How can healthcare serve both human and environmental health?

Abstract

Healthcare has a large environmental footprint due to unique aspects stemming from human health and safety requirements; however, negative environmental impact is itself worsening human health. This feedback loop is explored using a system model to encompass the influence of individual and societal decisions on the health-healthcare-environment system. Using Meadows' System Leverage Points, healthcare interventions to reverse the damaging cycle are recommended including: embracing a holistic view of health; explicitly including environmental health as a goal of healthcare; compensating for health outcomes rather than treatments; and improving information flows on the health impacts of individual and social decisions. These changes can act on both environmental and human health, shifting to a beneficial feedback loop between healthcare, health, and the environment.

Introduction

Healthcare, though often missed as a major source, is responsible for 4.4% of global greenhouse gas (GHG) emissions (Healthcare Without Harm, 2021). In the US, healthcare contributes to more than 10% of national emissions (Figure 1) (Eckelman and Sherman, 2016). This is because of factors unique to developed healthcare stemming from its purpose to improve human health safely: large built facilities, single use equipment waste, and pharmaceutical pollutants. Examples are listed in Table 1. The total impact assessment of the UK National Health Service (NHS) is summarized in Figure 2, showing that direct emissions are about a quarter of the total, while supply chain constitutes almost two-thirds (NHS England, 2022). In summary, developed healthcare has a large environmental impact (EI).

Table 1: Unique impacts of healthcare on the environment

Healthcare feature	Environmental impact	Reference
Large built facilities and transportation usage	Embodied carbon in buildings, transportation emissions	(NHS England, 2022)
Shift from reusable metal and glass instruments to single use-plastic devices for sterility and cost	Waste of 8-13 kg per bed per day in the US and 3-4 kg per bed per day across much of Europe and the UK	(Greene, 1986; Minoglou *et al.*, 2017; Practice Greenhealth, 2022)
Pharmaceutical production and disposal	Emissions intensive production; disposal through sewage leaks chemicals to environment which are metabolized in ways that while still largely unknown are negatively affecting organisms, especially in aquatic environments	(Gros *et al.*, 2010; Kummerer, 2010; Phillips *et al.*, 2015)

Anesthetics and inhaler use	Gases are released into the environment since they are never fully metabolized by patients, where they act as GHGs with global warming potentials of 50 to 2500 over 100 years	(Vollmer *et al.*, 2015)
Medical waste is classified as a biohazard to prevent disease transmission	Waste must be sterilized, often through incineration, before disposal	(US Environmental Protection Agency, 2022a)

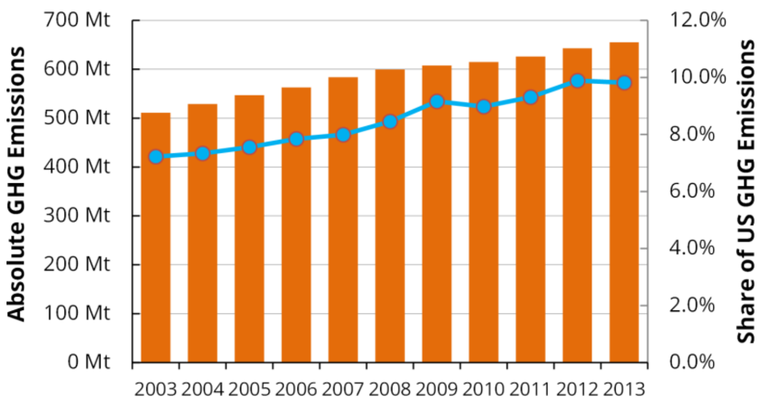

Figure 1: GHG emissions of the US healthcare system between 2003-13. The healthcare system comprises a significant portion of total emissions. Orange bar is absolute emissions, blue line is share of emissions (Eckelman and Sherman, 2016)

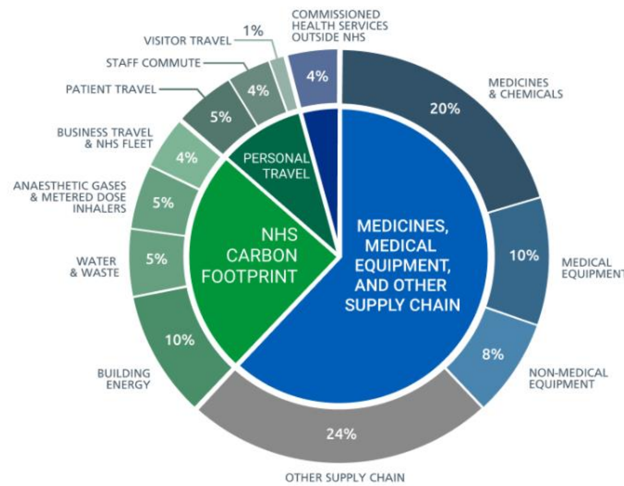

Figure 2: Proportion of carbon footprint of the NHS (Scopes 1-3) from 'Delivering a Net Zero NHS' (NHS England, 2022)

The impact of climate change on health is significant as well: the World Health Organization estimates that of disease burden and deaths globally, almost a quarter (24% and 23% respectively) are because of environmental factors (Prüss-Üstün and Corvalan, 2006). Rising temperatures, more extreme weather, and pollution all cause disease, mental health problems, injury, and death; food security is also threatened. The multiple channels of interaction are summarized in Table 2. Poor environmental quality is already endangering human health.

Table 2: Impacts of environmental issues on human health

Environmental issue	**Health impact**	**Reference**
Air pollution such as methane-created ozone, particulate matter, nitrous oxide, and other chemicals from fossil fuel burning and industrial sources	Asthma, respiratory issues, and cardiovascular disease	(Jerrett *et al.*, 2009; Kampa and Castanas, 2008)

Poor water quality from chemical or human waste pollution	Transmission of disease	(Prüss-Üstün and Corvalan, 2006)
Rising temperatures	Heat-related deaths	(Ebi *et al.*, 2018)
More frequent and severe extreme weather disasters	Injuries, deaths, post-traumatic stress disorder, anxiety, other mental health issues	(Ebi *et al.*, 2018)
Decreased quantity and quality of natural space	Mental health issues	(Bratman *et al.*, 2019; White *et al.*, 2019)
Food security impacted by extreme weather, pollution, water availability	Malnutrition, starvation	(Ebi *et al.*, 2018; van Dingenen *et al.*, 2009)
Socio-political events caused by climate change like migration and conflict	Injury, death, lack of healthcare, lack of food security	(Centers for Disease Control and Prevention, n.d.)

Thus, there is clearly a relationship between health, healthcare, and the environment, leading to the question: how can healthcare decrease its EI while improving health? If healthcare is a cause of climate change and climate change is a cause of poor health, there is a reinforcing feedback relationship[1] between healthcare and the environment. Yet, healthcare is not the only determinant of health, nor is the environment. In a complex system like healthcare with multiple stakeholders, regulations, and a seemingly simple aim to "do no harm," a reductive, or single-cause, approach is insufficient to analyze the system. A system model can explore the multiple influences on the system and thus find solutions (Meadows, 2008a). Therefore, the healthcare-health-environment system is investigated here to clarify improvements to human and environmental health.

Literature Review

Faezipour and Ferreira (2011) developed a system dynamics model to analyze healthcare sustainability. First, they modeled use of facilities and equipment and focused on supply-demand effects (appendix, Figure 5). More demand for healthcare services increases the equipment needed, using more energy and creating more waste; additionally, increasing the amount of equipment increases the accessibility of healthcare, enabling more use of healthcare. Second, they modeled the EI of healthcare. They asserted that healthcare becomes more efficient when the ecological footprint increases to the point that the public protests. The outcry causes the government to regulate EI, which increases research and development on efficient technology, which then decreases the footprint of the hospital (appendix, Figure 6). Lastly, they modeled energy consumption of healthcare and proposed that energy consumption decreases when energy efficiency increases: the supply-demand imbalance of energy

[1] A reinforcing, or positive, feedback loop occurs when stocks in the system increase each other, leading to an accelerating change in the same direction on both stocks. Conversely, a balancing, or negative, feedback loop occurs when stocks act oppositely on each other, creating a stablizing effect where the stocks are maintained at the desired level.

increases the cost, spurring more research and development on efficiency (appendix, Figure 7). They did not offer potential improvements but indicated that systems analysis could provide recommendations.

A second model was developed by Mutingi and Mbohwa (2014) which considered patient, staff, stakeholder (governments, suppliers, insurance companies), and organization (the hospital itself) satisfaction by the healthcare system. Environmental effects were captured under the organizational and stakeholder satisfaction. The model increased environmental footprint as resource usage increased, which decreased organizational and stakeholder satisfaction and economic prosperity (appendix Figure 8). Resource usage was decreased by organizational satisfaction through improved efficiency.

These two analyses ignore several important factors that could affect the sustainability of healthcare. First, Faezipour's model ignores the role of government or internal regulations on healthcare directly, such as mandating emissions limits or disclosures. The only mechanism they recognize for environmental improvement is market forces, potentially driven by more general government responses. Mutingi's model includes the government under stakeholder satisfaction but incorporates no mechanism for the government to affect sustainable healthcare. Second, the models ignore the effect of the environment on human health, which is significant as explained previously. Third, they ignore the societal landscape that the healthcare system sits in and its effect on health, healthcare operations, and the environment. The model proposed below – though less complex – addresses these issues.

Healthcare – Health – Environment System Model

The healthcare-health-environment (HHE) system model is shown in Figure 3. The Health stock is increased by more of the Environmental Quality stock and decreased by less Environmental Quality. This system also assumes a direct positive relationship between Healthcare and Health, where more Healthcare improves Health[2]. More Health, in turn, decreases the need for Healthcare (Center for Disease Control and Prevention, 2009), forming a balancing loop between the two.

Healthcare, as discussed previously, degrades Environmental Quality. Therefore, a reinforcing feedback loop is formed between Healthcare, Health, and Environmental Quality: less Environmental Quality decreases Health, which drives more Healthcare, which further decreases Environmental Quality.

These three stocks have been discussed up to this point; however, healthcare exists in the context of society and people which affect human and environmental health. The first factor, Social Infrastructure, is the norms, rules, and physical infrastructure that constitute society. Current Social Infrastructure decreases Environmental Quality. The dominance of car travel in the developed world, normalized meat consumption, resource-intensive building materials, and constant expansion into the natural world through consumption all come at costs to the environment including climate change and biodiversity loss (Rockström *et al.*, 2009). Social Infrastructure also has a negative effect on Health. The built environment and dominance of car travel decreases physical activity by preventing or discouraging active travel (Renalds *et al.*, 2010). Availability of fresh food (or lack thereof) can impact health (Walker *et al.*, 2010). Even working conditions (exposure to hazardous materials, shift work) or the stress of work

[2] This is not always true (Moynihan, yr) but is not addressed for scope.

itself can negatively affect health (Navarro and Berman, 2019). Thus, Social Infrastructure[3] worsens both Environmental Quality and Health.

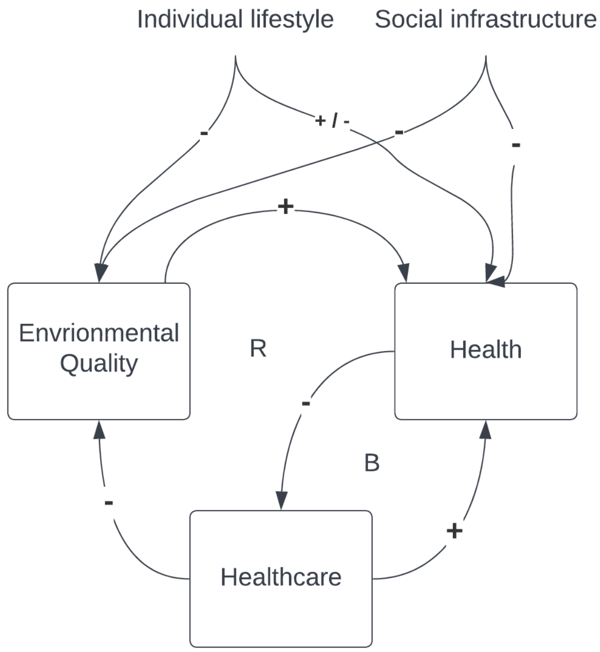

Figure 3: System model of climate change interactions with health and healthcare. R = Reinforcing feedback loop. B = Balancing feedback loop.

The second factor is Individual Lifestyle, which, though limited and influenced by the Social Infrastructure, is still a separate factor. Individual Lifestyle degrades the environment due to the Social Infrastructure but to varying degrees based on the individual choices. For example, personal choice in the foods consumed (amount of animal products, locality, and seasonality), transport options (car vs. public transport vs. active travel), energy use (housing, travel), and consumption (products bought) can increase or decrease the individual's EI compared to the societal average (Christensen, 1997). Individual Lifestyle also affects Health. Encompassed in Individual Lifestyle are diet, physical activity, and substance use such as smoking or drinking: healthier choices improve Health (Nyberg *et al.*, 2020).Though these choices are limited by the Social Infrastructure (e.g., living in a 'food desert' with limited fresh produce, working multiple jobs to survive reduces exercise time, etc.), the individual has some power to promote or worsen their Health. In conclusion, Individual Lifestyle and Social Infrastructure both affect components of the HHE system. Social Infrastructure generally degrades both Health and Environmental Quality while Individual Lifestyle can modify the degree to which the individual degrades the environment and can worsen or improve Health. The HHE system itself is a reinforcing loop that is accelerating towards worse human and environmental health.

[3] Social factors such as inequality also have a strong influence on both environmental and human health (Islam, 2015; Wilkinson and Pickett, 2009) but are excluded from this discussion for scope.

Analysis

Synergies and barriers revealed in the model

The model proposed reveals several synergies that could reverse the detrimental reinforcing feedback between poor health, healthcare, and the degradation of the environment. Tipping this vicious cycle into a virtuous one starts by improving the environment, which improves human health, decreasing the need for healthcare and further improving the environment. This could be achieved through several interactions. First, the EI of healthcare should be decreased. Second, social infrastructure that decreases EI is also usually directly beneficial for health as well, acting doubly on the feedback by further decreasing the need for care. Third, individual choices within the social infrastructure that are environmentally positive are also health positive, again acting doubly by improving the environment and health. Each of these routes helps improve the environment and human health. Only the first of the three, decreasing the EI of healthcare, is controlled directly by the healthcare system; however, decreasing EI by optimizing the current system rather than transforming is necessary but not sufficient to change the HHE cycle (de Hoop *et al.*, 2022; Pencheon, 2018). A barrier revealed by this model is that healthcare has limited influence on social infrastructure and individual lifestyles. Recommendations towards unlocking these synergies and overcoming barriers using Meadows' System Leverage Points (2008b) are discussed next.

System Leverage Points

Meadows (2008b) provides a list of the twelve most effective leverage points for changing a system, and number two on the list is shifting the system paradigm, or mindset. In the case of healthcare, the paradigm that must be shifted is the reductionist single-source view of illness and treatment that has been the basis of medicine for hundreds of years (Berg *et al.*, 2022; Marvasti and Stafford, 2012). Healthcare must embrace a more system-wide view of human health; environmental and social contexts and values must be included as they strongly impact health (Berg *et al.*, 2022). Recognizing the connections between human health and the environment requires embedding environmental purpose into healthcare (Fischer, 2014).

Shifting the healthcare paradigm to holistic health will necessitate expanding the goals of the healthcare system to include environmental health, leading to number three on the list of leverage points: changing the system goal. If the system goal includes environmental health, then healthcare must decrease its EI. For example, the NHS has already adopted this goal with its net zero pledge. This is influencing NHS operations, including procurement and finding new potential care pathways (NHS England, 2022). This goal shift has had ripple effects through the medical industry such as NHS suppliers setting their own emissions goals (Watts, 2021). Some new technology is already appearing to embrace this goal, such as anesthetic recycling technology (Hu *et al.*, 2021), reusable masks and gowns (Dawson *et al.*, 2022), and trials towards reprocessing even complex devices like pacemakers ('Project My Heart Your Heart', n.d.). Expanding healthcare's goal to include environmental health begins to reduce the vicious HHE cycle by decreasing the negative environmental effects.

To achieve the new goal of the healthcare system, another leverage point is needed: changing the rules of the system, number five on the list. In many healthcare systems, treatment is paid for rather than patient outcomes; thus, providers have less incentive to prevent illness than to treat illness (de Hoop *et al.*, 2022). For example, a provider can more easily bill for an insulin prescription than for diet and exercise change when managing diabetes (Marvasti and Stafford, 2012). As shown in the system model, increased treatment exacerbates EI. The system leverage point is to change metrics and rules to reflect the actual success of the system. Thus, healthcare needs to be measured by – and compensated for – the health of its patients. This is at the core of the value-based care (VBC) concept in which providers are paid based on outcomes rather than treatments (NEJM Catalyst, 2017). Some systems are recognizing this; US Medicare is moving towards value-based reimbursement since the passage of the Affordable Care Act (Jacobs *et al.*, n.d.), and there are some initiatives within the NHS to incorporate VBC (GIG Cymru (NHS Wales), 2019; Hurst *et al.*, 2019). By changing the rules to reward outcomes, healthcare systems can better improve health while decreasing EI, decreasing the need for healthcare treatments and utilizing the healthcare-health balancing feedback.

To realize better outcomes, healthcare must focus more on prevention and promotion of good health. Fostering prevention requires that healthcare must influence the individual lifestyles and social infrastructure that have an impact on both health and the environment. This is possible through leverage point number six, changing information flows. Information flows can close the feedback loop for decisionmakers by supplying information about the effects of their decision that were previously hidden. Healthcare providers can elucidate the health impacts of individual and societal or governmental decisions that affect the environment. Emphasizing the health impacts in the trusted voice of the physician is a highly effective tactic for shaping environmental decisions (Chivian, 2014; Pencheon, 2018). The health costs of environmental damage have produced past regulations; for example, the deadly Great Smog event in 1950s London led to the UK’s Clean Air Act (Brimblecombe, 2006), while similar public health concerns about air quality led to its American counterpart legislation (US Environmental Protection Agency, 2022b). On the individual scale, the health effects of lifestyle changes such as eating meat are a more effective reason to change than the environmental consequences (Fehér *et al.*, 2020). Working with a physician on a personal lifestyle and prevention plan that includes eating less meat, walking more, etc. has a doubly healthy effect by decreasing EI as well. Using the voice of healthcare to close the feedback loop on individual and societal choices on health (and by proxy environmental) impacts can help improve both human and environmental health, further activating the system synergies.

The four leverage points – shifting the paradigm, goals, rules, and information flows -- have been added to the system model in Figure 4 to summarize the new effects. The individual and social factors have been changed to Sustainability and Healthiness of Lifestyle or Infrastructure stocks to illustrate the effect of Healthcare.

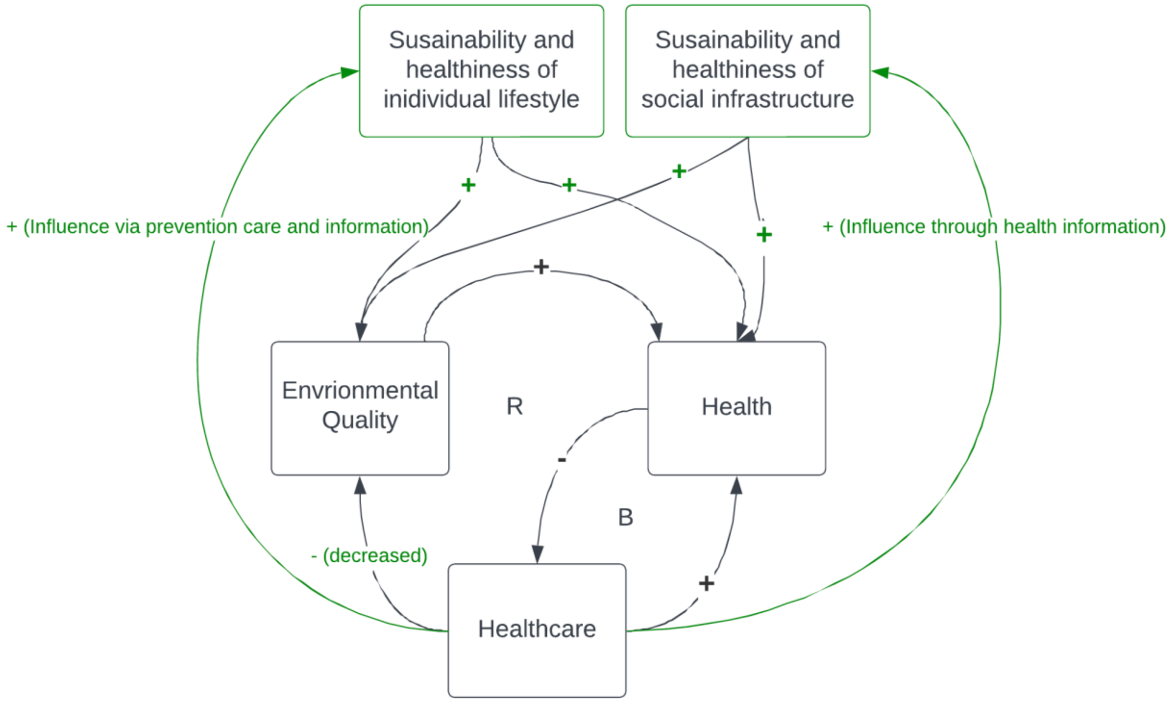

Figure 4: System model including recommendations from analysis, changes shown in green

Conclusion

Human and environmental health are interconnected, and both are influenced by social and individual lifestyles as shown by the health-healthcare-environment system model. Healthcare, especially in the developed world, has a negative environmental impact; thus the HHE system deteriorates human and environmental health. Using a system model to explore the multiple interactions revealed potential system synergies for improvement. These synergies were explored via Meadows' System Leverage Points. First, the healthcare system paradigm must convert to a holistic view of health and its many determinants. This will necessitate a change in the goal of healthcare to include environmental health. The goal change requires a rule change to promote health outcomes rather than treatments. Finally, healthcare should improve information flows to both individuals and social decisionmakers to elucidate the human health impacts of decisions which usually overlap with environmental impacts. This model is limited by the exclusion of social factors such as systemic inequality that affect both health and the environment; nevertheless, these leverage points can help move towards a beneficial cycle for better environmental quality, better human health, and less need for healthcare in its current definition.

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Appendix

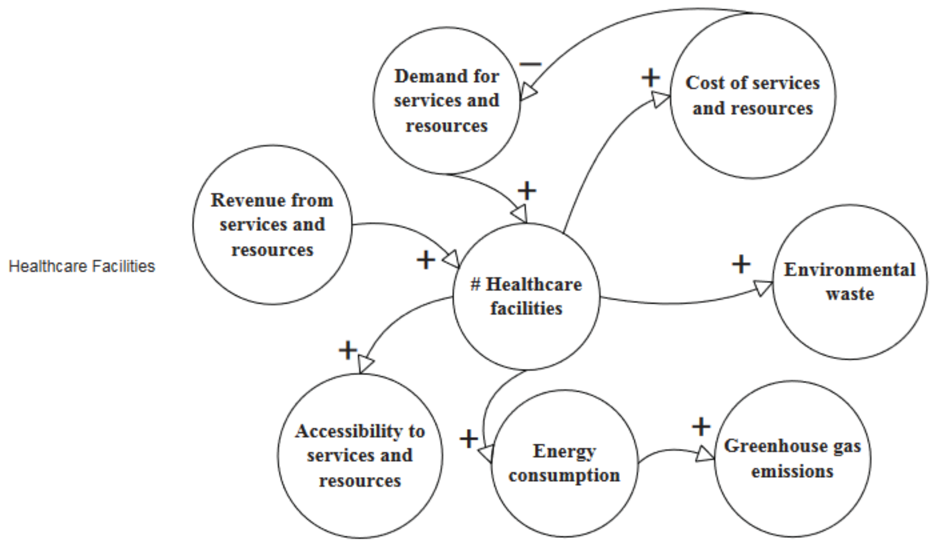

Figure 5: Example diagram from Faezipour and Ferreira (2011) showing the environmental impact of healthcare facilities.

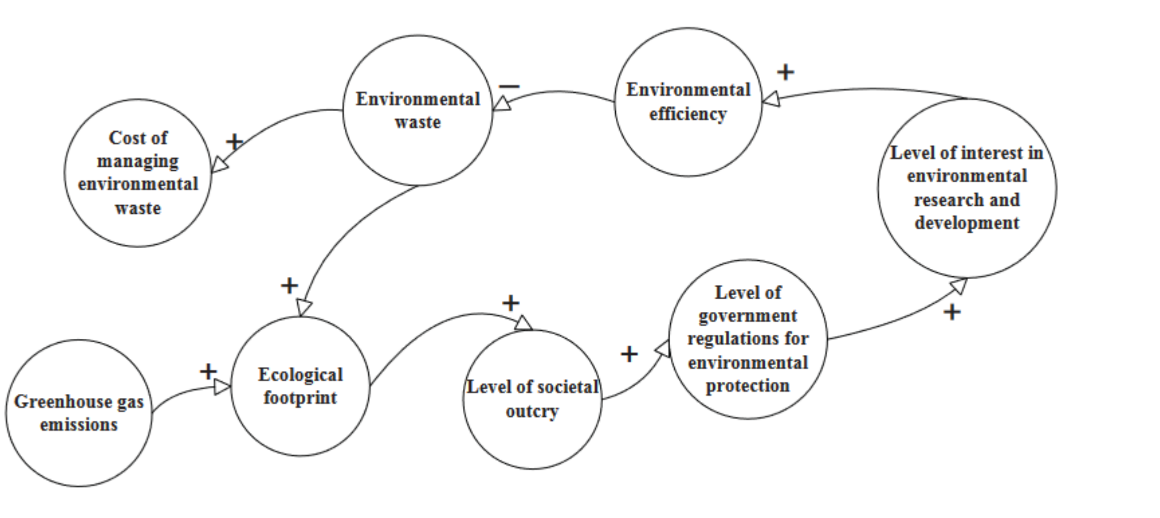

Figure 6: Model from Faezipour and Ferreira (2011) showing general environmental impact

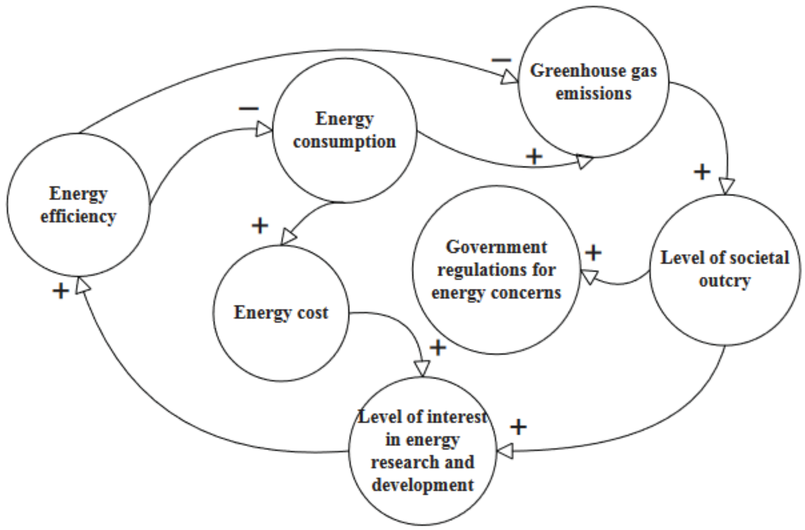

Figure 7: Model from Faezipour and Ferreira (2011) on energy use and impact

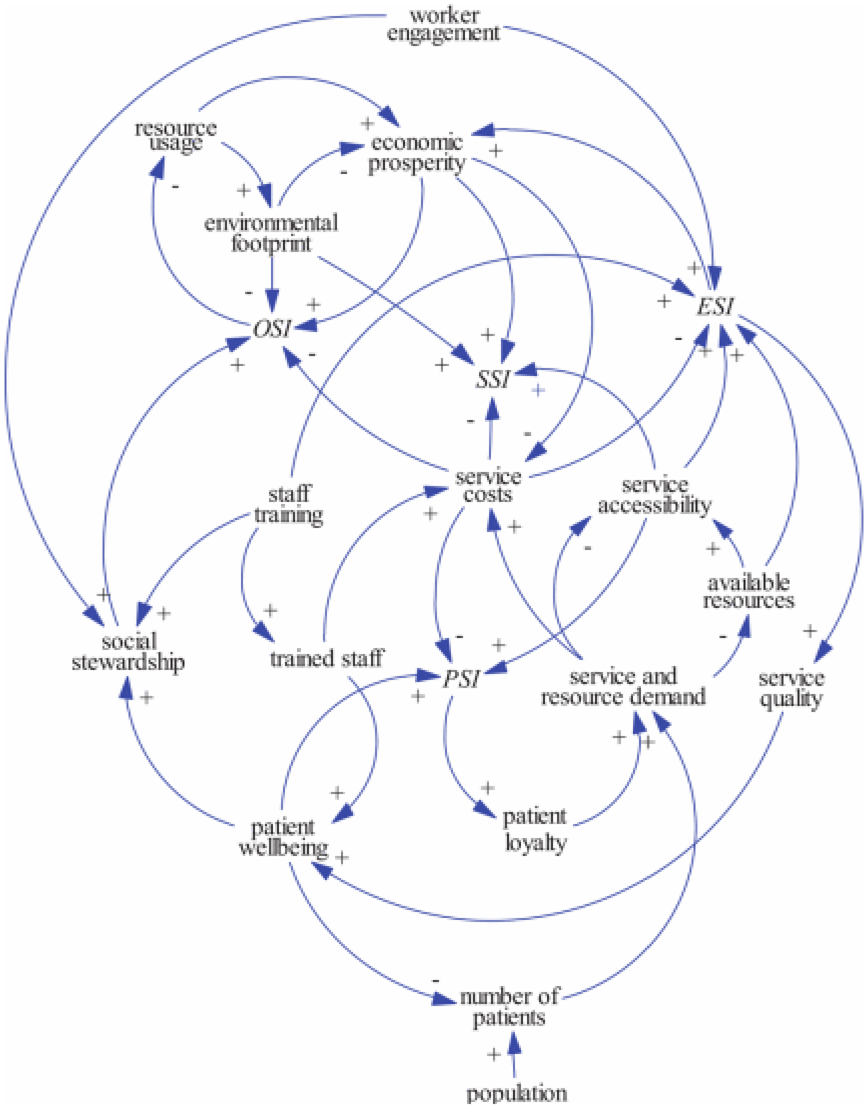

Figure 8: Model from Mutingi and Mbohwa (2014) on healthcare and its effects