Getting to zero
– Managing the impacts of waste

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Why waste is an essential element of net-zero analysis

The concept of net-zero buildings usually focuses on the energy that flows into the building in some metered form – electricity, diesel fuel, natural gas – but the reality is that the emissions footprint of a building as a locus of human activity goes much beyond. Indeed, failing to effectively recognize and manage the emissions resulting from the stream of physical objects into and out of the building leaves much opportunity for climate mitigation on the table.

For many years, climate emission calculations have included emissions from "Scope 1", "Scope 2" and "Scope 3" activities[1]. These categories extend the focus from direct on-site energy emissions (Scope 1); to generation of energy off site (Scope 2); to indirect emissions that are the consequence of the activities of the company, but occur at sources owned or controlled by another company. In the healthcare world, the UK's National Health Service first tried to catalog these broader impacts for the entire sector in that country in 2001.[2] That initial analysis showed that the building produces only about 20% of the total energy/emissions impact of a building, with by far the largest impact from products consumed and wasted (**Figure 1**).

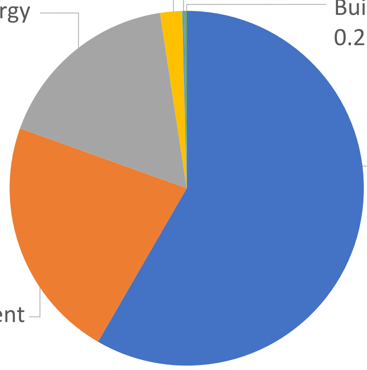

Figure 1. The ecological footprint of the National Health Service in England and Wales, by component, in 2001.

The work of the UK was extended by the International Federation of Hospital Engineers in its first ever projection of global greenhouse gas emissions for the global health sector.[3] This analysis determined that the global health sector currently accounts for approximately 2.6% of all emissions (Scope 1,2, and 3).

So, while it is clearly important for designers of the health sector to focus on the reduction of direct building energy consumption, a truer focus of net zero must also include the management of the healthcare material flow through that building. Yet, other than efforts to manage the waste stream to less costly and more compliant flows, we have historically not had much in the way of tools to help us manage these emission impacts at all. But, that is now changed.

Two new tools, one from the US EPA and one from a private consulting firm, provide the first attempts to extend the analysis of emissions footprint to the waste stream. For a serious focus on "net zero" energy buildings, these impacts must become part of the equation.

1 See, e.g. World Resources Council for Sustainable Development and World Resources Institute, The Greenhouse Gas Protocol, A Corporate Accounting and Reporting Standard, Revised, (file:///Users/waltervernon/Desktop/ghg-protocol-revised.pdf)

2 See, e.g., Best Foot Forward Ltd., Material Health, A mass balance and ecological footprint analysis of the NHS in England and Wales, April, 2004.

3 Troy Savage and Walt Vernon, "Greenhouse gas: global healthcare inventory," IFHE Digest, July 4, 2017, pp. 41. (http://ifhe.info/library/greenhouse-gas-global-healthcare-inventory)

The US EPA recently launched WARM, the Waste Reduction Model.[4] This tool has many beneficial features, including the presumption of scientific validity and impartiality. However, for the practitioner aiming at net zero for healthcare buildings, it falls short. The EPA tool, in particular, does not include certain critical categories of waste (infectious, pathological, and pharmaceutical) specific to the healthcare enterprise. Moreover, it ignores new technologies for waste conversion that are non-combustion. Finally, it focuses only on CO_2, and not the myriad of other climate-changing airborne emissions from the healthcare waste stream. Another tool has recently emerged that fills these critical gaps.

The hazards created by healthcare waste are complex, and its management much more so. It varies in type and quantity, risk profile, public perception, regulatory complexity, and available management methods. Laws and regulations across the globe require certain types of waste be treated in specific ways to render it into less-hazardous materials. These treatment options can be expensive, resource consumptive, and environmentally damaging; in fact, every method of waste management creates consequences for the natural world[5]. Most problematic is the treatment of infectious, pathological and pharmaceutical wastes. These wastes are a small portion of the total volume of waste coming out of a hospital, but they pose special complications. Pathological and infectious wastes obviously carry with them the risk of disease transmission. Health threats such as Ebola underscore the hazardous nature of these waste streams. Pharmaceutical wastes are chemicals that pose exposure risks to humans and wildlife. Many countries require these parts of the healthcare waste stream to be incinerated. With no real alternative, the WHO agrees[6] that, in the short run, incineration is a preferable strategy, though aspiring to better methods that produce no or few dioxins and furans in the future. Many parts of the world have no regulation, or at least, no effective regulation of medical waste disposal. Even where regulation exists, needed infrastructure to implement it may be seriously lacking, leaving a local facility with few options.

4 Available at https://www.epa.gov/warm.

5 See, e.g. Francesco Cherubini, Silvia Bargigli, and Sergio Ulgiati, "Life cycle Assessment (LCA) of waste management strategies: Landfilling, sorting plant and incineration," Energy 34 (2009), 2116 – 2123.

6 "Safe management of wastes from health-care activities", World Health Organization, 2nd edition, 2012.

EPA Waste Emission Reduction Techniques

Warm includes traditional waste reduction techniques, including source reduction, recycling, anaerobic digestion, composting, combustion, and landfilling, with a high degree of granularity. Indeed, this very granularity, while apparently improving the accuracy of its results, also makes data gathering and input daunting.

Waste to Energy Emission Reduction Techniques

The Healthcare Waste Calculator of IFHE introduces healthcare specific waste streams, simplifies to a degree the data gathering required, and introduces new waste management techniques specifically applicable to healthcare needs.[7]

Autoclaving, the most widely used non-incineration form of treatment system, sterilizes medical waste using steam and high pressure. These systems are limited to the treatment of pathogens (live infectious agents) and do little to render chemicals non-hazardous. Further, autoclaving does not render waste unrecognizable and in the U.S., many states required that before waste is landfilled, it must be unrecognizable, adding the need to shred treated waste. Autoclaving was used in many base scenario-planning cases.

Pyrolysis is an oxygen-free thermal treatment process that processes waste at temperatures between 750°F and 1500°F in the absence of air.[8] The lack of oxygenation is a critical difference between pyrolysis and combustion. The fuel used to initiate the "baking" of the waste can be natural gas, propane, or the gas generated by the pyrolysis process itself. This process first uses a pyrolytic chamber that reduces the waste to ashes and gases, and uses a "post-combustion" chamber to burn the produced gases at very high temperatures. This resulting synthetic gaseous (syngas) product of this and other conversion technologies is often referred to as syngas, and consists of hydrogen, carbon monoxide, and methane. Both off- and on-site facilities, as well as small- and large-scale pyrolytic systems are available. Today, pyrolysis is the most likely technology to be used for healthcare applications because of unit sizing more appropriate to in-house or smaller uses, and because, while still costly, it is relatively less than other CTs like gasification or plasma arc, briefly included below for edification.

7 See Walt Vernon, "The Complexities of waste management," IFHE Journal, January 1, 2016, p.53, (http://ifhe.info/library/the-complexities-of-waste-management).

8 California Integrated Waste Management Board. 2007. New and Emerging Conversion Technologies: Repot to the Legislature.

Gasification is a process in which organic waste is partially oxidized to form chemical reactions to produce carbon dioxide, carbon monoxide, and methane gases that create extreme high temperatures in the gasifier. The syngas that is generated from the three primary gases can be utilized for industrial and commercial process and products, including photographic film, coal, and petroleum, while the solid residue (slag), made non-hazardous by cooling, can be used for a variety of manufacturing products. Some versions of this technology use the gas to fuel the process, and extract heat energy from the system for use as an energy source.

Plasma Arc is another form of CT that uses extremely high temperatures, and is also very expensive. It may be a good solution for the chemical or ammunitions industry, is it probably overkill for on-site healthcare solutions.

Waste-to-energy (WTE) systems can be integrated into these CT systems rather easily, and because these systems can generate a large amount of syngas, the opportunity to generate energy is used in both the economic and environmental countermeasures. CT systems are applicable for waste treatment for infectious, pathological, sharps, and (if applicable) MSW.[9] However, RMW must be pre-treated and MSW must be shredded prior to the CT process, which is yet another complicating factor.

So where do we go from here? The volume and toxicity of waste is not getting any smaller. Existing systems are aging. New technologies are available. Health facilities need a plan. But in order to develop a plan, they need data on the health impacts of transporting waste long distances, on the real emissions of one technology over another, on the benefits, and impacts, of waste-to-energy compared to the impacts of energy from other sources. Is it more environmentally and health friendly to recycle waste that is transported hundreds of miles, and perhaps shipped overseas, or used in a local WTE/CT unit? The healthcare sector could greatly benefit from asking these tough questions so that, together, we might be able to make evidenced-based informed on the benefits and impacts of one technology over the other.

WasteCare Calculator [10]

The International Federation of Hospital Engineering recently published an article on a new Waste Treatment Calculator as a means for comparison and assessment of the different treatment scenarios specific to healthcare organizations. Not only is the tool specific to healthcare, but also it expands the consideration to all gaseous emissions, as well as including various waste to energy waste management processes. The Calculator compiles performance data, transportation considerations, and environmental emission factors from different types of waste treatment options presented in **Table 1**. The calculator references various emissions factors from landfilling, transportation (e.g., distance, fuels consumed, truck type), mass and energy balances, etc. wherever they are used so that can be changed when new data is available, or if there is simply a disagreement factor used.

Table 1. Waste treatment options.

Waste Management Technique	Considered by EPA Tool?	Considered by IFHE Tool?
Source Reduction	Yes	Yes
Recycling	Yes	Yes
Anaerobic digesting	Yes	
Composting	Yes	
Combustiont	Yes	Yes
Landfilling	Yes	Yes
Autoclave		Yes

The intent of the calculator is to be a free, globally-relevant, transparent, highly scientifically rigorous, and open-source tool for the measurement of waste management scenarios. The website clearly describes data sources and invites public input to improve the tool's accuracy.

The calculator user needs to understand and compile all of the information on what is happening today to create the Base scenario. This includes information relating to waste generation types and weights, where and how the waste if being managed. Then to further understand the assumptions of the scenarios to be analyzed, like the on-site and off-site, CT treatment systems need to be compared via CT systems and information and assumptions, summarized in **Figure 2**.

Analyzing WTE systems adds a certain complexity, but a necessary one that addresses the impacts of energy produced, and displaced. Material input specifications included waste, water, and oxygen consumption. Material

9 Los Angeles County Department of Public Works. 2007. Los Angeles County Conversion Technology Evaluation Report, Phase II report.

10 http://www.mazzetti.com/wastecare-calculator-help-revolutionize-medical-waste-management/

output specifications included syngas, water, and solid residue generation; recoverable residue generation (if applicable). Energy input specifications include energy from internal waste processing; natural gas and electricity consumption, and output includes net electricity export; internal plant "parasitic" consumption; energy losses from system. And of course, emissions from all sources, and of all types (including mercury, dioxins, and furans).

Calculator assessment example

To determine the validity of the Calculator, treatment scenarios were formulated that reflected real-world scenarios. The Base Model assumed that waste is treated using typically available treatment methods and actual distances for a 100-bed hospital in Southern California. **Table 2** summarizes the general assumptions for the scenarios. A critical assumption was that the total waste management operation included a progressive waste minimization and recycling program to minimize the total amount of waste of any kind that requires treatment, creating a recycling rate of 40%, while the other 60% of the waste requires treatment.

Per the Calculator requirements and assumptions, the total amount of waste in each scenario remains constant. It was assumed that 60% of the total waste quantity would require treatment and include 1) Dangerous Waste (DW: pathological and pharmaceutical waste that is required to be incinerated by regulations), 2) Regulated Medical Waste (RMW), and 3) MSW. All the analyzed scenarios are shown in **Table 3** with their specified assumptions that were included when analyzed within the Calculator. In the Base Model, the three waste streams are treated in different locations using different technologies. In the scenarios using CT's, the

Table 2. Assessment scenarios.

Item	Assumptions
Waste Generation	Total Generation Rate: 1.15 Tons/Day DW (5% of Total) RMW (10% of Total) MSW (45% of Total)
Hospital Size and Location	100 beds in Southern California
Treatment Facility Locations	Incineration: Chambers, TX Off-Site Treatment (CT & Autoclave): Vernon, CA Landfill: Lancaster, CA
Cost Considerations	Electricity, Water, Wastewater, Diesel Fuel, Labor, Landfill Disposal, Hauling, Off-Site Treatment
Hauling Schedule	Based on EPA Requirements 3 days for all types of untreated waste 90 days for residuals from on-site CT treatment

Table 3. Assessment scenarios.

Scenario Name	Waste Commingled?	Treatment System	System Location	Waste Disposed in Landfill
Base Model	NO	Incineration for DW Autoclave for RMW Landfill for MSW	All Off-Site	MSW Residuals from Treatment
Pyrolysis	YES	Pyrolysis – Small	On-Site	Residuals from Treatment

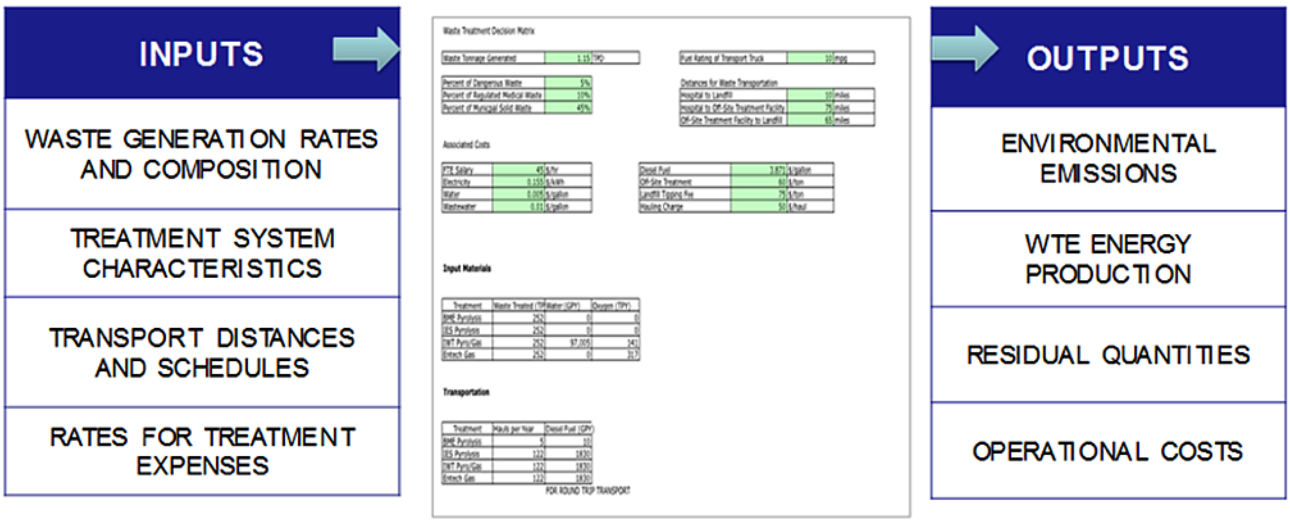

Figure 2. Inputs and Outputs of the Waste Treatment Calculator.

waste is "commingled" (only in the sense that they are going to the same location, but stored and managed according to regulations).

One important waste management question that was considered is if it is better to landfill MSW or include it in the total waste sent to the CT system, even though it is not required to be treated. For the specified scenarios, emissions were found to be greater for landfilling MSW than through a treatment system; a factor of four was reported for carbon dioxide emissions and a factor of two was reported for dioxin emissions for landfilling versus treatment. It was also beneficial to include MSW for adequate moisture content preservation during treatment and to reduce expenses.

Conclusion

This article probably raises more questions than it answers. But the healthcare sector needs solutions to address a waste dilemma that is not going away. Are conversion technologies really just incinerators in disguise? What are the emissions from a life-cycle analysis? For a hospital that is committed to human health and environmental protection (aren't we all?) and thinks they are making the right decision to ship waste to faraway places instead of treating waste closer to home, is that really the "right" decision? The IFHE invites the global community to review the WasteCare Calculator so we can all benefit from a viable, reliable decision making open-source tool. ■