Environmental sustainability in healthcare systems: role of frugal innovation

Greater use of frugal innovation has the potential to provide affordable healthcare with a lower environmental footprint, argue Cyan Brown, Yasser Bhatti, and Matthew Harris

Cyan Brown, 1 Yasser Bhatti, 2 Matthew Harris 3

The health sector has an important role in protecting human and planetary health by reducing its environmental impact. Health systems globally are collectively responsible for 4.4% of global net greenhouse gas emissions—equivalent to the emissions from 514 coal fired power plants annually—which damage health in several ways, including heatwaves and inhalation of pollutants.

High income countries are the main healthcare polluters, with health systems in Australia, Canada, the United States, and Switzerland each contributing over a ton of emissions per capita. Collective action has started to address this: over 50 countries have committed to developing climate resilient and low carbon health systems. Two high income countries and 12 low and middle income countries have also committed to reaching net zero carbon emissions on or before 2050, including the UK, Belgium, Malawi, and Sierra Leone. Many healthcare workers and patient groups additionally contribute to climate movements in healthcare such as HealthCare Without Harm and EcoMedics. To achieve these commitments and address the complexity of climate change, countries will need multiple strategies for mitigation and adaptation.

One such strategy is frugal innovations, which are designed to do more with fewer resources without compromising patient safety or clinical outcomes (box 1). For example, kangaroo mother care provides premature babies with 24 hour temperature support by using skin-on-skin contact with a parent or caregiver. For stable neonates, this approach removes the need for expensive incubators, run on electricity—an economic cost and environmental saving for the health system. The potential savings from resource-sparing frugal innovations warrant national attention from policy makers, but this will require an enabling policy, research, and business development environment.

is not always predicated on contributing to sustainability, it can lead to sustainable innovation.7

Key criteria for a frugal innovation6

• Substantial cost reduction—Frugal innovations are significantly cheaper than their mainstream standard. There is no agreement on the level of cost reduction, but frugal innovations should be affordable for people who are low and middle income consumers or offer cost savings at a system level. Affordability should be a key feature from inception

• Core functionalities—This relates to the user requirements of the innovation such as simplicity, ease of use, and essential function fulfilled. This criterion extends to sustainability in that a focus on core functions, often by repurposing existing resources, helps to reduce waste and therefore lower environmental impact

• Optimised performance—Frugal innovations need to meet the required standards of performance, safety, and regulatory clearance that allow them to fulfil their core purpose in different settings

Frugal innovation can promote sustainability

In many high income countries there is both financial and environmental pressure to reform the healthcare sector, with an emphasis on cost effective, sustainable healthcare spending. In the US, for example, the Affordable Care Act 2010 instituted value based reimbursement, which limits the amount providers can earn for services based on the results they deliver for patients. Frugal innovation in high income countries could help both lower the costs of their healthcare systems and reduce the disproportionate emissions that they produce. For example, after a frugal innovation to streamline cataract surgery at the Aravind Eye Hospital in India, a specific operation produces 30 times less CO2 than an equivalent operation in the UK as well as increasing capacity for the number of patients operated on.

Frugal innovations have been most widely developed and implemented in low and middle income countries. The primary driver in these countries is often reducing health inequities and providing care to more people, with environmental gains serving as a co-benefit. The innovations are sometimes noninferior to the gold standard, sometimes better, and sometimes just good enough. Good enough means there are certain trade-offs but, the innovations meet regulatory quality requirements while reducing costs. For example, clay pots can be used to store insulin at chilled temperature effectively
but lack other functions such as refined temperature control (table 1).\textsuperscript{10}
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<th>Frugal innovation</th>
<th>Description</th>
<th>Usage</th>
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<td>Portable and renewable energy for birth delivery</td>
<td>We Care Solar suitcases have been delivered to “last mile” healthcare facilities around the world to enable healthcare workers to provide effective and timely maternal and newborn care where there is no reliable electricity. Providing an affordable and reliable source of light helps improve the safety of deliveries at night.</td>
<td>We Care Solar has delivered more than 8240 solar suitcases to rural health centres, served more than 11 million mothers and newborns, and trained 34 911 healthcare workers.</td>
<td>The company estimates that use has eliminated 94 144 tons of CO2 over more than a decade. It trains local technicians to fix and maintain solar boxes to keep them in use, which also reduces the carbon footprint associated with relying on global supply chains for maintenance.</td>
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<td>Spoke and hub model of community care delivery</td>
<td>This model is built on anchor establishments (hubs) that offer a full array of services and secondary establishments (spokes) that offer a more limited range of services in more locations. The model has been shown to foster resource conservation, increase the return on investment, promote service excellence, and increase healthcare coverage.</td>
<td>Aravind eye care in India has used this model with great success. In 2018-19 it conducted 2833 eye camps, saw 563 941 outpatients at the spoke centres and treated 88 380 patients at the hub centres. This model has allowed Aravind to reach more people in rural areas while conserving resources.</td>
<td>The spoke secondary centres allow people to access healthcare without having to travel to the central hub location. This reduces the pollution associated with transport, conserves resources, and minimises wasteage in the value chain.</td>
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<td>Neonatal cooling device</td>
<td>Mira Cradle is an affordable cooling device to reduce brain injury in infants born with moderate hypoxic-ischaemic encephalopathy. Birth asphyxia is the second leading cause of newborn and neonatal death worldwide.</td>
<td>Over 500 hospitals globally are using Mira Cradle, and it has saved the lives of over 20 000 babies.</td>
<td>The Mira Cradle does not require a constant supply of electricity and water. The reusable cooling pads are frozen in mainstream refrigerators, making the system simple to produce, maintain, and operate. The simplicity of design and portability makes it easy to transport the device where home based births are preferred, leading to less travel to hospitals.</td>
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<td>Assembly line model of cataract surgery</td>
<td>Aravind Hospital in India has pioneered a frugal approach to cataract surgery that focuses on optimising the physical layout of theatres, task shifting, reducing and reusing waste, and maintaining safety.</td>
<td>This is one of the most common surgeries performed globally and is increasing with the ageing population. Aravind does on average 296 000 cataract surgeries a year and has an intraoperative complication rate of 1.1% and a rate of endophthalmitis of 0.02% compared with the US rate of 0.08%.</td>
<td>A single cataract replacement produces an estimated 180 kg of CO2 in the UK compared with 6 kg. In addition, Aravind wastes fewer medications and produces less waste.</td>
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<td>Clay pots for storage of insulin Product</td>
<td>Insulin loses potency when stored at high temperatures. Clay pots filled with water are effective at keeping insulin cool at standard room temperatures (20-25°C) in resource constrained settings where refrigeration is not available.</td>
<td>According to the International Diabetes Federation, almost 1 in 10 people are diabetic and a third do not have refrigeration at home. The clay pots provide a viable way for people without access to refrigeration to store insulin safely.</td>
<td>The clay pots are made of natural clay and do not use electricity. Compared with refrigerators they require less material to make, no energy to run, and are biodegradable. Refrigerators often end up in landfills and contribute to the burden of waste from appliances that cannot be recycled.</td>
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<td>Handheld point of care ultrasound (POCUS) in primary care</td>
<td>A portable ultrasonography probe that can connect to a compatible smartphone, providing a cost effective way to make quick diagnoses.</td>
<td>POCUS allows faster and more accurate diagnosis in primary care for cardiovascular, respiratory, gastrointestinal tract, obstetrics and gynaecology, and musculoskeletal complaints.</td>
<td>POCUS reduces the need for patients to travel to healthcare facilities with advanced diagnostic imaging facilities. In a study in Catalonia, average emissions per trip were reduced by 61.4 g of carbon monoxide, 14.8 g of nitric oxide, and 2.7 g of sulphur dioxide. It is also a much smaller machine that requires less material to produce.</td>
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<td>Menstrual cup</td>
<td>Menstrual cups are reusable, flexible, intravaginal devices, usually made of medical grade silicone, that can be used for menstrual management instead of disposable tampons and pads. The average cost is $25 (€20; £23) per device, substantially lower than the lifetime cost of disposable tampons or pads.</td>
<td>Studies have shown that using a menstrual cup decreases the risk of complications from using poor quality menstrual products such as rags in low income settings and may help reduce period poverty.</td>
<td>Most sanitary pads and tampons are disposable and have a high plastic concentration. 45 billion products are discarded annually, and in the US comprise 240 000 tons of solid waste a year. Disposable pads can take 500-800 years to break down, and each menstruator will use and dispose of 5000-15 000 pads in their lifetime as well as 180 kg of period packaging. Using a menstrual cup removes the need to repeatedly purchase disposal menstrual supplies that are environmentally harmful and costly.</td>
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<td>Telemedicine in place of in-person consultations</td>
<td>Telemedicine reduces the need for patients and healthcare staff to travel to engage in patient care. While telemedicine increases access to care, it may also exacerbate health inequities.</td>
<td>DoctHers and Sehat Kahani are social enterprises that leverage telemedicine in partnership with Norway’s telecom company Telenor in Pakistan to allow female doctors living in urban areas to offer consultations to lower income women living in rural areas.</td>
<td>A study in Sweden suggested that replacing physical visits with telemedicine appointments decreased carbon emissions by 40-70 times. A systematic review of the environmental impact of telemedicine across 14 studies conducted from 2009 to 2020 and in 7 high income countries found that the mean distance and emission savings per consultation were 334 12 km and 95.55 kg of CO2 for rural populations and 167 79 km and 37.7 tons of CO2 for urban populations.</td>
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Expanding the use of frugal innovations

The process of frugal innovation can differ depending on where it is first developed, since the process needs to take basic user and product requirements as well as specific geographical market and consumer preferences into account. Legal, regulatory, and safety requirements— as well as the stringency with which they are monitored and enforced—also vary between countries and may influence product and user requirements.

Innovation in high income countries (sometimes termed second degree frugal innovation) focuses on designing robust and cost effective health innovations for users based on geographical market preferences. The more cost effective frugal innovations hold the potential for use in low and middle income countries—for example, the Swoop portable MRI system requires no special power supply or cooling, unlike traditional MRI technology that is prohibitively expensive for even high income countries (table 1).

Reverse innovation happens when innovations developed in low and middle income countries are adopted by high income countries. One example is the Arbutus medical drill cover, which was developed in Malawi and Uganda by Canadian engineers and enables ordinary hardware drills to be used in sterile operating theatres. The drill cover was originally designed to be a reusable and washable cover in low income settings where expensive surgical grade drills were unavailable, but it has been adopted in the US as a disposable drill cover for use in emergency departments. As the US version is single use, the country has missed the environmental benefit of reusable, washable, and sterilisable bags.

Another way to conceptualise frugal innovation is to consider whether it is bottom-up or top-down. Bottom-up innovation often (but not always) involves communities in low and middle income countries that are responding to pro-social motivations, local needs, and business interests. The network is predominantly informal, and the scale is often domestic, such as We Care Solar, which provides solar powered suitcases for births to remote clinics. Top-down frugal innovation is largely done by large firms in high income countries, where market expansion is the primary objective and the secondary objective is to promote development. Reduced environmental impact may be a primary aim (eg, the reusable menstrual cup) or a secondary aim, as with portable point-of-care ultrasound machines (table 1). The network and stakeholders are primarily formal, and it is typically a large scale operation. However, not all top-down innovation occurs in high income countries. The General Electric (GE) Mac 400, a lightweight, portable electrocardiograph commissioned by GE’s Indian subsidiary, has disrupted the US electrocardiograph market.

Frugal innovation is not only for emerging markets

Because innovation tends to respond to specific needs in any given setting, some product innovations are less amenable to use in other settings than others. For example, the clay pot for insulin storage may have little appeal in settings that have easy access to refrigeration. However, as more climate change disasters like wildfires and flooding happen, stable electricity supply and access to certain technologies may be compromised and innovations such as the clay pot may become applicable in more areas. Furthermore, trade-offs are necessary to reduce our impact on the environment, and purposeful simplification in the choice of technologies, especially in high income countries, can help reduce unnecessary waste and pollution.

Some of the most environmentally and economically successful innovations in low and middle income countries, such as the use of kangaroo mother care (KMC) instead of incubators, still face barriers to use in high income countries, posing a loss for both human and planetary health. A systematic review and meta-analysis of seven well conducted randomised controlled trials showed that kangaroo mother care improved quality of care for premature, low birthweight babies and led to reductions in perinatal infection rates, hospital stay, and mortality. That there are no running costs or equipment needed only adds to the appeal. Despite this evidence, it is rarely used in high income countries, with some hospitals in Sweden and the US being among the exceptions.

One barrier to the more widespread use of kangaroo care is that there needs to be space for parents or caregivers to sleep with their babies in hospital wards, and policies and structural changes are needed to enable parents and hospitals to use this approach. As this example shows, attempts to translate or adopt innovation into another context are likely to encounter institutional, cultural, and
behavioural barriers that could limit or preclude successful implementation. However, a focus on the added benefit of reducing healthcare emission could help reduce the reluctance that some people in high-income countries may have about adopting a lower complexity frugal innovation.

**Enabling frugal innovation**

To help advance the development and uptake of frugal innovation it is important to focus on three areas—policy, research, and business model innovation. At a policy level, one of the ways to enhance the sustainability of new products or innovations that are submitted for regulatory approval would be to embed environmental considerations in the decision making criteria. Health technology assessment agencies in the UK and Canada have already committed to include environmental sustainability in the appraisal process. There is also scope for hospital value analysis committees, which make purchasing decisions, to include sustainability in their decision criteria to encourage a focus on sustainability from the outset of innovation processes. The committees could have an important role in adopting frugal innovations. For example, estimates suggest that if UK acute trusts swapped all their high-grade surgical orthopaedic drills for the Arbatus drill-clip system, they could each save nearly £250 000 a year. Success in meeting national targets for the healthcare sector to reduce its carbon footprint relies on local decision making processes.

Research to understand the environmental effect of frugal innovations is another area needing attention. One of the main priorities is to further work on lifecycle assessments, which quantify carbon emissions. For product innovations, the cost of safely disposing of medical devices at the end of life should be considered as well as the implications for solid waste that ends up in landfills. Frugal innovations focus on cost reduction throughout the value chain from production, servicing, and disposal in product lifecycle value and this drives environmentally favourable solutions such as recycling, reusing, and the circular economy. However, lifecycle assessments have not been done for a lot of frugal interventions, including many of those cited here, although most are likely to be favourable from an environmental standpoint given their focus on minimising resource use. However, frugal innovations are not inherently sustainable, and their entire lifecycle must be considered, particularly when they are transferred from low-income to high-income countries.

Business model innovation is also vital to encourage the adoption of frugal innovation. Many innovations emerge through ingenious improvisation by users and suppliers, rather than from formal research and development. Access to capital to fund the development of frugal innovations can be challenging. Grants, social impact bonds, and blended finance are all possible options for finance as they can accommodate outcomes that are not exclusively about making a profit. The right type of funding and support could enable research to help support regulatory and intellectual property clearance of many frugal innovations in multiple jurisdictions, which is key for scaling. Frugal innovations focus on the triple bottom line (environmental, societal, and economic benefit) but through cost reduction rather than making profits, and this will cause tension among stakeholders in technology markets.

**Approaching the tipping point**

Increasing the uptake or creation of frugal innovations in high-income countries may help to make the healthcare system more sustainable. However, this needs to happen alongside other initiatives to decarbonise the biggest sources of emissions in the healthcare sector. For example, 40% of healthcare sector emissions are from use of electricity and gas, especially for heating or cooling. Although frugal innovation can contribute by reducing resource use, there is still a need to implement other strategies, such as moving to clean energy sources.

High-income countries can embrace frugal innovation as part of their decarbonisation strategy, but many poorer countries use it as a necessity. The healthcare sectors of low and middle income countries are not the main contributors to the global health carbon footprint, even though many of the severe consequences of the climate crisis are borne by the people who live in these countries. Surfacing and acknowledging this inequity is an important aspect of environmental justice. The narrative about frugal innovation needs to change from being about creating more affordable healthcare options mainly in lower income countries, towards producing options that can help all countries to reduce emissions and costs, while maintaining quality of care. This can be supported by a purposeful curation of frugal innovations from low and middle income countries, establishing a rationale for their use in high income countries, and advocating for their adoption. Furthering reciprocity in innovation, built on mutual learning and partnerships, between high and low income countries will go a long way to achieve this ambition.

**Key messages**

- Frugal innovations do more with less for more people, but also have the potential to reduce the environmental impact of healthcare globally
- Although many frugal innovations arise in response to resource restrictions in lower income countries, they are also applicable in high-income countries
- Frugal innovations are adapted to user needs, barriers, and norms in different geographical contexts and therefore require local assessments of environmental impact
- Wider dissemination of frugal innovations in health requires changes in financing, policy, and research structures.

Contributors and sources: CB is a medical doctor with expertise in frugal innovation and biosdesign, MH is a senior lecturer in public health, and YB is a scholar of strategy and innovation. All three authors conceptualised the article, CB did the initial drafts and MH and YB contributed to writing, editing, and final review. CB is the guarantor.

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