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Going Green: Sustainability in the Gynecological Operating Room of a Tertiary Referral Center

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ABSTRACT

OBJECTIVE: Climate change has immediate effects on women's health. Hospitals and operating rooms are major contributors to greenhouse gas (GHG) emissions and waste. This study aims to reduce the environmental impact of gynecologic surgery through a structured approach involving three key strategies.

MATERIALS AND METHODS: We conducted a prospective experimental study in the operating rooms (ORs) of the Gynecology and Obstetrics Clinic at Padua University Hospital. The study was structured into three phases: (1) an initial assessment of waste production, (2) training and education of the Green Team, and (3) evaluation of waste production and the use of single-use versus reusable instruments after Green Team implementation. At the end of these three phases, data analysis was performed with a particular focus on environmental impact, measured in terms of CO₂ emissions, and cost savings.

RESULTS: Regarding data analysis in terms of waste reduction, CO₂ savings, and cost savings, 193 Minor Surgery procedures were performed, leading to a total waste reduction of 131.99 kg. In Medium Surgery, 230 procedures resulted in a reduction of 100.79 kg, while in Major Surgery, 162 procedures led to a waste reduction of 45.48 kg. Overall, across all categories, a total of 278.26 kg of waste was eliminated from 585 surgeries. The cumulative CO₂ reduction amounted to 1,148.26 kg, with total cost savings of €267.81 from waste reduction efforts.

CONCLUSION: This study demonstrates that through teamwork and the establishment of a Green Team, it is possible to achieve a significant reduction in waste, leading to a decrease in CO₂ emissions and cost savings.



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1. INTRODUCTION

1.1. THE CLIMATE CHANGE

The climate change crisis poses a central threat to public health. Climate change refers to significant shifts in Earth's temperatures and weather patterns [1,2]. While natural phenomena once played a major role, human activities have been the primary driver since the 1800s, mainly due to the burning of fossil fuels like coal, oil, and gas [3,4]. These processes release greenhouse gases (GHGs), such as carbon dioxide and methane, which trap heat in the atmosphere and contribute to global warming. Deforestation and agriculture further accelerate emissions. As a result, Earth's surface is now 1.1°C warmer than in the late 1800s, with the last decade being the hottest on record. Besides rising temperatures, climate change leads to droughts, wildfires, floods, ice melting, and biodiversity loss [5-7].

1.2. HEALTHCARE SYSTEM AND GAS EMISSIONS

The healthcare sector is a significant contributor to greenhouse gas emissions, with the impact of its operations often overlooked in climate discussions. As highlighted in the 2022 Lancet Countdown Report, healthcare emissions now account for 5.2% of global emissions [8]. The U.S. healthcare system alone contributes 27% of global healthcare-related emissions and 4.5% of worldwide carbon emissions. In 2013, healthcare emissions in the U.S. reached 655 million tons of CO₂ equivalents, reflecting a 30% increase over the previous decade. Moreover, healthcare facilities generate 5 million tons of waste annually, with hospitals producing 29 pounds of waste per bed per day, and operating rooms alone are responsible for more than 30% of a hospital's solid waste [9].

Globally, healthcare is an essential sector for public health, but it also plays a significant role in exacerbating climate change. In England, the NHS contributes 25% of public sector greenhouse gas emissions, primarily from carbon dioxide. The NHS has set an ambitious goal to achieve carbon neutrality by 2050 under the "For a Greener NHS" initiative. In the U.S., over 1.7 million tons of plastic waste are generated annually by healthcare, a number expected to rise as the reliance on single-use plastics increases [10,11].

The supply chain is the largest contributor to the NHS's carbon footprint, responsible for 59% of emissions. Operating theatres, due to their high resource consumption, contribute heavily to this footprint. Surgical procedures themselves produce between 6 kg and 814 kg of CO₂ equivalents per operation, with the highest emissions comparable to driving 2,273 miles in a petrol car. The main



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sources of emissions in surgery include the procurement of consumables, the energy used in operating theatres, and anesthetic gases [10-12].

As the demand for healthcare rises, fueled by an aging population and medical advancements, emissions are expected to increase, worsening climate-related health crises. Enhancing the sustainability of healthcare can reduce environmental impacts while bolstering the sector's resilience to the health emergencies driven by climate change.

Key Contributors to Healthcare Emissions [13]

1. **Energy Use:** Operating rooms consume up to six times more energy than other hospital areas due to the need for precise temperature and ventilation control. Energy-saving measures like LED lights and efficient scheduling can help reduce energy consumption.
2. **Anesthetic Gases:** Inhaled anesthetics, especially desflurane, are potent greenhouse gases. Many hospitals are reducing their use of high-GWP gases, transitioning to more environmentally friendly alternatives.
3. **Disposable Supplies:** Disposable medical supplies account for 60-70% of emissions from surgeries. Reusable equipment can significantly reduce emissions, with studies showing up to 90% reduction in some cases.
4. **Waste Generation:** Operating rooms generate 21-33% of hospital waste. The need for sterility leads to the use of single-use plastics, but reusable options can reduce both waste and emissions.

1.3. THE 5'R

Greening is defined as actions or practices that enhance environmental outcomes. Encouraging the greening of the perioperative environment can be achieved gradually, without necessitating a significant overhaul of current systems. The fundamental principles of decreasing waste in the operating room are the same as the cornerstone strategies of waste minimization: reduce, reuse and recycle. Recently, experts have suggested the addition of 2 extra R's — rethink and research [14].

1.3.1. *REDUCE*

Proper waste segregation is crucial in operating rooms, where a significant portion of waste is improperly classified as biohazardous, leading to unnecessary high-energy processing costs. Hospitals can reduce costs and environmental impact by educating staff on proper disposal and



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improving access to waste receptacles. Effective segregation at Magee-Womens Hospital of UPMC led to a 47% reduction in biohazard waste, saving over \$89,000 [15].

Fluid waste management is another area for reduction, as operating rooms generate large volumes of liquid waste. Traditional disposal methods pose risks to workers and the environment. Closed collection systems, which directly discharge fluids into sanitary sewers, can minimize exposure and reduce biohazard waste, as seen at Good Samaritan Hospital, which saved \$85,000 by diverting 250,000 lb of fluid waste [15].

Switching to reusable sharps containers can also cut costs and waste, with institutions like the University of Maryland Medical Center saving \$70,000 annually. Similarly, optimizing energy use in operating rooms by reducing ventilation during unoccupied times or switching to LED lighting has proven to lower energy costs and environmental impact [16-18].

Medical packaging, including excessive plastic use and blue sterile wrap, contributes significantly to operating room waste. Switching to reusable hard metal cases can reduce waste and costs, as demonstrated by MetroWest Medical Center, which cut disposal of sterile wrap by 5,606 lbs, saving nearly \$30,000. Additionally, hospitals can partner with manufacturers to recycle polypropylene from blue sterile wrap into other products.

Finally, reducing overage—unused surgical inventory that is opened but discarded—can help minimize waste and costs. Hospitals can work with suppliers to customize surgical packs to avoid unnecessary items, as seen at the University of Minnesota Medical Center, where reformulating packs saved \$81,278 and reduced waste by 5,332 lbs. Donation programs like REMEDY and Operation Green also help repurpose surplus materials for medical aid in developing countries [18].

1.3.2. REUSE

Reprocessing medical equipment allows single-use devices, such as saw blades, trocars, and catheters, to be safely reused, either within hospitals or through third-party companies. This practice reduces waste, lowers disposal costs, and enables hospitals to repurchase reprocessed devices at a 50% cost reduction. In 2008, reprocessing services helped US hospitals save over \$138 million and prevent 4.3 million pounds of waste [19,20].

Reusable surgical linens, including gowns, drapes, and table covers, also contribute to waste reduction. While single-use linens dominate in US hospitals, studies show that reusable alternatives offer superior environmental and financial benefits. The University of Maryland Medical Center, for example, saved \$38,000 in hauling costs and avoided 138,748 pounds of waste by switching to reusable linens [19,20].



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1.3.3. RECYCLE

During surgical setup, a significant amount of high-quality recyclable plastics is generated. Installing collection containers allows for easy recycling, reducing waste and cutting hauling costs nearly in half (\$68 vs. \$121 per ton). Hospitals can also negotiate rebates for recycled plastics. Additionally, materials like paper, cardboard, and metal can be collected for recycling in operating rooms. Some hospitals have achieved recycling rates of up to 40% of total waste, leading to substantial cost savings and additional revenue from industrial recyclers [21].

1.3.4. RETHINK

Hospitals must reconsider waste management practices, particularly incineration, which releases harmful pollutants like dioxins and furans, contributing to environmental contamination and health risks such as hormonal disruptions and infertility. Transitioning to alternative treatment methods—including thermal, chemical, irradiative, or biological approaches—can significantly reduce emissions and environmental impact. A successful example is Canada's strategy to close incinerators and enforce strict emissions targets, which led to an 87% decrease in dioxin and furan emissions between 2000 and 2005 [22].

Anesthetic gases also pose a major environmental challenge, as only 5%-20% of delivered gases are metabolized by patients, while the rest are vented into the atmosphere. These gases have a global warming potential 2000 times higher than CO₂. In 2005, emissions from anesthetic gases in Canadian hospitals were equivalent to the annual emissions of 68,000 people. Implementing gas capture and recycling programs, like those used at Sunnybrook Health Sciences Centre, can drastically cut emissions while reducing costs [23].

Environmental stewardship teams are essential in leading sustainability initiatives by improving awareness, promoting responsible purchasing, and coordinating waste audits. Hospitals have significant purchasing power and can drive demand for sustainable products. In Ontario, the Green Hospital Champion Fund currently supports 90 hospital waste audits, helping institutions identify areas for improvement, reduce waste, and optimize sustainability efforts while maintaining high-quality patient care [24].

1.3.5. RESEARCH

There is a clear need for updated research on hospital greenhouse gas emissions and waste, as the most recent data date back to 2008 and 2001, respectively. Despite new sustainability initiatives, few

quality-improvement studies have rigorously assessed their impact, and many lack independent verification, leading to potential bias. A stronger evidence-based approach is essential to ensure credibility. Key research areas should include updated environmental impact statistics, life cycle analyses of medical materials, cost comparisons, and the development of eco-friendly devices that maintain high standards of patient care. [25]

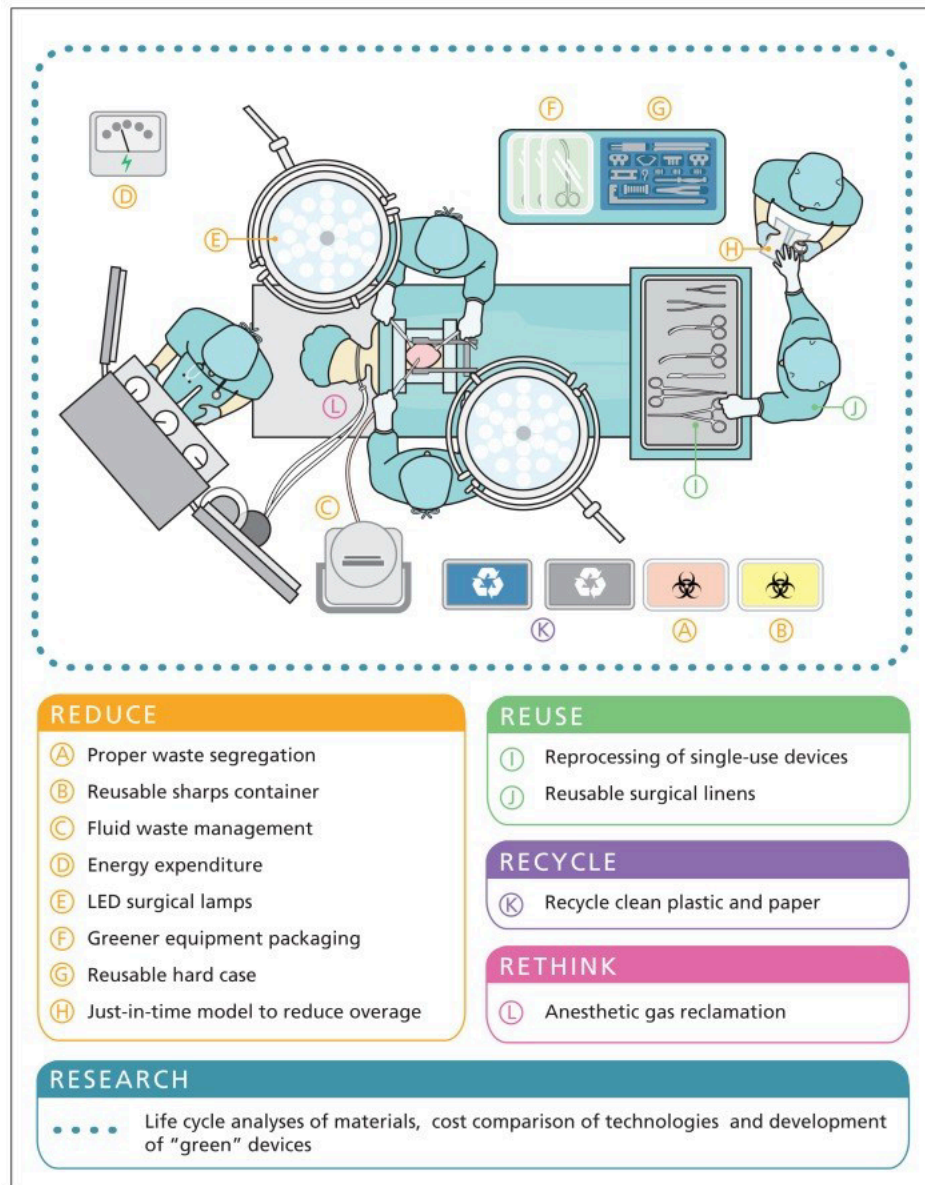


Fig 1. The 5R's to green the operating room [14]



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1.4. PRINCIPLES OF SURGICAL SUSTAINABILITY

Surgeons play a key role in reducing healthcare's environmental impact by integrating sustainability into their practice. Sustainable surgery focuses on delivering quality care while minimizing resource use and waste. These principles are crucial during crises like COVID-19 and for managing the growing backlog of elective procedures. Sustainable practices should enhance efficiency, reduce waste, and balance patient outcomes with environmental, social, and financial sustainability. Adapting the *Centre for Sustainable Healthcare's* principles to surgery can drive change by optimizing resources, improving supply chains, and cutting energy use, benefiting both patient care and the environment [13].

1.4.1. SURGICAL DISEASE PREVENTION

Preventing surgical diseases requires a stronger focus on public health initiatives that promote healthy behaviors, such as reducing red meat consumption, exercising more, quitting smoking, and moderating alcohol intake. By supporting national policies and collaborating with primary care, surgeons can help reduce the demand for surgical interventions and improve overall population health.

1.4.2. PATIENT EDUCATION/EMPOWERMENT

Surgeons play a vital role in educating patients to optimize their health, reduce surgical risks, and improve fitness for surgery. Lifestyle changes, such as weight-bearing exercises for osteopenia, alcohol cessation for liver disease, smoking cessation, and healthier diets, can significantly impact disease progression and outcomes. Encouraging adherence to medications like immunosuppressants for inflammatory bowel disease and avoiding harmful ones, like NSAIDs in diverticular disease, helps prevent complications and the need for surgery.

Patients should also be educated on when to seek medical help, reducing unnecessary hospital visits and optimizing healthcare resources. General practitioners can aid by ensuring appropriate referrals. These approaches not only improve well-being but also reduce the environmental impact of surgical care.

Given the current challenges in surgical service availability due to COVID-19, healthcare should shift from reactive treatment to proactive health maintenance. Raising awareness about uncertainties in surgical scheduling may further motivate patient engagement in prevention strategies, leading to better health outcomes.



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1.4.3. LEAN SERVICE DELIVERY

Lean management principles optimize surgical pathways by improving resource use, including equipment, time, and workforce capacity. This involves streamlining patient pathways, reducing unnecessary outpatient visits, and minimizing patient travel. Virtual clinics, adopted during COVID-19, can continue for certain appointments. Lean models improve efficiency, reduce costs, and likely result in carbon savings.

Reducing consumables in surgeries is key, questioning routine use and avoiding unnecessary equipment. Unnecessary packaging and double wrapping should be minimized, and rarely used single-use items should be removed from sets. However, rethinking reusable instrument sets may not always lower the carbon footprint due to fixed costs for decontamination.

1.4.4. LOW CARBON MODELS OF CARE

Low carbon treatment options

When optimizing patient pathways, it's important to consider clinical efficacy, financial costs, social implications, and carbon footprints. Focusing on clinical effectiveness ensures that environmental impacts are necessary and reduces the need for further interventions. Some surgical approaches, such as minimally invasive procedures, may have higher carbon footprints than traditional methods, though studies have yet to fully consider factors like hospital stay length or complication rates.

Non-surgical alternatives should be explored, especially when surgery has limited effectiveness. For conditions like early appendicitis, non-operative management can have a lower carbon footprint. However, for chronic conditions, surgery may have a lower long-term environmental impact compared to ongoing medical treatment. This aligns with initiatives like Getting It Right First Time and Choosing Wisely, which promote efficient resource use, shared decision-making, and evidence-based interventions.

Reusable equipment

Reusable surgical items, like instruments and linens, typically have a lower carbon footprint than single-use equivalents when considering sterilization and laundering, though some studies with coal-based electricity show the opposite. Single-use plastics, such as drapes and suction tubing, significantly contribute to surgical carbon footprints. Switching to reusable alternatives, like rigid aluminium containers, reduces both carbon and plastic footprints and lowers long-term costs.



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Many single-use items are produced under exploitative labor conditions, including child labor in countries like Pakistan and Mexico. The UK government supports continuing the use of reusable items during COVID-19, as the virus can be inactivated like other coronaviruses. When reusables aren't feasible, "resposable" devices or reprocessing single-use items can be considered. Efforts to develop scalable reusable PPE should be encouraged.

Maintenance, repair and recycling

To maximize resource use, we should apply circular economy principles by focusing on maintenance, repair, and recycling to extend the lifespan of consumables and capital goods. Surgeons, sterile service departments, and perioperative staff should actively monitor equipment for defects and ensure proper care. While most trusts have repair contracts, these are often underused. A significant portion of theatre waste is recyclable, and efforts should be made to improve recycling. Although waste management is an environmental challenge, it only accounts for a small fraction (0.1%) of the NHS carbon footprint and is not the focus of this report.

1.5. STRATEGIES TO MINIMIZE THE IMPACT OF SURGERY

To reduce the environmental footprint of surgery, various strategies focus on material reduction, recycling, energy optimization, and waste management. Key areas of focus include rethinking single-use products, improving waste segregation, and optimizing energy consumption [26].

Single-Use Products: These items, especially in surgical settings, contribute significantly to carbon footprints due to production, waste management, and transportation. Reusable instruments have been found to lower emissions by 40–66% compared to single-use devices [27]. Despite concerns about sterilization, reusable instruments remain a more sustainable option, with proper optimization of the sterilization process reducing energy use. Reducing wasted supplies, such as unopened items, can further minimize waste and costs without affecting surgical efficiency [28].

Waste Segregation: Misconceptions in waste sorting lead to excessive biohazard waste, which requires energy-intensive disposal methods like incineration. Training and improving waste sorting practices can reduce unnecessary waste, mitigating environmental harm [29].



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Anesthetics: Anesthesia gases like desflurane and sevoflurane contribute heavily to greenhouse gas emissions. Transitioning to intravenous anesthesia (TIVA) using propofol can reduce CO₂ emissions by up to 80%, and it offers additional patient recovery benefits [30].

HVAC Systems: HVAC systems consume the majority of energy in operating rooms. Solutions such as off-hour modes, energy-efficient lighting, and reduced airflow during unoccupied periods can cut energy use by up to 50%, offering both environmental and financial benefits.

By adopting these strategies, surgical settings can significantly reduce their environmental impact while maintaining high standards of care [31].



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2. PURPOSES

This study aims to reduce the environmental impact of gynecologic surgery through a structured approach involving three key strategies:

1. Assessing Waste Production Before the Green Team formation: Conducting an initial evaluation of waste generation in Operating Rooms (OR) A and B of the Gynecology Clinic to establish a baseline.
2. Establishing an OR Green Team: Creating a dedicated team to implement and promote sustainable practices in the operating room.
3. Waste Reduction and Minimization of Unnecessary Devices:
 - Recycling OR Materials: Educating staff on recyclable materials and conducting regular waste audits to identify opportunities for improved recycling.
 - Reusable OR Items: Identifying high-cost disposable instruments and evaluating reusable alternatives.
4. Assessing Waste Production After the Green Team Implementation: Re-evaluating waste generation in OR A and B to measure the impact of the Green Team's interventions.



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3. MATERIALS AND METHODS

3.1. DESIGN OF THE STUDY

This is a prospective experimental study conducted in the Operating Rooms (ORs) of the Gynecology and Obstetrics Clinic at Padua University Hospital. The study was structured into three phases: the first phase involved analyzing the current waste production; the second phase focused on training and educating the Green Team; and the third phase assessed the waste production and the use of single-use versus reusable instruments after the Green Team's training. At the end of the three phases, a data analysis will be conducted, with a particular focus on the environmental impact, measured in terms of CO₂ emissions, and a cost analysis.

3.1.1. *PHASE 1: DATA COLLECTION OF THE CURRENT SITUATION (MONTHS 1-10)*

WASTE PRODUCTION ANALYSIS- BEFORE GREEN TEAM FORMATION:

- Monitor the type and quantity of waste generated during gynecologic surgeries.
- Categorize the waste according to the European Classification into the following four types:
 - Plastic (European Waste Category 15.01.02)
 - Cardboard (European Waste Category 20.01.01)
 - Dangerous medical waste (European Waste Category 18.01.03) defined as healthcare waste contaminated by biological liquids such as blood and various secretions, or waste from environments and patients in infectious isolation: gauze, gloves, cannulae, drainage, catheters, drips, masks.
 - General waste (European Waste Category 20.01.03)

3.1.2. *PHASE 2: GREEN TEAM FORMATION AND TRAINING (MONTHS 11-15)*

CREATION OF THE GREEN TEAM:

- Select team members: gynecologic surgeons, nurses, OSS.
- Appoint a team leader to coordinate efforts and ensure alignment of sustainability activities.

TRAINING:

- Provide training for Green Team members on sustainability principles, waste management, and reduce di single use in the operating room.



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DEVELOPMENT OF A SUSTAINABLE ACTION PLAN:

- Develop an action plan to reduce waste, explore alternatives to single-use devices, enhance recycling efforts, and improve sustainability in the operating room.
- Introduce CO2 emission reduction strategies based on surgical waste and instrument usage analysis.

3.1.3. PHASE 3: EVALUATION AND COMPARISON OF RESULTS (MONTHS 16-26)

WASTE PRODUCTION ANALYSIS-AFTER GREEN TEAM FORMATION:

Continue to monitor waste production, identifying changes in the volume and type of waste generated:

- Waste reduction after green team formation
- CO2 reduction of waste managing: Measure data on saving in CO2 emissions resulting from waste reduction and the increased use of reusable instruments
- Cost reduction of waste managing: Collect data on cost savings related to waste reduction and the use of reusable instruments.

3.2. DATA ANALYSIS (MONTHS 27-36)

The effectiveness of the project will be evaluated by comparing the data from Phase 1 with the results obtained after implementing the sustainability initiatives. The success of the project will be measured through various indicators, including:

- Reduction in waste generation
- Reduction in single-use devices.
- Improvement in recycling practices and waste management efficiency.

This structure ensures that each phase is well-monitored and provides the ability to compare results to assess the continuous improvement of sustainable practices in the operating room.

Sub-analysis: Subsequently, surgeries were also classified into three groups, based on the complexity of the procedures: minor, medium, and major surgery, to analyze the environmental impact of each type.



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To calculate the carbon footprint of the specific waste, the weight in kg of each type of waste has been multiplied by the waste coefficient:

$$\text{Total CO}_2 \text{ emissions} = \text{CO}_2 \text{ Emissions Coefficient of the specific type of waste} * \text{kg of the specific type of waste}$$

Type of waste	Coefficient to calculate CO ₂ emissions based on weight
Plastic	3.72
Paper	0.95
General waste	5.00
Hazardous Waste	3.80

Table 1. waste coefficients for specific waste

To analyze the CO₂ savings after the recycling protocol was set up, the following analysis was made:

$$\text{CO}_2 \text{ emissions savings} = \text{CO}_2 \text{ emitted after the protocol} - \text{CO}_2 \text{ before the protocol}$$

Therefore, to calculate the cost of the specific waste, the price/kg has been multiplied by the kg of waste produced:

$$\text{Total Cost} = \text{cost/kg} * \text{kg of the specific type of waste}$$

Type of waste	Costs of disposal
Plastic	0.80 €/kg
Paper	0.25 €/kg
General waste	0.35 €/kg
Hazardous Waste	1.40 €/kg

Table 2: costs of disposal of specific waste

To calculate the cost savings after the recycling protocol was set up, the following analysis was made:

$$\text{Cost savings} = \text{cost after the protocol} - \text{cost considering that all the waste would have been disposed of as hazardous}$$

4. RESULTS

4.1. PHASE 1: DATA COLLECTION OF THE CURRENT SITUATION (MONTHS 1-10)

4.1.1. WASTE PRODUCTION ANALYSIS- BEFORE GREEN TEAM FORMATION

Over a 10-month period (January 2022 – October 2022), a total of 512 surgeries were conducted, generating 5,811.52 kg of waste in the Operating Rooms (ORs) of the Gynecology and Obstetrics Clinic at Padua University Hospital in particular:

- **Minor surgeries:** 174 procedures, producing 1,328.41 kg of waste (Table 3).
- **Medium surgeries:** 197 procedures, generating 2,167.08 kg of waste (Table 4).
- **Major surgeries:** 141 procedures, resulting in 2,316.03 kg of waste (Table 5).

Below are the tables categorized by type of surgery (Minor, Medium, and Major), type of procedure, each of which is further divided by type of waste.

Minor Surgery	N	Plastic Tot/ Mean±SD (Kg)	Paper Tot/ Mean±SD (Kg)	General Waste Tot/ Mean±SD (Kg)	Hazardous Waste Tot/ Mean±SD (Kg)	Tot Waste/ Mean±SD (Kg)
<i>Laparoscopy: bilateral salpingo-ovariectomy</i>	82	107,42 1,31 ± 0,20	59,86 0,73 ± 0,11	60,68 0,74 ± 0,11	531,36 6,48 ± 0,97	759,32 9,26 ± 1,3
<i>Exploratory Laparoscopy</i>	57	44,81 0,79 ± 0,12	25,02 0,44 ± 0,07	25,40 0,45 ± 0,07	221,38 3,88 ± 0,58	316,61 5,55 ± 0,83
<i>Ovarian Cyst Removal</i>	35	35,79 1,02 ± 0,15	19,98 0,57 ± 0,09	20,27 0,58 ± 0,09	176,44 5,04 ± 0,76	252,48 7,21 ± 1,08

Table 3: quantity of waste produced in phase 1 sorted out by category in Minor Surgery

Medium Surgery	N	Plastic Tot/ Mean $\pm$ SD (Kg)	Paper Tot/ Mean $\pm$ SD (Kg)	General Waste Tot/ Mean $\pm$ SD (Kg)	Hazardous Waste Tot/ Mean $\pm$ SD (Kg)	Tot Waste/ Mean $\pm$ SD (Kg)
Laparoscopy: hysterectomy + bilateral salpingo-ovariectomy	76	140,22 1,85 $\pm$ 0.28	46,74 0,62 $\pm$ 0.09	93,48 1,23 $\pm$ 0.18	654,36 8,61 $\pm$ 1.29	934,8 12,3 $\pm$ 1.84
Laparotomy: hysterectomy + bilateral salpingo- ovariectomy	17	21,42 1,26 $\pm$ 0.19	12,50 0,74 $\pm$ 0.11	23,2 1,37 $\pm$ 0.21	121,38 7,14 $\pm$ 1.07	178,5 10,5 $\pm$ 1.57
Transvaginal hysterectomy	47	46,06 0,98 $\pm$ 0.15	23,03 0,49 $\pm$ 0.07	69,09 1,47 $\pm$ 0.22	322,42 6,86 $\pm$ 1.03	460,6 9,8 $\pm$ 1.47
Laparoscopy: miomectomy	38	66,76 1,76 $\pm$ 0.26	31,04 0,82 $\pm$ 0.12	35,50 0,93 $\pm$ 0.14	234,61 6,17 $\pm$ 0.93	367,91 9,68 $\pm$ 1.45
Laparotomy: miomectomy	8	10,51 1,31 $\pm$ 0.20	4,90 0,61 $\pm$ 0.09	5,60 0,70 $\pm$ 0.10	37,06 4,63 $\pm$ 0.69	58,07 7,26 $\pm$ 1.09
Robot: hysterectomy + bilateral salpingo- ovariectomy	11	30,10 2,74 $\pm$ 0.41	8,36 0,76 $\pm$ 0.11	11,7 1.06 $\pm$ 0.16	117,04 10,64 $\pm$ 1.60	167,2 15,2 $\pm$ 2.28

Table 4: quantity of waste produced in phase 1 sorted out by category in Medium Surgery

Major Surgery	N	Plastic Tot/ Mean $\pm$ SD (Kg)	Paper Tot/ Mean $\pm$ SD (Kg)	General Waste Tot/ Mean $\pm$ SD (Kg)	Hazardous Waste Tot/ Mean $\pm$ SD (Kg)	Tot Waste/ Mean $\pm$ SD (Kg)
Laparoscopy: total hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy +/- paraortic lymphadenectomy	52	106,8 2,06 $\pm$ 0.31	35,9 0,69 $\pm$ 0.10	71,2 1,37 $\pm$ 0.2	498,5 9,58 $\pm$ 1.44	712,4 13,7 $\pm$ 2.05
Primary debulking surgery / Interval debulking surgery	50	152,3 3,05 $\pm$ 0.46	40,6 0,81 $\pm$ 0.12	71,1 1,42 $\pm$ 0.21	751,0 15,02 $\pm$ 2.25	1015,0 20,3 $\pm$ 3.04
Emivulvectomy / Total vulvectomy + inguinal lymphadenectomy	11	24,25 2,20 $\pm$ 0.33	14,04 1,28 $\pm$ 0.19	18,98 1,73 $\pm$ 0.26	119,36 10,85 $\pm$ 1.63	176,63 16,06 $\pm$ 2.41
Laparoscopy: radical hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy	20	28,0 1,40 $\pm$ 0.21	14,0 0,70 $\pm$ 0.10	42,0 2,10 $\pm$ 0.32	196,0 9,80 $\pm$ 1.47	280,0 14,00 $\pm$ 2.10
Robot: hysterectomy + bilateral salpingo- ovariectomy + pelvic lymphadenectomy	8	22,5 2,81 $\pm$ 0.42	5,3 0,66 $\pm$ 0.10	10,6 1,32 $\pm$ 0.20	93,6 11,72 $\pm$ 1.76	132,0 16,5 $\pm$ 2.48

Table 5: quantity of waste produced in phase 1 sorted out by category in Major Surgery



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4.2. PHASE 2: GREEN TEAM FORMATION AND TRAINING (MONTHS 11-15)

During November 2022-February 2023, the Green Team was formed and trained to lead sustainability initiatives within the organization. We followed the Program in Global Surgery and Social Change by Harvard Medical School (<https://www.pgssc.org/>)

The key activities carried out included:

4.2.1. WEEKLY TRAINING FOR NURSES

- The Green Team conducted weekly one-hour lessons for nurses on best practices for waste recycling.
- The goal was to improve the segregation and disposal of recyclable materials, ensuring a more efficient and environmentally responsible waste management system.

4.2.2. TRAINING FOR SURGEONS

- The training emphasized minimizing the use of disposable instruments.
- Surgeons were encouraged to adopt reusable alternatives whenever possible to reduce waste and environmental impact. Specifically, the implementation of bipolar scissors and reusable instruments was promoted, including:
 - ROBI Kelly Grasping Forceps Clickline by Storz
 - ROBI Scissors 5mm Bipolar by Storz
 - Bipolar scissors for laparotomy in minor and medium surgeries, replacing the use of LigaSure.

4.2.3. ACHIEVED RESULTS

- By the end of this phase, the Green Team had established a solid foundation for sustainability efforts.
- Healthcare professionals were equipped with practical strategies to reduce environmental impact while maintaining high standards of patient care.

4.3. PHASE 3: EVALUATION AND COMPARISON OF RESULTS (MONTHS 16-26)

4.3.1. WASTE PRODUCTION ANALYSIS- AFTER GREEN TEAM FORMATION

Over a 10-month period, a total of **512 surgeries** were conducted, generating **6,370.16 kg of waste** in the Operating Rooms (ORs) of the Gynecology and Obstetrics Clinic. In particular:

- **Minor surgeries:** 193 procedures, producing **1,330 kg of waste** (Table 6).
- **Medium surgeries:** 230 procedures, generating **2,390.78 kg of waste** (Table 7).
- **Major surgeries:** 162 procedures, resulting in **2,649.22 kg of waste** (Table 8).

Below are the tables categorized by type of surgery (Minor, Medium, and Major), type of procedure, each of which is further divided by type of waste.

Minor Surgery	N	Plastic Tot/ Mean±SD (Kg)	Paper Tot/ Mean±SD (Kg)	General Waste Tot/ Mean±SD (Kg)	Hazardous Waste Tot/ Mean±SD (Kg)	Tot Waste/ Mean±SD (Kg)
Laparoscopy: bilateral salpingo-ovariectomy	87	108,75 1,25 ± 0.19	60,03 0,69 ± 0.10	53,07 0,61 ± 0.09	522,87 6,01 ± 0.90	744,72 8,56 ± 1.28
Exploratory Laparoscopy	65	42,25 0,65 ± 0.10	25,35 0,39 ± 0.06	20,80 0,32 ± 0.05	227,50 3,50 ± 0.53	315,90 4,86 ± 0.73
Ovarian Cyst Removal	41	37,31 0,91 ± 0.14	20,50 0,50 ± 0.07	19,68 0,48 ± 0.07	191,88 4,68 ± 0.70	269,37 6,57 ± 0.99

Table 6: quantity of waste produced in phase 3 sorted out by category in Minor Surgery

Medium Surgery	N	Plastic Tot/ Mean±SD (Kg)	Paper Tot/ Mean±SD (Kg)	General Waste Tot/ Mean±SD (Kg)	Hazardous Waste Tot/ Mean±SD (Kg)	Tot Waste/ Mean±SD (Kg)
Laparoscopy: hysterectomy + bilateral salpingo-ovariectomy	90	154,80 1,72 ± 0.26	49,50 0,55 ± 0.08	98,10 1,09 ± 0.16	736,20 8,18 ± 1.23	1038,60 11,54 ± 1.73
Laparotomy: hysterectomy + bilateral salpingo-ovariectomy	15	17,85 1,19 ± 0.18	10,65 0,71 ± 0.11	19,5 1,30 ± 0.20	105,9 7,06 ± 1.06	153,0 10,26 ± 1.54
Transvaginal hysterectomy	53	49,29 0,93 ± 0.14	24,38 0,46 ± 0.07	75,79 1,43 ± 0.21	360,40 6,80 ± 1.02	509,86 9,62 ± 1.44
Laparoscopy: miomectomy	45	77,40 1,72 ± 0.26	36,00 0,80 ± 0.12	40,50 0,90 ± 0.14	276,30 6,14 ± 0.92	430,20 9,56 ± 1.43
Laparotomy: miomectomy	10	12,20 1,22 ± 0.18	5,50 0,55 ± 0.08	6,10 0,61 ± 0.09	45,60 4,56 ± 0.68	69,40 6,94 ± 1.04
Robot: hysterectomy + bilateral salpingo-ovariectomy	17	44,03 2,59 ± 0.39	10,37 0,61 ± 0.09	15,13 0,89 ± 0.13	177,65 10,45 ± 1.57	247,18 14,54 ± 2.18

Table 7: quantity of waste produced in phase 3 sorted out by category in Medium Surgery

Medium Surgery	N	Plastic Tot/ Mean $\pm$ SD (Kg)	Paper Tot/ Mean $\pm$ SD (Kg)	General Waste Tot/ Mean $\pm$ SD (Kg)	Hazardous Waste Tot/ Mean $\pm$ SD (Kg)	Tot Waste/ Mean $\pm$ SD (Kg)
Laparoscopy: total hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy +/- paraortic lymphadenectomy	60	118,2 1,97 $\pm$ 0.30	38,4 0,64 $\pm$ 0.10	77,4 1,29 $\pm$ 0.19	569,4 9,49 $\pm$ 1.42	803,4 13,39 $\pm$ 2.01
Primary debulking surgery / Interval debulking surgery	62	183,52 2,96 $\pm$ 0.44	47,74 0,77 $\pm$ 0.12	81,84 1,32 $\pm$ 0.20	925,66 14,93 $\pm$ 2.24	1238,36 19,98 $\pm$ 3.00
Laparoscopy: radical hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy	18	24,48 1,36 $\pm$ 0.20	12,06 0,67 $\pm$ 0.10	37,08 2,06 $\pm$ 0.31	175,5 9,75 $\pm$ 1.46	249,12 13,84 $\pm$ 2.08
Emivulvectomy / Total vulvectomy + inguinal lymphadenectomy	8	17,44 2,18 $\pm$ 0.33	10,16 1,27 $\pm$ 0.19	13,60 1,70 $\pm$ 0.26	86,48 10,81 $\pm$ 1.62	127,68 15,96 $\pm$ 2.39
Robot: hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy	14	38,36 2,74 $\pm$ 0.41	8,4 0,60 $\pm$ 0.09	17,36 1,24 $\pm$ 0.19	162,54 11,61 $\pm$ 1.74	226,66 16,19 $\pm$ 2.43

Table 8. quantity of waste produced in phase 3 sorted out by category in Major Surgery

4.3.2. WASTE SAVING AFTER GREEN TEAM FORMATION

Minor Surgery	N	Δ Plastic tot/ Mean $\pm$ SD (kg)	Δ Paper tot/ Mean $\pm$ SD (kg)	Δ General Waste tot/ Mean $\pm$ SD (kg)	Δ Hazardous Waste tot/ Mean $\pm$ SD (kg)	Δ Tot Waste/ Mean $\pm$ SD (kg)
Laparoscopy: bilateral salpingo-ovariectomy	87	5,22 0,06 $\pm$ 0,01	3,48 0,04 $\pm$ 0,01	11,31 0,13 $\pm$ 0,02	40,89 0,47 $\pm$ 0.07	60,90 0,70 $\pm$ 0.10
Exploratory Laparoscopy	65	9,10 0,14 $\pm$ 0.02	3,25 0,05 $\pm$ 0.01	8,45 0,13 $\pm$ 0.02	24,70 0,38 $\pm$ 0.06	44,85 0,69 $\pm$ 0.10
Ovarian Cyst Removal	41	4,51 0,11 $\pm$ 0.02	2,87 0,07 $\pm$ 0.01	4,10 0,10 $\pm$ 0.01	14,76 0,36 $\pm$ 0.05	26,24 0,64 $\pm$ 0.10

Table 9. Waste reduction in Minor Surgery

Following the implementation of Green Team training, a significant reduction in waste generation was observed across various types of minor surgeries (Table 9). We have completely eliminated the use of single-use devices, such as bipolar and Ligasure, and now exclusively use reusable ROBI bipolar scissors. The waste reduction percentages were calculated by comparing the total waste generated per procedure before and after the training. For Laparoscopy: bilateral salpingo-ovariectomy, the total waste per single surgery decreased from 9.26 kg to 8.56 kg, representing a reduction of 7.57% after the Green Team training.

In the case of Exploratory Laparoscopy, waste per single surgery was reduced from 5.55 kg to 4.86 kg, achieving a waste saving of 12.43%.



For Ovarian Cyst Removal, the total waste per single surgery was reduced from 7.21 kg to 6.57 kg, showing an 8.87% reduction.

When combining the waste reductions across all three interventions, the total waste produced before the green team training was 22.02 kg, while after the training it was 20.00 kg.

This results in a total waste reduction of 2.02 kg, which corresponds to an overall reduction of 9.96% across all single procedures.

Medium Surgery	N	Δ Plastic tot/ Mean $\pm$ SD (kg)	Δ Paper tot/ Mean $\pm$ SD (kg)	Δ General Waste tot/ Mean $\pm$ SD (kg)	Δ Hazardous Waste tot/ Mean $\pm$ SD (kg)	Δ Tot Waste/ Mean $\pm$ SD (kg)
Laparoscopy: hysterectomy + bilateral salpingo-ovariectomy	90	11,7 0,13 $\pm$ 0.02	6,3 0,07 $\pm$ 0.01	12,6 0,14 $\pm$ 0.02	38,7 0,43 $\pm$ 0.06	68,3 0,76 $\pm$ 0.11
Laparotomy: hysterectomy + bilateral salpingo-ovariectomy	15	1,05 0,07 $\pm$ 0.01	0,45 0,03 $\pm$ 0.01	1,05 0,07 $\pm$ 0.01	1,20 0,08 $\pm$ 0.01	3,75 0,24 $\pm$ 0.04
Transvaginal hysterectomy	53	2,65 0,05 $\pm$ 0.01	1,59 0,03 $\pm$ 0.01	2,12 0,04 $\pm$ 0.01	2,65 0,05 $\pm$ 0.01	9,02 0,18 $\pm$ 0.03
Laparoscopy: miomectomy	45	1,80 0,04 $\pm$ 0.01	0,90 0,02 $\pm$ 0.01	1,35 0,03 $\pm$ 0.01	1,35 0,03 $\pm$ 0.01	5,40 0,12 $\pm$ 0.02
Laparotomy: miomectomy	10	0,9 0,09 $\pm$ 0.01	0,6 0,06 $\pm$ 0.01	0,9 0,09 $\pm$ 0.01	0,7 0,07 $\pm$ 0.01	3,1 0,32 $\pm$ 0.05
Robot: hysterectomy + bilateral salpingo-ovariectomy	17	2,55 0,15 $\pm$ 0.02	2,55 0,15 $\pm$ 0.02	2,89 0,17 $\pm$ 0.03	3,23 0,19 $\pm$ 0.03	11,22 0,66 $\pm$ 0.10

Table 10. Waste reduction in Medium Surgery

Following the implementation of the Green Team training, a notable reduction in waste generation was observed across medium surgeries (Table 10). We have reduced the use of single-use devices by 20% in Laparoscopic/Laparotomic hysterectomy with bilateral salpingo-oophorectomy.

For Laparoscopic hysterectomy with bilateral salpingo-oophorectomy, the total waste per single surgery decreased from 12.3 kg to 11.54 kg, reflecting a reduction of 6.18%.

Laparotomic hysterectomy with bilateral salpingo-oophorectomy showed a smaller reduction, with waste per single surgery decreasing by 2.29%, from 10.5 kg to 10.26 kg.

In the case of Transvaginal hysterectomy, the total waste per single surgery was reduced by 1.84%, from 9.8 kg to 9.62 kg. Laparoscopic myomectomy procedures saw a modest reduction in waste, with a decrease of 1.24%, from 9.68 kg to 9.56 kg.

For Laparotomic myomectomy, the reduction was more substantial, with waste dropping by 4.41%, from 7.26 kg to 6.94 kg. Lastly, Robotic hysterectomy with bilateral salpingo-oophorectomy also showed a reduction in waste, dropping by 4.34%, from 15.2 kg to 14.54 kg.

In total, the overall reduction in waste was approximately 3.78% in medium surgeries.

Major Surgery	N	Δ Plastic tot/ Mean $\pm$ SD (kg)	Δ Paper tot/ Mean $\pm$ SD (kg)	Δ General Waste tot/ Mean $\pm$ SD (kg)	Δ Hazardous Waste tot/ Mean $\pm$ SD (kg)	Δ Tot Waste/ Mean $\pm$ SD (kg)
Laparoscopy: total hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy +/- paraortic lymphadenectomy	60	5,4 0,09 $\pm$ 0.01	3,0 0,05 $\pm$ 0.01	4,8 0,08 $\pm$ 0.01	5,4 0,09 $\pm$ 0.01	18,6 0,31 $\pm$ 0.05
Primary debulking surgery / Interval debulking surgery	62	5,58 0,09 $\pm$ 0.01	2,48 0,04 $\pm$ 0.01	6,2 0,10 $\pm$ 0.01	5,58 0,09 $\pm$ 0.01	19,84 0,320 $\pm$ 0.05
Laparoscopy: radical hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy	18	0,72 0,04 $\pm$ 0.01	0,54 0,03 $\pm$ 0.01	0,36 0,02 $\pm$ 0.01	0,90 0,05 $\pm$ 0.01	2,88 0,16 $\pm$ 0.02
Emivulvectomy / Total vulvectomy + inguinal lymphadenectomy	8	0,16 0,02 $\pm$ 0.01	0,08 0,01 $\pm$ 0.01	0,24 0,03 $\pm$ 0.01	0,24 0,03 $\pm$ 0.01	0,80 0,10 $\pm$ 0.01
Robot: hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy	14	0,98 0,07 $\pm$ 0.01	0,84 0,06 $\pm$ 0.01	1,12 0,08 $\pm$ 0.01	1,54 0,11 $\pm$ 0.02	3,36 0,24 $\pm$ 0.02

Table 11. Waste reduction in Major Surgery

Following the implementation of the green team training, a reduction in waste generation was observed across different types of major surgeries (Table 11).

For Laparoscopy: total hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy +/- paraortic lymphadenectomy, the total waste per surgery decreased from 13.7 kg to 13.39 kg, representing a reduction of 2.26% after the green team training.

In the case of Primary Debulking Surgery / Interval Debulking Surgery, waste per single surgery was reduced from 20.3 kg to 19.98 kg, achieving a waste saving of 1.58%.

For Laparoscopy: radical hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy, the total waste per single surgery decreased from 14.00 kg to 13.84 kg, showing a 1.14% reduction.

In emivulvectomy / total vulvectomy + inguinal lymphadenectomy, waste per single surgery was reduced from 16.06 kg to 15.96 kg, resulting in a reduction of 0.62%.

For Robotic hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy, waste per single surgery was reduced from 16.5 kg to 16.19 kg, reflecting a waste saving of 1.45%.

When combining the waste reductions across all five types of major surgeries, the total waste produced before the green team training was 80.56 kg, while after the training, it was 79.36 kg. This results in a total waste reduction of 1.2 kg, which corresponds to an overall reduction of 1.41% across all major surgery procedures.

Considering all surgical categories—Minor, Medium, and Major Surgeries—the total waste reduction achieved was 3.19%.



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Over the course of 10 months, this is the total waste reduction we've achieved:

- For Minor Surgery, we conducted 193 surgeries, resulting in a total waste reduction of 131.99 kg.
- For Medium Surgery, we completed 230 surgeries, leading to a waste reduction of 100.79 kg.
- For Major Surgery, we performed 162 surgeries, saving 45.48 kg of waste.

In total, across all categories, we saved 278.26 kg of waste from 585 surgeries.

4.3.3. CO₂ REDUCTION OF WASTE MANAGING

Minor Surgery CO ₂ (kg) reduction	N	ΔPlastic tot/ Mean±SD (kg)	ΔPaper tot/ Mean±SD (kg)	ΔGeneral Waste tot/ Mean±SD (kg)	ΔHazardous Waste tot/ Mean±SD (kg)	ΔTot Waste/ Mean±SD (kg)
<i>Laparoscopy: bilateral salpingo-oophorectomy</i>	87	19,42 0,22 ± 0.03	3,31 0,04 ± 0.01	56,55 0,65 ± 0.10	155,38 1,79 ± 0.27	234,66 2,70 ± 0.40
<i>Exploratory Laparoscopy</i>	65	33,85 0,52 ± 0.08	3,09 0,05 ± 0.01	42,25 0,65 ± 0.10	93,76 1,44 ± 0.22	173,95 2,66 ± 0.40
<i>Ovarian Cyst Removal</i>	41	16,77 0,41 ± 0.06	2,73 0,07 ± 0.01	20,50 0,50 ± 0.08	56,09 1,37 ± 0.20	96,09 2,35 ± 0.35

Table 12. CO₂ reduction in Minor Surgery

For Laparoscopic Bilateral Salpingo-Oophorectomy, the CO₂ emissions before the establishment of the Green Team were 33.88 kg. After the Green Team's intervention, emissions decreased to 31.20 kg, leading to a 7.91% reduction in CO₂ emissions.

For Laparoscopic Exploratory Surgery, CO₂ emissions before the Green Team's formation were 20.35 kg. Following the implementation of sustainable practices, emissions dropped to 17.69 kg, resulting in a 13,7% reduction.

For Ovarian Cyst Removal, the initial CO₂ emissions before the Green Team's introduction were 26.40 kg. After adopting greener practices, emissions were reduced to 24.05 kg, achieving an 8.9% decrease in CO₂ output.

So, the total reduction in CO₂ emissions across all Minor Surgeries is 7.71, which represents an 10.20% reduction (Table 12).

Medium Surgery CO ₂ (kg) reduction	N	ΔPlastic tot/ Mean±SD (kg)	ΔPaper tot/ Mean±SD (kg)	ΔGeneral Waste tot/ Mean±SD (kg)	ΔHazardous Waste tot/ Mean±SD (kg)	ΔTot Waste/ Mean±SD (kg)
<i>Laparoscopy: hysterectomy + bilateral salpingo-ovariectomy</i>	90	43,52 0,48 ± 0.07	5,99 0,07 ± 0.01	63,0 0,7 0 ± 0.10	147,06 1,63 ± 0.24	259,57 2,90 ± 0.43
<i>Laparotomy: hysterectomy + bilateral salpingo-ovariectomy</i>	15	3,91 0,26 ± 0.04	0,43 0,03 ± 0.01	5,25 0,35 ± 0.05	4,56 0,30 ± 0.05	14,14 0,94 ± 0.14
<i>Transvaginal hysterectomy</i>	53	9,86 0,19 ± 0.03	1,51 0,03 ± 0.01	10,60 0,20 ± 0.03	10,07 0,19 ± 0.03	31,14 0,60 ± 0.09
<i>Laparoscopy: miomectomy</i>	45	6,70 0,15 ± 0.02	0,90 0,02 ± 0.01	6,75 0,15 ± 0.02	5,13 0,11 ± 0.02	19,43 0,43 ± 0.06
<i>Laparotomy: miomectomy</i>	10	3,35 0,33 ± 0.05	0,57 0,06 ± 0.01	4,5 0,45 ± 0.07	2,66 0,26 ± 0.04	110,78 1,11 ± 0.17
<i>Robot: hysterectomy + bilateral salpingo-ovariectomy</i>	17	9,50 0,56 ± 0.08	2,42 0,14 ± 0.02	14,45 0,85 ± 0.13	12,27 0,72 ± 0.11	38,63 2,27 ± 0.34

Table 13. CO₂ reduction in Medium Surgery

For Medium Surgery procedures, the reduction in CO₂ emissions after the formation of the green team varies across different types of interventions. For Laparoscopy: hysterectomy + bilateral salpingo-ovariectomy, the total CO₂ emissions reduced from 46.34 kg to 43.44 kg, resulting in a 6.26% reduction. The Laparotomy: hysterectomy + bilateral salpingo-ovariectomy saw a reduction in CO₂ emissions from 40.17 kg to 38.43 kg, which is a 4.32% decrease. The ITV procedure experienced a reduction in emissions from 37.54 kg to 36.89 kg, resulting in a 1,73% reduction. For Laparoscopy: myomectomy, CO₂ emissions reduced from 34.98 kg to 35.43 kg, marking a 1.29% decrease. Finally, Laparotomy: myomectomy recorded a reduction in CO₂ emissions from 26.54 kg to 25.44 kg, which corresponds to a 4.15% reduction. For Robotic: hysterectomy + bilateral salpingo-ovariectomy, the total CO₂ emissions reduced from 56,65 kg to 54.38 kg, resulting in a 4.01% reduction. Overall, the total CO₂ reduction percentage for medium surgeries was 3.46%, with the total CO₂ emissions decreasing of 8.25 kg after the formation of the green team (Table 13).

Major Surgery CO2 (kg) reduction	N	Δ Plastic tot/ Mean $\pm$ SD (kg)	Δ Paper tot/ Mean $\pm$ SD (kg)	Δ General Waste tot/ Mean $\pm$ SD (kg)	Δ Hazardous Waste tot/ Mean $\pm$ SD (kg)	Δ Tot Waste/ Mean $\pm$ SD (kg)
<i>Laparoscopy: total hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy +/- paraortic lymphadenectomy</i>	60	20,09 0,33 $\pm$ 0.07	2,85 0,05 $\pm$ 0.01	24,00 0,40 $\pm$ 0.06	20,52 0,34 $\pm$ 0.05	67,46 1,13 $\pm$ 0.17
<i>Primary debulking surgery / Interval debulking surgery</i>	62	20,76 0,33 $\pm$ 0.05	2,36 0,04 $\pm$ 0.01	31,00 0,50 $\pm$ 0.08	21,20 0,34 $\pm$ 0.05	75,32 1,21 $\pm$ 0.18
<i>Laparoscopy: radical hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy</i>	18	2,68 0,15 $\pm$ 0.02	0,51 0,03 $\pm$ 0.01	1,80 0,10 $\pm$ 0.02	3,42 0,19 $\pm$ 0.03	8,41 0,47 $\pm$ 0.07
<i>Emivulvectomy / Total vulvectomy + inguinal lymphadenectomy</i>	8	0,59 0,07 $\pm$ 0.01	0,08 0,01 $\pm$ 0.01	1,20 0,15 $\pm$ 0.02	0,91 0,11 $\pm$ 0.02	2,78 0,34 $\pm$ 0.05
<i>Robot: hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy</i>	14	3,65 0,26 $\pm$ 0.04	0,80 0,06 $\pm$ 0.01	5,60 0,40 $\pm$ 0.06	5,85 0,42 $\pm$ 0.06	15,90 1,14 $\pm$ 0.17

Table 14. CO2 reduction in Major Surgery

The CO2 reduction for each type of Major Surgery after the Green Team implementation is as follows: For Laparoscopy: total hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy, the CO2 emissions before were 51.58 kg, and after the Green Team intervention, they were reduced to 50.46 kg, resulting in a total reduction of 1.12 kg, which corresponds to a 2.19% decrease. In Primary debulking surgery / Interval debulking surgery, the CO2 emissions were 76.29 kg before the intervention and 75.06 kg after, leading to a 1.23 kg reduction, equivalent to a 1.61% decrease. For Laparoscopy: radical hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy, CO2 emissions dropped from 53.57 kg to 53.10 kg, resulting in a total reduction of 0.47 kg, which is a 1.06% decrease. In the case of Emivulvectomy / Total vulvectomy + inguinal lymphadenectomy, emissions before the intervention were 59.24 kg, decreasing to 58.90 kg after, leading to a 0.34 kg reduction, corresponding to a 0.64% decrease. Finally, for Robot-assisted hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy, CO2 emissions were 62.23 kg before and 61.09 kg after, resulting in a total reduction of 1.14 kg, equivalent to a 1.85% decrease.

The total CO2 emissions for Major Surgery before the Green Team intervention amounted to 302,89 kg. After the implementation of the Green Team, the total emissions were reduced to 298.61 kg. This results in an overall CO2 reduction of 4.28 kg, which corresponds to a 1.14% total reduction in CO2 emissions across all major surgeries (Table 14).



Over a period of 10 months, the total reduction in CO2 emissions across all types for all surgeries is as follows:

- For Minor Surgery, a total of 504.7 kg of CO2 was saved.
- In Medium Surgery, the total reduction amounted to 473.69 kg of CO2.
- For Major Surgery, the reduction in CO2 emissions reached 169.87 kg.

In total, the cumulative CO2 reduction across all surgeries over the 10-month period was 1148.26 kg.

4.3.4. COST REDUCTION OF WASTE MANAGING

Minor Surgery Reduction of costs €	N	ΔPlastic tot/ Mean±SD (kg)	ΔPaper tot/ Mean±SD (kg)	ΔGeneral Waste tot/ Mean±SD (kg)	ΔHazardous Waste tot/ Mean±SD (kg)	ΔTot Waste/ Mean±SD (kg)
Laparoscopy: bilateral salpingo-ovariectomy	87	4,18 0,05 ± 0.01	0,87 0,01 ± 0.01	3,96 0,05 ± 0.01	57,25 0,66 ± 0.10	66,26 0,76 ± 0.11
Exploratory Laparoscopy	65	7,28 0,11 ± 0.02	0,81 0,01 ± 0.01	2,96 0,05 ± 0.01	34,58 0,53 ± 0.08	45,63 0,70 ± 0.11
Ovarian Cyst Removal	41	3,61 0,09 ± 0.01	0,72 0,02 ± 0.01	1,44 0,04 ± 0.01	20,66 0,50 ± 0.08	26,43 0,64 ± 0.10

Table 15. Cost reduction in Minor Surgery

Medium Surgery Reduction of costs €	N	ΔPlastic tot/ Mean±SD (kg)	ΔPaper tot/ Mean±SD (kg)	ΔGeneral Waste tot/ Mean±SD (kg)	ΔHazardous Waste tot/ Mean±SD (kg)	ΔTot Waste/ Mean±SD (kg)
Laparoscopy: hysterectomy + bilateral salpingo- ovariectomy	90	9,36 0,10 ± 0.02	1,58 0,02 ± 0.01	4,41 0,05 ± 0.01	54,18 0,60 ± 0.01	69,52 0,77 ± 0.12
Laparotomy: hysterectomy + bilateral salpingo- ovariectomy	15	0,84 0,06 ± 0.01	0,11 0,01 ± 0.01	0,37 0,02 ± 0.01	1,68 0,11 ± 0.02	3,00 0,20 ± 0.03
Transvaginal hysterectomy	53	2,12 0,04 ± 0.01	0,40 0,01 ± 0.01	0,74 0,01 ± 0.01	3,71 0,07 ± 0.01	6,97 0,13 ± 0.02
Laparoscopy: miomectomy	45	1,44 0,03 ± 0.01	0,23 0,01 ± 0.01	0,47 0,01 ± 0.01	1,89 0,04 ± 0.01	4,03 0,10 ± 0.02
Laparotomy: miomectomy	10	0,72 0,07 ± 0.01	0,15 0,02 ± 0.01	0,31 0,03 ± 0.01	0,98 0,10 ± 0.01	2,17 0,22 ± 0.03
Robot: hysterectomy + bilateral salpingo- ovariectomy	17	2,04 0,12 ± 0.01	0,64 0,04 ± 0.01	1,01 0,06 ± 0.01	4,52 0,27 ± 0.04	8,21 0,48 ± 0.06

Table 16. Cost reduction in Medium Surgery

Major Surgery Reduction of costs €	N	ΔPlastic tot/ Mean±SD (kg)	ΔPaper tot/ Mean±SD (kg)	ΔGeneral Waste tot/ Mean±SD (kg)	ΔHazardous Waste tot/ Mean±SD (kg)	ΔTot Waste/ Mean±SD (kg)
<i>Laparoscopy: total hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy +/- paraortic lymphadenectomy</i>	60	4,32 0,07 ± 0.01	0,75 0,01 ± 0.01	1,68 0,03 ± 0.01	7,56 0,13 ± 0.02	14,31 0,24 ± 0.04
<i>Primary debulking surgery / Interval debulking surgery</i>	62	4,46 0,07 ± 0.01	0,62 0,01 ± 0.01	2,17 0,04 ± 0.01	7,81 0,13 ± 0.02	15,06 0,25 ± 0.04
<i>Laparoscopy: radical hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy</i>	18	0,58 0,03 ± 0.01	0,14 0,01 ± 0.01	0,13 0,01 ± 0.01	1,26 0,07 ± 0.01	2,11 0,12 ± 0.02
<i>Emivulvectomy / Total vulvectomy + inguinal lymphadenectomy</i>	8	0,13 0,02 ± 0.01	0,02 0,003 ± 0.01	0,08 0,01 ± 0.01	0,34 0,04 ± 0.01	0,57 0,08 ± 0.01
<i>Robot: hysterectomy + bilateral salpingo-ovariectomy + pelvic lymphadenectomy</i>	14	0,78 0,06 ± 0.01	0,21 0,02 ± 0.01	0,39 0,03 ± 0.01	2,16 0,15 ± 0.02	3,54 0,26 ± 0.04

Table 17. Cost reduction in Major Surgery

The total cost savings from waste disposal reduction across different surgery categories are as follows: (Table 16,17,18)

- Minor Surgery: The total cost savings amounted to €138.32, considering the reductions from laparoscopic bilateral salpingo-ovariectomy, exploratory laparoscopy, and ovarian cyst removal.
- Medium Surgery: A total cost saving of €93.90 was achieved, including various procedures such as laparoscopic and laparotomic hysterectomies, transvaginal interventions, myomectomies, and robotic hysterectomies.
- Major Surgery: The cost savings for major surgeries reached €35.59, derived from procedures like total hysterectomy with lymphadenectomy, primary debulking surgery, radical hysterectomy, vulvectomy, and robotic-assisted interventions.

Overall Cost Savings

Summing up all categories, the total cost savings from waste reduction efforts is €267.81.



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5. DISCUSSION

The climate change crisis poses a central threat to public health. The healthcare sector plays a significant role, contributing 10% of total U.S. greenhouse gas (GHG) emissions and generating 5 million tons of waste annually, with operating rooms alone responsible for over 30% of hospital waste [7].

The effects on women's health are severe, increasing risks of preterm birth, congenital defects, pregnancy complications, cardiopulmonary diseases, food insecurity, and gender-based violence during climate disasters. As proponents of women's health, OB/GYNs must advocate for sustainable surgical practices [6,7].

Recognizing this urgency, the American College of Obstetricians and Gynecologists (ACOG) has called for action to curb emissions and address the harmful effects of environmental toxins on women's health [32-34].

Gynecologic surgeries produce the highest amount of waste compared to other surgical fields, with an average of 11.1 kg per procedure, exceeding the overall surgical average of 10.17 kg per case. Hysterectomy, the second most frequently performed major surgery in the United States, accounts for over 516,000 cases annually, generating approximately 212,000 metric tons of CO₂ equivalents per year. The environmental impact of a hysterectomy largely depends on the surgical technique used. To align gynecologic care with sustainability goals, this commentary underscores the need for waste reduction, energy-efficient practices, and climate-conscious medical care. While laparoscopic and robotic surgeries offer benefits such as smaller incisions, reduced pain, and faster recovery, they consume more resources, generate more waste (especially disposable electronics and plastic packaging), and carry higher costs. Sustainable innovation is essential to balance technological advancements with environmental responsibility [35-37].

5.1. SUMMARY OF MAIN RESULTS: GOING GREEN IN GYNECOLOGY

The implementation of Green Team training has not only led to a measurable reduction in surgical waste but has also highlighted the varying environmental impact of different surgical techniques in terms of CO₂ saving and cost saving. While sustainability initiatives successfully reduced waste across all categories - 9.96% in minor surgeries (2.02 kg), 3.78% in medium surgeries (13.06 kg), and 1.41% in major surgeries (1.2 kg) - the data also emphasize how certain procedures inherently produce more waste per operation.

In medium surgeries, transvaginal interventions (ITV) consistently generated the least waste per procedure (9.62 kg post-training), reinforcing their lower environmental footprint compared to



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laparoscopic, laparotomic, and robotic approaches. On the other hand, robotic-assisted procedures stood out for their significantly higher waste production per surgery, with robotic hysterectomy generating 14.54 kg of waste post-training, more than its laparoscopic (11.54 kg) and laparotomic (10.26 kg), despite optimization efforts.

Similarly, in major surgeries, procedures involving extensive dissection and lymphadenectomy, such as radical hysterectomy and primary debulking surgery, resulted in particularly high waste production (13.84 kg and 19.98 kg post-training, respectively). Despite the Green Team's efforts, the structural requirements of these surgeries—including disposable instruments and procedural complexity—make them inherently resource-intensive. Reducing single-use devices in major surgery remains challenging due to its high level of complexity.

Over a 10-month period, 585 surgeries were performed, leading to a total waste reduction of 278.26 kg. However, this study underscores the need to critically assess surgical techniques beyond waste reduction efforts, focusing on structural modifications to minimize the overall environmental burden of high-waste procedures.

The implementation of the Green Team has led to a measurable reduction in CO₂ emissions across all surgical categories. However, the data highlight significant differences in environmental impact depending on the type of surgery, with robotic and major procedures continuing to generate the highest emissions despite sustainability efforts.

Among minor surgeries, the initiative achieved the most substantial reduction, with emissions dropping by 10.20% overall. Laparoscopic exploratory surgery showed the greatest improvement, reducing its carbon footprint by 13.7%, from 20.35 kg to 17.69 kg per procedure. Medium surgeries also benefited from the Green Team's efforts, with an overall CO₂ reduction of 3.46%. Laparoscopy-assisted hysterectomy and myomectomy showed moderate decreases, while transvaginal hysterectomy (ITV) stood out as the most environmentally sustainable option, generating the lowest CO₂ emissions per procedure (36.89 kg post-training).

In contrast, major surgeries showed the smallest improvement, with an overall reduction of 1.14% in CO₂ emissions. Primary debulking surgery remained the most carbon-intensive procedure, producing 75.06 kg of CO₂ even after sustainability measures were introduced.

Notably, robotic-assisted hysterectomy continued to generate the highest emissions per surgery, exceeding both laparoscopic and laparotomic approaches.

However, the data highlight significant differences in environmental impact depending on the type of surgery, with robotic and major procedures continuing to generate the highest emissions despite sustainability efforts.



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Over a period of ten months, the Green Team's efforts led to a cumulative CO₂ reduction of 1148.26 kg across 585 surgeries. Minor procedures contributed the most to this reduction, saving 504.7 kg of CO₂, followed by medium surgeries with 473.69 kg, and major surgeries with 169.87 kg. While these results demonstrate meaningful progress in reducing emissions, they also emphasize the need for targeted interventions in high-emission procedures, particularly robotic and complex oncologic surgeries, to further minimize the environmental impact of surgical care.

Our data align with existing literature regarding CO₂ emissions in surgical procedures. Specifically, laparoscopic and robotic hysterectomies exhibit significantly higher mean CO₂ emissions compared to vaginal hysterectomies, with the increased emissions largely due to the use of single-use plastic supplies. In literature, robotic hysterectomies produce the highest CO₂ emissions, with a 44% increase in greenhouse gas emissions compared to traditional laparoscopic hysterectomy. This elevated CO₂ output in robotic surgeries can be attributed to several factors, including higher energy consumption, increased waste generation, and greater anesthetic requirements associated with the use of robotic systems [38-39].

While robotic surgery often leads to better clinical outcomes, it comes at the cost of significantly greater environmental footprint, primarily driven by the increased resource consumption and waste production involved. This highlighted the importance of considering sustainability and waste reduction strategies when implementing such technologies in clinical practice, especially when seeking to reduce the healthcare sector's carbon footprint [40].

The waste reduction efforts led to total cost savings of €267.81 across all surgeries. Minor surgeries saw the highest savings (€138.32), followed by medium (€93.90) and major procedures (€35.59). These results highlight the financial benefits of sustainable surgical practices.

5.2. STRAIGHT AND LIMITS

A key strength of this study is its demonstration that engaging and fostering collaboration between nurses and surgeons within the Green Team can lead to a 3.19% reduction in waste, resulting in a CO₂ savings of 1,148.26 kg in just 10 months. With a structured four-month training program, the Green Team educates other staff members, aiming to raise awareness across the entire operating room team and further enhance sustainability efforts.

A limitation of this study is that a significant portion of surgical activity is performed by newly specialized surgeons and residents. In medium-complexity procedures, such as hysterectomies for large uteri, they still rely on single-use devices, unlike more experienced surgeons. This is particularly true for residents and newly specialized surgeons, who require these devices when operating on more complex cases. As a university hospital, our priority is to ensure the highest level of patient safety



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during training. Nonetheless, these surgeons have been actively engaged and educated in green surgery principles.

5.3. FUTURE PROSPECTIVE

Moving forward, we aim to collaborate with our anesthesia colleagues to minimize the use of inhaled anesthetics, which are significant contributors to greenhouse gas emissions in the operating room. Additionally, we have already begun the process of transitioning to energy-efficient LED surgical lights, reducing both energy consumption and environmental impact. These initiatives represent just the beginning of a broader commitment to integrating sustainable practices into gynecologic surgery, ensuring that patient care and environmental responsibility go hand in hand.

6. CONCLUSION

With our study, we have demonstrated that through teamwork and the establishment of a Green Team, it is possible to achieve a significant reduction in waste when combined with better utilization of surgical instruments by surgeons and increased attention to waste separation by nurses, resulting in a reduction of CO₂ emissions. Expanding the Green Team to include anesthesiologists and targeting the purchase of better LED lights—initially more costly but amortized over time due to their lower energy consumption and reduced CO₂ production—will have an even greater impact on the operating room's overall sustainability.



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7. REFERENCES

- [1] Watts N, Amann M, Arnell N, et al. The 2020 report of the Lancet Countdown on health and climate change: responding to converging crises. *Lancet* 2021;397:129–70.
- [2] US Energy Information Administration. Commercial buildings energy consumption survey: energy usage summary. 2016. Available at: <http://www.eia.gov/consumption/commercial/reports/2012/energyusage>. Accessed November 12,2022.
- [3] Dynamic WHO dashboard for island states highlights barriers and progress on climate change and health. *Saudi Med J* 2021; 42:702–703.
- [4] Eckelman MJ, Sherman J. Environmental impacts of the U.S. health care system and effects on public health. *PLoS One* 2016;11: e0157014.
- [5] United Nations. 2021c. “What Is Climate Change?” United Nations. United Nations. August 4, 2021. <https://www.un.org/en/climatechange/what-is-climate-change>.
- [6] Knowlton K, Lemery J, Sorensen C. Global climate change and human health: from science to practice, 2nd ed. John Wiley & Sons; 2021.
- [7] Landrigan PJ, Fuller R, Acosta NJR, et al. The Lancet Commission on pollution and health. *Lancet* 2018;391:462–512.
- [8] van Daalen KR, Romanello M, Rocklöv J, et al. The 2022 Europe report of the Lancet Countdown on health and climate change: towards a climate resilient future. *Lancet Public Health*. 2022 Dec;7(12):e993.
- [9] Practice Greenhealth. Available at: [https:// practicegreenhealth.org/](https://practicegreenhealth.org/). Accessed March 29,2022.
- [10] “UK Health Services Make Landmark Pledge to Achieve Net Zero.” 2021. GOV.UK. November 9, 2021. <https://www.gov.uk/government/news/uk-health-services-make-landmark-pledge-to-achieve-net-zero>.
- [11] Pietrabissa, Andrea, Luigi Pugliese, Matteo Filardo, Stefania Marconi, Alba Muzzi, and Andrea Peri. 2022. “My OR Goes Green: Surgery and Sustainability.” *Cirugia Espanola* 100 (6): 317–19.
- [12] Pietrabissa, Andrea, and Patricia Sylla. 2023. “Green Surgery: Time to Make a Choice.” *Surgical Endoscopy* 37 (9): 6609–10.
- [13] Rizan, C, M Reed, F Mortimer, A Jones, R Stancliffe, and MF Bhutta. 2020. “Using Surgical Sustainability Principles to Improve Planetary Health and Optimise Surgical Services Following the COVID-19 Pandemic.” *The Bulletin of the Royal College of Surgeons of England* 102 (5): 177–81.



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- [14] Kagoma, Yoan, Nathan Stall, Edward Rubinstein, and Douglas Naudie. 2012. "People, Planet and Profits: The Case for Greening Operating Rooms." CMAJ : Canadian Medical Association Journal 184 (17): 1905.
- [15] Greening the OR: guidance documents. Reston (VA): Practice Greenhealth 2011. Available: www.c4spgh.org/HCW1_Presentations/GOR_FullSet_Guidance%20Docs_Web_042711.pdf (accessed 2011 Dec. 1).
- [16] Saver C. Going green in the OR brings financial, environmental gains. OR Manager 2011;27:1,10-3.
- [17] Love C. Operating room HVAC setback strategies. Chicago (IL): The American Society for Healthcare Engineering; 2011.
- [18] Tuenge JR. LED Surgical Task Lighting Scoping study: a hospital energy alliance Project. Richland (WA): United States Department of Energy; 2011.
- [19] Hill L. The three legged stool of regulated medical waste reduction. Reston (VA): Practice Greenhealth; 2010.
- [20] Conrardy J, Hillanbrand M, Myers S, et al. Reducing medical waste. AORN J 2010;91:711-21.
- [21] Shaner H, McRae G. Invisible costs/visible savings: innovations in waste management for hospitals. Surgical Services Management 1996;2:17-21.
- [22] Blue-Zone Technologies. Hospital anesthetic gas discharges and the environment: prevent the vent [factsheet]. Mississauga (ON): Canadian Centre for Pollution Prevention; 2005.
- [23] Brent P. A greener way to get anesthetized. Globe and Mail [Toronto] 2010 Oct 25.
- [24] Ontario Hospital Association. Green Hospital Champion Fund. Toronto (ON): The Association; 2011. Available: www.oha.com/CurrentIssues/Issues/Green%20Healthcare/Pages/GreenHospitalChampionFund.aspx (accessed 2011 Dec.).
- [25] Hancock T. Doing less harm: assessing and reducing the environmental and health impact of Canada's health care system. Branchton (ON): Canadian Coalition for Green Health Care; 2001.
- [26] Trieu E, Ramirez-Caban LC, Shockley ME. Review of sustainable practices for the gynecology operating room. Curr Opin Obstet Gynecol. 2024 Aug 1;36(4):324-329.
- [27] Lam K, Gadi N, Acharya A, et al. Interventions for sustainable surgery: a systematic review. Int J Surg 2023; 109:1447–1458



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REACT EU



- [28] Boberg L, Singh J, Montgomery A, Bentzer P. Environmental impact of singleuse, reusable, and mixed trocar systems used for laparoscopic cholecystectomies. PLoS One 2022; 17:e0271601.
- [29] Hsu S, Thiel CL, Mello MJ, Slutzman JE. Dumpster diving in the emergency department. West J Emerg Med 2020; 21:1211–1217.
- [30] Gasciauskaitė G, Lunkiewicz J, Tucci M, et al. Environmental and economic impact of sustainable anaesthesia interventions: a single-centre retrospective observational study. Br J Anaesth 2024. S0007-0912(23)00692-X.
- [31] WormerBA, AugensteinVA, Carpenter CL, et al. The green operating room: simple changes to reduce cost and our carbon footprint. Am Surg 2013; 79:666–671.
- [32] American College of Obstetricians and Gynecologists. ACOG-climate change and women's health position statement. 2016. Available at: <https://medsocietiesforclimatehealth.org/wpcontent/uploads/2016/10/ACOG-Statement.pdf>. Accessed March 28, 2022.
- [33] Malley CS, Kuylenstierna JCI, Vallack HW, Henze DK, Blencowe H, Ashmore MR. Preterm birth associated with maternal fine particulate matter exposure: a global, regional and national assessment. Environ Int 2017; 101: 173–82.
- [34] The Medical Society Consortium On Climate And Health (MSCCH). Mission & consensus statement. Available at: <https://medsocietiesforclimatehealth.org/about/mission-and-consensus-statement/>. Accessed April 5, 2022.
- [35] Shoham MA, Baker NM, Peterson ME, Fox P. The environmental impact of surgery: a systematic review. Surgery 2022; 172:897–905.
- [36] Thiel CL, Eckelman M, Guido R, et al. Environmental impacts of surgical procedures: life cycle assessment of hysterectomy in the United States. Environ Sci Technol 2015; 49:1779–1786.
- [37] Ramani S, Hartnett J, Karki S, et al. Carbon dioxide emissions and environmental impact of different surgical modalities of hysterectomies. JSLS 2023; 27:e2023.00021.
- [38] Chan KS, Lo HY, Shelat VG. Carbon footprints in minimally invasive surgery: good patient outcomes, but costly for the environment. World J Gastrointest Surg 2023; 15:1277–1285.
- [39] Papadopoulou A, Kumar NS, Vanhoostenberghe A, Francis NK. Environmental sustainability in robotic and laparoscopic surgery: systematic review. Br J Surg 2022; 109:921–932.



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e della Ricerca



REACT EU



- [40] Thiel CL, Eckelman M, Guido R, Huddleston M, Landis AE, Sherman J, Shrake SO, Copley-Woods N, Bilec MM. Environmental impacts of surgical procedures: life cycle assessment of hysterectomy in the United States. *Environ Sci Technol*. 2015 Feb 3;49(3):1779-86.