcare services during and beyond pregnancy.
Streamlining antenatal appointments, **Whittington NHS Hospital Trust**	1,396	230	• Unanimous support among surveyed patients for combined appointments when clinically appropriate. • Flexible approach benefits women reducing disruption to daily responsibilities. • Enhanced relationships within the multidisciplinary team (MDT) can lead to improved job satisfaction. • 15 minutes of consultant time will be saved per appointment. • While appointments will be 10 minutes longer for the midwifery team, it negates the need for follow up of results post consultant appointment and onward referrals which take more than 10 minutes.	• Better coordination of care plans and more robust multidisciplinary team working, resulting in more cohesive patient care. • Supports equitable access for patients (e.g. for women facing transport difficulties or other barriers).
Improving care for women with hyperemesis, **Norfolk and Norwich University NHS Hospital Trust**	762,044	6,462	• Reduced impacts on work, family life, relationships, daily activities, e.g. "*Having IV fluids at home has meant I can participate in family life*" and "*My husband is able to go to work and my son has his mummy back".* • Increased staff confidence and satisfaction *"We are buzzing with the difference we are able to make for patients now…".*	• Person-centred care ensuring women are listened to, and their care adapted to best suit them in terms of medication regime and location of care. • Improved care and outcomes for women with diabetes who can continue their usual medication.

Project	Financial savings	Environmental (CO2e) savings	Social outcomes	Clinical outcomes
Improving postnatal hypertension care, **Imperial College Healthcare NHS Trust**	14,465	58,645	• Prior to the project patient feedback cited longer hospital stays contributing to poor sleep, feelings of isolation, poorer bonding with their baby, and pain from repeated blood tests. • Positive feedback received from women, e.g. "*we felt there was more consistency in care, and we quickly came to a routine of medication in order to be able to leave*". • 100% resident doctors surveyed found the new guideline 'useful' and there was an 82% increase in those feeling 'confident' in managing postpartum hypertension.	• Postpartum stay was 2.6 days shorter • 2.92 fewer sets of blood tests per patient. • No patients were discharged on more than one anti-hypertensive, compared to 28% in the pre-intervention group. • No unplanned reviews or readmissions compared to 10 in the pre-intervention group.
Improving outcomes with perineal massage, **South Warwickshire University NHS Foundation Trust**	64,795	1,887	• Increased staff knowledge and confidence. • Counselling on perineal massage adds time to midwifery appointments. Time constraints remain a barrier for staff. • Project supports women to overcome barriers to implement massage, e.g. lack of knowledge, concerns about safety, social stigma. • Perineal massage reduces trauma which can have many impacts on women's daily lives, e.g. increased need for private transport, higher laundry costs, and use of incontinence products.	• Early discussions and better access to information improve care, confidence, and uptake – improving timeliness and efficiency of care. • Increased use of perineal massage reduces risks of OASI, trauma, and episiotomy, improving pelvic health, mental well-being, and reducing future healthcare needs.
Streamlining antenatal appointments, **Imperial College Healthcare NHS Trust**	1,872	24,262	• Of 54 women surveyed: 45/54 preferred virtual service • Several benefits to women: less time off work, easier with childcare, partner being able to participate in appointment, less frustrating waiting at home or work than in clinic. • Average of £11.35 in transport costs saved per patient • MDT benefits: midwives valued being able to offer virtual clinics, admin teams valued guidance on timing of appointments, registrars found the prioritisation and allocated time for counselling rewarding.	• Improved efficiency and person-centred care, with women reporting a "*much better understanding of what to expect*". • Improved timeliness of care • High patient perception of value of virtual appointments (average score to *"how valuable did you find the appointment"* was 9.6).
Total savings	**£860,669**	**101,263 kgCO2e**		

Phase 3: “Share learning”

Through a series of events and the recommendations included in the main report we have, and will continue to, engage with and empower the wider maternity workforce to make changes in their practice and to advocate for change at a local and national level. Through the collaboration of two major maternity professional organisations (RCOG and RCM) we have a direct pathway to broad implementation of the findings detailed in this report. SHC provide a valuable link between clinicians and industry, and we have started meaningful discussions to drive forward innovation in sustainable maternity care.

Industry engagement activity

An Industry Engagement Roundtable was held as a 2-and-a-half-hour online workshop on Tuesday 21st January 2025. The roundtable discussed the barriers and opportunities to innovating and marketing enhanced products and services to improve maternity service equity and sustainability and to explore options to enhance collaboration to inform and accelerate action.

Over the course of the roundtable, we explored:

- Applying a care pathways approach to target carbon and inequity hotspots in maternity care.
- The role of frontline clinicians in driving the transition to greener and more equitable maternity care.
- How healthcare industries are responding to health challenges.
- What the current challenges for implementing change are and how we can collaborate to unlock opportunities for innovation.

Ninety-eight individuals received invitations to participate and 26 attended (9 project partners, 9 health system actors, 1 academic and 7 industry representatives).

Industry was receptive to constructive dialogue but the twin factors, that individual companies represent a small part of a highly fragmentary supply base in maternity service procurement and much of the product and service portfolios utilised by maternity services are not unique to that clinical specialism, limit the ability to engage effectively. Further, it is difficult for individual actors to identify specific activities that might form part of concrete improvement pledges, although commitment to engage in dialogue is a valuable potential outcome. Similarly, on the clinician side, time constraints on current delivery models and local focus for activity mean that the only practicable route to clinical needs being articulated would be through the Royal Colleges. After the event, we have sought to engage collective voices through their respective trade or professional representative bodies and this may prove a more productive route to engage industry in a pre-competitive and collaborative manner. Follow up is being conducted through engagement with workshop output materials to all invited participants and direct engagement with industry representative and partner organisations, such as the Association of British HealthTech Industries (ABHI) and Health Innovation Networks (HINs).

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Appendix 1: Search Strategy

Ovid MEDLINE(R) <1946 to March Week 5 2024> MESZ

1 Carbon footprint/ 1252

2 Greenhouse gases/ 2788

3 (((Carbon or CO2 or "greenhouse gas*") adj (emission* or footprint or reduc*)) or "Low carbon").mp. 17088

4 Analgesia, Obstetrical/ or Anesthesia, Obstetrical/ or Birth setting/ or Birthing Centers/ or Breast feeding/ or Delivery rooms/ or Doulas/ or exp Fetal Monitoring/ or exp Fetal Therapies/ or exp Fetus/ or Hospitals, Maternity/ or exp Infant, Newborn/ or Labor pain/ or exp maternal health services/ or Midwifery/ or Nurse Midwives/ or exp obstetric surgical procedures/ or Obstetricians/ or obstetrics/ or "Obstetrics and Gynecology Department, Hospital"/ or exp pregnancy/ or exp pregnancy complications/ or exp Prenatal Diagnosis/ or exp Reproductive Physiological Phenomena/ 2170757

5 (matern* or obstet* or midwi*).kw,jw,in. 683029

6 (1 or 2 or 3) and (4 or 5) 217

7 limit 6 to (english language and humans) 86

Embase <1974 to 2024 Week 14>

1 exp *greenhouse gas emission/ 8180

2 (((Carbon or CO2 or "greenhouse gas*") adj (emission* or footprint or reduc*)) or "Low carbon").mp. 36318

3 1 or 2 37574

4 limit 3 to pregnancy - wide 287

5 (matern* or obstet* or midwi*).kf,jx,in. 1055578

6 3 and 5111

7 4 or 6 363

8 limit 7 to (human and english language) 222

Maternity & Infant Care Database (MIDIRS) <1971 to March 26, 2024>

1 (((Carbon or CO2 or "greenhouse gas*") adj (emission* or footprint or reduc*)) or "Low carbon").mp. 23

Ovid MEDLINE(R) Epub Ahead of Print <April 08, 2024>

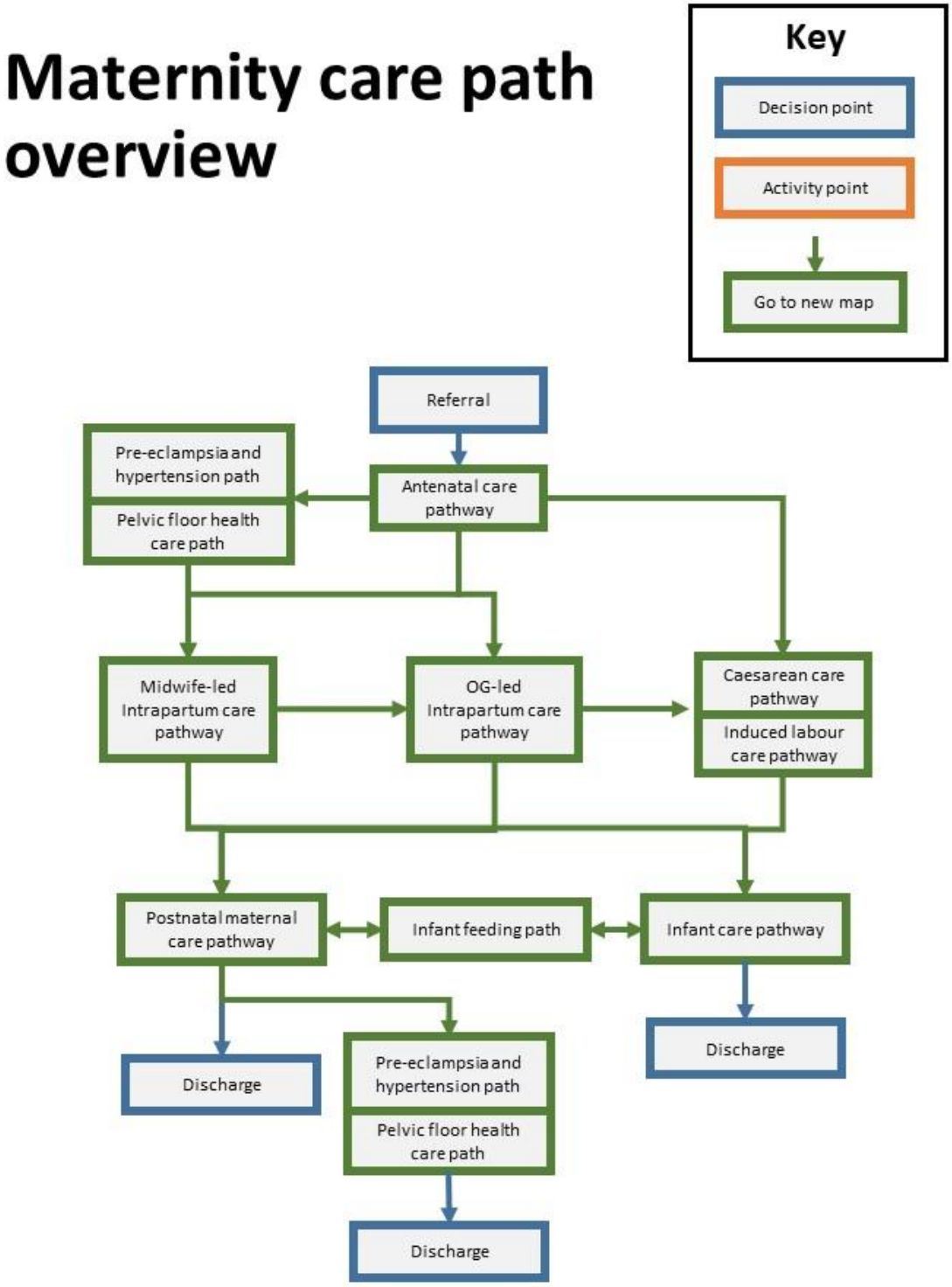
Ovid MEDLINE(R) In-Process & In-Data-Review Citations <1946 to April 08, 2024>

1 (((Carbon or CO2 or "greenhouse gas*") adj (emission* or footprint or reduc*)) or "Low carbon").mp. 948

2 (Obstetric* or Matern* or Midwi* or Birth or Childbirth or labour or pregnan*).mp,jw,in. 20712

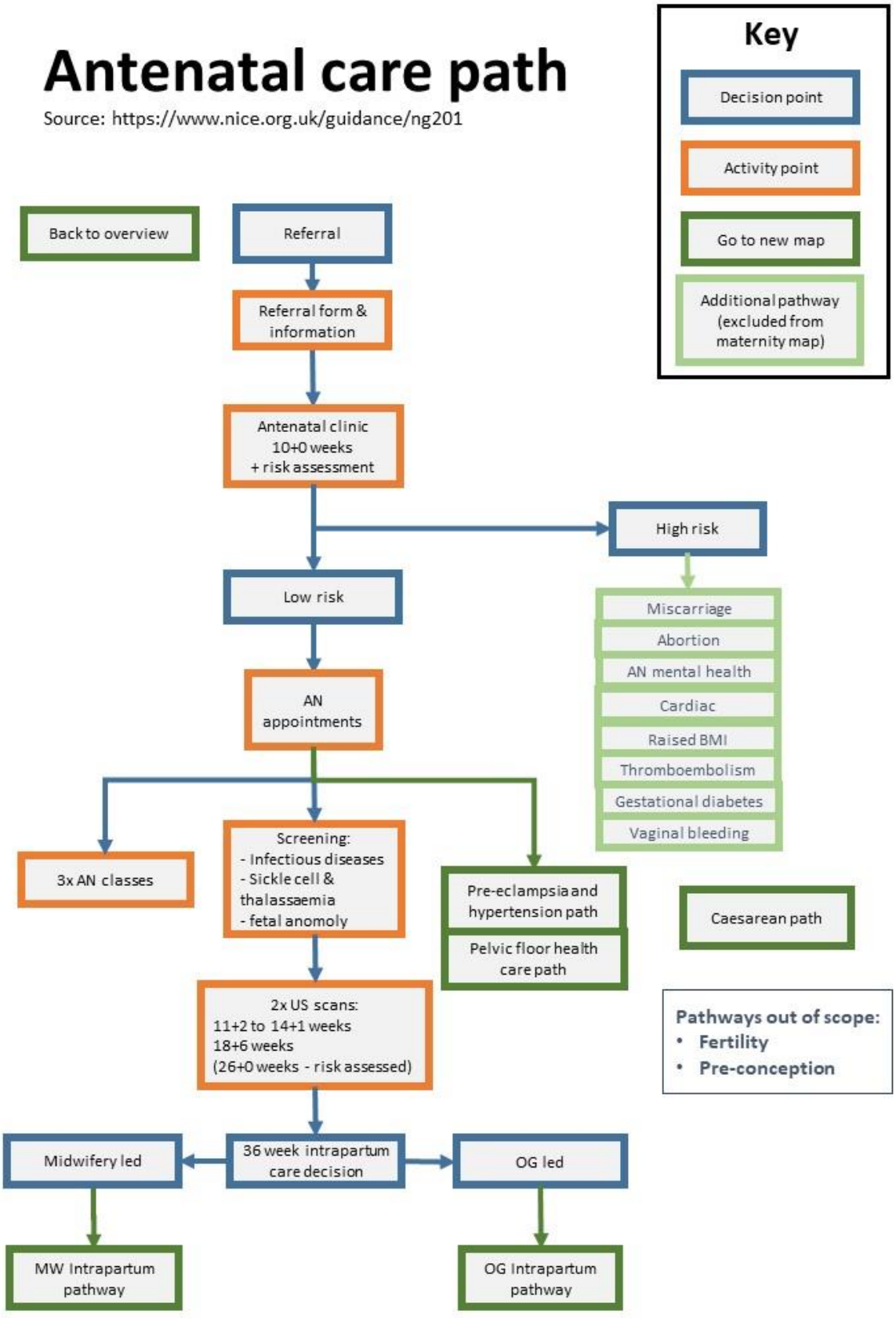
3 1 and 26

Appendix 2: Maternity care pathway maps



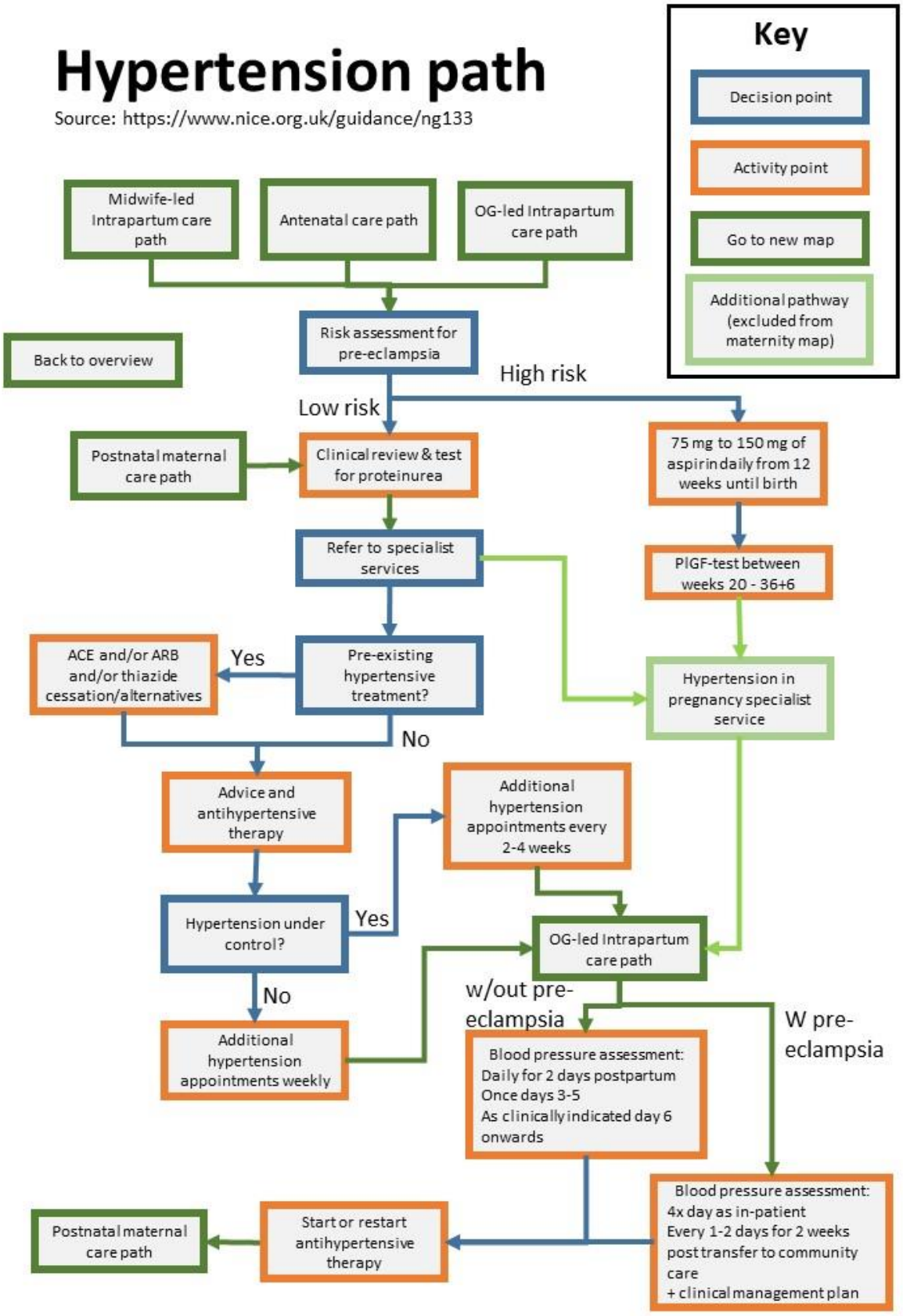
Antenatal care path

Source: https://www.nice.org.uk/guidance/ng201



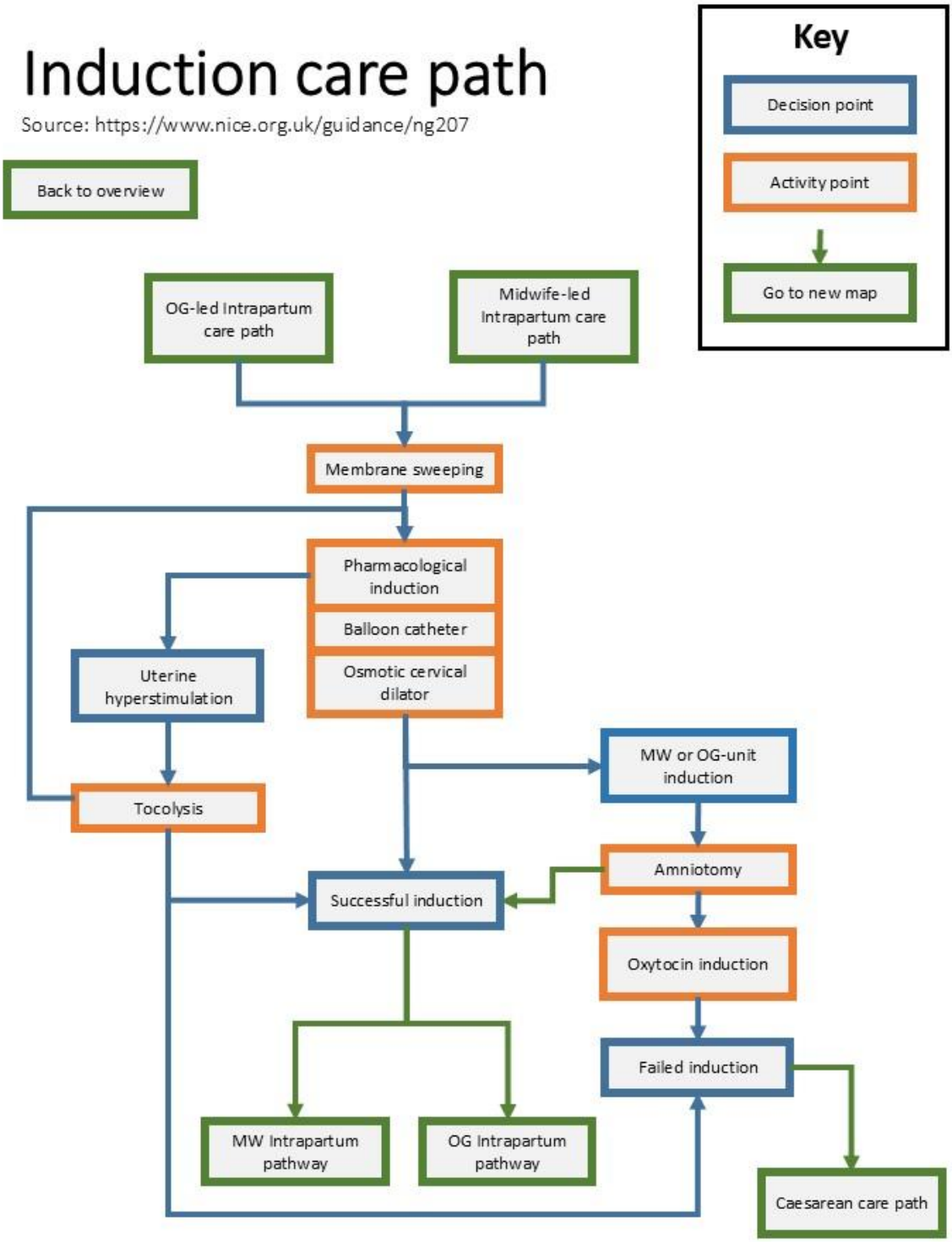
Hypertension path

Source: https://www.nice.org.uk/guidance/ng133



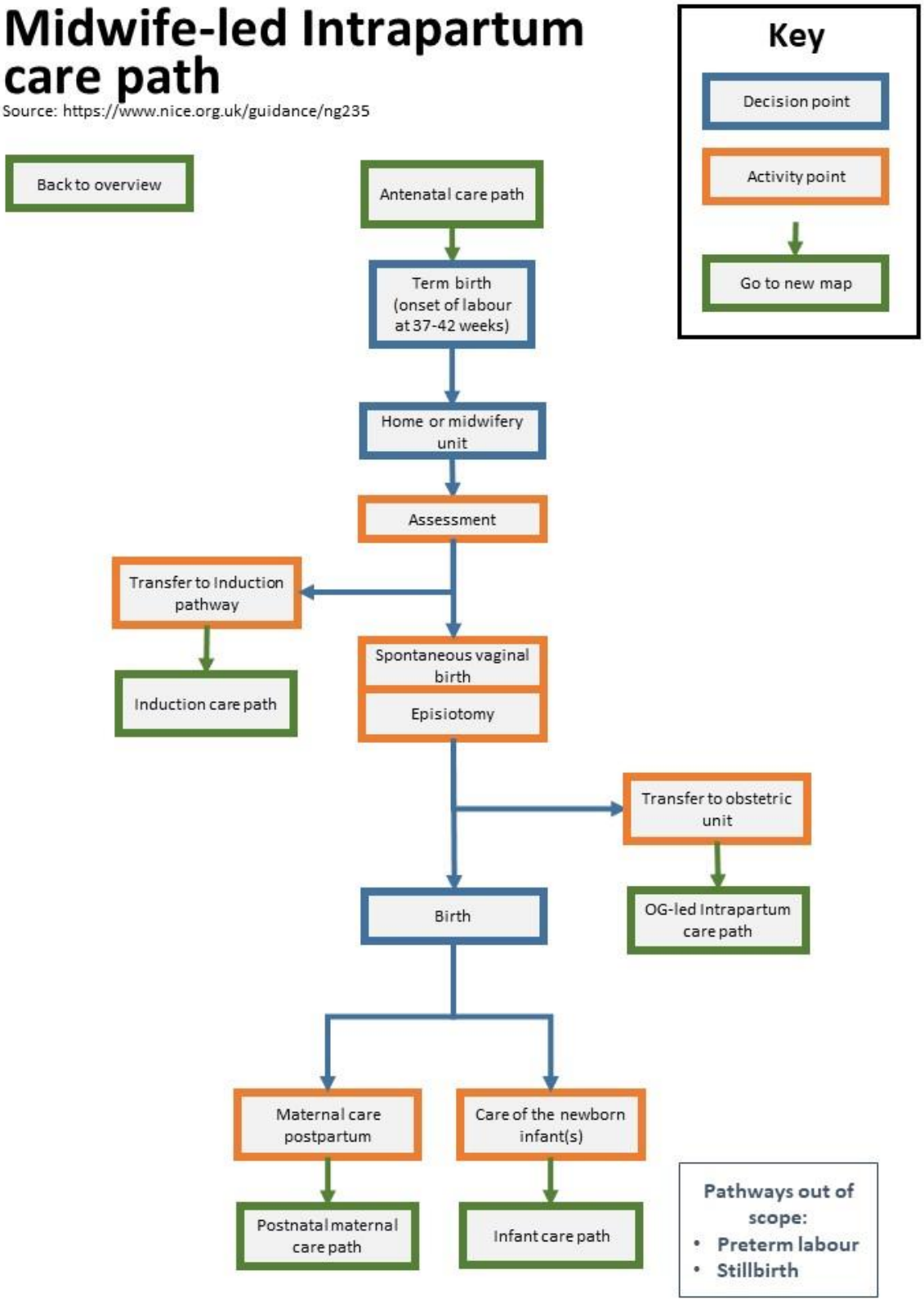
Induction care path

Source: https://www.nice.org.uk/guidance/ng207



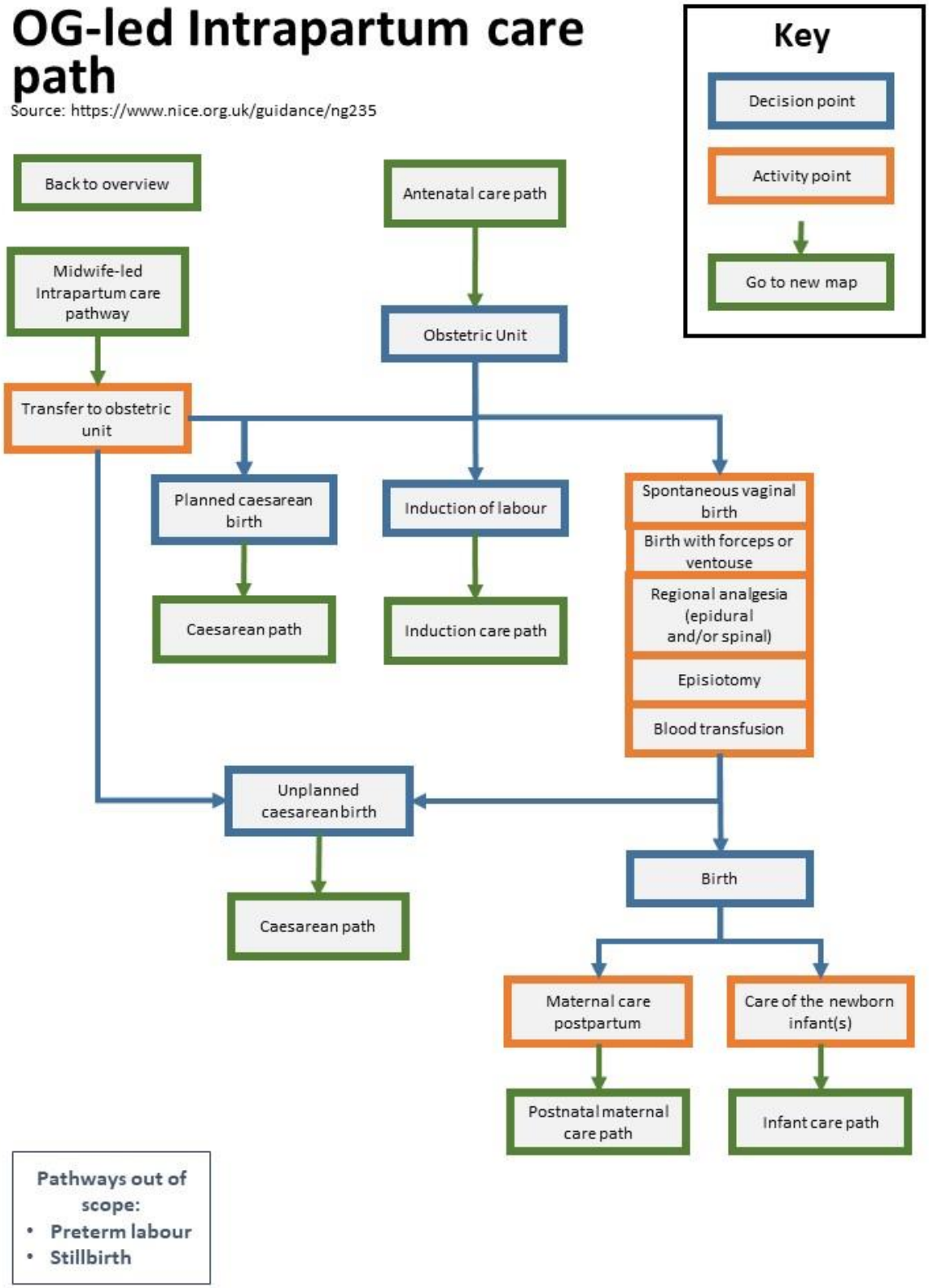
Midwife-led Intrapartum care path

Source: https://www.nice.org.uk/guidance/ng235



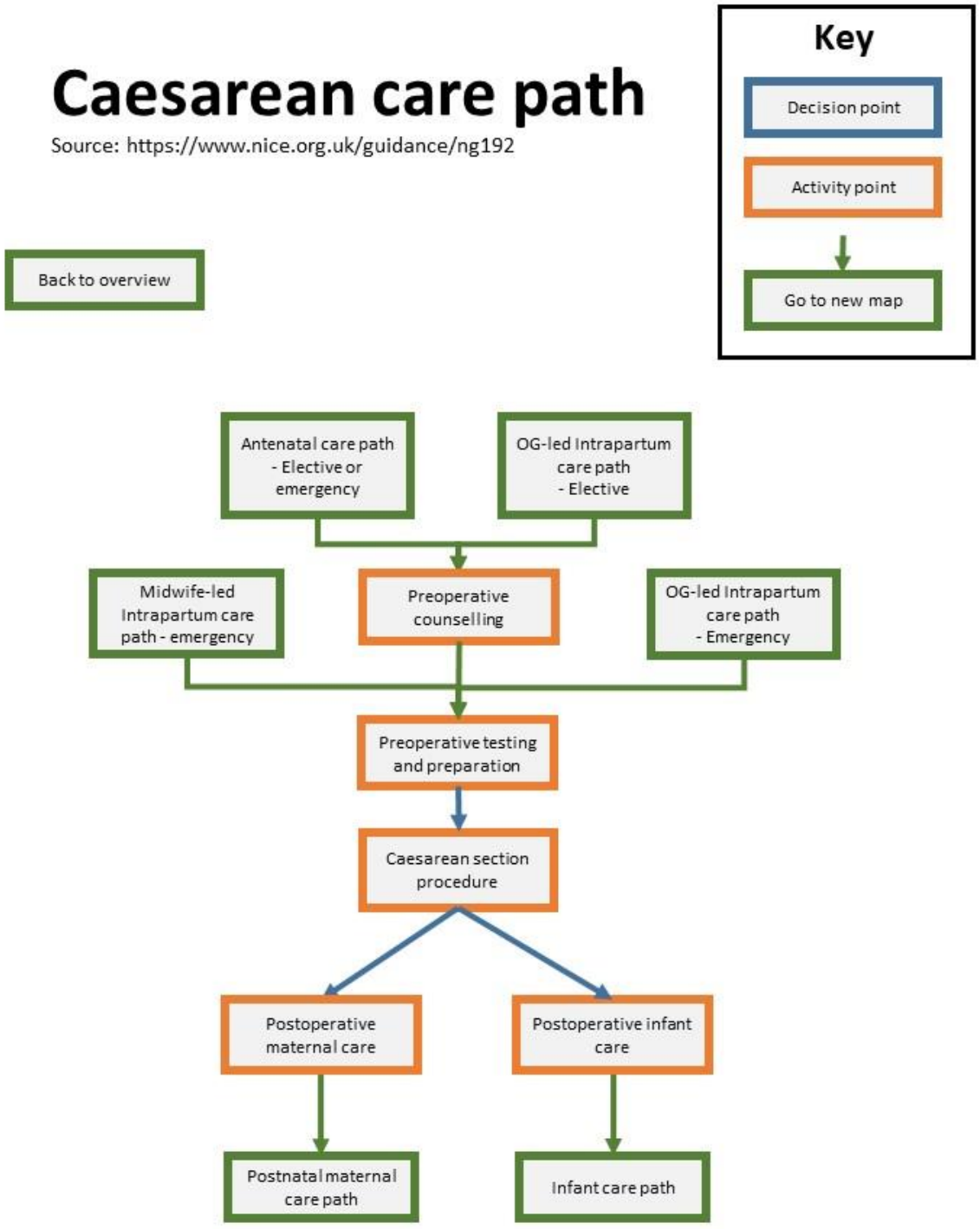
OG-led Intrapartum care path

Source: https://www.nice.org.uk/guidance/ng235



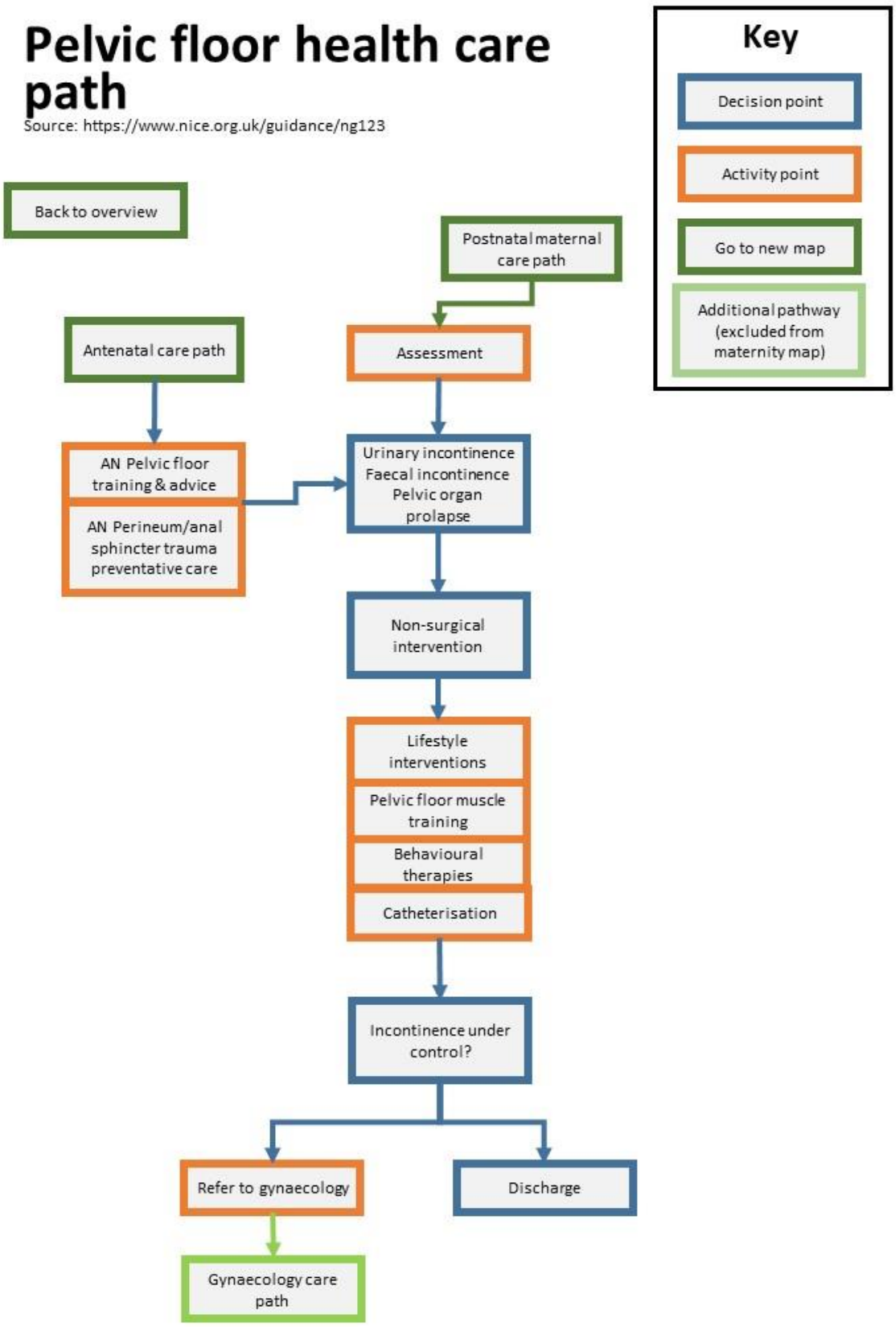
Caesarean care path

Source: https://www.nice.org.uk/guidance/ng192



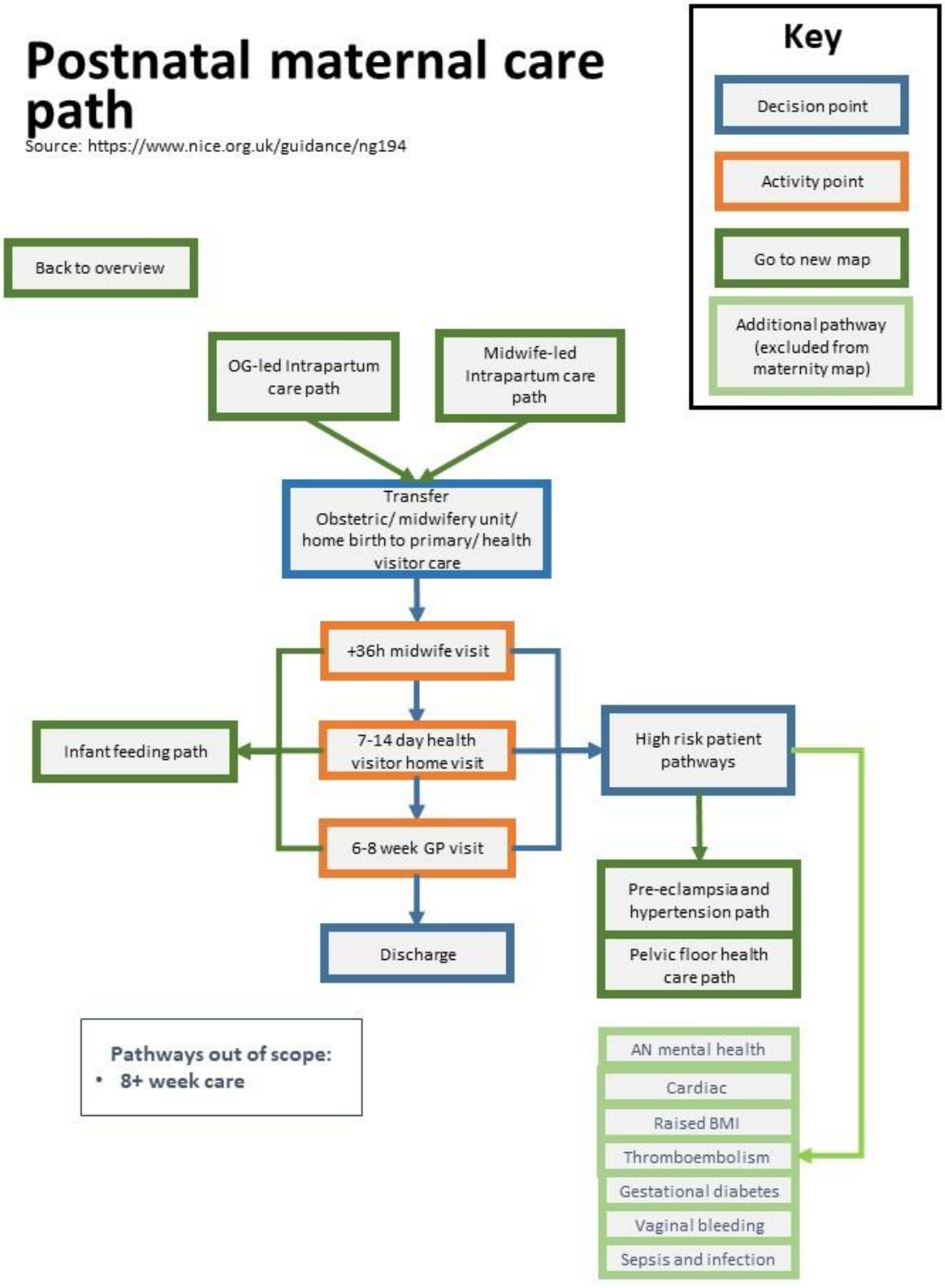
Pelvic floor health care path

Source: https://www.nice.org.uk/guidance/ng123

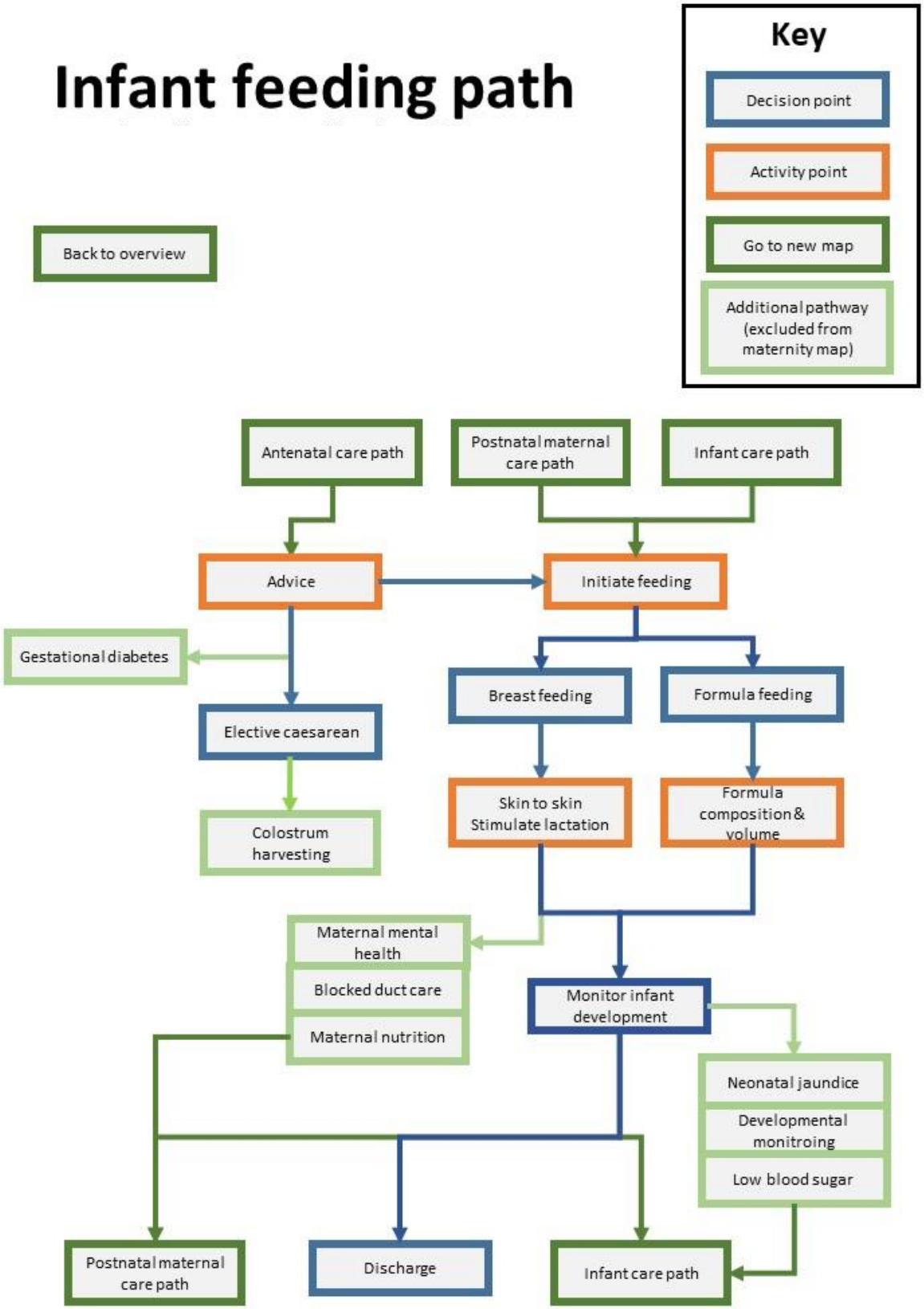


Postnatal maternal care path

Source: https://www.nice.org.uk/guidance/ng194



Infant feeding path



Appendix 3: Assumptions around pathways, activity data, emissions factors

Activity data	Assumptions	Activity data	Carbon footprint (kgCO2e)	Sources
	In this report, the term 'women' includes all people going through the different maternity pathways			
Antenatal (AN) care pathway	Women with no previous pregnancies have 10 antenatal visits, women with previous pregnancies have 7(47) Number of women receiving antenatal care is the same as the number of births. Due to lack of data, number of women who had received antenatal care before suffering a miscarriage or ectopic pregnancy are not included.			
Referral	1/3 referred by post	Sending a 2-page letter by post	0.2835	Greener NHS. Business Case Carbon Impact Tooling V3.01 (60)
	1/3 referred by email	Sending an email (emission factor for a long email, that takes 10 minutes to write and 3 minutes to read, sent from laptop to laptop)	0.017	Miker Berners-Lee (2020). How Bad are Bananas.(61)
	1/3 referred by phone/telehealth	Outpatient phone consultation (31 minutes)	0.1	Greener NHS. Business Case Carbon Impact Tooling V3.01(60)
Setting (AN appointments/classes)	All have 2 appointments at hospital (for scan) (47)	Outpatient appointment (1 hour, carbon footprint of low intensity inpatient day as estimated in Care Pathways: Guidance on Appraising Sustainability - Inpatient Day Module' divided by 24)	1.58	SDU 2015: Care Pathway Guidance (56,57)
	10% have all their appointments at hospital	GP appointment	1.1	

Activity data	Assumptions	Activity data	Carbon footprint (kgCO2e)	Sources
	2% appointments are home visits	Appointment at midwife led hub	1.1	
	50% have first appointment by phone (still need to come in for blood test)	Antenatal classes	1.1	
	Of the rest: 50% of appointments take place at midwife led hub and 50% at GP surgeries			
Women's travel	Travel distance to GP and midwife led hub is the same. It is based on pathway patient travel module of SHC.	Roundtrip to hospital (elective care)	5.8	SDU 2015: Care Pathway Guidance (55)
		Roundtrip to GP	1.12	
		Roundtrip to midwife-led hub	1.12	
Staff travel	Staff travel recorded separately for home-visits, assumed same distance and mode of transport as women's travel to hospital	Roundtrip - staff travelling to women's homes (carbon footprint the same as patients travelling to hospital for elective care.	5.8	SDU 2015: Care Pathway Guidance (55)
	Staff travel is part of carbon footprint of healthcare settings for visits at GP/midwife-led-hub/hospital, not included separately			
Blood tests	Full blood count and blood group is tested twice (47)	Full-blood count blood test - including phlebotomy, vials and laboratory tests	0.1864	Spoyalo et al. 2023 (62)
	Rhesus D status, antibodies, screening for Hep B, Syphilis and HIV and fetal anomaly blood test is done once (47)	Per other blood test includes only the vial as GHG emissions of actual tests not known	0.032	
Scans	Two scans per person	Ultrasound scan – adjusted to reflect UK electricity mix	0.19	McAlister et al. 2022 (63)

Activity data	Assumptions	Activity data	Carbon footprint (kgCO2e)	Sources
Hypertension	Data on number of women with: • Pre-existing hypertension complicating pregnancy, childbirth and the puerperium, and • Gestational [pregnancy-induced] hypertension • Women with unspecified hypertension have been proportionally allocated to the group of women with pre-existing and gestational hypertension taken from NHS Digital Maternity Statistics 2022-23 (54) Women with pre-eclampsia have not been included. Assumed that 50% women with pre-existing hypertension have less severe and 50% more severe hypertension. Data on number of additional antenatal visits due to hypertension: • Less severe pre-existing hypertension: 7 AN visits (every 4 weeks from 12 weeks onwards) • More severe pre-existing hypertension: 14 AN visits (every 2 weeks from 12 weeks onwards) • Gestational hypertension: 20 AN visits (weekly blood test plus 2 additional scans) taken from NICE Guidance (47).			
Women's travel	Round trip travel distance to GP and midwife led hub is the same, based on SHC pathway patient travel module.	Round trip to GP/midwife led hub/antenatal classes	1.12	SDU 2015: Care Pathway Guidance (55)
	Round trip travel distance to GP and Outpatient appointment is based on pathway patient travel module of SHC.	Round trip to hospital (elective care)	5.8	

Activity data	Assumptions	Activity data	Carbon footprint (kgCO2e)	Sources
Staff travel	Staff travel for antenatal visits at GP, midwife led hubs or at hospital are included in the setting (not reported separately).	n/a	n/a	
Setting (visits)	1/3 additional AN visits at GP 1/3 additional AN visits at midwife led hub 1/3 as outpatient appointment	Outpatient appointment (1 hour, carbon footprint of low intensity inpatient day as estimated in Care Pathways: Guidance on Appraising Sustainability - Inpatient Day Module' divided by 24)	1.58	SDU 2015: Care Pathway Guidance (56,57)
		GP appointment	1.1	
		Midwife led hub	1.1	
Blood tests	Number of blood tests for women with gestational hypertension based on NICE Guidance (47): • From 12 weeks onwards, weekly blood tests - full blood count, liver and renal function tests. • 1x Placental Growth Factor (PLGF) test Weekly urine tests were excluded due to lack of emission factors	Full blood count (includes phlebotomy, vials and test)	0.186	Spoyalo et al. 2023. (62)
		Other blood test (includes only the vial as the GHG emissions of actual test is unknown)	0.032	
Pharmaceuticals	Based on NICE guidance (47) and British National Formulary(64)	Tablet of Aspirin (assumed aspirin has the same carbon footprint as paracetamol)	0.0382	Davies et al 2023. (65)

Activity data	Assumptions	Activity data	Carbon footprint (kgCO2e)	Sources
	1 tablet of 75mg Aspirin per day from 12 weeks onwards => 196 tablets per person. For women with gestational diabetes: 1 tablet of 100 mg Labetalol twice a day from 12 weeks onwards => 392 tablets per person. For women with pre-existing hypertension: Swapping current medication for Labetalol, assumed medications have similar carbon footprint, therefore not included.	Packet of Labetalol (56 tablets per pack)	5.19	Based on cost (0.581 kgCO2e/£) (66)
Ultrasounds	Based on Nice Guidance: Every 4 weeks scan (5 in total) (47)	Ultrasound scan	0.19	McAlister et al. 2022.(63)
Postnatal (PN)	Number of • Birth • Women discharged in the same day taken from NHS Digital Maternity Statistics 2022-23 (54)			
Women's travel	Round trip travel distance to GP and Outpatient appointment is based on pathway patient travel module of SHC.	Round trip to GP	1.12	SDU 2015: Care Pathway Guidance (55)
		Round trip to hospital (elective care)	5.8	

Activity data	Assumptions	Activity data	Carbon footprint (kgCO2e)	Sources
Staff travel	Staff travel for postnatal visits at home by midwife and health visitor included separately, with roundtrip distance being the same as patient travelling to hospital Staff travel for postnatal visits at GPs or at hospital are included in the setting (not reported separately)	Round trip for home visits (carbon footprint the same as patients travelling to hospital for elective care)	5.8	SDU 2015: Care Pathway Guidance (55)
Setting (visits)	Women discharged on the same day will receive a home visit by midwife day after birth 50% new parents will receive home visits by midwife on day 3 and 5, 50%, will see the midwife at the hospital 50% parents receive health visitor visit between week 7 and 14 postnatal at home, 50% see the health visitor at the GP surgery All women see the GP 6-8 weeks after birth	GP appointment	1.1	SDU 2015: Care Pathway Guidance (56,57)
		Midwife led hub	1.1	
		Outpatient appointment (1 hour, carbon footprint of low intensity inpatient day as estimated in Care Pathways: Guidance on Appraising Sustainability - Inpatient Day Module' divided by 24)	1.58	
Induction for labour	Data on method of onset of birth - number of surgical inductions (by amniotomy), medical inductions (includes the administration of agents either orally, intravenously or intravaginally) and combined inductions (surgical and medical) - taken from NHS Digital Maternity Statistics 2022-23 (54). All inductions are conducted as inpatients. Carbon footprint of induction is solely based on the number of additional antenatal inpatient days due to the induction process, as data on number and type of pharmaceuticals and devices used for induction not available. Number of additional antenatal inpatient			

Activity data	Assumptions	Activity data	Carbon footprint (kgCO2e)	Sources
	days due to induction calculated: number of antenatal inpatient days for spontaneous onset minus number of antenatal inpatient days for induction As no separate data on augmentation available, it is assumed that the number of women receiving augmentation are included in the number of women receiving induction			
Women's travel	Not included. Included as part of the delivery carbon footprint.	n/a		
Staff travel	Not included as already part of inpatient bed day	n/a		
Setting (bed days)	Number of surgical inductions, 0.71 additional antenatal days Number of medical inductions, 0.87 additional antenatal days Number of combined induction, 1.16 additional antenatal days Number of unknowns of method of onset proportionally allocated.	Low intensity inpatient bed day	37.9	SDU 2015: Care Pathway Guidance (56)
Scans	No available data on scans during induction.	n/a		
Pharmaceuticals	No available data on the usage of pharmaceuticals and devices for induction at national level, therefore they have been excluded.	n/a		
Entonox	No available data on Entonox® use during the induction process, so additional use of Entonox® during the induction process has not been included.	n/a		

Activity data	Assumptions	Activity data	Carbon footprint (kgCO2e)	Sources
Intrapartum care	Data on number of births, methods of delivery (modes of birth), types of anaesthetic used, and duration of birth episodes taken from NHS Digital Maternity Statistics 2022-23 (54). Spontaneous delivery includes normal delivery (spontaneous vertex), spontaneous other delivery , other breech delivery – in this report the term spontaneous vaginal birth is used Instrumental delivery includes low forceps cephalic delivery, other forceps delivery, ventouse (vacuum) delivery, breech extraction delivery – in this report the term assisted vaginal birth is used Caesarean delivery includes elective caesarean delivery, other/emergency caesarean delivery Delivery episode includes antenatal and postnatal inpatient bed days			
Women's travel	Round trip included from admission to discharge.	Round trip to hospital (elective care)	5.8	SDU 2015: Care Pathway Guidance (55)
Staff travel	Staff travel not included for hospital births as part of carbon footprint of inpatient bed days Staff travel included for home birth.	Round trip to home birth (carbon footprint the same as patients travelling to hospital for elective care).	5.8	SDU 2015: Care Pathway Guidance (55)
Setting (bed days)	Inpatient stays lasting 7 or more days, it was assumed that they would stay in for 7 days.	Low intensity inpatient bed day	37.9	SDU 2015: Care Pathway Guidance (56)
Pharmaceuticals		Remifentanil per person (For 4-hour period of labour via administration pump. EF includes drug manufacturing, disposables, packaging, waste, electricity to power administration pumps and supplemental Oxygen).	0.75	Pearson, F. Sheridan, N. and Pierce, J.M.T. 2022.(17)
		Morphine per person (For 4-hour period of labour via intramuscular injection. EF includes drug manufacturing, disposables, packaging, waste).	0.08	Parvatker et al. 2019.(67)

Activity data	Assumptions	Activity data	Carbon footprint (kgCO2e)	Sources
Entonox	No available data from NHS Digital on number of births using Entonox. Instead, it was assumed that 76% of women used Entonox® during labour (Spil et al, 2024) (11).	Entonox® per birth (For 4-hour period of labour, intermittent inhalation via demand valve used for 18min.h-1. EF includes drug manufacturing, unmetabolized gas release, disposables, packaging, waste and supplemental Oxygen).	237.33	
Epidural/Causal/ Spinal/GA	Data on proportion of type of anaesthetic/ analgesic used before or during delivery taken from NHS Digital Maternity Statistics 2022-23 (54).	Epidural per person (For 4-hour period of labour via administration pump. EF factor includes drug manufacturing, disposables, packaging, waste and electricity to power administration pumps).	1.2	Pearson, F. Sheridan, N. and Pierce, J.M.T. 2022. (17) Parvatker et al. 2019. (67)
		Sevoflurane per hour of surgery per person (assumed sevoflurane is anaesthetic gas of choice for GA)	5.9	Sustainable Healthcare Coalition
		Spinal anaesthesia per person (Spinal anaesthesia less oxygen supplementation).	7.14	Spil et al. 2024. (11)
Birth	Number of births with an unknown mode of birth were apportioned to number of spontaneous vaginal, assisted vaginal and caesarean births.	Caesarean birth (EF associated with birth includes energy, laundry, PPE, disposables, and reusable instruments)	31.21	Spil et al 2024. (11)
		Vaginal birth at hospital (EF associated with birth includes energy, laundry, PPE, disposables, and reusable instruments)	9.4	
		Vaginal birth at home (EF associated with birth includes energy, laundry, PPE, disposables, and reusable instruments)	5.93	
Perineal tear	Perineal tear needing suturing occurs in 45% of vaginal births (Spil et al, 2024) (12>11).	Perineal tear suturing at hospital	3.07	Spil et al 2024. (11)
		Perineal tear suturing at home	1.7	

Activity data	Assumptions	Activity data	Carbon footprint (kgCO2e)	Sources
Pelvic floor	Only included the surgical repair and post-surgery treatment and follow-up of women with 3rd and 4th degree tears. 6 out of 100 births (6%) for first time mothers and less than 2 in 100 births (2%) of births for women who have had a vaginal birth before have 3rd and 4th degree of perineal tears, taken from RCOG (52)			
Women's travel	Round trip to 1 outpatient follow-up appointment	Round trip to hospital (elective care)	5.8	SDU 2015: Care Pathway Guidance (55)
Staff travel	Included as part of outpatient appointment	n/a		
Setting (visits/classes/bed days)	All women with 3rd and 4th degree tear will have 1 outpatient follow-up appointment (OPA)	Outpatient appointment (1 hour, carbon footprint of low intensity inpatient day as estimated in Care Pathways: Guidance on Appraising Sustainability - Inpatient Day Module' divided by 24)	1.58	SDU 2015: Care Pathway Guidance (57)
Scans	All women with 3rd and 4th degree tear will receive 1 scan during OPA	Ultrasound scan	0.19	McAlister et al. 2022.(63)
Pharmaceuticals	4 x 1g Paracetamol/ day for 10 days	Tablet of Aspirin (assumed aspirin has the same carbon footprint as paracetamol)	0.038	Davies et al 2023. (65)
	3 x Amoxicillin/day for 7 days	Amoxicillin	0.91	Based on cost (0.581 kgCO2e/£) (62)
	2 x 15 ml Lactulose /day for 10 days	300 ml bottle	1.65	Based on cost (0.581 kgCO2e/£) (62)
Surgery	1 hours of surgery to repair 3rd and 4th degree perineal tears, includes catheter	1 hour of surgery	22.43	Sustainable Healthcare Coalition. 2024.
		Catheter	1.51	Based on cost (0.581 kgCO2e/£) (62)
Infant feeding	Number of live births taken from NHS Digital Maternity Statistics 2022-23. Number of unknown birth status were apportioned to number of live and still births.			

Activity data	Assumptions	Activity data	Carbon footprint (kgCO2e)	Sources
Infant feeding	74% of women-initiated breast feeding (68). It was assumed that 74% exclusively breastfed week 1 and 2. 49% of infants exclusively or partially breastfed at 6-8 weeks after birth (53), however, it was assumed for this project that 49% of infants are exclusively breast fed from week 3-8.	2 months of formula milk (Formula milk factor includes production of the formula milk, production of feeding bottles, preparation of the formula milk, sterilisation of bottles, 15% of formula is wasted)	100	Andresen et al. 2022.(31)
		2 month of breast feeding (Breast feeding factor is based on additional nutritional needs of women).	72.5	