Materials in Transition

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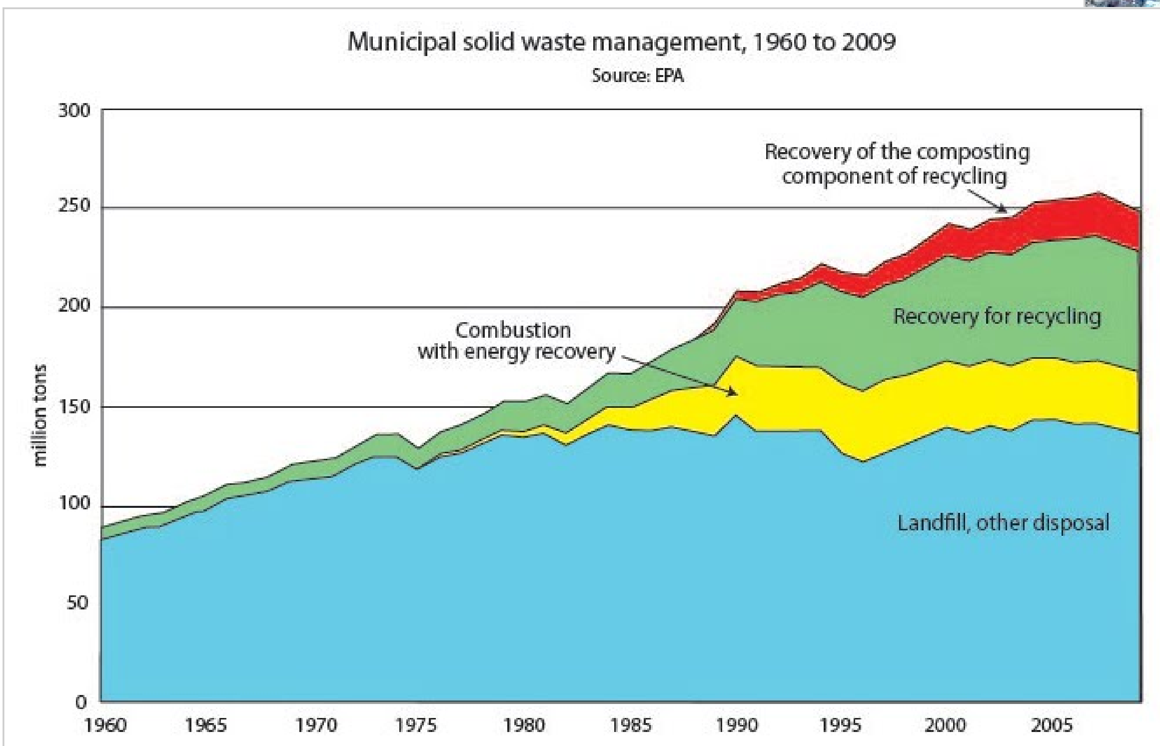
Why is waste a problem?

Currently**,** the United States sends 143 million tons of waste to the landfill each year.[i]



This amounts to 54% of the total U.S. waste stream taking up valuable land resources each year[ii]. Although recycling is available in most of the US, the recycling rate for all potentially recyclable materials remains around 25%.[iii] More specifically, the plastic recycling rate is much lower at 8%, which is a major issue because plastic is an extremely popular material due to its light-weight, space-efficient, and durable nature.

Ironically the reasons why consumers prefer plastics are the same reasons that plastics pose such an environmental and energetic problem; plastics take 500 years to degrade[iv], and are made from oil, a decreasingly depleted resource. Material waste, especially plastic waste, causes overflow in landfills, harm to marine life, production of both noxious and greenhouse gases, and economic waste.[iii] 17% of packaging waste is from plastics, and has the lowest recovery rate of all packaging materials.[i]

The graph above shows how waste production rates have changed in the U.S. over time. Clearly, waste production has grown since the mid 20th century as consumption and population rose. Fortunately, the rate landfill disposal per year has plateaued as recovery through recycling, composting, and energy recovery (find out more on the Waste to Energy Systems page) has increased. However, this does not mean that the amount of landfill wast has leveled out or decreased, but rather that landfills are growing at a steady rate as of 2009. Because the waste in landfills is not recovered to be reused, turned into energy, or composting, the materials put into landfills are our major concern. This waste has grown over time has consumption, production capacity, and an inability to recognize the need to recycle grew in the United States. Visit the Production and Recycling Timeline to learn more about materials throughout U.S. history.

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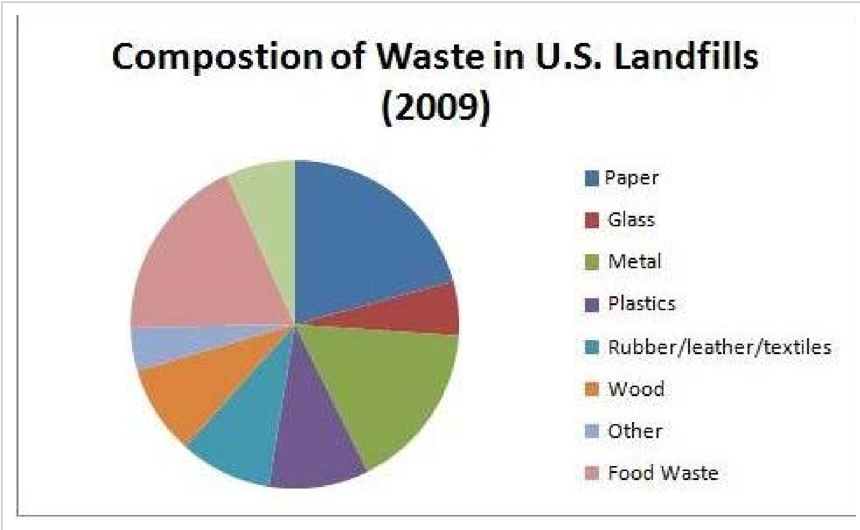

the composition of waste that goes into the landfills in the United States as of 2009. Many of these products, including paper, food waste, and yard waste, are compostable, meaning they will biodegrade and thus will not pose a major environmental or health threat in the landfill. However, materials that cannot biodegrade, especially **metal** and **plastics**, can cause environmental and health damage through leaching of toxic chemicals.

Only 1% of plastics are recycled worldwide, thus a large percentage ends up in landfills where they never biodegrade. Instead, plastic polymers are "photodegraded" by UV rays, a process in which the macromolecules are activated by the absorption of photons of light, causing them to slowly cleave into smaller pieces (J. F. Rabek). The degradation of HDPE (high-density polyethylene), the polymer used to make commercial plastic bags, can release oxidation byproducts such as various organic compounds containing toxins, including chlorinated compounds (Ingun Skjevrak et al). These chemicals can get into the food supply of animals and humans alike. The Algalita Marine Research Foundation cites that "broken, degraded plastic pieces outweigh surface zooplankton in the central North Pacific by a factor of 6-1. That means six pounds of plastic for every single pound of zooplankton." Which means, when birds and sea animals are looking for food -- more often, they are finding plastic. Additionally, metals and plastics require high energy input for production, meaning dumping of such materials is a substantial waste of potential recovery through recycling, reuse, or energy recovery.

Measuring the time we leave lights on and use our cars is a more straight forward way to gauge energy consumption, but metal and plastic use involves a significant energy cost that must be considered in order to reach sustainable levels of energy consumption. A detailed discussion of the energy involved in primary and secondary production processes and the energy lost in landfill space is discussed in the Energy Consumption in Plastics Production and the Energy Consumption in Aluminum Production section.

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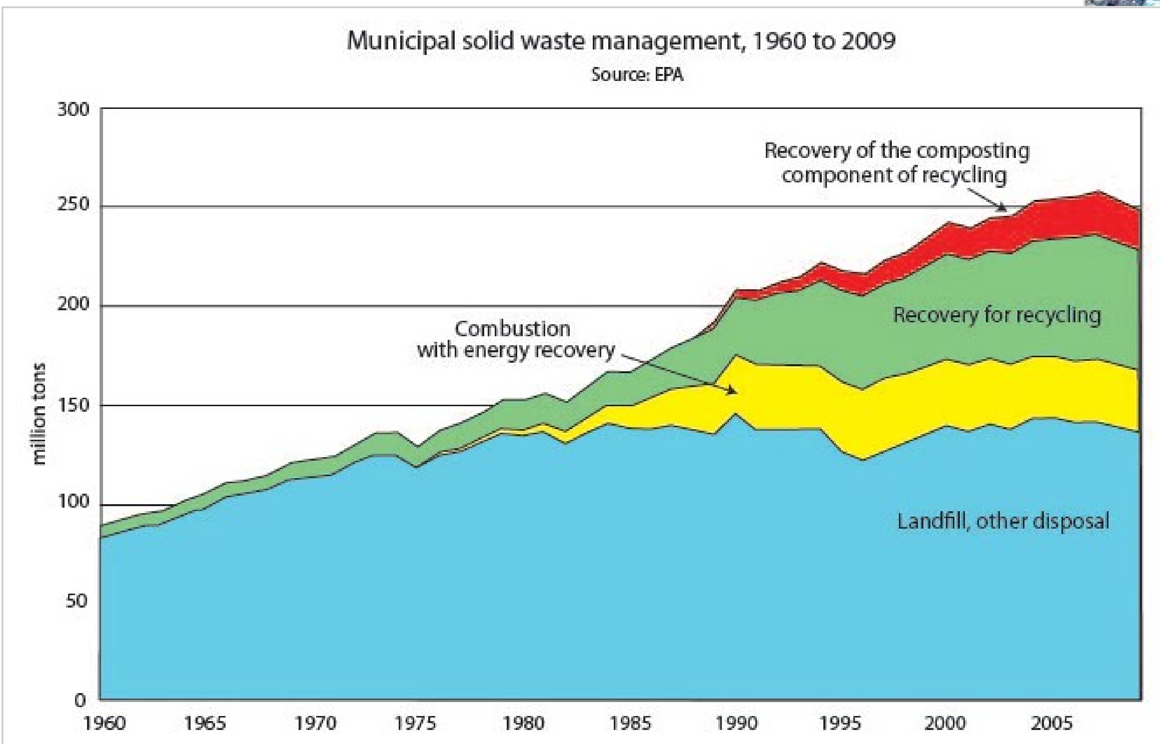

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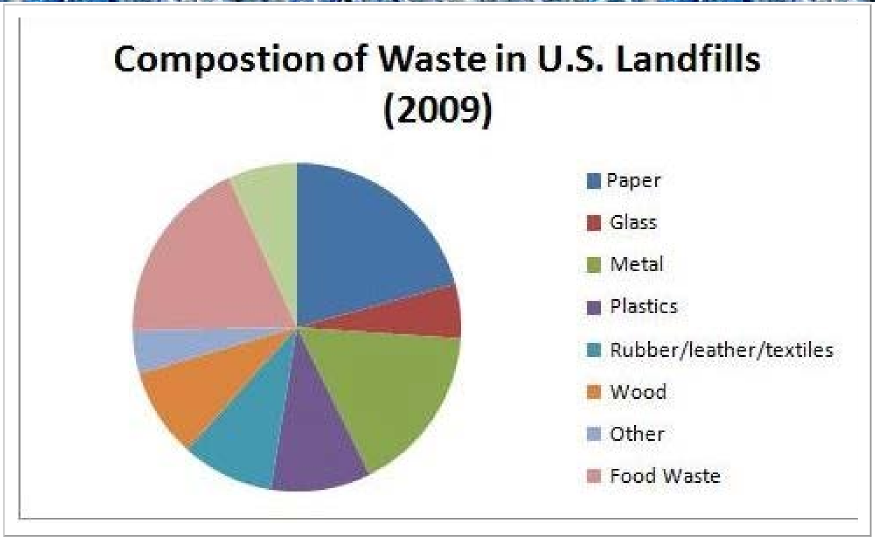

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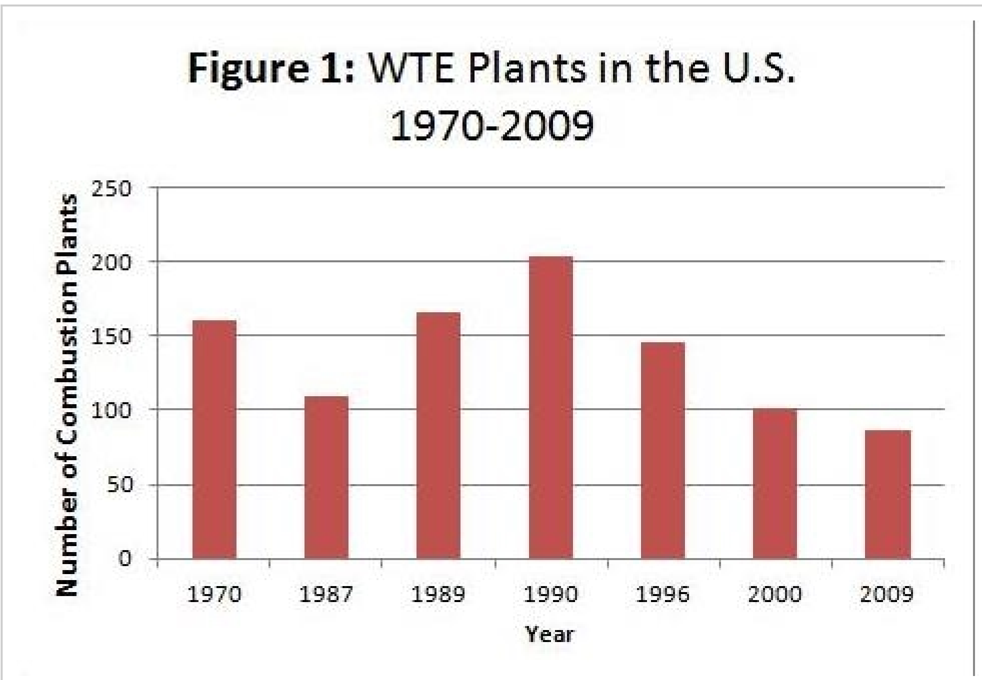
Waste to Energy Systems

Should the United States Congress pass the Waste-to-Energy Act of 2011 (H.R. 66) to increase tax incentives for investment in WTE facilities?

Waste to energy (WTE) is the process of taking waste products, from plastics to wood to food scraps, and transforming that waste into energy in the form of electricity, gas, or oil. A more detailed description of WTE is found in the Technology Background. Many WTE facilities currently exist throughout the world, though not all WTE plants use the same feedstock or methods of energy extraction. Some systems use energy either directly from combustion of waste or from methane produced by decomposing waste [i]. Newer systems currently in development isolate certain products,especially plastic, from the waste to produce energy resources in the form of oil[ii]. This page aims to explain the history and current status of WTE in order to better approach the question: Should the United States Congress pass the Waste-to-Energy Act of 2011 (H.R. 66) to increase tax incentives for investment in WTE facilities?



The History of WTE Facilities

In the 1920s, the U.S. started to use incineration energy to create electricity from steam generation. By 1930, 700 waste incinerators existed in the U.S., though not all of these facilities were used to capture energy and they were not held to any stringent health or environmental standards. The Clean Air Act, passed in 1970, required all waste incinerators to capture the energy produced through combustion. In the 1980s, the federal government appropriated funds through tax credits for WTE systems, leading to the creation of 46 new plants during this decade. However, these tax credits were allowed to lapse and no new WTE plants have been built in the United States since 1996 [iii]. This corresponds to the decline in WTE plants seen in **Figure 1**. Today, 0.4% (2,720 megawatts) of total US power production is produced by the 87 currently functioning WTE plants in the country [iv]. In contrast, Denmark, with a population one fifty-fifth the size of the United States, has 29 WTE facilities that supply 80% percent of total heating and 20 % of total electricity in many Danish cities. Additionally, Denmark sends the same percentage of its waste to waste to energy systems as the U.S. sends to landfills, which can be seen in **Figure 2** [v]. While waste to energy systems may not be the best option for waste management, Denmark clearly leads the U.S. in reducing wasted disposal in landfills.

Waste-to-Energy Act of 2011 (H.R. 66):

US

Figure 2: Waste Disposal Methods in the U.S. vs. Denmark

Representative Lloyd Doggett of Texas proposed the Waste-to-Energy Technology Act (H.R. 66) in January of 2011, which would reinstate the WTE incentives of the 1980s by giving a 30% tax credit for investment in WTE facilities [vi]. Changes at the national level would affect local debates over construction of WTE facilities by providing incentives for waste management companies to invest in WTE systems. As seen in the history of WTE in the U.S. in **Figure 2** to the right, reduction in financial support for WTE facilities led to an immediate halt of WTE plant construction in the 1990s [vii]. The WTE debate is thus well summarized in the opposing sides of the Waste-to-Energy Technology Act of 2011, which discussed in the Debate Over WTE page.

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Subpages (3): Conclusions Technology Background The Debate Over WTE

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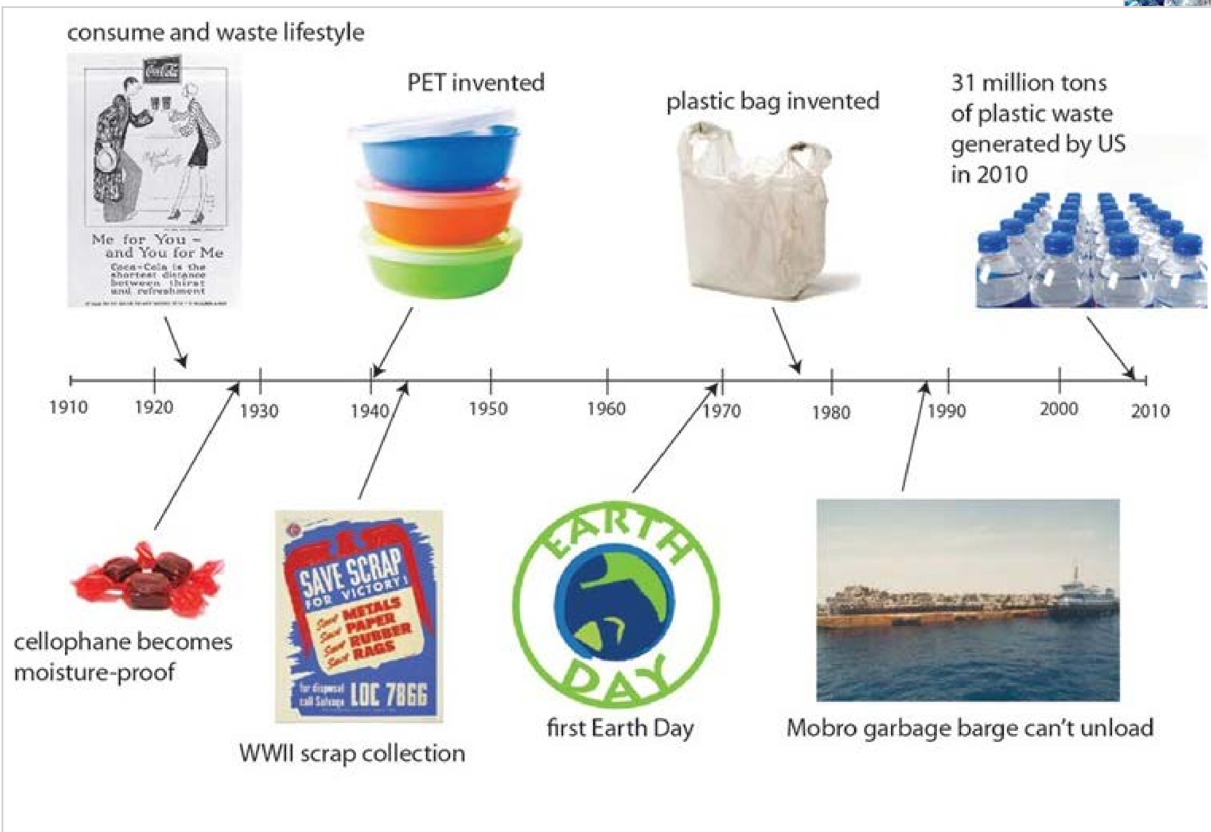

*photo sources listed at the bottom of this page

Ability/Infrastructure to Consume

Before the changes that stemmed in the Industrial Revolution, agricultural economies simply did not have the means to produce and consume materials at an elevated rate, as we do today. With the switch of energy dependence from agriculture based fuels to coal, England was able to concentrate its efforts on producing more than just agricultural goods. But for these new products to become widespread several infrastructural transformations needed to take place. These important changes in structure included swift urbanization, development of extensive transportation infrastructure, and specialization of the commercial sector.[i] With increased specialization, populations concentrated in urban or industrial areas, and the ability to efficiently transport material goods, all coming to a head in the mid 1800s, production and material consumption boomed. The second half of the nineteenth century continued to be an important time for changes in material use, because widespread use of plastic was first introduced, through the movie industry[ii], aluminum was first extracted from its ore[iii], and thermal cracking was invented.[iv] These developments are the basis of modern plastic and aluminum industries.[iii][iv]

Growth in Production and Consumption

With the introduction of such important materials as plastic and aluminum in the last half century, American's experienced a huge growth in material production, as well as a change in attitudes toward consumption. By 1920 assembly lines became the most common form of factory design, streamlining mass production and changing the way people thought about materials.[v] Additionally, the Roaring '20s are often cited as the decade when Americans embraced our current "consume-and-waste" lifestyle; recycling and re-using, once done by all, was now considered low class behavior.[vi] To further encourage this type of wasteful behavior convenient, single use materials, such as cellophane[ii], polyethylene terpthalate (PET)[vii], and saran wrap [xii] were invented in the next few decades, and put into wide circulation. These plastic materials are extremely useful because they are waterproof, lightweight and durable, making them ideal for packaging and preservation.

Awareness of Waste

The first real national awareness of all of the materials that were going to waste in the US occurred during World War II. Civilian drives for scrap metal, textiles, and even paper were an important part of the war effort at home, and have been cited as the first nationwide organized recycling effort.[vi] Although this may represent a start of awareness concerning material waste, no real headway in changing America's actions and widespread beliefs in peace-time was made until the 1970s. The first ever Earth Day was celebrated on April 22, 1970, which began a recycling and re-use movement that many Americans embraced.[viii] A year later the state of Oregon passed the nation's first Bottle Bill, so that certain recyclable beverage containers could be redeemed at local grocery stores for several cents each.[ix] Since these recycling and re-use benchmarks, awareness has spread considerably and many Americans are now much more conscious of how their consumer decisions effect their country's waste stream.

Continued Consumption

Despite an apparent growing awareness of the United States' waste problem, production of materials did not slow in the end of the 20th century. In fact, materials such as plastic bags[x] and aluminum cans[viii] became much more prevalent, only adding to the waste stream. In 1987 the Mobro garbage barge traveled along the U.S. East Coast, unsuccessfully searching for a place to unload its waste. This event brought landfills and recycling to the forefront of public awareness[ii], yet global plastic production approached 100 million tons per year in 2007.[xi] Of this plastic, 27% percent of plastic bottles were recycled in 2008, but only 8% of all plastics were recycled, due to limitations of efficiency.[xii]

Conservation Efforts

In the last five years, serious efforts have been made to combat the extensive amount of waste the US produces. In 2007 San Francisco became the first city to ban plastic bags from large shopping centers[xii] and Oregon expanded their bottle bill to include more types of plastic, a model which has been adopted by 11 other states.[ix] In this last year alone, the city of Portland was the first city in Oregon to ban the plastic bag in groceries[xii], and the bottle bill was expanded further.[xiii] Although these important conservation efforts should not be ignored, as a whole America is still actively consuming and wasting much of the material it produces, despite awareness of the energetic wastefulness of this process.

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Energy Consumption in Plastics Production

Material production and consumption in the United States has grown dramatically throughout the last century, reaching a total waste generation of 243 million tons in 2009 alone [i]. Plastics made up 12% of this waste stream in 2009, amounting to almost 80,000 tons of plastic generated in the U.S. per day [[ii]]. The way in which these plastics are made has a substantial impact on the energy consumption in the production process.

Making plastics from raw materials

Crude oil extraction: Many plastics on the market today are made of polyethylene terephthalate (PET) or high density polyethylene (HDPE), which are both petroleum products [iii]. This means that the first step of the life cycle is the extraction of crude oil from underground reservoirs. In this process work is done on, and by, drilling and pumping machinery, in order to extract the crude oil [iv].

Refining of oil: Fractional distillation, the process used to refine crude oil, takes advantage of the fact that the hydrocarbons that petroleum is made up of each have a different boiling point. Crude oil is heated until all of the components become gaseous and it is then transferred to a distillation column, and each of the products is collected at a certain height as the gases cool into liquids [v]. This process separates products such as gasoline and PET into usable forms. In this case work is done on the system, and the product, heat, is harnessed in order to complete the phase changes required to transfer liquid petroleum into gases. The raw materials for plastics are then condensed into plastic resins in the form of small pellets of plastic, which can then be melted into the shape of the final product. The diagram of **Figure 2** to the right shows outlines the key steps in the production of plastics from raw materials.

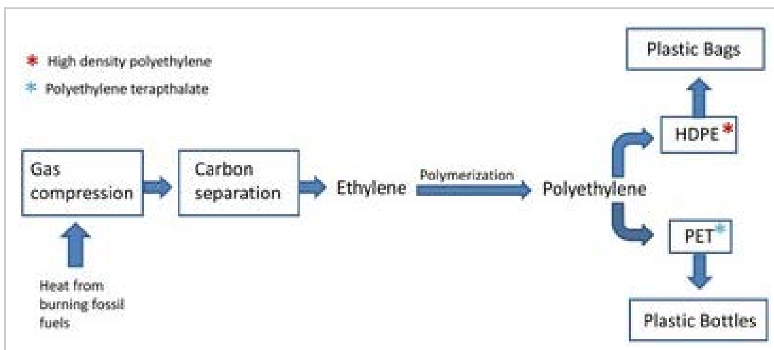
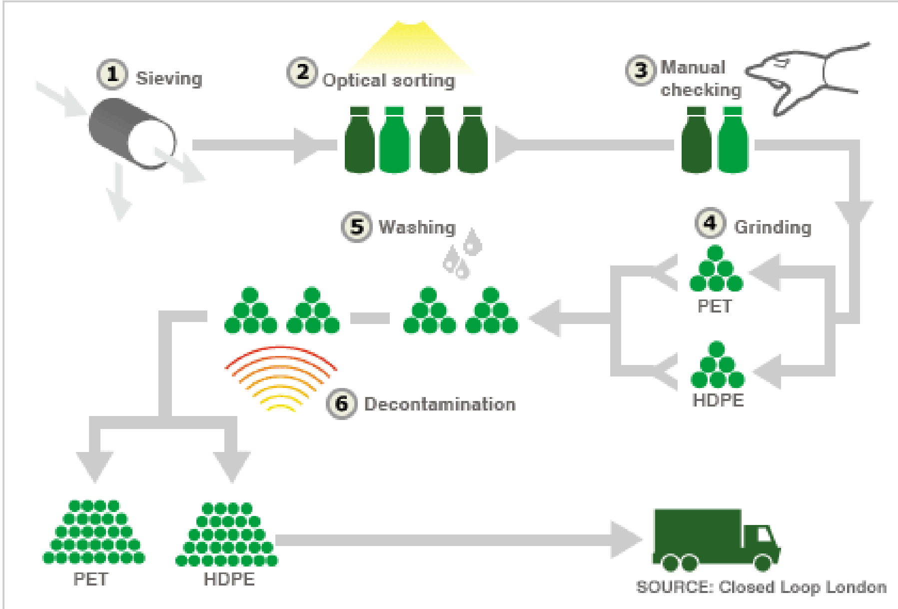


***Figure 1:** Schematic of virgin plastics production* [xix]

Recycling plastics into new plastics

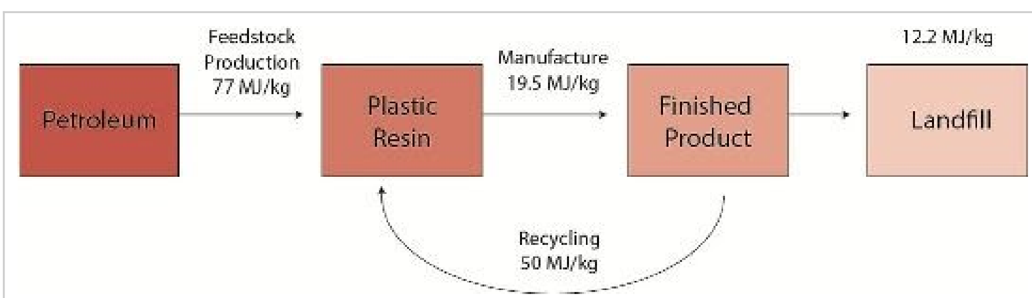
The energy requirements for recycling plastics come from the acquisition, sorting, melting, and processing that is required to produce final plastic resins that can be turned into a consumer product. Currently, end-of-life plastics are picked up from domestic and industrial locations and sent to a sorting facility, where the plastics are sieved, sorted, and checked before they are compacted into a bail and sold to reclaimer companies. These companies break up the plastic bails and send the plastic pieces through a shredder to make small flakes. The flakes are then cleansed, melted, and sent through an extruder, forming thin strands of plastic, which are then cut in plastic pellets. These pellets are then sold to plastic producers [vi]. Companies such as MBA Polymers add extra steps of sorting plastics by type and grade, allowing for more types of plastics to be consumed and produced through the recycling process [vii]. Figure 1 shows a simplified schematic of this recycling process.

***Figure 2**: Recycling plastics to feedstock resins [viii]*



Electrical work is needed to power bail breakers, extruders, shredders, and cleaning systems (washing, rinsing, and drying of plastics). This work generally comes from turbogenerator plants which convert mechanical energy from a spinning turbine into electrical energy available for work, typically using coal as a fuel source [ix]. Energy is also lost through heat in the process of melting the plastics for reshaping, functioning of various recycling machinery, and in the initial generation of electricity at the turbogenerator. Increased heat capture at each of these steps could increase the efficiency of recycling systems.

***Figure 3:** Plastic production energy requirements per kg (sources)*



What are the energy costs of plastic production?

Plastics production from both virgin materials and recycled products requires energy input. However, the energetic cost of recycling plastics into new products is less than the energy involved in acquiring raw materials from petroleum. As diagramed in **Figure 3** to the right, production of plastic resin from petroleum raw materials involves 77 MJ per kg of resin, versus 50 MJ per kg of resin from recycled plastics. Manufacture of the final product is approximately equivalent for both recycled and virgin plastic. However, the major loss of energy in virgin plastic production comes from solar energy that is lost when unrecycled plastic materials go to the landfill. Plastics take up approximately 25% of the total landfill area in the U.S., for a total of 140,000 acres devoted to plastics alone [x]; [xi]. Based on how much solar energy reaches each region of the U.S. and where landfills are distributed geographically, landfills lose 12.2 MJ of solar energy per kg of plastic waste [xii],[xiii],[xiv]. This number also takes into account an average potential energy efficiency for photovoltaic cells of 10%, meaning that the total solar energy that hits landfills is 10 times the number cited [xv].

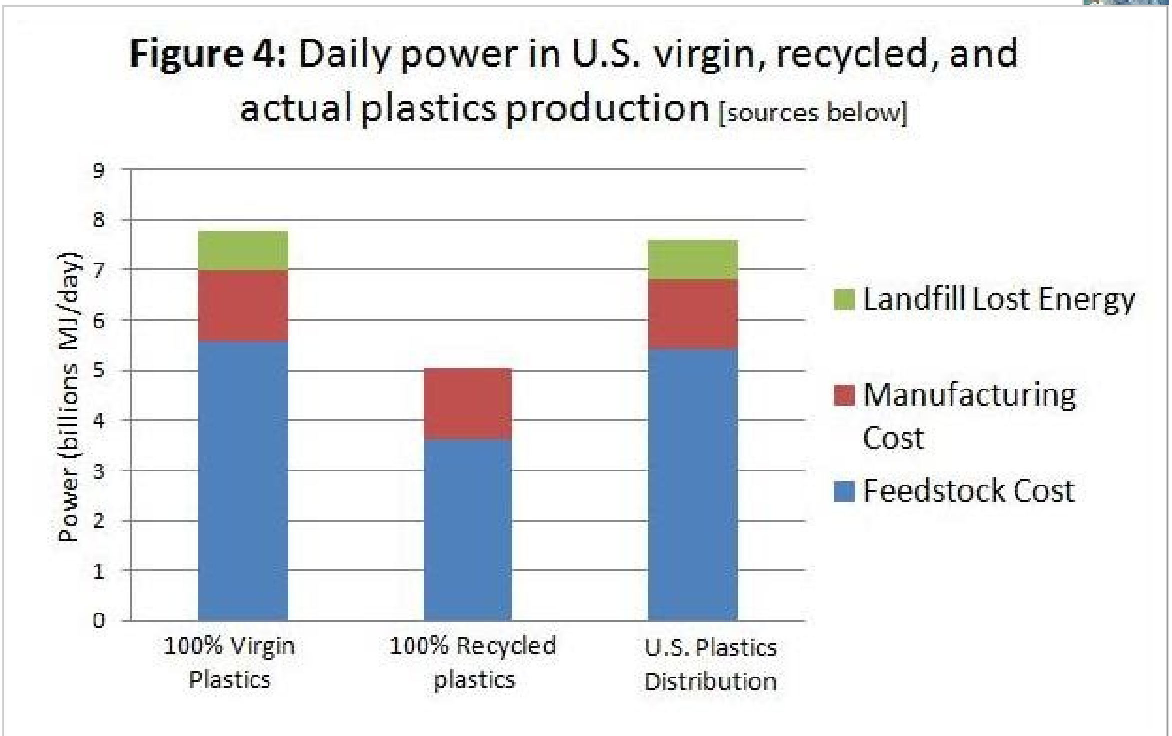


Figure 4 to the left displays how these numbers relate to the actual amount of plastic material used in the U.S. per day. Based on our daily production of 80,000 tons of plastic waste, the U.S. would use 7,278,248,881 MJ/day if all of our plastics were to be produced from virgin materials, while we would only use 5,036,000,000 MJ/day if all of our plastics were from recycled materials [xvi]. Currently, only 8% of plastics are recycled, so that actual daily energy consumption for plastics in the U.S. is much closer to the values for virgin plastics production, as the “U.S. Plastics Distribution” bar indicates. The 57,826,700 MJ going to plastics production in the U.S. each day equates to 57,826,700 gallons of gasoline, or 15% of the U.S. daily gas consumption [xvii]. All of these values are based on PET plastic, which is the most common type of plastic in commercial use [xviii]. The values also do not take into account the energy saved from not producing a new product when plastics are recycled.

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Figure 3 and 4 Sources:

Total plastic waste in US: "Common Wastes & Materials." *EPA.gov*. US Environmental Protection Agency, 15 Nov. 2011. Web. 08 Dec. 2011. <http://www.epa.gov/osw/conserve/materials/plastics.htm>.

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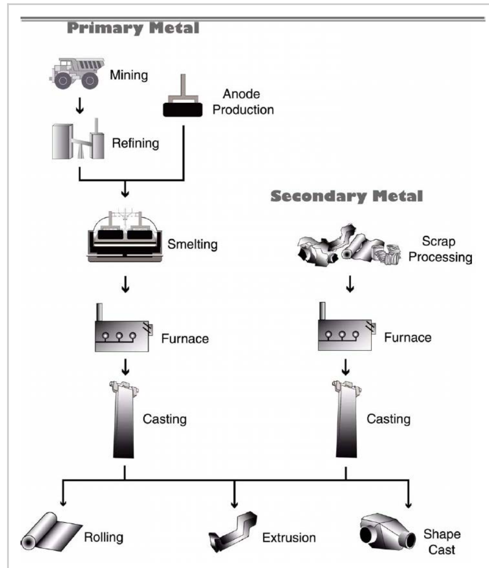
Materials in Transition

Search this site

Energy Consumption in Aluminum Production

Aluminum requires a significant amount of energy input for production and recycling. This is especially true in the United States where we ship in most of our aluminum raw materials. A more detailed description of the potential benefits of aluminum is described in the Aluminum-Zero Waste section. Let's look at production of both primary and secondary aluminum to understand how it is made and the costs it entails.



Primary Aluminum Production

In a general sense, aluminum is produced in five steps: mining, refining, smelting, heating, and casting (see **Figure 1** on the right).

For the first step, bauxite, an aluminum ore, is collected through strip mining. Then, the bauxite is refined into alumina. The refining process releases 16.7 kg of carbon dioxide equivalent and consists of four steps: digestion, clarification, precipitation and calcination (see **Figure 2** below).

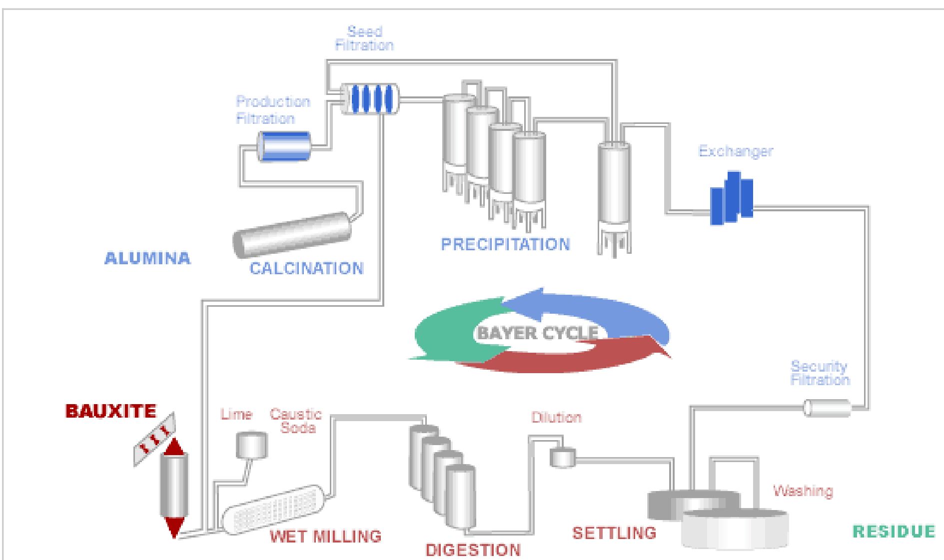


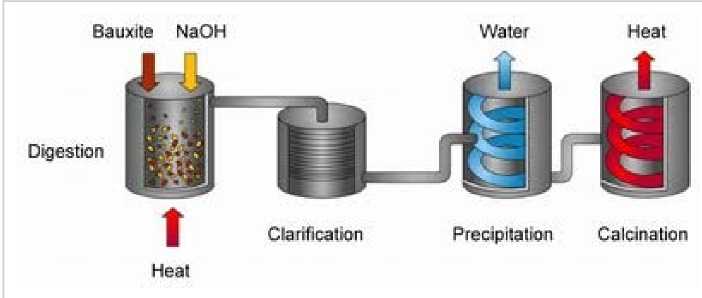
Figure 1:

Schematic of aluminum production

Figure 2: *Aluminum refining process*

Calcination is the most energy intensive of the steps because it requires use of high temperatures. Much of the heat is lost during calcination (see **Figure 3**).

Figure 3: *Calcination process*



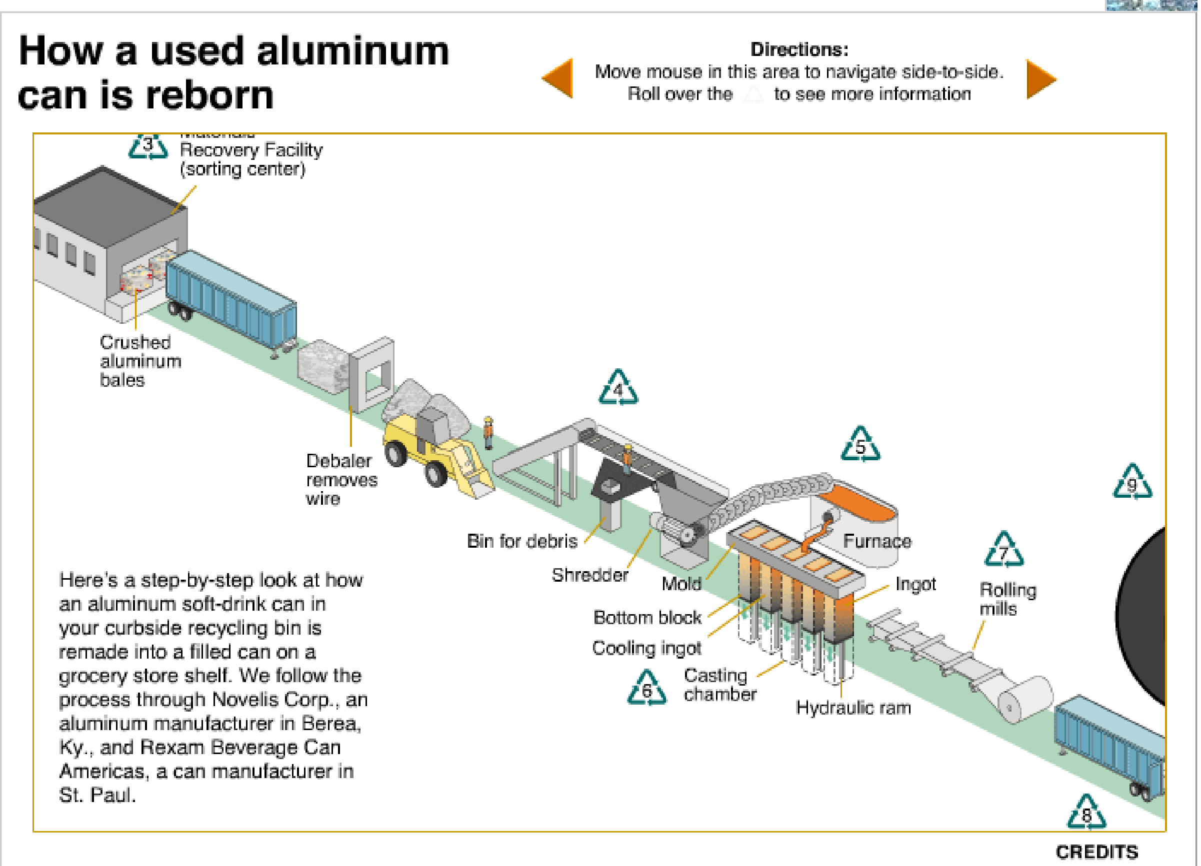
Next, the alumina is separated into its elemental components, oxygen and aluminum, in a process called smelting. Smelting requires the use of carbon anodes for the electrical reduction of alumina. Then, the aluminum is put through a furnace to remove its impurities. After the furnace, the aluminum is cast into molds to create ingots. The entire production of primary aluminum ingots from mined bauxite ore consumes about 23.8 kWh per kilogram of aluminum. If we include the energy requirements involved with producing the electricity used, the consumption goes up to about 62.2 kWH per kilogram of aluminum.

Aluminum production in the United States consumes about 45.7 x 10^9 kW/h of direct energy per year (this does not include the energy used to produce the electricity consumed). The smelting and heating components of production consume the most energy, using 46% and 27% respectively.[5] To put this gigantic number, almost 46 billion kW/h of energy, into perspective: it is enough to power about 52 million 100 Watt light bulbs for a year.[6] The American aluminum industry consumes about 1% of domestic energy use and 3.3% of domestic primary production energy.[7]

Secondary Aluminum Production

Aluminum recycling consumes about 5% of the amount of energy that aluminum production consumes. The recycling process begins with the collection and processing of used aluminum. After the collected aluminum is cleaned, it goes through the same last two steps of aluminum production: heating and casting.

Click the image below for an excellent visualization of the recycling process of an aluminum can.



Efficiency

In 2003, the United States conserved 167 x 10^9 kW/h of energy through aluminum recycling. Secondary aluminum production only uses 5% of the energy that primary production does [5].

This energy conservation comes from the numerous steps of primary production that secondary aluminum production skips. There are also large energy savings from the drastic decrease in transport fuel that is used to import bauxite ore for primary production.

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Materials in Transition

Search this site

The Team

Welcome to the **Material Girls** page! Our mission is to understand the uses and misuses of human materials that contribute to our consumption of energy in material production, processing, and transportation.

Kate Liddle Broberg is researching *plastic water bottles* and the processes involved in bottle recycling.

Erin Madison's topic covers the *Plastic Bag Controversy*, a current debate surrounding the benefits and problems with traditional plastic bags. She will also research more energy efficient and environmentally-friendly *alternatives* to plastic bags.

Rachelle DiGregorio is researching the *Zero Waste Movement* with a focus on how primary and secondary *aluminum production* affect energy consumption and product lifecycles.

Lauren Hawkins' topic covers *waste to energy systems* and will evaluate the energy efficiency and processes behind turning waste materials into energy sources for consumption.

Materials in Transition

Search this site

Why is waste a problem?
Production and Recycling Timeline
Energy Consumption in Plastics Production
Energy Consumption in Aluminum Production
The Team
Bottled Water Issues
Thermodynamics
Plastic Bag Controversy
Opposing Sides of the Bag Ban
From the cradle to the grave
The Energetics of Plastic Bag Recycling
Could it work?
Waste to Energy Systems
Technology Background
The Debate Over WTE
Conclusions
Aluminum // Zero Waste
Final Thoughts

Bottled Water Issues

Should the University of Oregon ban distribution and sales of bottled water on campus?

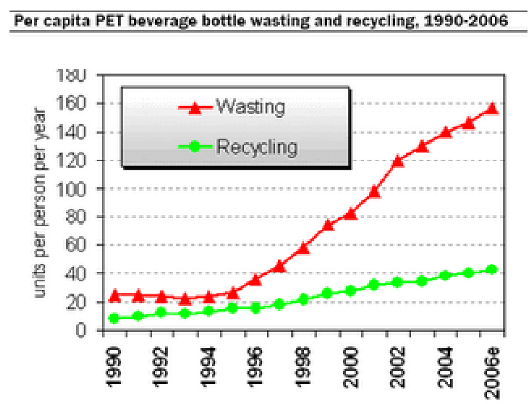
History of Bottled Water:

Records of bottled water in the United States date back to the 1760s, when it was sold in Jackson's Spa, Boston.[i] But bottled water did not become popular until the 1850s when glass production became cheap enough for widespread use of bottled water in American cities.[ii]

From the mid 19th century until 1913, when chlorination of municipal water made it impractical, bottled water was an important staple in American life, by provided safe drinking water for much of the population.2 Surprisingly, bottled water made a comeback only decades after the introduction of safe tap water to the US, due mostly to ingenious marketing and advertising, which was pioneered by Perrier. Bottled water was toted by companies as a healthy alternative to municipal water supplies, claiming that it could even be used as a health supplement. Although the bottled water trend began in Europe, growing concerns about water pollution in America made tap water less appealing, creating a higher demand for bottled water in the states.[i]

The 1970s were an important decade for current trends in bottled water consumption; "yuppies" helped to make bottled water a trendy purchase[1], Daniel C. Wyeth introduced the first disposable

This low recycling rate is unfortunately coupled with a much higher rate of single-use plastic bottle waste, as the graph below indicates. Although recycling rates are continuing to rise, consumption and waste rates are growing at a faster pace. These two figures illustrate the need for changes in consumption patterns as well as promotion of recycling.



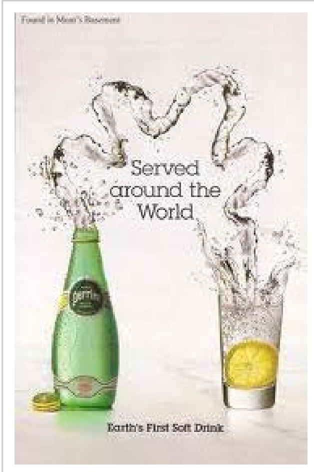
(source: sustainablebusiness.com)

Based on data such as these, a group on the U of O campus has begun a campaign to eliminate single use plastic bottles at the university.

CJL's "Take Back the Tap":

Climate Justice League (CJL) is University of Oregon's very own campaign driven advocacy group for climate justice. This U of O club was founded in January 2010 by a group of students interested in environmental issues and inspired to take action by the PowerShift West conference. One of CJL's headlining campaigns is Take Back the Tap (TBT), which strives to eliminate the sale and distribution of bottled water on the U of O campus.[xiv]

TBT's campaign coordinator Manny Garcia says that CJL chose to start the TBT campaign because it was the kind of project with which the club could make significant



PET bottle[iii] Perrier launched a $5 million dollar campaign to promote their imported bottled water in America[1], and Oregon passed the country's first Bottle Bill[iv]. By the '80s a majority of refillable beverage bottles were replaced with single use plastic PET bottles, and the chasing arrow symbol was created to "greenwash" plastic products.[3]

Despite increased recycling rates, and trends moving toward multiple use bottles and tap water, bottled water is still highly visible in American life, and is a major component of the United State's waste stream.

It is so prevalent worldwide that author Nicholas Dege predicted that global bottled water production would overtake alcoholic beverage production. Some of the reasons Dege cites that apply to the US are rising rates of obesity, the importance of image in current lifestyles, successful marketing, water as an all-day beverage, taste preference, and habit.[v] This continuing reliance on bottled water in the US is a problem because it is an incredible waste of both energy and money, has many environmental consequences, and may be making Americans less healthy than if they chose to drink tap water.

Impact of Bottled Water:

Energy costs:

It takes approximately 3.4 megajoules of energy to make a 1-liter plastic bottle, cap and packaging. In 2006 Americans bought an estimated 31.2 million liters of bottled water, which used more than 106 million megajoules of energy (which is equivalent to the energy in 17 barrels of oil), produced more than 2.5 million tons of CO_2, and consumed about 3 liters of water for every liter sold.[vi] For more specific information on the energy costs of single-use plastic bottles please see the Thermodynamics page on this site.

Economic costs:

change close to home, and tackle the root of the problem, by changing consumption patterns at the University. He identified the most important reasons behind the elimination of bottled water on campus, saying that bottled water is overpriced, often almost 3000 times as expensive as tap water, unhealthy, and extremely wasteful.

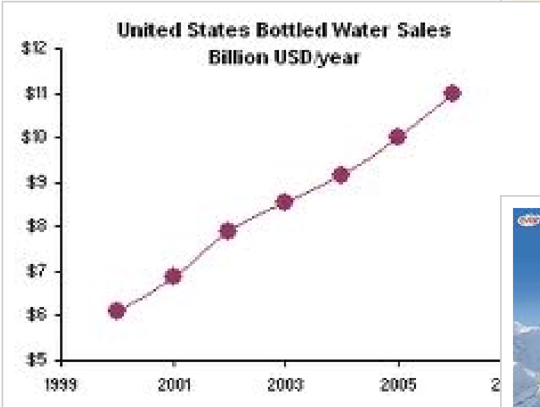
Garcia was proud to share that TBT has succeeded in making the ASUO bottled water free, and they have launched a bottled water free pilot program with many of the vendors in the EMU. Despite this progress, he said that the TBT campaign has faced significant opposition, mostly from Pepsi, which has significant ties to U of O athletics. For example, Pepsi has a contract with the University that requires bottles of Aquafina brand water to be visible in the first row of Matthew Knight Arena at all basketball games. This type of advertisement at a University event is what TBT hopes to eliminate, but Garcia says that while students seem very supportive of the project, the administration has remained mostly neutral on the issue. When asked whether he thought eliminating bottled water was feasible on all American college campuses, Garcia explained that he thought colleges and universities were one of the easiest places for a waste reducing campaign such as TBT to succeed.[xv]

CJL has used "free water" stickers on campus water fountains to highlight the availability of Eugen's tap water to students, faculty and staff.

Proponents of Bottled Water:

The two major proponents of bottled water are simply the large, often multinational, corporations that produce and sell bottled water, and the consumers that purchase it because of its convenience. In areas where municipal water supply is not safe bottled water can be an important source of healthy drinking water, but because Eugene has a very clean and healthy water supply this is not applicable for the University of Oregon. Although it is clear why bottled water producers support the continuation of their product, why do consumers continue to spend millions of dollars on a beverage that comes out of their tap for a fraction of the price? Authors and historians have attributed this seemingly illogical obsession with bottled water to highly successful advertising and marketing of this product.[1,2,7] Bottled water advertisements often depict

The global bottled water market is estimated to be worth $22 billion, and is dominated by countries with access to clean tap water. Over 89 billion liters of bottled water are traded internationally, often in reciprocal trades that span half of the globe[vii], and consumers spend about $100 billion per year on bottled water.[viii]



(source: geology.com)

Health costs:

Despite popular belief, government estimates state that about one fourth of bottled water is simply bottled tap water. Approximately 60-70% of bottled water sold in the US is exempt of FDA standards, because it is sold in-state only. When comparing EPA regulations on municipal water to the FDA's bottled water regulations, the National Resources Defense Counsel found that for those bottled water products that do fall under FDA regulation, the rules are much less strict than those governing tap water. Additionally, about one third of bottle water tested in NRDC's study contained at least one type of contaminant.[ix]

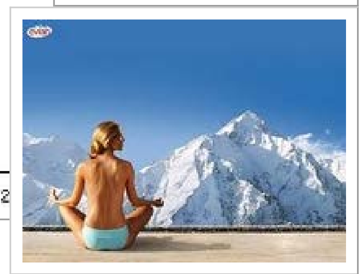
Environmental costs:

In the year 2006 alone American consumption of bottled water produced more than 2.5 million tons of CO_2.[6] Additional environmental impacts of the bottled water industry include huge amounts of plastic bottles in American landfills, the "great pacific garbage patch," and countless wildlife deaths due to ingestion of plastic[x]. Because plastic is so durable it takes 500 to 1000 years to degrade, meaning that even if we stop production of single-use plastic bottles now, the effects of past plastic production will continue for many centuries.[xi]

Eugene's Tap Water:

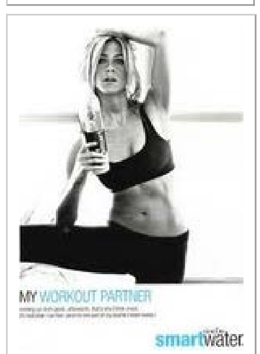
The Eugene municipal water supply is provided by the Eugene Water and Electric Board (EWEB). EWEB is Oregon's largest customer-owned utility and was founded in 1911 after Eugene experienced a widespread typhoid epidemic. For one hundred years EWEB has provided Eugene with clean, safe water, using the McKenzie river as the area's main water supply. River water taken from the McKenzie is disinfected, treated for taste and odor control, pH, particulate removal and corrosion control. Over ten different methods are used to treat Eugene's water, which has been named "the nations best drinking water" by Organic Style magazine.[xii] Residents in Eugene, as well as much of the United States, are lucky to have such high quality drinking water that comes straight from their taps.

beautiful, remote and "untouched" landscapes, in an effort to convince the consumer that their water comes from the most pure and natural source.



As discussed earlier, this is certainly not always the case. Advertisers are also fond of using the health angle; they would like consumers to think that bottled water is the beverage that will help them live a happy, active lifestyle. The advertisements below are examples of this strategy.

Although bottled water is certainly more healthy than the other bottled beverages offered by many of these companies, they offer no proof that bottled water is more healthy than tap water.
Lastly, bottled water companies use the sex appeal of celebrities and models to promote their product. This was apparent in several of the images above, but is especially striking in the advertisement below.



Due to innovative and intelligent marketing, bottled water companies have convinced millions of consumers to buy a product that is much more expensive, less well monitored, more harmful to the environment, and much more energetically costly to the

environment.

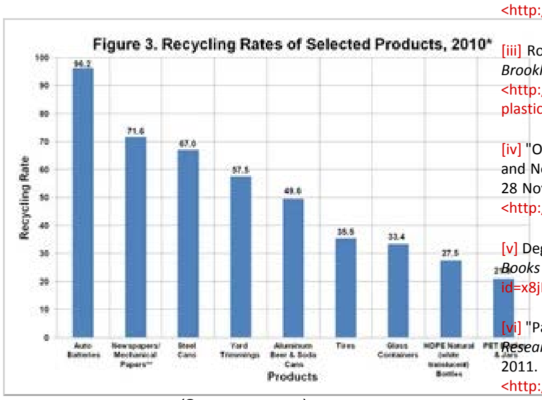
The Bottle Bills and Recycling:

The state of Oregon is notable not only for their excellent municipal water, but also for their leadership in recycling initiatives. In 1971 House Bill 1036, the nation's first "bottle bill," was passed by Oregon's house and senate, and signed into law by Governor Tom McCall. This groundbreaking bill required that all carbonated and malt beverage cans and bottles be returnable. This bill sprung from Oregon citizens' awareness of an increasing litter problem, and also emphasized the importance of conserving resources.[xiii]

Since then, 11 other states have adopted similar container deposit laws in order to combat the wasteful practice of landfilling recyclable materials. Oregon revised and expanded its original bottle bill in 2007, requiring that water and flavored water bottles be redeemable. Since the 1980s, when PET bottles became common, these types of containers were recycled, but this revision made it mandatory that they be returnable.[xiii]

The most recent revision of Oregon's bottle bill was signed into law in July of 2011. It expanded the 2007 bill, by mandating that juice, tea, and most other non-carbonated beverage containers be returnable. This law has also provided incentive for recycling, by raising the deposit from five to ten cents by 2018 if recycling rates do not rise. Lastly, this recent expansion calls for the opening of more deposit redemption centers around the state.[xiii]

Despite the awareness of recycling in Oregon, and increasingly around the country, recycling rates for plastic bottles remain the lowest of any product, as the figure below indicates.



(Source: epa.gov)

Conclusion:

Based on everything discussed above, it is clear the CJL and their Take Back the Tap campaign should be supported on the U of O campus. Single-use bottled water is overpriced, unhealthy, detrimental to the environment, and very energetically costly. The sale and distribution of water on campus promotes wasteful consumption of a product than can be easily replaced by reusable water bottles and Eugene's high quality tap water. Bottled water is an illogical purchase, driven by America's consume and waste culture, and encouraged by clever advertising. Join CJL in promoting a bottled water free campus, and stop buying single-use plastic bottles of water!

---

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Subpages (1): Thermodynamics

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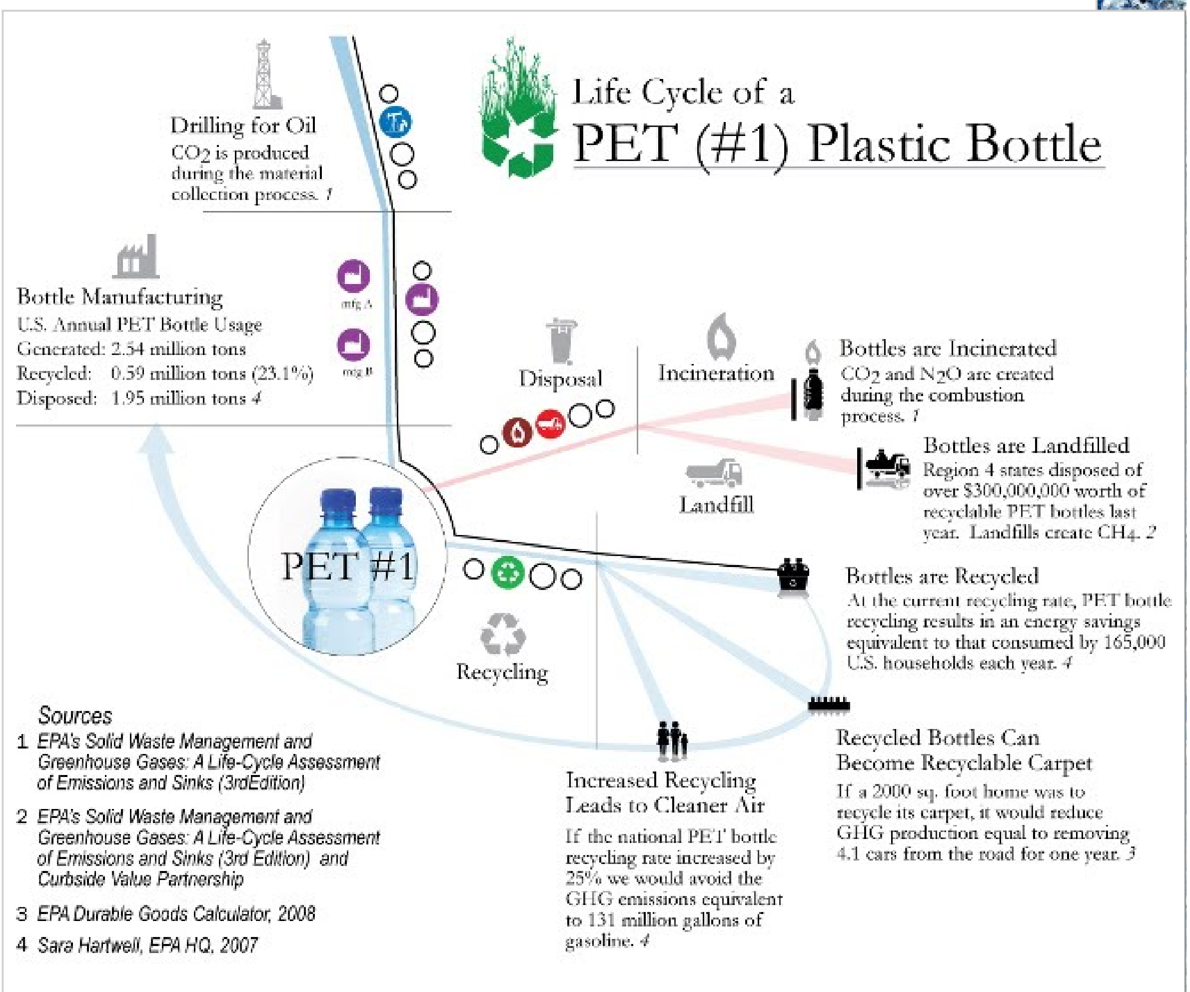
Thermodynamics

The Thermodynamics of a Plastic Bottle’s Life Cycle

The Pacific Institute estimates that "Producing the bottles for American consumption [of bottled water] required the equivalent of more than 17 million barrels of oil (not including the energy for transportation), bottling water produced more than 2.5 million tons of carbon dioxide, [and] it took 3 liters of water to produce 1 liter of bottled water"[i]. As you can see, the process of producing bottled water is an energetically costly endeavor, partially because of how many steps there are to the process. Every step of this cycle requires energy, from exploration for oil to recycling used bottles, energy is lost in the form of heat. The diagram below provides an overview of some of the energetic and environmental costs that the production of single use PET bottles create.[ii]



The key steps in a plastic bottle's life cycle are as follows:

- **Crude oil extraction:** Most plastic bottles on the market today are made of polyethylene terephthalate (PET), which is a petroleum product.[iii] This means that the first step of the life cycle is the extraction of crude oil from underground reservoirs. In this process work is done on, and by, drilling and pumping machinery, in order to extract the crude oil. An estimated 4% of world oil and gas is used as plastic feedstock, and an additional 3-4% is combusted to provide energy for their manufacture.[iv]
- **Shipment to oil refineries:** Once it has been extracted, crude oil is usually transported to an oil refinery in container tankers [iii] , which themselves run on oil. In the process of transportation work is done on, and by, an internal combustion engine, which emits heat and work as a result.
- **Refining of oil:** Fractional distillation, the process used to refine crude oil, takes advantage of the fact that the hydrocarbons that petroleum is made up of each have a different boiling point. Crude oil is heated until all of the components become gaseous and it is then transferred to a distillation column, and each of the products is collected at a certain height as the gases cool into liquids.[v] This process separates products such as gasoline and PET into usable forms. In this case work is done on the system, and the product, heat, is harnessed in order to complete the phase changes required to transfer liquid petroleum into gases.
- **Plastic Manufacturing:** Bottling plants must take preforms of PET, small cylinders of plastic, and shape them into a usable plastic product. Life-cycle assessments have shown that the energy required to produce this PET resin is 70-83 MJ of thermal energy per kg of PET resin.[vi] This process is commonly done in two ways: extrusion modeling, which uses force on a screw to push plastic through a die that shapes the PET into a bottle, or injection molding, where melted plastic is forced into a cold mold in the shape of a bottle.[vii] In each of these molding techniques work is done on the plastic to force it into a marketable shape. Gleick and Cooley report that the amount of energy required for this process is approximately 20 MJ/kg of finished bottle product.
- **Sterilizing of bottles:** Plastic bottles that will be used to hold beverages must be sterilized before they can be filled. Bottling plants will use a dry sterilization process that utilizes hydrogen peroxide at a low pressure, because it significantly reduces bacteria.[viii]
- **Water processing**: The water found in commercial bottled water bottles usually comes from either surface and groundwater systems, or municipal water systems. Treatment of this water is generally conducted at the bottling plant, and can consist of reverse osmosis, ultraviolet radiation, ozonation, or ultrafiltration. The energy cost of these processes vary widely, but are almost negligible in comparison to the embodied energy of the bottle.[vi]
- **Filling, capping, labeling and packaging:** Most bottles are filled, capped, labeled and packaged mechanically[iii], meaning that electrical work is done on, and by, machines which complete these tasks. Labeling and packaging materials are often also plastic, and the energy requirements for the creating of these materials must be taken into account when quantifying the embodied energy of a plastic bottle. Gleick and Cooley estimate the energy requirement for this step of the life-cycle to be approximately 0.014 MJ per bottle.
- **Shipping to distributors:** Once the bottling process is complete, all beverages must be shipped to a distributor. This requires quite a significant amount of energy, ranging from 1.4 MJ to 5.8 MJ, depending on how far the product is traveling.[vi]
- **Consumption:** Once consumers purchase bottled beverages there may be several added energy concerns to consider. First, the consumer may transport themselves to the store, and their product back home via fossil fuel based transportation, thus adding to the already high transportation energy cost. Secondly, consumers may prefer bottled water that has been chilled at the distributor, and may also choose to refrigerate their beverage at home before consumption. The energy to cool a bottle of water to average refrigerator temperature has been estimated at 0.2 MJ.[vi]
- **???:** After the beverage is consumed several things that could happen to the plastic bottle: it could be reused, despite the possible health risks involved, it could be recycled, or it could be thrown out. Each of these possibilities has its own set of energetic requirements, one of which our group paper will examine. One study concludes, "All the bevearage packaging materials and sizes have a lower environmental impact if they are recycled rather than disposed of in landfills or incineration plants, because of the energy and raw material savings it entails."[ix]

Table 5. Total energy requirements for producing bottled water. (Note: we assume here an average ratio of three kWh (thermal) per kWh (electrical) and 3.6 MJ kWh^{-1}.)

	Energy intensity ($MJ_{(th)}\ l^{-1}$)
Manufacture plastic bottle	4.0
Treatment at bottling plant	0.0001–0.02
Fill, label, and seal bottle	0.01
Transportation: range from three scenarios	1.4–5.8
Cooling	0.2–0.4
Total	5.6–10.2

The steps of a plastic bottle's life cycle, seen above [vi], are clearly numerous and costly, in the economic, energetic, and environmental senses. Table 5 shows the energetic costs in mega joules, as calculated by Gleick and Cooley. For every non-spontaneous process in a plastic bottles' life cycle, energy had to be provided, and in most cases heat was a waste product of these processes.

The third thermodynamic property that needs to be examined is efficiency. Each step also has an efficiency associated with it, none of which is one hundred percent, meaning that for each process involved a fraction of energy is wasted, usually as heat. For example, the efficiency of an internal combustion engine can be calculated thermodynamically, by measuring the amount of wasted heat, or by fuel efficiency, which is measured in units of miles per gallon, but the average car only has an engine efficiency of 18-20%.[x] So for each part of the plastic bottle life cycle that requires transportation, only about 19 percent of the energy put into the system is actually working to move the vehicle. Finally, the topic of entropy must be discussed. Every time work is done on a system, the system becomes more ordered, decreasing entropy. In order to balance this decrease in entropy, something needs to become disordered somewhere else in the system. As mentioned above, heat is often a waste product of work being done on a system, and it can also account for the equalizing of entropy in the system.

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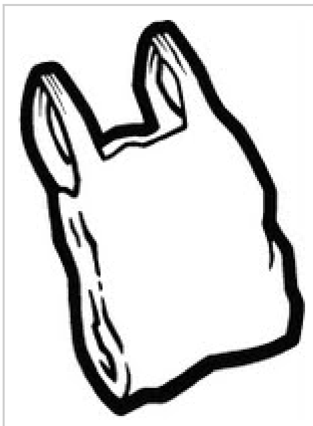
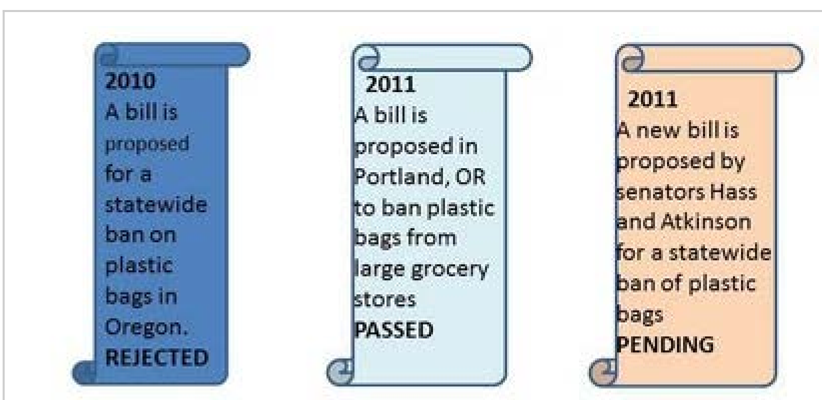
Plastic Bag Controversy



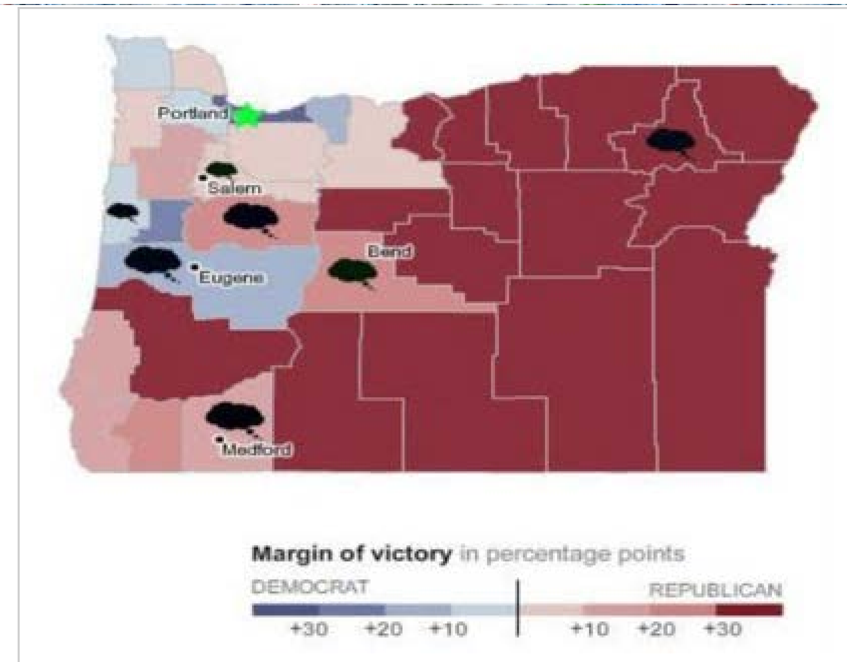
Here's the issue: plastic bags are made from petroleum, a non-renewable resource. More than **1.6 billion gallons of oil** are used each year just for the manufacture of single-use plastic bags. Each plastic bag contains roughly 16 mL of petroleum, a seemingly small amount that adds up very quickly when you consider the fact that 1 million of these bags are used every single minute worldwide. Locally, it is estimated that Oregonians use **1.7 billion single-use plastic bags** each year-that's **444 per person**, per year, and roughly **39,000 in an average lifetime**.

The question is currently under debate is: should single-use high density polyethylene bags be banned from Oregon's grocery stores?

This issue has been through Oregon legislation for two years now, reaching the 75th Legislative Assembly just last year. The Ban the Bag campaign launched by Oregon's chapter of Surfrider, an organization that works to clean Oregon's coasts, failed to motivate legislation to Ban the Bag from Oregon's grocery stores in 2010. Since then, a number of Oregon's cities have begun to think about their own city-wide plastic bag bans, including Portland, who passed a bag ban this year. During the 76th legislative Assembly in January, legislators will vote on Senate Bill 536, a bill which, if passed, would ban single-use plastic bags from Oregon's grocery stores, as well as implement a tax on paper bags, which would still be available for use. The goal of the bill is to encourage the use of reusable bags. Click here to see an inspiring video showing footage of the Legislative Assembly in which Portland banned plastic bags: "444 plastic bags per man, woman, and child, every single year. That is a bad habit worth kicking. Aye!" A concluding quote from Mayor Sam Adams at the Assembly.



To the right is a map of



Oregon, showing the various cities that have been contemplating city-wide bag bans from large grocery stores. Included in this map are Salem, Corvallis, Eugene, Medford, Ashland, Tillamook, La Grande, and Portland, who recently passed a ban on single use bags from all "large" grocery stores. Newport also just passed a city-wide ban on plastic bags.The definition of "large," is delineated by the annual gross income of the store in question.

Below are two videos, both of which demonstrate the public awareness that has stemmed from this controversy. Plastic bag debates and articles are literally in the news every day-it is this type of open consciousness that can lead to large-scale change.

Parody music video illustrating the plastic bag controversy

This parody video was made to "make a dot," meaning the creators made it in order to make their own personal contribution to the world, for an issue that is a global concern.

The video below was made by Oregon's citizens in conjunction with Surfrider, a national group working to decrease pollution along the coasts.

The video raises many important questions, such as what plastic bags are made of, where they end up, and what we should be doing about this issue. It was created to raise support for the statewide ban in 2010, and has continued use in preparation for the next Legislative Assembly.

A video being used by Oregon to create support for the ban

Subpages (2): Glossary of Important Terms Opposing Sides of the Bag Ban

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Opposing Sides of the Bag Ban

FACT: about 1 million plastic bags are used every minute on our globe
FACT: the Guiness Book of World Records named plastic bags "the most ubiquitous consumer item in the world" listed in their Top Records of the Decade.

All in Favor: All those on this side support the ban of HDPE bags in Oregon's grocery stores. Supporters of this position include individual cities and citizens in Oregon, many of Oregon's grocery stores, several Oregon senators, and a major advocacy group called Surfrider. With the sponsorship of two Oregon senators (Hass and Atkinson), Oregon proposed a statewide ban on HDPE checkout bags (Senate Bill 536), which was subsequently rejected by the 75th Oregon Legislative Assembly. A new proposal was submitted in 2011 by the same senators, which proposed a city-wide ban of plastic bags in Portland, which passed and is now under way. Senator Hass has been a major proponent of this controversy, stating during a phone interview that his interest started "just by being in nature and realizing the plastic bags hanging in trees will outlive the trees." Hass sees that Oregon has had a "long legacy of environmental stewardship," and because of this, "we should be the first state in the country to ban the bag." He believes that SB 536 mostly failed on an economic basis, in which the argument consisted of the sentiment that, "Oregon has bigger problems to worry about, and this ban on bags is just going to cost us jobs and money, on the misapprehension that this bill would impose a tax on citizens."

All Opposed: Continued production and supply of single-use high density polyethylene bags. Those in favor of this proposition include chemical companies that create the polymers used in plastic bags (including the American Chemical Society), the companies that use the polymers to make plastic bags such as Hilex Poly, the largest manufacturer of plastic bags in the US. Hilex Poly has started their own campaign: "Bag the Ban", which they are advertising to Oregon through their website. Hilex Poly claims to consumers that the important thing is not to ban bags, but to make recycling programs more effective. Hass agrees: "of course everyone agrees that recycling programs should be more effective, but that isn't going to happen in the near future. Even recycling plants in Oregon support the Ban. Let's focus on what we are capable of." Hilex Poly also proposes that reusable bags are unsanitary, as they can carry bacteria, and that a ban on bags would unemploy many workers in all stages of the industry.

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Fact 1: 1 Greenwire, Environment and Energy Publishing LLC. July 22, 2004.

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Showing **5** files from page Why is waste a problem?.

Subpages (2): From the cradle to the grave Glossary of Important Terms

Materials in Transition

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From the cradle to the grave

In order to make a plastic bag, you must first extract oil. For information on the use of oil in plastic production see Energy Consumption in Plastics Production, under "raw materials." The oil, a complex array of large and small hydrocarbons, must then be distilled into its components, most importantly ethane molecules. Ethane must then be converted into ethylene, its double-bonded alkene form, which then must be polymerized into polyethylene, the major component in high-density polyethylene (HDPE) plastic grocery bags.

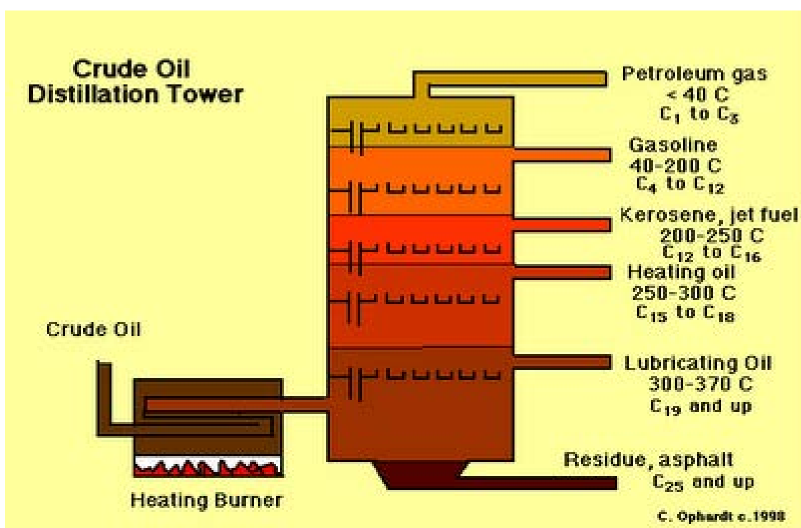
Here it is step-by-step:

Production of Ethylene

Ethylene can be produced either by

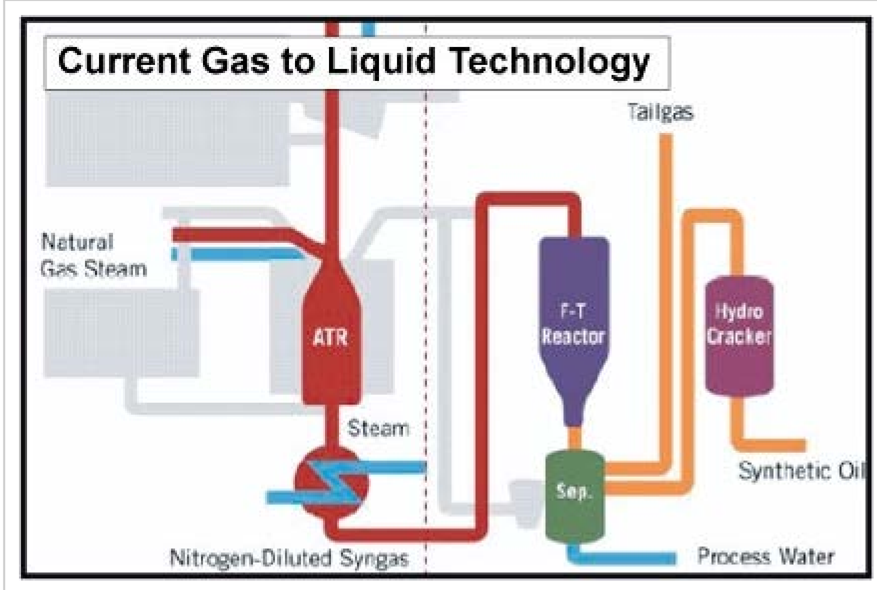
1. Extraction from natural gas using fractional distillation followed by steam cracking (the technique for converting alkanes to alkenes) (750 - 900^{o}C) followed by liquefaction of the gas (-100^{o}C) and then further fractional distillation
OR
2. Extraction from crude oil using fractional distillation followed by steam cracking (750 - 900^{o}C) of the naphtha or gas-oil fractions followed by liquefaction of the gas (-100^{o}C) and then further fractional distillation.

Fractional distillation of oil or natural gas:



The crude oil is fed through a furnace, in which the mixture of hydrocarbons is superheated. Each hydrocarbon has a different boiling point based on their molecular structure. In general, larger molecules (ones with longer carbon chains), boil off at higher temperatures, and thus will be collected during distillation after the temperature at which smaller hydrocarbons begin to boil off. Ethane becomes a gas at less than 40 degrees C (which is typical for hydrocarbons that are one to three carbons in length). The petroleum gas is then collected and cracked.

The



cracking process involves taking the gaseous petroleum and cracking it into smaller molecules of ethane, which can then be converted to ethylene through the use of pressure and steam heat within a reactor. The process requires water, which must be heated through the combustion of natural gas into steam.

The cracking process typically involves endothermic equilibrium reactions such as:

- $C_2H_6(g) \rightleftharpoons C_2H_4(g) + H_2(g)$ $\triangle H = +138$ kJ mol^{-1}
- $C_3H_8(g) \rightleftharpoons C_2H_4(g) + CH_4(g)$ $\triangle H = +81$ kJ mol^{-1}

To maximize the rate of the cracking reactions

- the temperature can be increased so that the gas particles move more quickly and collide more often
- increase the pressure which forces the gas particles closer together and collide more often
- no catalyst is needed to increase the rate of this reaction since the steam provides the required activation energy

To maximize the yield of ethylene, by Le Chetalier's Principle

- increasing the temperature of the reactions favours the formation of products since the reactions are endothermic. So increasing the temperature speeds up the rate of the reaction and increases the yield of ethene.
- a decrease in pressure would favour the the formation of products since there are more gaseous product molecules than there are gaseous reactant molecules. However, a decrease in pressure would slow down the rate of the reaction. For this reason the pressure is kept at or below atmospheric pressure.
- removing the product will favour the formation of more product thereby increasing the yield of product. Equilibrium is therefore never actually achieved.(http://www.ausetute.com.au/ethene.html)

Once ethylene has been yielded, it must be polymerized into polyethylene or HDPE in the case of plastic bags.

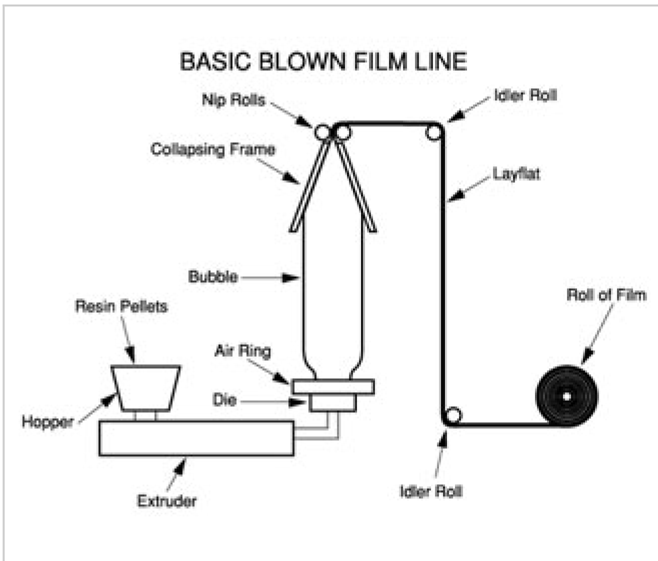
Production of HDPE

1. Production of HDPE by addition polymerization with a supported metal oxide catalyst requires:
   - temperature ~300^{o}C

- 1 atmosphere pressure (101.3kPa)
- aluminium-based metal oxide catalyst (metallocene catalyst)
  The catalyst can be used in a variety of operating modes including fixed-bed, moving-bed, fluid-bed or slurry processes
- The ethylene monomer is fed with a paraffin or cycloparaffin diluting agent.
  After polymerization the polymer (polythene) is recovered by cooling or by solvent evaporation.

2. Production of HDPE by coordination polymerization requires:
   - temperature 50-75^{o}C
   - slight pressure
   - a coordination catalyst is prepared as a colloidal suspension by reacting an aluminium alkyl and titanium chloride ($TiCl_4$) in a solvent such as heptane (C_7H_{16}).
   - The polymer (polythene) forms as a powder or granules which are insoluble in the reaction mixture. When the polymerization is completed, the catalyst is destroyed by adding water or alcohol to the reaction mixture. The polymer (polythene) is then filtered or centrifuged off, washed and dried.(http://www.ausetute.com.au/polythen.html)

Once the HDPE resin is collected, it it used by bag manufacturers such as Hilex Poly to create the plastic bags that you can find in grocery stores. Creating a plastic bag from HDPE requires the use of blown film extrusion.

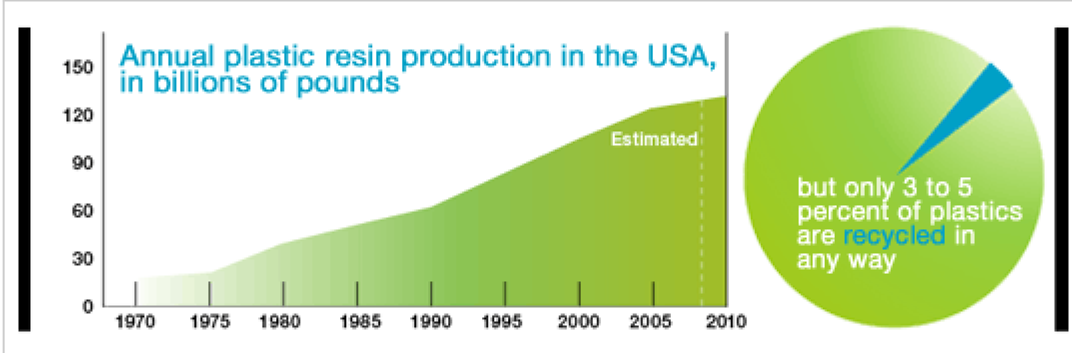


Process Of Blown Film Extrusion

The extrusion of plastic melt is done via an annular slit die, generally vertically, for the formation of a thin walled tube. The introduction of air takes place through a hole present in the die's center for blowing up the tube just like a balloon. The cooling of the hot film is done by the high-speed air ring that blows onto it. This air ring is mounted on the top of die. Then following procedures take place:

- The tube of the film continues its movement upwards (constantly colling) till is is passed via nip rolls. Here, the tube is flattened for the creation of “lay-flat” tube of film. Also known as collapsed tube, this lay-flat tube goes back to the extrusion tower via rollers.
- On the higher output lines, exchange of air (which is available in the bubble) takes place. This is called IBS (Internal Bubble Cooling).
- Then the lay-flat film is kept as it is or its edges are slit off for producing 2 flat film sheets & wound up onto the reels. If kept as it is, the film's tube is created into bags by the process of sealing all across the film's width along with cutting or perforating. This process is carried out at a later stage or in line with the process of blown film.

Plastic production vs. plastic recycling:



It is clear that plastic production has skyrocketed in the past 40 years, and it is also clear that plastics are being treated as disposable, even though they are made out of finite resources. Plastics as a whole have a 3-5% recycling rate worldwide, while plastic bags have only a 1% recycling rate. In order to reduce the negative effects that plastics have on our environment (see Why is waste a problem?), we must not only close the production-recycling loop, but also greatly decrease our consumption.

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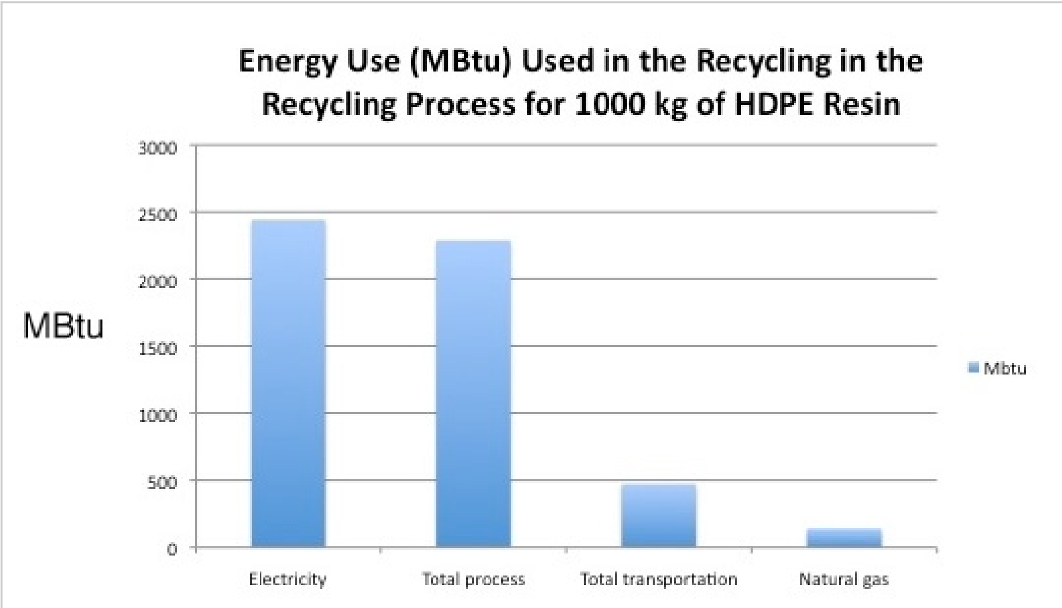
The Energetics of Plastic Bag Recycling

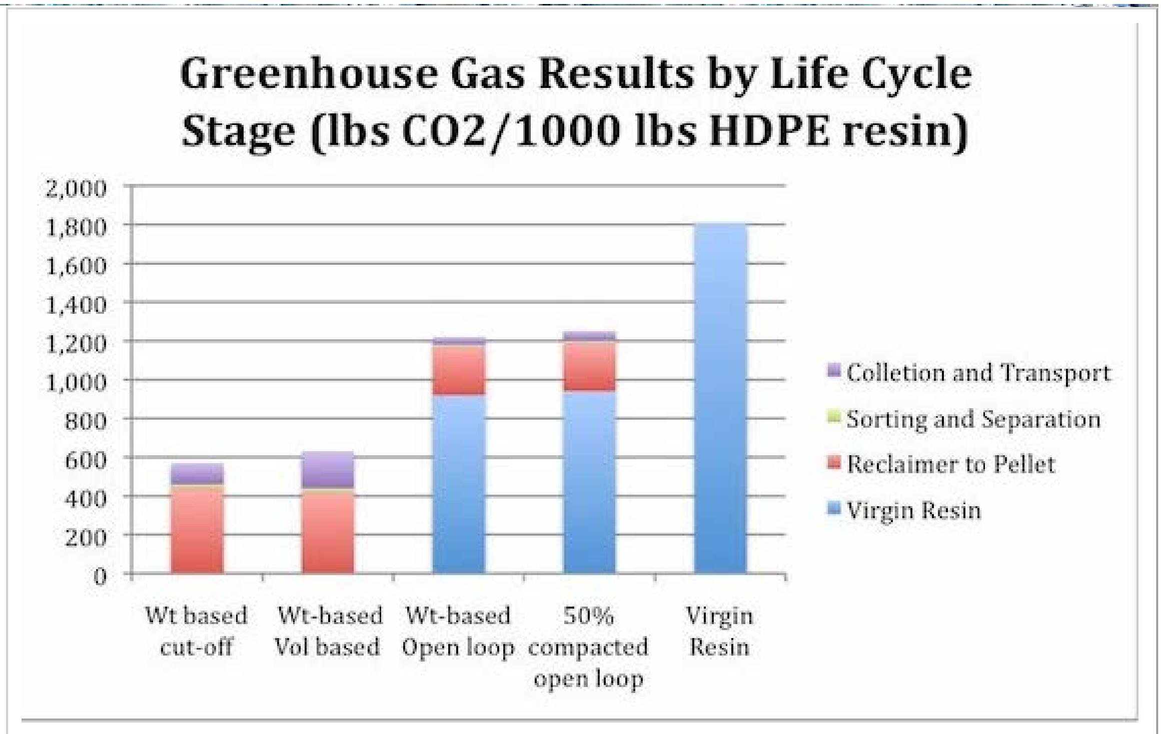
To see the energy costs for making plastic in the US, please see Energy Consumption in Plastics Production, Figure 4: Daily Power in US virgin, recycled, and actual plastics production.



Above is a graph that shows the energy used in the recycling of HDPE products, including plastic bags. As this graph makes evident, the entire process uses 2440 MBtu of energy, mostly in the form of electricity. One of the major issues involved in plastic recycling is the transportation that is necessary to bring the bags to the facilities, which on average is 535 miles. In Eugene, if you bring your plastic bags back to a grocery store, they will be bundled and shipped to another state for processing. Sanipac's distribution center ships the plastic bags that it receives to International Paper, a company that essentially melts the plastic for reuse as plastic lumber, according to the Waste Management Department at the distribution center for Sanipac.

**An important note from Sanipac: plastic bags are not accepted for curbside pickup- instead, bring all plastic bags back to any large grocery store (including Safeway, Market of Choice, Fred Meyer etc), or the Waste Management Center in Eugene, where they will package and ship them off. The fact that many do not know this fact is a testament to the inadequacy of the current plastic bag recycling system.

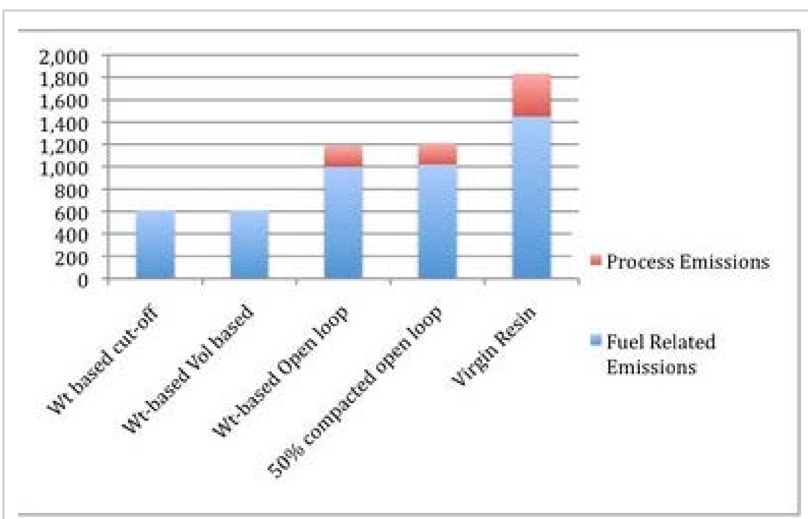
Other than the energetics of recycling, the recycling of HDPE also releases green house gases into the atmosphere, as shown by the graph below, which also compares the gases released by the life cycle of virgin plastic.



It is important to note that the "Wt-based" columns represent the recycling systems which use Waste to Energy mechanisms for plastic disposal (for more information, see Waste to Energy Systems. These systems do not use virgin resins to produce energy, but nonetheless still release green house gases such as methane, nitrous oxides, and sulfur oxides. An "open loop" system, is the one in which we largely have now: plastic is produced, and then it is not 100% reclaimed for reuse, but rather enters the waste stream. The production of virgin plastic by far releases the most environmentally harmful gases, but all open loop systems release nearly as much, mostly in the handling of the virgin resins. The average CO_2 emissions for recycling plastic in an open loop system is roughly 3:1 (2,746 lbs CO_2:1000 lbs HPDE resin).

The graph below compares the fuel emissions and process emissions for creating recylced HDPE pellet from virgin plastic.

Figure: The fuel and process emissions for recycling plastic (lbs CO2/1000 lbs HDPE pellets)



It is important to note that the transportation emission costs related to plastic recycling greatly outweighs the process emissions, which shows that the current recycling system is not functional. If plastic has to be transported over 500 miles in order to be recycled, then in order to make plastic recycling more useful we must alter the system such that recycling is a more local institution. It is counter-intuitive to transport fuel-based plastics in an effort to preserve their reusability by using so much fuel and energy to do so.

Works Cited
All of the above graphs were produced using information collected by the EPA, in a report created for the Plastics Division for the American Chemistry Council.

Franklin Associates. *Life Cycle Inventory of 100% Postconsumer HDPE and PET Recycled Resin From Postconsumer Containers and Packaging*. Rep. no. 36666.00.001.001. American Chemical Council, INC., 19 Jan. 2011. Web. 25 Oct. 2011.
http://plastics.americanchemistry.com/Education-Resources/Publications/Life-Cycle-Inventory-of-Postconsumer-HDPE-and-PET-Recycled-Resin.pdf

Subpages (1): Could it work?

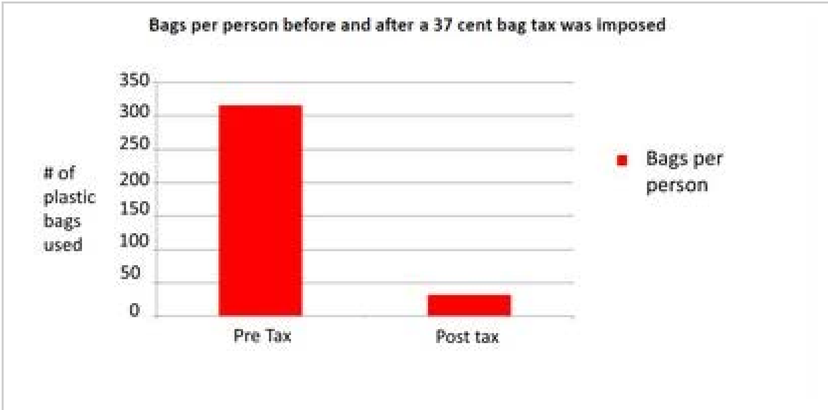
Materials in Transition

Search this site

Plastic Bag Controversy > Opposing Sides of the Bag Ban > Glossary of Important Terms > The Energetics of Plastic Bag Recycling >

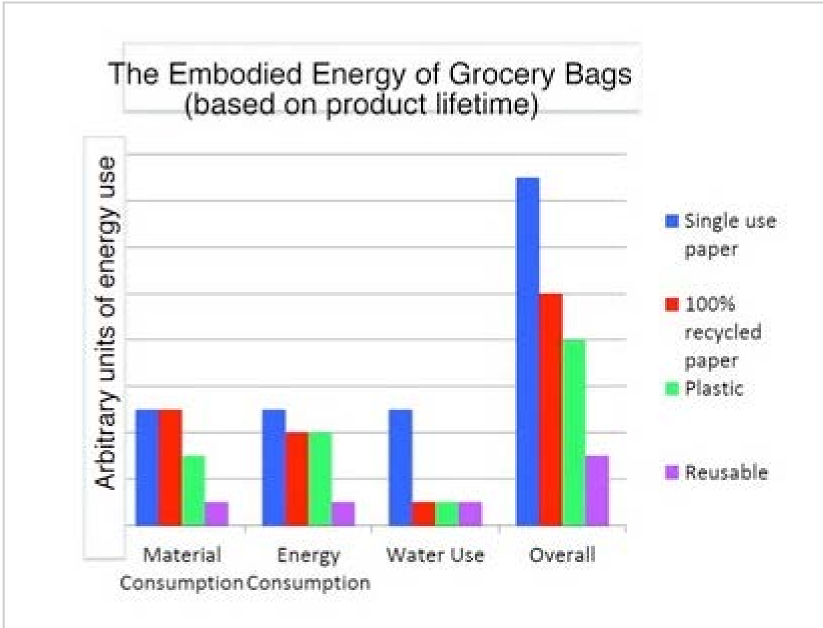
Could it work?

Below is a graph based on the results of a study conducted by the Irish Department of Environment



In 2001 Ireland consumed 1.2 billion plastic bags (328/person in one year). In 2002, they became the first country in the world to place a tax on plastic bags at grocery stores. A plastic bag consumption tax of 37 cents was imposed in 2002, which decreased bag use by 93.5% (to 21 bags per person/year). It also reduced Ireland's oil usage by 18 million liters. A larger scale success story can be found in China, a country with a population of 1,338,299,500 people, where single-use plastic bags have been taxed at grocery stores since 2008. In the year following the tax, an estimated 1.6 million tons of oil were saved, just through this measure, which also saved the country the production of 40 billion plastic bags (according to the University of Gothenburg in Sweden.) There is an important correlation between Ireland and Oregon, in that our consumption rates are strikingly similar (1.7 billion compared to 1.2 billion per year), which shows that there is a very real possibility that an outright ban on plastic bags could reduce our consumption of single-use products. This ban could make a difference. However, there is still the issue of the paper bag. The proposed Senate Bill for a statewide ban will still make paper bags available to consumers, which poses an energetic issue, even if the bags being used are made from 100% recycled materials. The graph below shows the energy used for single use paper,

single use paper that is made from 100% recycled material, single use plastic, and reusable bags. The study was conducted by an Australian



research company called Sustainability Victoria, (the full report can be found here*)* who were hired to compare the energetics of many types of grocery bags in terms of their material and energy consumption, water use, as well as many other components. The study found that paper bags are even less energetically favorable than single-use HDPE plastic bags. The story is similar for the 100% recycled paper bags that will be available to Oregon's shoppers if this bill is passed. It is important to note that reusable "non-woven plastic" bags are the most energetically favorable in every category being studied, including several not presented in this figure including kg CO_2 produced (discussed in The Energetics of Plastic Bag Recycling), litter effecting marine life, and litter in general. While this close study of HDPE bags shows that plastic bags should be banned from Oregon's grocery store, the current bill should be changed to include more incentive for using reusable bags. It is possible that paper bags should be banned as well based on this data. Mark Hass also believes that while individual cities are doing an excellent job of keeping this issue present by considering their own bans, this will most certainly end with a "patchwork of laws and regulations, that in the end will prove to be a muddled solution." Hass, as well as the other supporters of Ban the Bag, are still working towards this goal at a state level, which I believe to be the best solution. ***"Let's focus on what we are capable of." Let's become the first state in the United States to ban single-use plastic bags.*** Click here to sign an online petition to show your support for the state-wide ban!

A special thanks to Senator Mark Hass, who took the time to answer my questions in my writing of this report.

Materials in Transition

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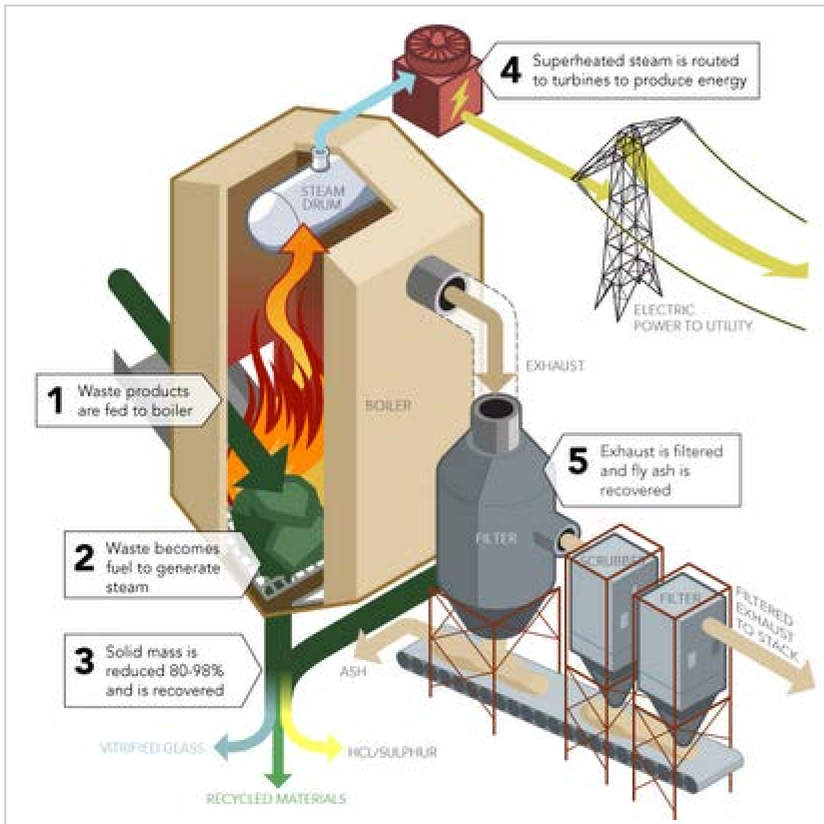
Waste to Energy Systems >

Technology Background

The primary method of energy extraction from waste materials is from the combustion of waste in order to produce steam that spines a turbine in order to produce electricity through a generator,



diagrammed in the figure to the right. Other forms of waste-to-energy plants include melting plastics into crude oil, collection of methane gas from landfills, gasification of waste, and other methods [i]. This website will focus on the use of combustion plants because they are substantially more common today.

For waste combustion, the waste is initially burned by a fire and the heat created is used to drive a boiler that uses steam to drive a turbine[ii]. The work done on the turbine then spins a coiled wire through a large magnet, creating an electrical current that is passed out of the generator and into community power lines[iii]. The figure to the right displays this process from initial waste to combustion to final electricity generation. Much of the heat produced in comubstion is lost, however, especially in systems with minimal insulation in the steam-turbine elements[i]. The efficiency of combustion-driven waste to energy plants is measured through energy output per unit of waste. On average, energy recovery systems can generate 590 kWh per ton of waste[iv]. This number is critical to understanding the energetic comparison of WTE to recycling discussed in the Debate Over WTE page.

[i] "Energy Recovery." *Plastics*. American Chemistry Council, 2011. Web. 10 Oct. 2011. <http://plastics.americanchemistry.com/EnergyRecovery>.

[ii] Rosenthal, Elisabeth."Europe Finds Clean Energy in Trash, but U.S. Lags." *New York Times*. 12 April 2010. Web. 9 Oct. 2011. <http://www.nytimes.com/2010/04/13/science/earth/13trash.html>.

[iii] "The Energy Story - Chapter 6: Turbines, Generators and Power Plants." *Energy Quest Room*. California Energy Commission, 2011. Web. 10 Oct. 2011. <http://www.energyquest.ca.gov/story/chapter06.html>.

[iv] Kaplan, P., Joseph Decarolis, and Susan Thorneloe. "Is It Better to Burn or Bury Waste for Clean Electricity Generation." *Environmental Science & Technology* 43.6 (2009): 1711-717. *Wiley Online*. Web. 9 Oct. 2011.

Diagram source:

"Energy From Waste - Recovery Systems - Services - Pro Enviro Ltd." *Low Carbon Technologies and Skills Consultants - Pro Enviro Ltd*. Pro Enviro. Web. 09 Dec. 2011. <http://www.proenviro.com/UK/services/recovery_systems/energy_from_waste_combustion.htm>.

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The Debate Over WTE

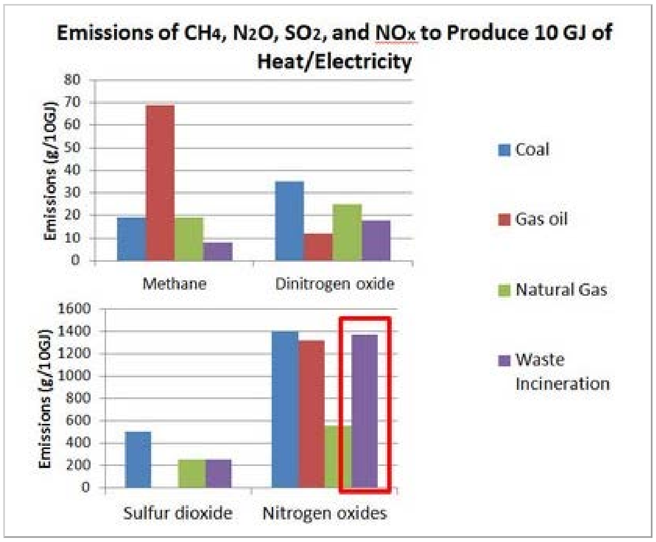
The information below outlines the main topics brought up by both sides of the debate. The comparisons and statistics used largely focus on plastic materials because plastics are one of the most problematic parts of the waste stream due to their inability to biodegrade, the nonrenewable petroleum required for their production, and their high energy cost of production.

Pro H.R. 66: Those in support of H.R. 66 include the U.S. EPA, waste recovery companies including Covanta and Agilyx, the American Chemistry Council, executives at Wheelabrator Technologies, and the Energy Recovery Council. These groups argue that WTE plants produce lower emissions than traditional fuels, reduce reliance on diminishing fossil fuels (for more info visit this site on peak oil), increase profits compared to recycling, inability to recycle many materials, and use a sustainable source of energy as fuel.

Against H.R. 66: Those who oppose H.R. 66 include New York Public Interest Research Group, GrassRoots Recycling Network, the Global Alliance for Incinerator Alternatives, and the Environmental Integrity Project (EIP). Generally these groups assert that energy recovery is only seemingly environmentally friendly because WTE plants still emit numerous pollutants, rely on continued production of waste from often nonrenewable resources, ignore the potential for many items to be recycled, do not save energy compared to recycling, and do not always have higher profits than recycling companies.

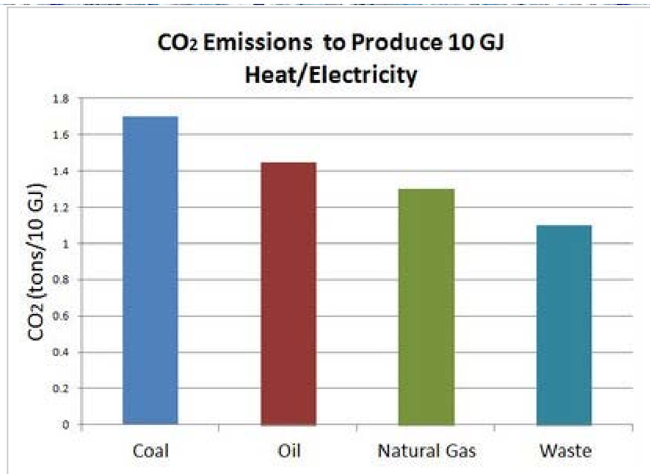
Let's look at what both sides have to say about WTE **emissions**, **renewability**, **financial profits and costs**, **recyclability of waste**, and **energy costs**.

Emissions

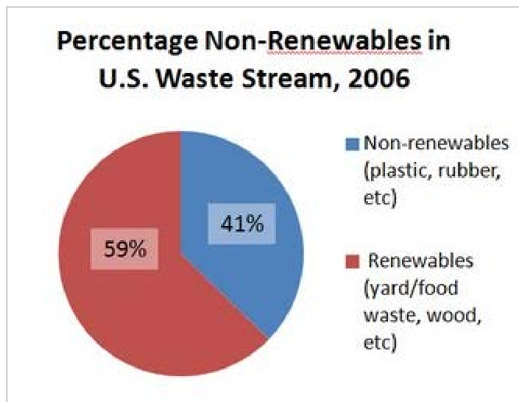


Researchers associated with the EPA and North Carolina State University highlight the efficiency and reduced CO_2 emissions of using waste combustion compared to methane extraction from waste[i]. Additionally, newer WTE plants such as the Covanta Energy plant in northern Massachusetts have reduced their emissions to 80% below the Clean Air Act guidelines[ii]. Combustion WTE plants certainly produce lower CO_2 emissions in comparison to traditional fuel sources, with approximately 2/3 the emissions of coal powered electricity generators as seen in the graph to below. Methane emissions are also reduced by WTE plants, especially compared to gas oil fuel sources. However, emissions of other pollutants, especially nitrogen oxides, by WTE facilities are comparable or higher than those produced by other fossil fuel sources, as shown in the graph to the right [iii].

Main point: WTE is generally a good alternative to traditional fuel sources, but is not an entirely clean energy resource.



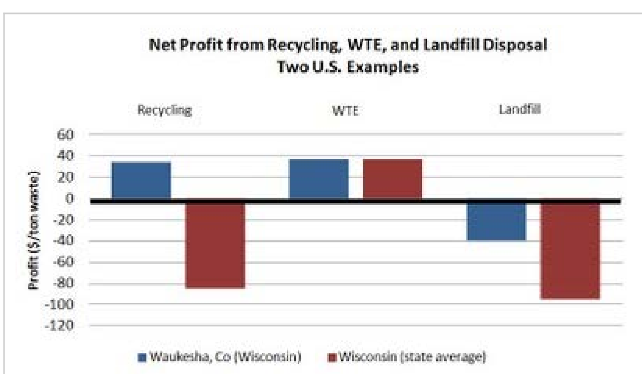
Renewability



The Energy Recovery Council states, “Waste-to-energy is renewable because its fuel source---garbage---is sustainable and non-depletable.”[iv] However, Global Alliance for Incinerator Alternatives, an international lobby against waste incineration, argues that much of the U.S. waste stream comes from nonrenewable resources such as oil[v]. Indeed, **41%** of the U.S. municipal waste stream comes from **non-renewable** materials, including materials such as plastic, which come from limited resources like petroleum[vi].

Main point: Waste is NOT renewable unless we change the contents of our waste stream to consist entirely of products that can be sustainably produced (ie food, yard waste, paper, etc).

Profit comparisons



Many people argue that recycling is too costly in order for it to be a viable alternative to energy recovery, despite the potential environmental benefits. Mayor Bloomberg of New York City, for example, has struggled with supporting investments in recycling programs[i]. Indeed, some regions see net cost (shown as a negative net profit in the graph to the left) of recycling programs, while WTE programs nearly always see a net profit through the money gained in selling electricity. This is the case in the state of Wisconsin as a whole[viii]. However, regions like Waukesha County in Wisconsin see regular net profits from recycling through the selling of recycled materials. The differences between these regions and similar cities across the U.S. lie in the ownership of recycling processing, location of processing plants, and market demand for recycled materials. Thus, moderate changes in recycling infrastructure can indeed lead to profits instead of losses through recycling. Net profits between recycling and WTE are generally comparable, while landfills always show a net cost in every region[ix].

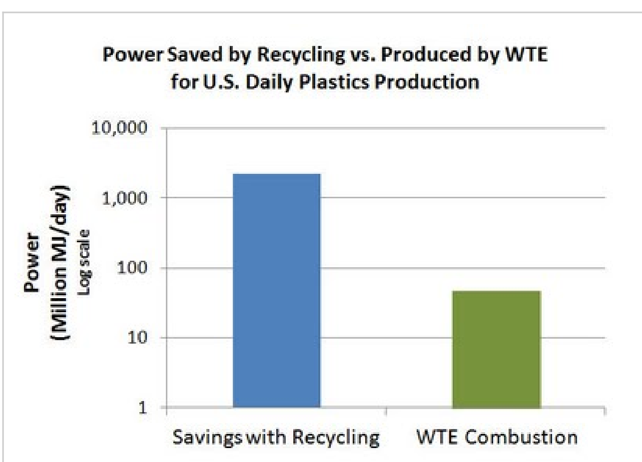
Main point: Monetary cost is not a consistently valid reason to oppose recycling programs in favor of WTE. WTE and recycling are both better financial options compared to landfills, even if recycling has a net cost.

Recyclability of materials

Groups such as the WTE operating company Wheelabrator Technologies see WTE as a valuable method of dealing with waste that cannot be recycled [i]. This is valid in the US today, where only 8% of plastics can be recycled, largely due to the inefficiency of sorting and separating systems[vi]. Under these circumstances, it would be best to send unrecyclable plastics to WTE plants rather than landfills. However, companies such as MBA Polymers are promoting new plastics recycling technologies which could bring recycling rates as high as 100% with energetically efficient systems[xii]. Check out this TED Talk (right) by Mark Biddle to find out more about how he plans to change the nature of plastics recycling [xiii].

Main point: Inability to recycle all materials is a valid argument for keeping WTE plants open today, but is not likely to be a long term concern as new technologies development.

Energy comparisons



GrassRoots Recycling Network argues for recycling as a better method of utilizing the energy contained in waste materials [v]. Though energy recovery by its very name seems to be favorable in terms of potential energy gain, recycling (of plastics specifically) can save more energy than WTE can produce per unit. The figure to the left shows a calculation of potential energy saved if all of the plastic used in the US in one day were to be made from recycled plastics (cost difference between recycled and virgin as discussed on the Energy Consumption of Plastics Production page) and calculation of energy potentially made from energy recovery of that same amount of plastic through WTE combustion. This information displays that plastic recycling saves more energy than could be made by WTE [xv]; [xvi];[xvii]; [xviii];[vi];

[xx];[xxi];[xxii]. The energy potentially saved through plastics recycling is 2.242 billion MJ/day, equivalent to enough energy to power **56,600 homes** for an entire year with the amount gained in one day [xxii].

Main point: Energy saved from recycling exceeds the potential energy production from WTE, even without taking into account the energy saved by not producing more plastic products.

---

[i] Rosenthal, Elisabeth."Europe Finds Clean Energy in Trash, but U.S. Lags." *New York Times*. 12 April 2010. Web. 9 Oct. 2011. <http://www.nytimes.com/2010/04/13/science/earth/13trash.html>.

[ii] LaMonica, Martin. "Waste to Energy: Green or Greenwash? | Green Tech - CNET News." *Technology News - CNET News*. 21 Oct. 2011. Web. 09 Dec. 2011. <http://news.cnet.com/8301-11128_3-20123706-54/waste-to-energy-green-or-greenwash/>.

[iii] "Waste to Energy in Denmark." *Z-mags.com*. 2006. Web. 21 Nov. 2011. <http://viewer.zmags.com/showmag.php?mid=wsdps>.

[iv] "Waste to Energy News." *Energy Recovery Council*. 6 Oct. 2011. Web. 10 Oct. 2011. <http://www.energyrecoverycouncil.org/>.

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[vi] "Municipal Solid Waste in the United States." *EPA.gov*. US Enivronmental Protection Agency, 2009. Web. 20 Nov. 2011. <http://www.epa.gov/epawaste/nonhaz/municipal/pubs/msw2009rpt.pdf>.

[viii] Clement, Douglas. "Recycling— Righteous or Rubbish? - Fedgazette - Publications & Papers." *The Federal Reserve Bank of Minneapolis*. 1 Mar. 2005. Web. 09 Dec. 2011. <http://www.minneapolisfed.org/publications_papers/pub_display.cfm?id=1524>.

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[xiii] "Mike Biddle: We Can Recycle Plastic | Video on TED.com." *TED: Ideas worth Spreading*. Oct. 2011. Web. 09 Dec. 2011. <http://www.ted.com/talks/mike_biddle.html>.

[xv] Gyorki, John R. "Practical Photovoltaic Systems are No Longer Light Years Away." Design World. 19 January 2009. 7 November 2011. <http://www.designworldonline.com/articles/3289/9/Practical-Photovoltaic-Systems-are-No-Longer-Light-Years-Away.aspx

[xvi] Gleick, P. H., and H. S. Cooley. "Energy Implications of Bottled Water." IOPscience::.. Welcome! Environmental Research Letters, 19 Feb. 2009. Web. 06 Nov. 2011. <http://iopscience.iop.org/>.

[xvii] Umberto, Arena, Maria L. Mastellone, and Floriana Perugini. "Life Cycle Assessment of a Plastic Packaging Recycling System." *The International Journal of Life Cycle Assessment* 8.2: 92-98. Web. <http://www.springerlink.com/content/76466372964h1810/>.

[xviii] "Solar Map." *Arizona Solar Center*. 2011. Web. 15 Nov. 2011. <http://www.azsolarcenter.org/images/articles/az/solmap.gif>

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[xxi] "The Agilyx Process." *Agilyx*. 2011. Web. 10 Oct. 2011. http://www.agilyx.com/our-technology/.

[xxii] Kaplan, P., Joseph Decarolis, and Susan Thorneloe. "Is It Better to Burn or Bury Waste for Clean Electricity Generation." *Environmental Science & Technology* 43.6 (2009): 1711-717. *Wiley Online*. Web. 9 Oct. 2011.

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Rosenthal, Elisabeth."Europe Finds Clean Energy in Trash, but U.S. Lags." *New York Times*. 12 April 2010. Web. 9 Oct. 2011. <http://www.nytimes.com/2010/04/13/science/earth/13trash.html>.

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MBA Polymers: Our Company. MBA Polymers, 2011. Web. 10 Oct. 2011. <http://www.mbapolymers.com/home/our-company>.

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Total plastics use in the US: "Municipal Solid Waste in the United States." *EPA.gov*. US Enivronmental Protection Agency, 2009. Web. 20 Nov. 2011. <http://www.epa.gov/epawaste/nonhaz/municipal/pubs/msw2009rpt.pdf>.

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Total solar radiation in US: "Solar Map." *Arizona Solar Center*. 2011. Web. 15 Nov. 2011. <http://www.azsolarcenter.org/images/articles/az/solmap.gif>.

Total landfills by region: "Municipal Solid Waste in the United States." *EPA.gov*. US Enivronmental Protection Agency, 2009. Web. 20 Nov. 2011. <http://www.epa.gov/epawaste/nonhaz/municipal/pubs/msw2009rpt.pdf>.

Total landfill area US: Trzupek, Rich. "Talking Trash: A View From the Cheap Seats." *A View From the Cheap Seats*. 30 July 2008. Web. 20 Nov. 2011. <http://trzupek.wordpress.com/2008/07/30/talking-trash/>.

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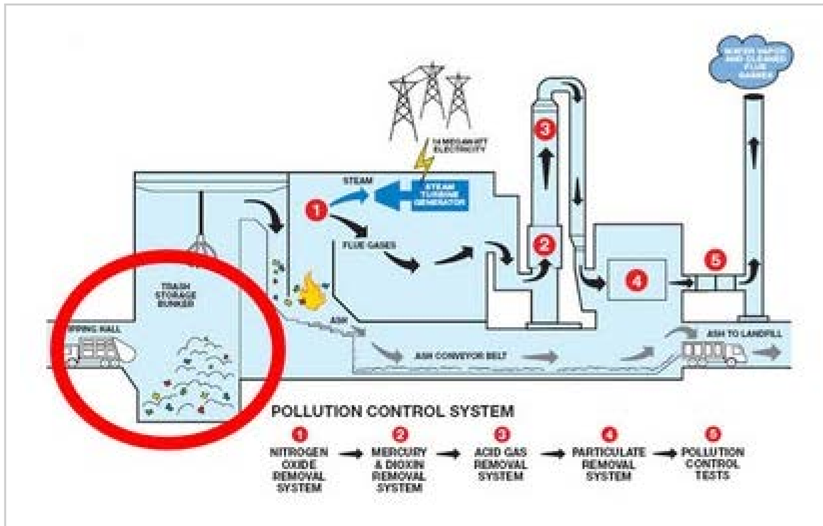
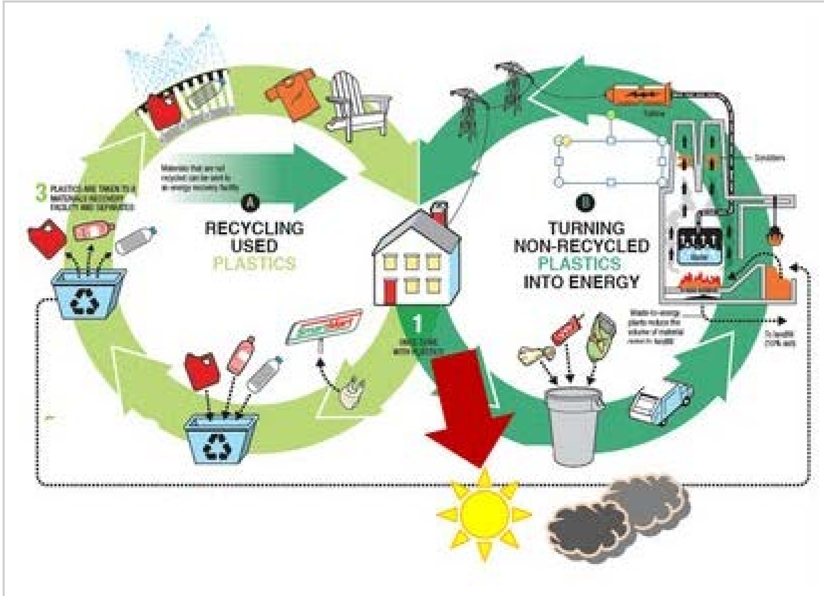
Conclusions



Congress should **vote NO** on house bill 66. WTE plants are a good temporary compliment to deal with current wastes while we work to increase the efficiency and feasibility of large scale recycling, but it is not long term solution that should be invested in today. WTE feedstock is the most significant argument against WTE investment; energy recovery relies on the continued generation of waste as highlighted in the image to the right. This is a problem because this supports an open loop in which we continue to extract wastes from non renewable resources without reusing those materials. Energetically, energy recovery does not reap the maximal stored energy in waste materials, particularly in plastics, compared to the energy saved through plastics recycling.

This pro WTE graphic from the American Chemistry Council (to the left) initially displayed how recycling and waste to energy can complement



one another [i]. However, this graphic incorrectly showed energy recovery from plastics as closed loop. In reality, energy from waste is used to fuel homes and then is lost as heat and produces pollutants, as has been added into the diagram. Only recycling can be truly represented by a closed loop because recycled materials, if processed correctly, can continue to be recycled. Recycling systems must be made more efficient and cost effective before they can be relied on entirely. Thus, governmental funds should be used to support programs and companies, such as MBA Polymers, to increase the efficiency of recycling so that this loop can grow, while the WTE loop diminishes accordingly.

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[i] Diverting Plastics from the Landfill. Plastics Make It Possible. American Chemistry Council, 19 Mar. 2010. Web. 09 Nov. 2011. <http://plasticsmakeitpossible.com/2010/05/plastic-innovations-in-packaging-through-the-decades/>.

Image sources:

WTE Diagram

"Waste-to-Energy Electricity Generation." *Ecomaine*. 2011. Web. 09 Dec. 2011. <http://www.ecomaine.org/electricgen/index.shtm>.

WTE/Recycling Loop

Diverting Plastics from the Landfill. Plastics Make It Possible. American Chemistry Council, 19 Mar. 2010. Web. 09 Nov. 2011. <http://plasticsmakeitpossible.com/2010/05/plastic-innovations-in-packaging-through-the-decades/>.

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Aluminum // Zero Waste

Should the federal government initiate a policy to discourage scrap aluminum from being exported?

Waste is a huge problem in the United States. Even with recycling, incineration and composting initiatives, we are still filling up landfills at a constant rate -- the volume of garbage continues to climb.

One proposed way to close the material use loop is “Zero Waste.” The Zero Waste (ZW) philosophy calls for the reduction (and eventual elimination) of waste and toxics through many steps including product life cycle redesign.[1] This means that ZW supporters would have it that products, and the systems that create them, are designed with extended use and material reuse in mind. With these products, we can reduce and eventually avoid the need for primary production. **Figure 1** on the left demonstrates how ZW regards the different options for waste management.

For the large-scale implementation of ZW, at the federal level for example, buy-in is required from many parties including the federal government, product designers and producers, consumers, and material management. Visit the ZW Alliance website for a full description on how they plan to face many of these obstacles.

Figure 1: Waste Spectrum showing Zero Waste Preferences

On a smaller scale, some great progress is being made. The family in the video to the right, for example, strives to live a ZW lifestyle and their progress is quite impressive. Another interesting example of progress towards ZW is the company TerraCycle, which collects non-recyclable materials and makes them into usable products. On the waste spectrum, TerraCycle's recovery is a great start, but in order for the Zero Waste movement to really take hold, we need to focus on materials that will reduce and eventually eliminate the need for primary production.

Aluminum - A Practical Zero Waste Material

Aluminum is a great material to help Zero Waste become a viable option in America. Its durable, flexible, and lightweight qualities make it an extremely viable replacement for products like plastic packaging containers and heavy steel car parts. Visit Aluminum Leader's website to better understand how many products already depend on the material.

The best part about aluminum is its recycling properties, which are the main reason why the material is such a good candidate for ZW product redesigns. It can hypothetically be recycled an infinite number of times because it retains its structural integrity throughout the recycling process (the hypothetical piece comes from inefficiencies in recycling systems that create non-reusable waste). Recycling aluminum only uses 5% of the energy that primary production consumes. [2]

The process of aluminum production (both primary and secondary) is key to understanding why aluminum is such a valuable resource for the Zero Waste movement. A more detailed description is available on the Energy Consumption of Aluminum Production page, but here is a brief overview: Primary production begins with bauxite, aluminum ore which is gathered through strip mining. Then, the bauxite is refined to create a substance called alumina. Through a process called smelting, aluminum is produced for the alumina.The process, along with secondary production, is visualized in the figure below.

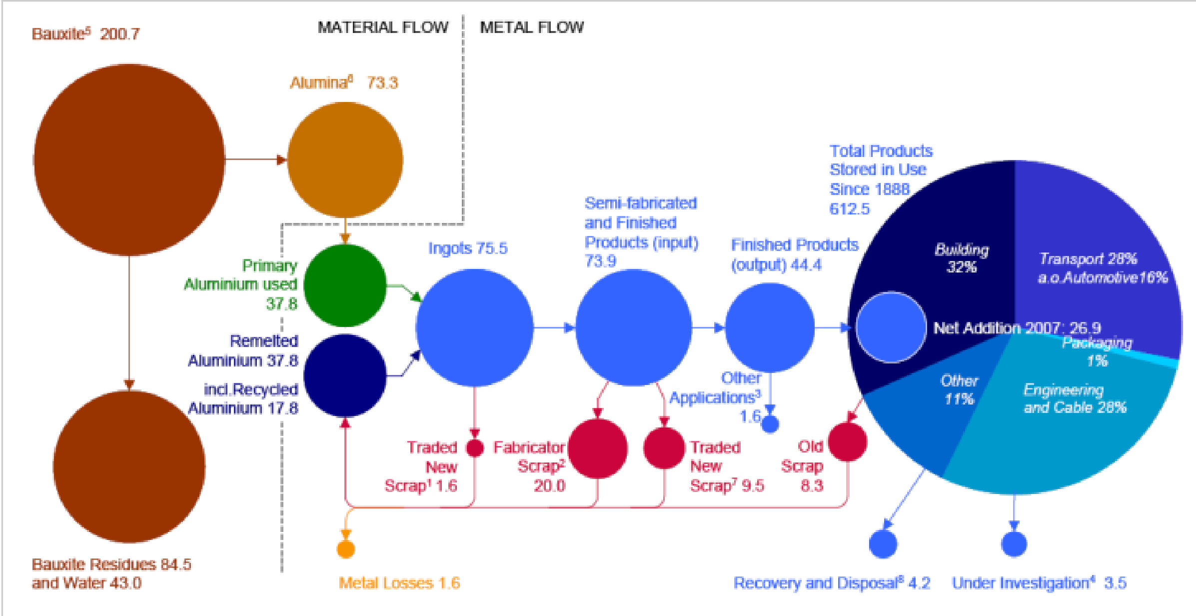

Figure 2: Aluminum Primary and Secondary Production Processes, Source: International Aluminum Institute

In 2007, US primary production of aluminum reached 2,554 thousand metric tons.[3] At the same time, the amount of bauxite produced in the US was not significant enough to measure, according to the USGS.[4] We know that America's bauxite and aluminum production numbers can't be telling the whole story because If we look back to **Figure 2**, we can see that the material volume diminishes as we move from bauxite to primary aluminum. According to the EPA, the general rule is that it takes 4 tons of bauxite to make 2 tons of alumina, which make only 1 ton of aluminum.[5] Aluminum ends up being only one quarter of the weight of its feedstock, the bauxite ore. If America were making aluminum only from domestically produced bauxite, our primary aluminum supply would be almost nothing.

All of this leads to the fact that we are importing a lot of bauxite and alumina into the US every year to meet our current production rate. In 2007, we imported 11,200 thousand tons of bauxite and 2,440 thousand tons of aluminum to reach the production level of 2,554 thousand metric tons. The big feedstock producers are Australia, Brazil and China.[6] Global trade issues aside, the energy and emissions costs from shipping extremely heavy bauxite overseas is enough to make any energy-aware American scream.

What's worse is that once we are done using our aluminum here in America, we ship a lot of it back overseas to be recycled by someone else. Much of it goes to China, strengthening their construction and automotive industries. *New Yorker* journalist John Seabrook put it simply: "In a sense, China's industrial might is being created out of the ruins of our own."[7] This opens up an entirely different set of questions, but is worth mentioning as political and economic relationships between the US and China evolve.

The Real Issue

The main issue is that while aluminum is a great material to support the Zero Waste movement, the American aluminum industry doesn't follow the ZW philosophy – it is an open product loop in which reuse is not the ultimate priority.

Which brings me to the main question: *Should the federal government initiate a policy to discourage scrap aluminum from being exported?* I put the emphasis on exports of aluminum because as exports are limited, we will have to do something with the excess amount of scrap (hopefully recycle it), which will consequently limit our need for exports.

And my answer is yes. The government should help to keep aluminum, with its sustainable and renewable material cycle, in the country. This transition could make a huge dent in global emissions and meet the zero waste standards of reuse.

One way for the government to limit export is with an export tariff. This would mean that all scrap sold to non-US buyers would have an extra fee tacked on to it. In South Africa, secondary aluminum producers are asking the country's Department of Trade and Industry to impose an export tariff on scrap metal. Numerous studies concluded that the policy would be a "local beneficiation of South Africa's resource of scrap, creating jobs, encouraging investments and leading to socioeconomic upliftment."[8]

In America, the money raised from this kind of tariff could be put towards strengthening aluminum recycling infrastructure, so that our facilities could grow as our need to recycle does. Whether it be an export tariff or other incentives for scrap traders to sell domestically, the government actively work to localize our aluminum industry.

Works Cited

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[3] "ITP Aluminum: Aluminum Industry Profile." *Energy Efficiency and Renewable Energy*. U.S. Department of Energy, 1 Feb. 2011. Web. 09 Dec. 2011. <http://www1.eere.energy.gov/industry/aluminum/profile.html>.

[4] "Bauxite and Alumina." *USGS Minerals Information*. U.S. Geological Survey, Jan. 2011. Web. 9 Dec. 2011. <http://minerals.usgs.gov/minerals/pubs/commodity/bauxite/mcs-2011-bauxi.pdf>.

[5] "Energy Trends in Selected Manufacturing Sectors: Opportunities and Challenges for Environmentally Preferable Energy Outcomes." *Sector-Based Information and Resources*. U.S. Environmental Protection Agency, Mar. 2007. Web. <www.epa.gov/sectors/pdf/energy/report.pdf>.

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[7] Seabrook, John. "American Scrap: An Old-School Industry Globalizes." *The New Yorker*. 14 Jan. 2008. Web. 09 Dec. 2011. <http://www.booknoise.net/johnseabrook/stories/culture/scrap/scrap.pdf>.

[8] Odendaal, Natasha. "Call to Impose an Export Tariff on Scrap Metal." *Engineering News*. 24 Sept. 2010. Web. 09 Dec. 2011. <http://www.engineeringnews.co.za/article/the-decline-of-the-secondary-aluminium-industry-2010-09-24>.

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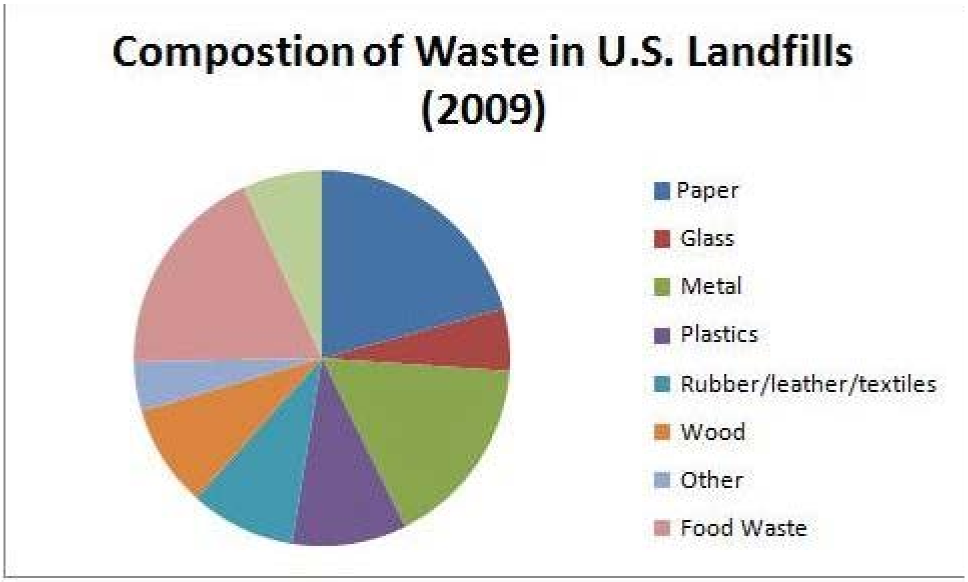
Final Thoughts

Through an

investigation of plastic and aluminum production and recycling, waste to energy methods, plastic bottle use, and plastic bag use, we have come to the conclusion that the citizens and government of the United States need to work together to reduce primary material production and use.

Additionally, we must increase recycling and reuse in order to close the production and consumption loop of potentially hazardous and energy-consuming products, primarily plastic and metals. Through these methods, we can best retain the embodied energy of waste materials and avoid excessive use of non-renewable resources.

Image source:
"Reduce Reuse Recycle." *Ecycler*. 3 Sept. 2010. Web. 9 Dec. 2011. <http://blog.ecycler.com/2010/09/03/reduce-reuse-recycle/>.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