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Case report

A “Whole of system approach” to develop environmental sustainability in a Singapore Healthcare System

Brandon X. Lum[a], Rebecca Y. Lee[b,*], Boon Woei Lee[b], Bee Lok Hoong[b], Eugene H. Liu[c,d]

[a] Corporate Planning & Development Department, National University Hospital, National University Health System, 1E Kent Ridge Road 119228, Singapore
[b] Corporate Infrastructure Office, National University Health System, 1E Kent Ridge Road, 119228, Singapore
[c] Yong Loo Lin School of Medicine, National University of Singapore, 10 Medical Drive, 117597, Singapore
[d] Department of Anaesthesia, National University Hospital, National University Health System, 1E Kent Ridge Road, 119228, Singapore

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ABSTRACT

Introduction: While healthcare systems have to prepare for the impact on global health due to climate change, the healthcare sector must reduce carbon emissions and become environmentally sustainable. This paper provides an overview of how a healthcare system in Singapore, the National University Health System (NUHS), is transiting to sustainable healthcare.
Case presentation: NUHS used a “whole of system approach”, developing a system for governance, accountability, and management, and building internal capability to decarbonize healthcare. This was managed by a newly formed Office of Sustainability, to address the system’s carbon footprint in clinical care, facilities management, and procurement. Strategies on sustainability focused on emissions and consumption that were material and significant to NUHS were pursued.
Discussion: NUHS encountered several challenges in the implementation of certain initiatives such as limited manpower and funding, managing supplier relationships and changing clinical practices. A key focus was to build internal capabilities and prioritize strategies to drive sustainability within the health system. Ensuring the availability of funding enabled the implementation of sustainability initiatives as well. Additionally, a growing workload with Singapore’s aging local population would reduce the impact of sustainability initiatives on NUHS’ carbon footprint.
Conclusion: This paper aims to assist other healthcare systems embarking on their sustainability journeys to formulate a plan to decarbonize.

1. Introduction

Climate change poses a threat to global public health, especially with the increase in global temperatures and changes in weather patterns. Healthcare has emerged as one of the top contributors to climate change accounting for 4–5 % of all global GHG emissions. It is crucial to address healthcare’s contribution to the global carbon footprint emissions. This report details the planning and implementation of the National University Health System (NUHS) environmental sustainability program. It explores the challenges encountered during planning and execution and the valuable lessons learned throughout the process.

2. Case presentation

2.1. The setting

As a public sector healthcare group of three hospitals and 7 polyclinics, National University Health System (NUHS) provides a full range of care for the 1,300,000 population in the Western part of Singapore [1]. The growing healthcare burden on the population urgently necessitates a reduction in Singapore’s high per capita healthcare carbon footprint [2].

The tropical location and small size of Singapore presents several important challenges in developing a health system sustainability program. First, all healthcare facilities require year-round energy intensive air conditioning due to annual temperatures above 27 °C [3]. Second, limited land availability means that waste must be incinerated prior to burial in designated landfills, diminishing the environmental advantages of using biodegradable materials and further increasing carbon emissions [4]. Furthermore, the scarcity of land

* Corresponding author at: 1E Kent Ridge Road, #13-00, Singapore 119228.
E-mail addresses: brandon_lum@nuhs.edu.sg (B.X. Lum), rebecca_yy_lee@nuhs.edu.sg (R.Y. Lee), boon_woei_lee@nuhs.edu.sg (B.W. Lee), bee_lok_hoong@nuhs.edu.sg (B.L. Hoong), eugene_liu_hc@nuhs.edu.sg (E.H. Liu).

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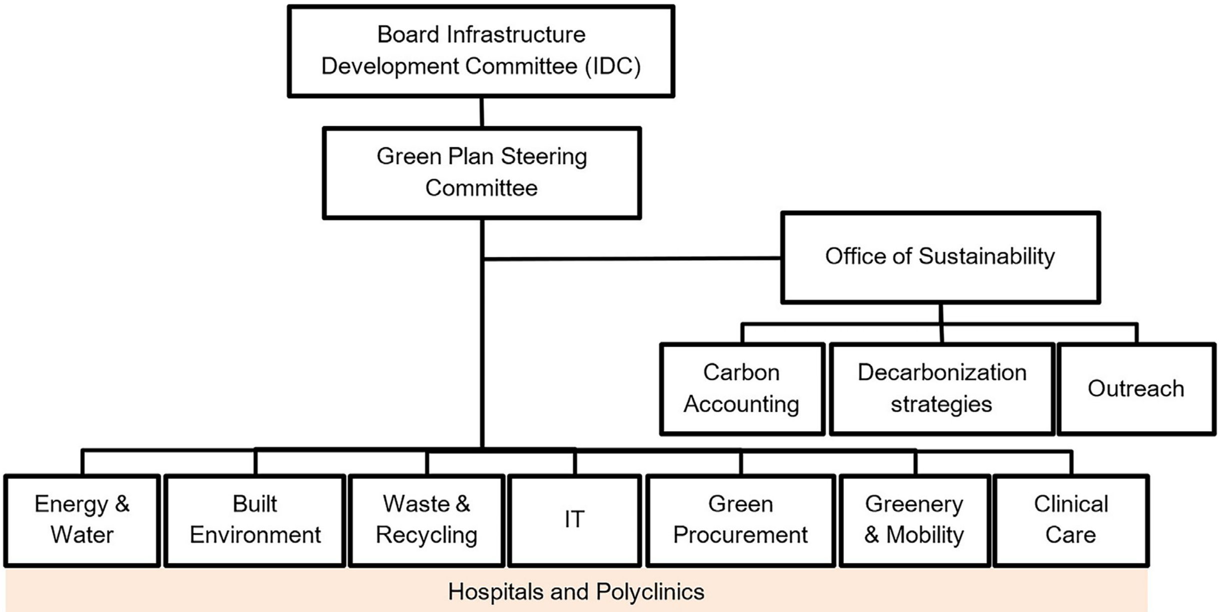

Fig. 1. Organization chart of NUHS' sustainability governance.

also restricts the implementation of large-scale renewable energy projects that harvest solar energy. Most buildings in Singapore are tall with low roof-to-floor area ratios, limiting the potential for rooftop solar panels. High humidity and frequent cloud cover reduce the efficiency of solar panels at capturing energy [5,6]. These local conditions significantly influenced the approach to sustainability taken by NUHS.

2.2. *The approach*

NUHS established a new Office of Sustainability (OS) in 2021 to drive environmentally sustainable healthcare. OS managed projects, carbon accounting, research, staff engagement and education. Taskforces spanning NUHS' hospitals and polyclinics were established to drive system wide decarbonization in these domains: energy use, water use, waste management, procurement, built environment, greenery, IT and clinical care. This empowered a "whole of system approach" to address sustainability in NUHS, across areas of clinical, operations, procurement, finance, facilities management, and infrastructure.

A new senior management committee led by NUHS' Group Chief Executive was established to facilitate implementation of NUHS's Green Plan. The NUHS Board's Infrastructure Sub-committee provided oversight and advice [ref Fig 1].

To incentivize staff ownership of environmental sustainability, senior management included one sustainability indicator in NUHS's annual 'balanced scorecard'. This scorecard comprised of ten indicators that measure NUHS' overall performance on metrics such as patient satisfaction, employee engagement and financial performance. These were measured annually and impacted staff compensation. The carbon footprint of NUHS's total electricity usage was selected as the sustainability indicator, as this was a large component of the total footprint and had reliable and measurable data.

Carbon accounting was implemented to establish baselines, guide target setting, monitor progress of decarbonization initiatives, cost the impact of carbon taxes, prepare for future disclosure requirements. A combination of top-down and bottom-up approach was employed to account for Scope 1, 2 and 3 emissions, using quantity-based data where possible [ref Table 1]. NUHS took an organizational boundary approach in decarbonization, and categorized carbon footprint as 'operating carbon' and 'capital carbon' [7].

Capital carbon comprised the embodied carbon in major equipment and infrastructure projects. Capital carbon is accounted for in the year of purchase and is not spread over the years of the asset's lifespan. Operating carbon comprised the goods and materials used in NUHS operations. Local emission factors, derived for various categories based on the movement of goods and services between industry sectors and countries, were obtained from the Eora

Table 1
Approach across Scopes 1, 2 & 3.

Scope	Data collection methodology and indicators	Key sustainability strategy
1	Bottom-up approach through activity and quantity-based data • Quantity of high global warming potential gases reduced (year-on-year) • Global Warming Potential of gases	To reduce the use of anesthetic gases with high Global Warming Potential (e.g. Desflurane, Nitrous Oxide)
2	Bottom-up approach through activity and quantity-based data • Quantity of electricity reduced (year-on-year) • Grid emission factor of electricity	To reduce electricity consumption by implementing operational changes, technology and educating the staff.
3	Top-down approach using spend-based data	Procurement-based: To engage with vendors to supply activity-based data to compute the embodied carbon of the goods procured Development of circularity pathways Waste: To reduce waste production and identify new recycling pathways

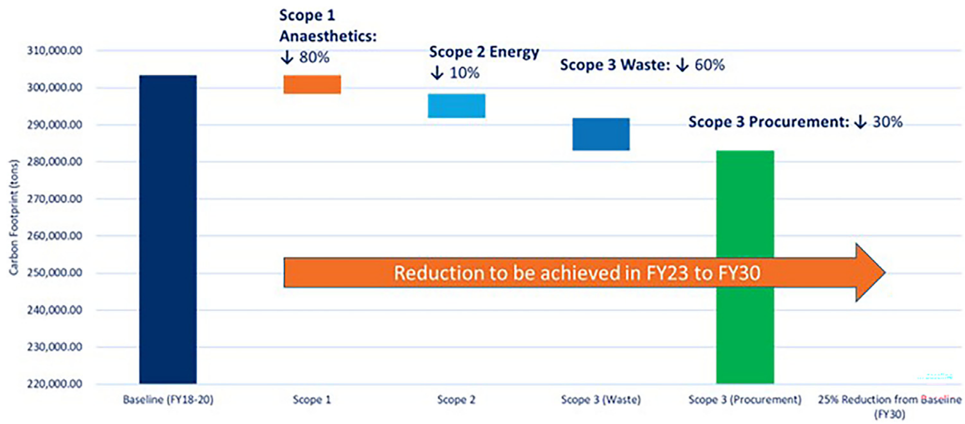

Fig. 2. NUHS' roadmap to 2030 targets across the various scopes.

Environmentally Extended Multi-Region Input Output (EE-MRIO) database. These were used to calculate spend-based carbon emissions in carbon dioxide equivalents (CO_2e) [8]. Understanding the carbon footprint enabled NUHS to set a target to reduce its operating carbon footprint by 25 % by 2030.

Projects were evaluated for their reduction of emissions, and financial costs or savings. The Marginal Abatement Cost (MAC) curve methodology was used to evaluate projects' financial savings or costs per ton of carbon abated in the projects. NUHS prioritized projects which both reduced carbon and saved money [9]. This approach is further elaborated in the following section.

To influence suppliers to improve the sustainability of their products and services, NUHS added environmental sustainability criteria into tender evaluation. These criteria contributed 5 to 10 % of a supplier's total score in a 'Price-Quality-Environment (PQE) tender evaluation framework.

To drive healthcare's circular economy, NUHS worked first on reducing and reusing materials, and then approached waste as a resource, developing new pathways of recycling materials, and refurbishment of equipment.

Communication with stakeholders was preplanned in all projects. The infection control team were engaged early, and a senior clinician served as the point of contact, for queries on safe practices. The strategy and annual workplan to achieve NUHS' sustainability goals were communicated by senior management to all staff, and departments were encouraged to develop sustainability projects.

Achievements were highlighted in communication via emails, webinars, and digital noticeboards to encourage staff. Published evidence such as papers on sustainable anesthetics and environmentally friendly practices was harnessed wherever available, and NUHS incorporated teaching on environmental sustainability in grand rounds, annual sustainability events, orientation programs for new staff, and in departments' education programs.

2.3. Results

The baseline carbon footprint was 304 ktons CO_2e. The plan to reduce operating carbon footprint by 25 % by 2030 comprised reductions of 80 % in Scope 1 (mainly anesthesia gases), 10 % in Scope 2 (purchased electricity), and 60 % in waste and 30 % in procurement among Scope 3 emissions [ref Fig 2].

Projects which both saved carbon and had net financial savings were prioritized for project funding support. The MAC curve of major projects is shown in Fig. 3.

Decarbonization focused first on emissions that were controllable, and not dependent on suppliers. Most scope 1 emissions were from inhalational anesthesia drugs, in particular desflurane, and nitrous oxide (N2O), and the anesthesia departments worked to reduce their usage [10]. Pipeline N2O supply to operating room (OR) complexes were progressively turned off, with residual clinical needs provided using by small cylinders directly mounted on the anesthesia machines. NUHS has reduced these emissions by 58.3 % from the baseline [11].

NUHS focused on reducing electricity usage in hospital facilities with high energy consumption. Air flow in the ORs were reduced when they were not used for surgery, while maintaining pressure differential, temperature, and humidity parameters. This led to an approximate reduction of 2.8 % of the building's energy consumption.

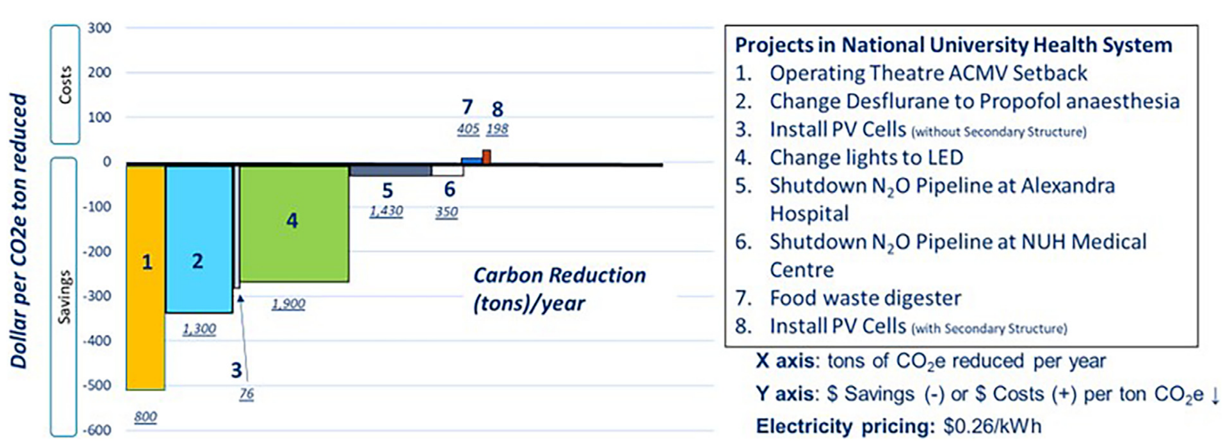

Fig. 3. Marginal Abatement Cost Curve (MACC) of projects across NUHS. The MACC shows the marginal financial costs or savings of abating carbon emissions. It plots the marginal cost of abatement on the y-axis against the quantity of emissions abated on the x-axis.

Radiology equipment were adjusted to lower energy usage settings when not in use. NUHS also re-scheduled the operating hours of air conditioning in clinics to better match operating needs and changed fluorescent lights to energy efficient LED lights. However, NUHS' energy consumption continued to increase due to the increasing workload.

Environment criteria and the PQE framework were implemented after extensive engagement with suppliers. As most suppliers lacked carbon accounting experience and data, they were unable to provide product specific carbon footprints, and there was no supplier reporting framework on embodied carbon. NUHS engaged suppliers in developing their carbon footprint and encouraged suppliers to participate in the Carbon Disclosure Project (CDP) which would facilitate their ability to provide environmental sustainability information. Because of the lack of quantitative carbon data from suppliers, the PQE framework started by evaluating qualitative environmental sustainability data.

NUHS expanded its Value Based Care clinical program, defining 'high-value' as good clinical quality at low cost and low carbon, and aimed to reduce low-value care [12]. Stopping unnecessary tests and treatments can reduce staff workload, reduce waiting times for patients who truly need these treatments, and save costs and save carbon. A key project involved reducing prescriptions of metered dose inhalers (MDI) and changing to dry powder inhalers (DPI) which have lower CO_2e, in treating asthma and chronic bronchitis. Research had showed that clinical outcomes across patients using MDIs and DPIs were similar [13].

The infection control team advised on clinical safety and infection prevention, including reduction of OR air change rates and recycling projects. *Re*-thinking and changes of several clinical practices led to several circular economy projects to reduce use of new equipment, reuse equipment, and new recycling streams. This included stopping the use of paper to line examination couches; reuse of anesthesia breathing circuits; recycling of PVC intravenous fluid bags, single use metal surgical instruments and packaging of surgical items; and refurbishment of radiology equipment [14]. NUHS installed food waste processors for two hospitals, diverting 15 to 20 tons of food waste monthly away from municipal waste incineration.

3. Discussion

This report summarizes a whole of healthcare system approach to environmental sustainability, involving clinical, operations, procurement and finance teams, prioritizing projects that both reduced carbon and delivered financial savings. There were several challenges: healthcare demands are continually increasing with the ageing population that NUHS serves, medical facilities are energy intensive, and clinical quality and safety necessitated material intensive practices and supply chain resiliency. The tropical climate necessitates extensive use of air conditioning.

Carbon accounting was challenging due to the complex supply chain, absence of existing data architecture, and the lack of company and product specific data, especially for Scope 3 emissions. More Life Cycle Analyses are needed to guide clinical choices and procurement. A pragmatic approach for supply chain emissions is to limit quantification to direct or "tier 1″ suppliers' emissions from energy use, transport, and waste.

Our suppliers varied widely in their data availability, environmental sustainability plans and practices. Contracts were all consumption based, with no circular economy and take back schemes, except for radiology equipment. Hence it was essential to design a calibrated procurement approach starting with qualitative environmental criteria, before transitioning to quantitative data once suppliers' capabilities improved.

Department level leadership and ownership were crucial in driving environmental sustainability.

Rethinking and changing clinical and operational practices were challenging, and support from senior clinicians and infection control staff were key enablers. For some high carbon footprint treatments, there are alternative treatments with lower carbon, and which are arguably better clinically. For example, using propofol intravenous anesthesia and avoiding desflurane and nitrous oxide can reduce post operative nausea and vomiting [15]. More work is needed to incorporate environmental sustainability into undergraduate and postgraduate training, and not leave learning to chance.

The governance structure was intended to align all staff to care for patients and care for the planet. The top-down ambitious target was set to drive transformation rather than incremental changes, and to convey the urgency of decarbonization. Staff provided many ground-up ideas and solutions that enabled decarbonization and net financial savings.

While some projects such as installation of electricity submeters, use of heat reflective paints on roofs and stopping the use of single use plastics do not greatly reduce the carbon footprint, they were part of inculcating sustainability in NUHS and changing individual behavior [16,17].

Internal funding enabled novel initiatives or those without financial payback, such as food waste digestors and increasing greenery in the estates, hospital campuses under the health system. Annual allocation of operating budget for such projects also conveys to staff the importance of environmental sustainability.

There is a need to relate the carbon incurred in care to the output delivered and outcomes achieved. Efficiency metrics relating CO_2e to workload units of care, and specialty specific metrics can enable better evaluation of resource usage and the effectiveness of interventions. Expanding the scope of the circular economy with suppliers, and the application of carbon pricing in financial decisions, can enable environmental sustainability.

4. Conclusion

Extensive work is needed as healthcare systems and mankind have limited time to avoid being outrun by climate change. A "whole-of-system" approach is needed to effectively reduce the carbon footprint of healthcare. Setting an ambitious target with a combination of top down and ground up initiatives are needed to drive change. These must be enabled by manpower and financial investments. It is important to learn from other industries and countries, and to then adapt and tailor decarbonization measures for healthcare.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Brandon X. Lum: Writing – review & editing, Writing – original draft. **Rebecca Y. Lee:** Writing – review & editing, Writing – original draft. **Boon Woei Lee:** Writing – review & editing. **Bee Lok Hoong:** Writing – review & editing. **Eugene H. Liu:** Writing – review & editing.

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