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ACHIEVING ENERGY INDEPENDENCE: *Methods and Case Studies in Healthcare for Use of Waste to Energy Technologies*

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ABSTRACT
This article reviews Waste to Energy (WTE) technologies that are currently available and how the healthcare sector can employ these for waste management and revenue generation. The available literature is reviewed to discuss specific case studies. The case studies also explore the role of local communities in these ventures. The financing, operations and maintenance of WTE projects is the key to their feasibility. Understandably it lies outside the core business of healthcare. The article reviews concepts such as Power Purchase Agreement (PPA) and Energy Performance Services Contract (EPSC), which are third-party investments and are used for similar energy projects. The article concludes with remarks; why these projects make business and environmental sense and how symbiosis between the communities and their large consumers, such as healthcare, is the key to sustainable development.

KEYWORDS: Waste to Energy (WTE), Healthcare Buildings, Power Purchase Agreement (PPA), Energy Performance Services Contract (EPSC), communities, symbiosis

1.0 INTRODUCTION
The healthcare industry is the biggest generator of waste in the United States, the second largest consumer of energy and consistently among the top ten users of water in any community[1]. The stated purpose of Energy Independence and Security Act (EIA) of 2007 is "to move the United States towards greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products, buildings and vehicles, to promote research on and deploy greenhouse gas capture and storage options and to improve the energy performance of the Federal Government, and for other purposes[2]."

The impact of EIA elsewhere is likely to be limited without healthcare's participation. According to a 2009 report, an average hospital spends about $72 million annually on the procurement of materials for its operations[3]. This is the second major cost of healthcare operations after labor[4]. A vast majority of those materials turn into waste. Hospitals are responsible for approximately 5.9 million tons of waste annually[5].

Symbiosis is close and often long-term interaction between two or more different biological species. All natural ecosystems are filled with examples of the inter-dependence for their own survival where biotic and abiotic components are linked together through nutrient cycles and energy flows. Figure 1 shows the seamless cycle between the waste and creation in nature. The "producers" employ photosynthesis to fuel nearly all other organisms by using "waste" as the nutrient.

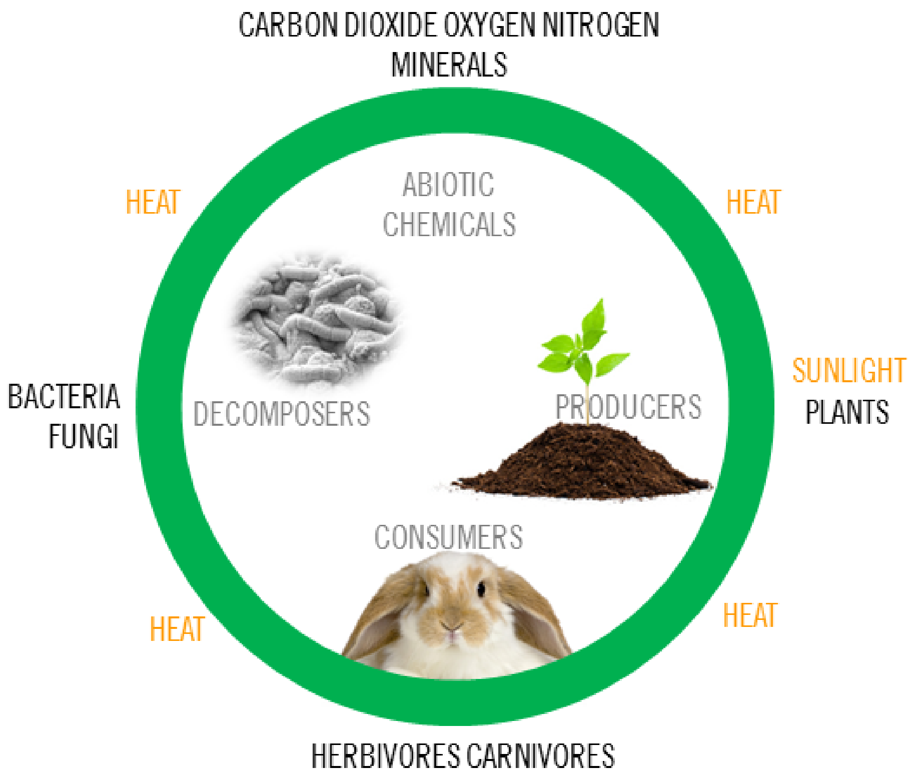

Figure 1: Waste absorption cycle in nature.

The interaction between the living and non-living organisms creates a man-made ecosystem which is comparatively less complex than a natural ecosystem. It is also at risk of disintegration since many of the key ingredients of naturally sustainable ecosystems are missing.

In order for the man-made physical environment to be sustainable, the cycles of creation and waste need better understanding. Tipping the balance to one side has repercussions for the environment and economics.

The United States produces largest per capita waste in the world at 4.5 lb per person per day[6]. In recent years there have been some efforts for reducing waste at multiple levels. According to the Environmental Protection Agency (EPA), we recycle about 34 percent of municipal solid waste (MSW) in the United States. There are about 87 operational MSW-fired power generation plants that are responsible for about 0.3 percent of total power generation. The rest of the solid waste ends up in landfill. Similarly there are about 400 plants that generate electricity from landfill gases. But the majority of them fail to capture the heat that is a by-product of power generation. Figure 2 shows the total energy consumption against the tiny fraction of waste being absorbed back by the US population as energy and recycled goods[7].

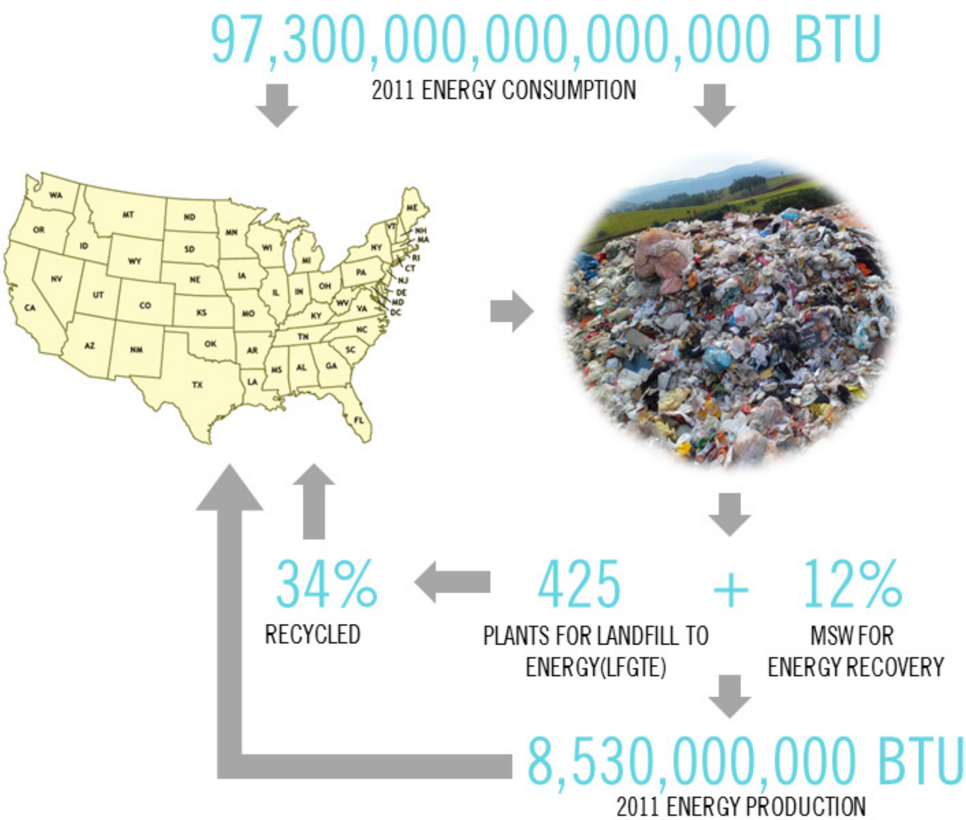

Figure 2: Energy consumption and waste cycle in United States.

Our planet has never seen this much human population in its existence. It required only 40 years for the population to double from 2.5 billion to 5 billion after 1950[8]. We are also consuming resources and producing waste at a much faster rate compared to our ancestors. Figure 3 shows a steep rise in per capita use of energy in the last 200 years.

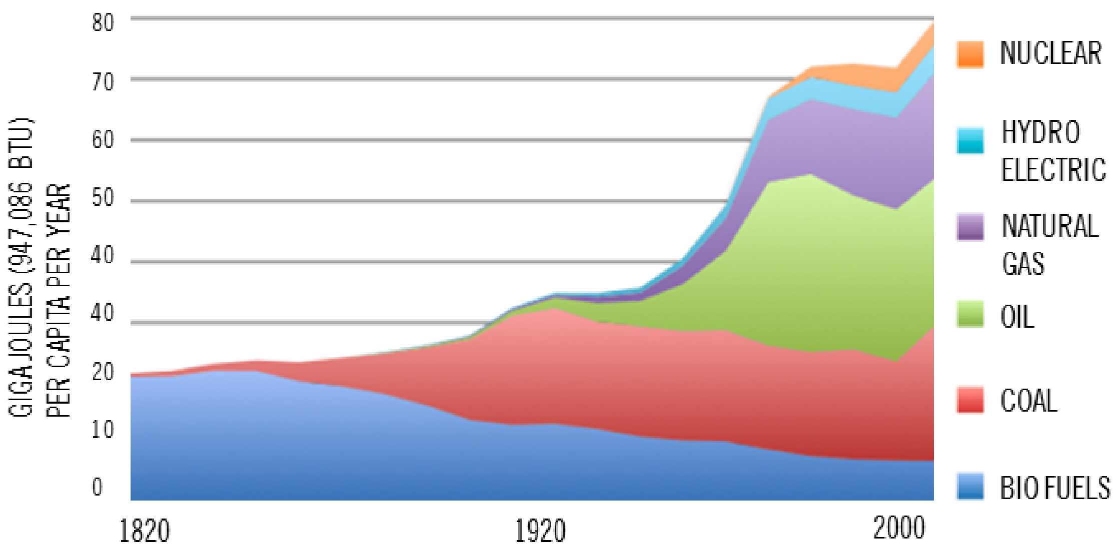

Figure 3: Energy consumption in the world (per capita) in last 200 years.

With population and energy consumption increasing at these rates, we are likely to generate waste proportionately.

With these statistics, the question is can the man-made ecosystems achieve the carbon and energy economy of natural systems?

WTE projects are a potential solution, since they provide a crucial link to that quest.

1.1 Healthcare and Waste

Healthcare operations are an integral part of developed communities. They are also one of the largest consumers of the resources. Hospitals produce 25 pounds of waste per day per staffed bed[9]. The environmental footprint of that waste is even larger, since the manufacturing process creates about 32 pounds of waste to make one pound of product in the United States[9].

Healthcare waste is complex because of its sheer volume and also because a small but significant amount of that waste, about 15–20 percent, is regulated by multiple agencies including EPA, OSHA, DOT, the Joint Commission, DEA, and others. Items such as regulated medical waste (RMW), pharmaceutical and hazardous chemical waste and radiological waste are 10 to 100 times more costly to manage than solid waste or recyclables[9].

Non-regulated waste, which makes up around 85 percent of majority of the hospitals' total waste stream, is not different from the waste generated by a hotel, where up to 60 percent is either recyclable or compostable[9].

Managing this waste is an economic and environmental challenge for the healthcare industry. The WTE projects can pool similar resources from the adjoining communities to create a local source of energy. Figure 4 shows the options that healthcare industry has.

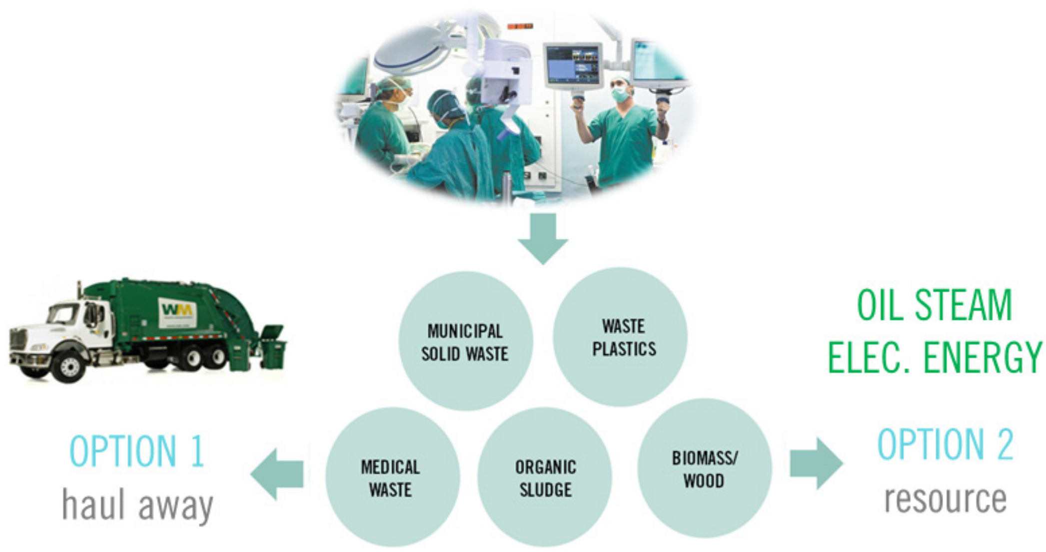

Figure 4: Healthcare waste management options.

The article reviews established and conceptual case studies in healthcare to demonstrate how waste management techniques can be used to improve energy and environmental impacts. It also addresses the economic aspect.

1.2 The Healthcare Energy Independence Challenge

Energy consumption in the healthcare sector in the United States is estimated to be 60 percent more than for similar size of facilities in Scandinavian countries[10]. The lower cost of utilities in the United States has allowed the industry to stay operational with these statistics. It can also be attributed to the lack of environmental regulations for buildings.

A recent study conducted by University of Washington in collaboration with the leading design/construction professionals of healthcare industry, established that a baseline Energy Use Intensity (EUI) of 250 kBtu/sf/year can be reduced to 100 kBtu/sf/year with efficient design of the systems for the new acute care facilities[10]. EUI for buildings is equivalent to miles per gallon (MPG) for auto industry. It measures the building's energy usage per year, based on the building's area. Figure 5 shows the baseline and target energy usages for healthcare to achieve this goal in different areas of energy utilization.

From the utility cost standpoint, it makes a strong business case for the energy efficient strategies since such efficiency would result in significant savings on a yearly basis.

The goal of energy independence can be realized by first optimizing the energy usage in healthcare buildings, which are typically the largest consumers of any local community. EUI reduction for healthcare would also help addressing the resilience of these systems in emergency situations. A building that consumes less energy would last longer with the limited resources.

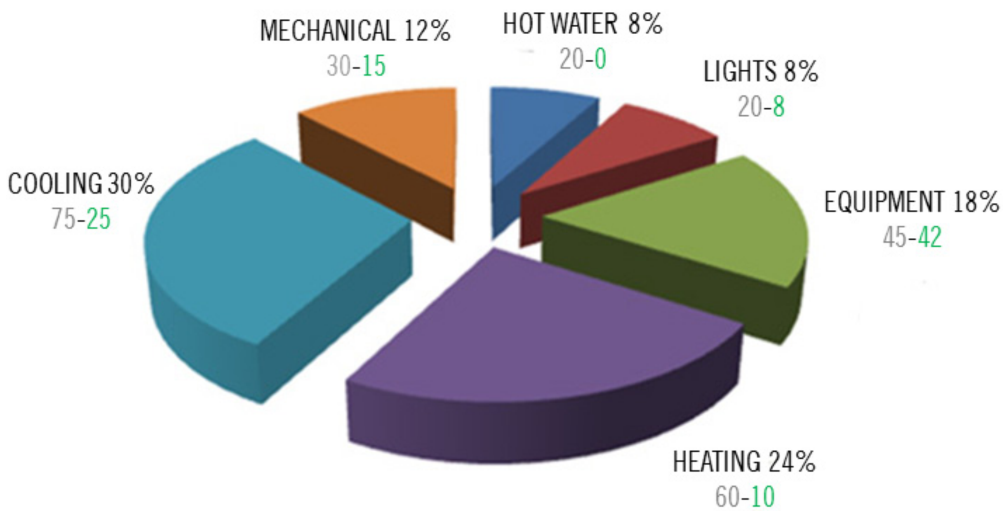

Figure 5: Energy usage split in healthcare buildings. The grey number represents baseline EUI, green number is the target EUI for reducing overall energy consumption. Together it will reduce the EUI from 250 to 100 kBtu/sf/year for acute healthcare facilities.

In reality this is the step one prior to the design for energy independence or resilience or both.

1.3 Project Delivery Systems

Healthcare facilities are starting to have a proactive approach in energy management according to the current surveys[11]. Newer and more improved technologies are being reviewed to upgrade the existing systems.

Most acute care facilities are sound businesses of larger scale that are well established in the communities. The operational cost reduction by employing energy efficiency methods is significant. The return on this investment for the energy upgrades in hospitals is so strong that there is potential for outside investment; if the capital is not available in the operational budget.

Energy Performance Services Contract (EPSC) and Power Purchase Agreement (PPA) are some of the prevalent project delivery systems that allow an outside entity to make an investment in an existing hospital for energy savings.

As these become more common, the energy efficiency goals will become more achievable. These contracts are also being employed for the on-site generation of electricity, steam, heat and chilled water. Utility companies are potential partners in these ventures since they can create an efficient local system by avoiding transmission losses and capturing heat that can be sold to the buildings.

2.0 OPPORTUNITIES FOR WASTE TO ENERGY (WTE)

In all nature-based ecosystems the process of waste absorption is treated as a stepping stone towards the production cycle. Various elements of nature help in the decaying process, while generating the nutrients that help rejuvenate the production process. In an ideal man-made sustainable system, these processes should be emulated to create maximum efficiency. The following section reviews the prevalent technologies for WTE.

2.1 Waste Management by Incinerators

The EPA regulations heavily control this age-old method of reducing the volume of waste. Incinerators have been commonly employed by hospitals to burn medical waste. These systems also earned bad reputation for failing to address the pollutants.

However, the fact remains that some of the waste generated in hospitals has high heating values. Additionally, heat is the most effective way of destroying the hazardous waste.

Current advances in this technology have made tremendous progress in reducing the pollutants from the process that uses the waste as fuel input and produces heat and electricity. Figure 6 shows how the pollutants are controlled at five steps in a plant operated by Eco-maine[12]. The heat generated by incinerators can be captured for heating water and running turbines in the simplest systems

2.2 WTE Beyond Incinerator

There are a number of technologies that are able to produce energy from waste and other fuels without direct combustion. Many of these have the potential to produce more electric power from the same amount of fuel than would be possible by direct combustion. This is due to the separation of corrosive components from the converted fuel. This allows higher combustion temperatures in boilers, gas turbines, internal combustion engines and fuel cells.

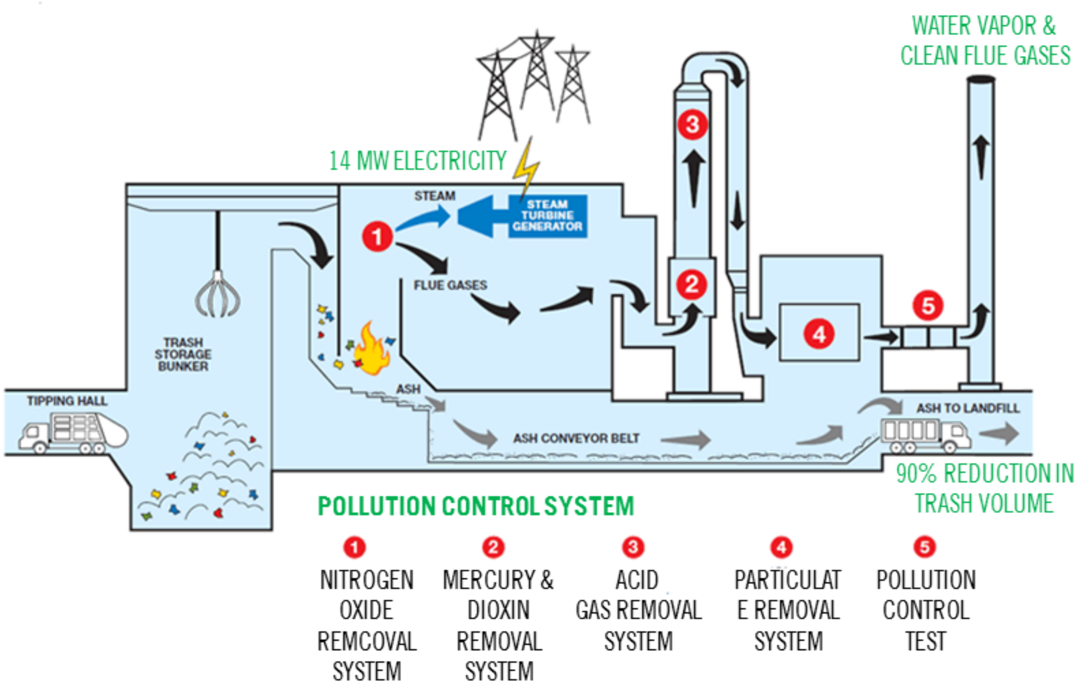

Figure 6: Pollution control for incinerator system.

A comparison of these technologies is shown in Tables 1 and 2. A Waste to Energy plant can have a combination of these technologies.

3.0 STRATEGIES FOR ENERGY INDEPENDENCE

The fossil fuel market is well established and commercially developed even though it is considered to have significant environmental, economic and political impact. It is also subject to the cyclical rise and fall of prices based on a variety of factors.

Lately the consolidated large consumers like hospitals are realizing that the unpredictable nature of energy prices is hurting their businesses.

Table 1: Brief overview of thermal WTE technologies.

	THERMAL TECHNOLOGIES			
	GASIFICATION	**THERMAL DEPOLYMERIZATION**	**PYROLYSIS**	**PLASMA ARC GASIFICATION**
HISTORY	Various patents from 1976	1980 patent for break even technology	1988 patent to meet air quality	2009 patent for WTE
PROCESS	Conversion of organic material into carbonaceous materials	Conversion of polymer into monomer or monomers	Thermochemical decomposition	Plasma torch powered by electric arc ionizes gas and catalyzes organic matter
FEEDSTOCK	Biomass	Biomass and plastic	Biomass, waste plastic and tires	Biomass, coal, oil sands, oil shale, MSW, hazmat, medical waste
REACTOR	>1300 F, Controlled steam and oxygen	600 PSI pressure, 480 F water	>800 F temperature, no oxygen, high pressure, endothermic, can be done in vacuum	Steam, electrodes, high voltage current, temperature of arc is 4000 to 25,000 F
OUTPUT	Synthetic gas	Light crude oil, carbon solids for fuel, fertilizers and filters	Char, biochar for soil enriching, bio oil, diesel oil, syngas, steel wire	Syngas, electricity and slag
USAGE	Fuel for gas engines and CHP plants	Sold as crude oil	Fuel for transportation and energy generation, steam	Slag grain is used in construction, metal is recovered and sold, syngas for electric and thermal energy
ADVANTAGES	Clean gas	85% yield efficiency process breaks down hazardous materials	Clean fuel, easier to meet air quality regulations than incinerators	Ecologically clean process, self-sustaining electric power
CHALLENGES	Efficiency is hard to achieve with MSW	Profitability is dependent on the cost of feedstock	Reducing the distance between biomass and pyrolysis facility	Investment cost, high energy required to run the plant
DEMOSTRATED PROJECT	Gussing, Austria and Pitea, Sweden	Carthage, Missouri, USA	Moscow, Russia	9 locations with 5 more projects in development

Table 2: Brief overview of non thermal WTE technologies.

	NON THERMAL TECHNOLGIES		
	ANAEROBIC DIGESTER	**ETHANOL FERMENTATION**	**MECHANICAL BIOLOGICAL TREATMENT**
HISTORY	First digester was built in 1859	Growth for etahnol industry began in late 1970's	First pilot projects were approved by Germany's federal governement
PROCESS	Microorganisms break down bio degradable material in the absence of oxygen	Metabolic process converts sugar to acids, gases and/or alcohol type of anaerobic digestiion	Combines refuse sorting facility with a form of biological treatment such as composting and industrial waste
FEEDSTOCK	Biomass	Sugarcane, corn, sugar beets, cassova	Curbside refuse
REACTOR	Acetogens and methanogens are introduced in digestor by seeding process	Sugars, endogenous organic electron acceptor, microbes	Mechanical sorting of waste and the biological treatment
OUTPUT	Methane, carbon dioxide, traces of contaminant gases, fertilizers, soil conditioners	Ethanol, lactic acid, hydrogen, heat, carbon dioxide, food for livestock, water	Ferrous/non ferrous metals, plastic, glass. Alternately produce refuse derived fuel (RDF) by using gasifier or incinerator
USAGE	Fuel for CHP units to generate heat and electricity, digestate as feedstock for ethanol production or for making fiberboard	Ethanol is fuel for automobiles and used as an antiseptic, byproducts are used as feedstock for chemical industry	RDF is used in cement kilns
ADVANTAGES	Reduces carbon emissions from landfills	Alternative low emission fuel for automobiles	Waste does not need to be separated, it reduces the use of waste vehicles and keeps the recycling rate high
CHALLENGES	Wastewater from the process needs treatment, contaminant gases need monitoring	Some consider it responsible for rising food costs	RDF is not considered a preferred option by environmentalists
DEMOSTRATED PROJECT	Oakland, California at EBMUD, USA	116 ethanol bio refineries in USA	Sao Sebastio, Brazil

Some healthcare facilities are looking at the alternative resources. The energy projects of Gundersen Lutheren Health Systems discussed in later sections were conceived as a result of that approach.

Interestingly, they are finding out that by investing in energy management projects they are contributing to the health of the patients and the environment while saving money. The indirect advantages include positive public relations, as well as differentiation from competitive healthcare systems.

Resourcing from Communities

An acute care hospital is a community by itself due to its scale and complexity of operations. Most WTE technologies besides incineration need large amount of waste to be cost effective. That is why these operations can benefit from the adjacent residential areas and businesses. A careful review is required for the anticipated amount of waste the entire community would generate. The business model for WTE plant should be such that it does not incentivize the production of waste.

Case study 1

Perkins+Will's concept design for Embassy Medical Systems in Sri Lanka turned to the adjacent community for its energy needs. An anaerobic digester was proposed as a source of renewable energy for the hospital needs. The digester for the project in Sri Lanka was designed to be fed by 50-75 percent sewage and 25-50 percent agricultural residue and organic garbage[13]. The feedstock was proposed to come from the surrounding rural areas on the inland.

The process produces a biogas, consisting of methane, carbon dioxide and traces of other 'contaminant' gases. This would be converted into natural gas that will power the cogeneration plant to generate steam. Steam would produce electricity by turning the turbine. It would then be sent to the absorption chiller to create chilled water. Figure 7 shows the associated logistics of this project.

The project has been presented to the local government and is yet to be built.

It made a powerful statement about the symbiotic relationship between waste and energy for a community meeting its needs by pooling resources.

One of the important lessons learnt from this case study was to understand the dynamics of the community. These projects should have the necessary support from the local leaders and the government.

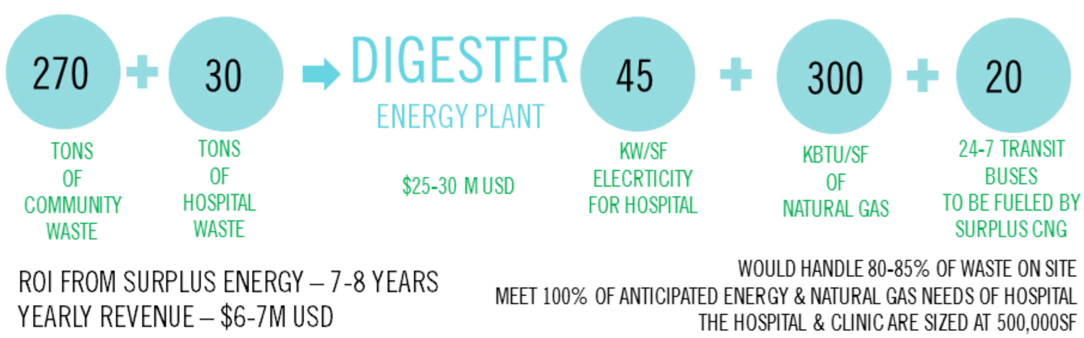

Figure 7: Conceptual diagram showing the operation of energy plant for Embassy Medical Center, Sri Lanka.

Case study 2
A Pyrolysis facility with medical waste and municipal solid waste (MSW) was studied by Phoenix Machinery, Safra for St George Hospital, University Medical Center in Beirut, Lebanon[14].

Lebanon generates about 11 tons of medical waste per day nationally, where 50 percent of it comes from Beirut the and surrounding areas. Most of it is dumped in the landfills without being treated. This has enormous long-term implications on landfill emissions and the health of scavenger population.
After considering various options for medical waste treatment, Pyrolysis was considered the most suitable option for the hospital. It is a controlled process of incineration of waste without the presence of oxygen. This process mainly produces three products:

- Syngas, used for producing steam
- Oil recovered from PVC, used for the generator
- Bio char, used in fertilizers or filters.

Since most of the feedstock is recovered in one of the three forms, emissions from the pyrolysis process are lower than the simple incineration. Additionally the process can be developed to handle a variety of wastes.

The system was designed to treat different wastes such as municipal solid waste (MSW), sewage and oil sludge, automotive shredder residuals, e-waste, rubber and tires, medical waste, plastics, agricultural waste as well as cleaning of the contaminated soil.

Figure 8 illustrates the associated business plan for the facility. For that country the return of investment was only 3.2 years.

3.1 Energy Management Projects of Gundersen Lutheran Health Systems (GLHS)

In 2007 the energy costs were increasing at a rate of $350,000 per year for GLHS. In February 2008, a program called "envision" was developed to achieve 100 percent energy independence by 2014 by its leadership[15]. Most projects that are coming out of this plan currently have multiple levels of engagement with the surrounding communities and local governments.

Case study 3
This was the collaboration between GLHS and a local brewery. The waste water in the brewery was being treated by employing Upflow Anaerobic Sludge Blanket (USAB) digester system which also generated bio gas.

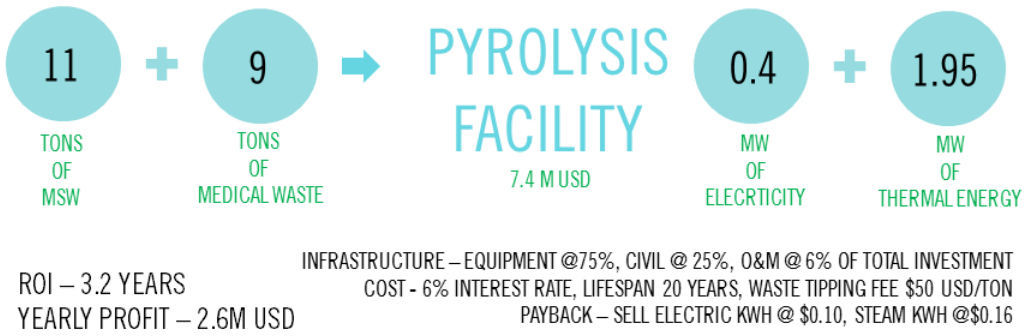

Figure 8: Conceptual diagram showing the operations of energy plant for St. George Hospital University Medical Center, Lebanon.

This was being exhausted to the atmosphere through a flue. GLHS decided to capture it to fuel a Combined Heat and Power (CHP) plant.

There were challenges in terms of controlling the hydrogen sulphide which could corrode the system. A good system of communication amongst various parties kept the project on track. Currently, the electricity is sold to the local utility company by GLHS. The recovered heat from the engine generator and exhaust system heats the digesters, boosting the biogas production levels in the winter months. The treated waste water is sent to the city waste water treatment facility and removed solids are used as soil amendments and/or sent to a landfill.

This is an example of a healthcare entity making an investment in the local community with benefits at multiple levels.

Case study 4
GLHS understood the value of teaming and partnering with other organizations to achieve its energy goals as it started a renewable landfill gas–fired energy project. The early analysis showed that a generator at the landfill site would be the cheapest option to generate electricity. But it would not capture any heat. This heat would be able to offset the thermal loads in the long run for the hospital. There was an opportunity to run a pipe from the landfill site to the hospital campus to transport landfill gases. GLHS reached out to USDOE Midwest Clean Energy Application Center for Research. Their analysis showed that engine generator's exhaust and jacket water system would supply significant portions of space heating and domestic hot water for two of the hospital campus buildings.

In September 2010, GLHS selected a turnkey engineering firm to design and build the landfill gas renewable energy project at their Onalaska campus. It is estimated that the county will collect approximately $300,000 a year from selling of the landfill gas to the hospital, while Gundersen Lutheran anticipated generating $800,000 a year in revenue from selling the electricity to the utility company and in addition realizing thermal energy savings from the recovered heat and avoided boiler fuel consumption.

This is an example of what a public-private partnership can achieve in a community for both its economy and the environment.

3.2 On-site Generation

According to the estimates, it takes 3 kWh of energy to deliver 1 kWh to the consumers. The rest is lost in transmission losses[16]. Current codes require a mandatory resilience for healthcare operations to continue in emergency situations. Hospitals need to have standby power via generators. Some hospitals are investing in CHP plants to have on site source of energy for additional redundancy. This is more efficient since fuel is used to generate both heat and electricity, while eliminating transmission losses. It also allows for better peak load management for utility companies.

The surplus heat and electricity can be sold to the other components of surrounding communities.

With contracts like PPA and EPSC the hospitals just have to provide the space for on-site energy generations systems. The utility company finances, manages and maintains the plant.

A similar contract between Hartford Steam Company, NJ and Hartford Hospital has the following features[17]:

- Provide 1.4 MW Fuel Cell CHP Plant by the year 2013
- Sell excess heat to the local magnet school.
- Low emission and quiet operation.
- Reduction of 6700 tons of CO_2 annually
- Plant will occupy only 2,250 SF of space
- Plant will operate on natural gas at 90 percent efficiency.

With this arrangement the hospital is meeting its own energy needs and also supporting the local school.

Conceptually a project like this could be fueled by waste instead of the natural gas, similar to the GLHS example. The logistics would need to be evaluated for the size of the hospital and the community that it serves.

4.0 CONCLUSION

There is a need to conceive the WTE projects as integral to the development of communities. This would help create local sources of energy, reduce the waste that goes into the landfill and generate local jobs.

The process of waste management is a stepping stone towards production process in nature. By exploring the symbiotic relationships between the waste and creation in various components of the community, we can create developments which may sustain themselves both economically and environmentally.

Healthcare delivery systems benefit from a reliable stand-alone energy delivery system in emergency situations. Recently many of the hospitals are improving their infrastructure in disaster-prone areas. On-site power generation plants are being considered an integral part of this strategy.

The WTE projects take that concept one step further by addressing the problem of waste that the healthcare industry has to deal with on daily basis.

The production of waste is continued even in an emergency scenario. In fact, one of the main issues in disaster situations is the waste management.

This waste can be channeled towards the production of energy as one of the first few things that could be done in these areas. It would be beneficial to a lot of functions that save life or normalize it after the disaster.
The ownership of such WTE system is dependent on the healthcare facility's comfort level with such a venture. Alternatively the contracts like PPA (Power Purchase Agreement) and EPSC (Energy Performance Services Contract) create the desired results without having to undertake the added responsibilities.

The selection of the system is dependent on the available feedstock from the hospital and the adjacent communities. The thermal and non-thermal processes can be combined to create the most efficient system for energy and other by-products.

Pyrolysis can handle a variety of waste with least amount of emissions. MBT promotes recycling without the need for curbside separation of refuge. Non thermal processes convert waste into nutrients for agricultural use. An ideal WTE system would consider the economics along with the population growth and other businesses of the area.

The local authorities and community leaders need to be taken into confidence for the issues relating to the emissions control. There are instances where these projects gain bad reputation due to the lack of proactive measures by the operators.

The next frontier for these projects would be to achieve the resource efficiency that is comparable to the eco systems found in nature.

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