2014

The global economic effects of going green with a focus on industry creation, transformation, and destruction

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Degree Type
Open Access Senior Honors Thesis

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Economics

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Keywords
environment, renewable energy, waste management, international

Subject Categories
Economics

THE GLOBAL ECONOMIC EFFECTS OF GOING GREEN WITH A FOCUS ON INDUSTRY CREATION, TRANSFORMATION, AND DESTRUCTION

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A Senior Thesis Submitted to the

Eastern Michigan University

Honors College

in Partial Fulfillment of the Requirements for Graduation

with Honors in April 2014 (International Business/Economics)

Approved at Ypsilanti, Michigan, on this date February 19, 2014

Introduction

Concern for the environment has been growing in recent decades under the title of *Going Green*, bringing about social, political, and economic changes including the development of new industries, the restructuring of old industries, and the creation of new areas for potential conflict between nations. Some more specific examples of these effects are the development and growth of renewable energy sources and technology, modifications to the waste management industry, the decline of the incandescent light bulb, the questionable future of the coal burning power plant, and the international waste trade. Within the renewable energy industry there is intense international competition for market share and resource access. International tensions within this industry are evidenced by the multiple complaints to the World Trade Organization (WTO) by the United States about China's alleged dumping practices (Carbaugh and St. Brown, 2012). The escalation of these trade disputes illustrates that nations have strong commitments to renewable energy industries. The second industry that has been significantly altered due to environmental concerns is the waste management industry. According to the U.S. Environmental Protection Agency (EPA), the U.S. generated approximately 250 million tons of solid municipal waste in 2011, with a recycling rate of 37.8% equivalent to only 87 million tons of waste. In contrast, according to the European Commission statistics, Germany created 363.5 million tons in 2010. Waste is a very large, and potentially lucrative industry; wealthy nations have been paying developing nations with lower environmental protection standards to import waste products that would be even more expensive to dispose of domestically since the 1980s (McKee, 1996)[1]. *Going Green* has also led to industry destruction in the incandescent light bulb industry and a contraction in the growth rate of coal as a primary energy source. These changes have been brought on by technological advancements intended to lower environmental impact. For instance, fluorescent light bulbs are more energy efficient than their

[1] McKee cites Pletka, D. 1988, "Developing nations as dump sites", Insight, Vol. 4 No. 33, 15 August, p. 31.

incandescent predecessors and the declining cost of wind-generated and solar-generated energy technologies makes coal obsolete. How integrated are these new *green* technologies into their respective industries and how has the integration rate grown? How have the national governments of the countries examined reacted to the new demand for environmental culpability, and therefore what have they done to support and promote *Going Green* domestically?

To answer these questions this paper analyze employment, production, government spending, and international trade in four key industries: renewable energy (both renewable energy technology manufacturing and energy production), waste management, incandescent light bulbs, and provide an outlook for coal burning power plants; for four different countries: the United States, China, Brazil, and Germany. The countries chosen have very different perspectives on environmental policy and cover the spectrum of economic development: industrialized markets, emerging markets, and developing markets. These topics will be analyzed for each country individually on the basis of their integration and utilization rates of modern green technology within their economies. The strength of their impact will be evaluated on the basis of their environmental and economic impacts, such as effects on greenhouse gas emissions, contamination prevention, in combination with the effects on government spending, international trade, and job creation internally and globally. This topic is significant because it measures the level of economic integration of Green industries throughout 4 major world economies. The utilization rates of environmentally conscious technologies and industry processes show a level of development beyond GDP and other conventional economic indicators.

The paper will begin by discussing the green industries. First, there will be a section on the global renewable energy industry, followed by the individual country analyses using implementation rate within national energy production, renewable energy technology production, exports/imports of technology and energy, and employment. The section will then be conclude by a comparison of the renewable energy industries within the four countries. The sources being referenced will be academic journals, governmental and independent organization statistical reports, governmental production reports, and previous research on the topic to provide projected data and alternative viewpoints. The data will be followed by a discussion of what the implications are for the results presented.

The next green industry to be presented will be the waste management industry. This section will also have descriptions of the different methods of waste management and their respective environmental impacts. Following that will be the data on the integration of new technologies, government spending, and production/revenue, and job creation. The data will be collected using the same sources as listed above. The data will be followed by a comparison of the waste management industries for each country and a discussion of what the implications are for the results presented.

After the green industries are presented this paper will discuss one declining industry, the incandescent light bulb industry, and one potentially declining industry, coal burning power plants. This paper will present data showing how these industries have declined in recent years on a global level. These last two topics and their implications will transition into a brief discussion of international environmental agencies and their activities.

Lastly, this paper will present conclusions about what the information discussed signifies for the global environment and economy, then also present the recommendations and projections of the author.

Definitions[2]

Going Green is defined as using the most advanced technology available to minimize the negative human impact on the environment in the forms of deforestation, greenhouse gas emissions, natural resource depletion, and contamination from leachate and other waste products.

Renewable energy is defined as energy that can be derived from non-exhaustible resources, examples include, but are not limited to, solar photovoltaic (PV) energy, solar thermal, wind, hydroelectric, and geothermal.

Solar Energy comes from radiation emitted by the sun, it can be used to heat water or can be captured and turned into electricity through the use of photovoltaic (PV) cells.

Wind Energy refers to the electricity produced through wind turbines from the natural kinetic energy of wind.

Waste management is the process in which a country handles its refuse. This includes landfill management, recycling programs, exportation, and combustion. This paper will not differentiate between national and private waste management agencies, since the purpose of this paper is to address the industry as a whole.

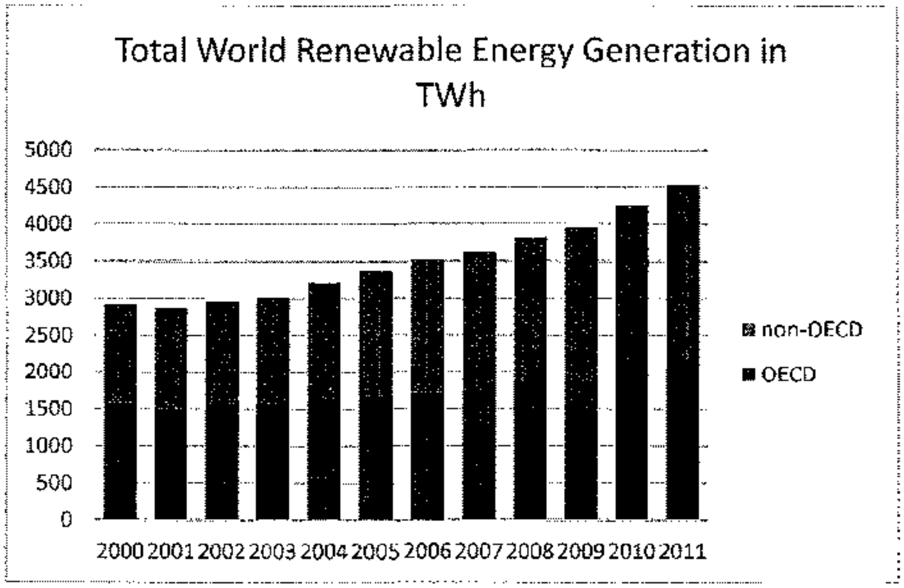
Municipal Solid Waste (MSW) can be either biodegradable or non-biodegradable, and it is non-hazardous waste generated from everyday life: households, industry, hospitals and other service industries

[2] All definitions were taken from the *OECD/IEA Renewable Energy Market and Policy Trends* 2004.

Renewable Energy Use

Global Overview

In recent decades a significant emphasis has been put on reducing dependence on fossil fuels as an energy source for two reasons: CO^2 emissions reduction and conservation of a limited resource. Renewable sources of energy include wind, solar thermal and photovoltaic (PV), hydroelectric, geothermal, and biomass which can be wood or certain kinds of solid waste. Though coal remains the world's leading source of energy (IEA, 2013), the share of renewable sources in energy production has been gradually increasing[3]. With the increased international focus on carbon emissions and air pollution, developing nations have come to realize the importance of sustainable clean energy production. In fact, the majority of renewable energy generation in 2011 came from non-OECD countries, 2412TWh versus 2126TWh from OECD nations (IEA, 2013). However, almost half of the non-OECD renewable energy generated came from China, which had just over 1034TWh by itself. To give additional perspective, in 2011 energy from renewable sources constituted approximately 19% of total consumed energy globally (REN21, 2013).



This increase in implementation of renewable sources within the overall global energy industry can be attributed to the increase in investment in renewable energy sources since 2005. According to Sahu et al. between 2005 and 2011 there was an increase in global investments in biofuel, solar, and wind equal

[3] Data for the graph was taken from the International Energy Agency (2013), Tracking Clean Energy Progress 2013, OECD/IEA, Paris. http://www.iea.org/etp/tracking/

to $207 billion (2013). For OECD countries specifically the annual amount of money invested in increasing renewable energy capacity has more than doubled since 2001, from $112.5 billion to $274.2 billion in 2012, with the largest amount going towards solar energy in 2012 (IEA, 2013). Though, investment in research and development as a share of total public spending for all OECD countries in 2011 made up a scant 4% (IEA, 2013). According to the Renewable Energy Policy Network, there are four areas under which renewable sources could replace fossil fuel and nuclear based fuels: energy creation, heating and cooling, fuels for the transportation industry, and energy creation for rural residents without access to grid services (REN21, 2013). The high potential for renewable energy makes investment in research and development vital in order for these technologies to achieve their full potential and maximize their benefits globally.

This section analyzes the domestic renewable energy markets of China, Brazil, the United States, and Germany with regard to the implementation of renewable energy technologies, their integration rate in final energy consumption, the use of government programs to support/promote those industries, and the impact of renewable energy technology manufacturing.

China

China's rapid economic growth in recent decades has created an almost equally large increase in their demand for energy. According to Kat Cheung in her 2011 working paper titled, "*Integration of Renewables: Status and Challenges in China*," the total amount of energy consumed by China increased 6% between 2008 and 2009 and has more than tripled since the year 2000. Cheung also states that China's primary source of energy is coal, which provides approximately 80% of their total energy supply (Cheung, 2011). However, China has recently been trying to mitigate its dependence on fossil fuels and has been investing in renewable sources of energy, particularly wind in recent years. In February of 2005 the Standing Committee of the National People's Congress published the *Renewable Energy Law* (REL) which then became effective on January 1st, 2006 (Schuman and Lin, 2012)[4]. According to Schuman and Lin, the REL had many purposes: promotion of development and utilization of renewable energy sources, create an increase in the total energy supply, improve the structure of the internal energy industry, make the energy supply more secure and stable, protection of the environment, and achievement of "economically and socially sustainable development" (2012).

While this legislation has lofty goals and good intentions, its implementation has been slow and somewhat ineffective. As of 2010, China has a total installed renewable energy capacity, including hydroelectric sources, of 26% of its total installed capacity (Sahu et al, 2013). Though the amount of energy supplied from non-hydro renewable sources has almost doubled every year since the enactment of the REL, it still accounts for less than 2% of China's total energy supply: wind power accounts for 0.7%, biomass accounts for 0.6%, and solar accounts for such a small percentage of the total that it's not even given (Cheung, 2011). When the mature hydroelectric industry in China is included in the total amount of renewable energy actually generated the percentage increases to 17% of total generated energy in 2009 (Cheung, 2011). However this share increased to 18% in 2010 with a share of 9% of total energy consumed (Sahu et al, 2013). While hydroelectric power sources are renewable sources of energy, their impact on the environment potentially has an equal to greater negative effect than fossil fuel use when one takes into account land necessary for reservoirs, and lost ecological diversity as well as emissions of greenhouse gasses.

China now has the largest installed capacity for wind generated energy in the world (Schuman and Lin, 2012; Liu and Goldstein, 2013) with a potential to generate 103.36 GW of power (Liu and Goldstein, 2013) which is still only 1.8% of its total energy capacity (Cheung, 2011). From roughly 47 GW of grid

[4] Schuman and Lin obtained their information on this legislation from:
National Peple's Congress (NPC), 2005. The Renewable Energy Law od the People's Republic of China (Original 2005 Version), available online in Chinese at new.xinhuanet.com/energy/2008-06/18/content_8392646.htm, and in English at www.npc.gov.cn/englishnpc/Special/CombatingClimateChange/2009-08/25/content_1515301.htm.

connected wind-generated energy capacity, in 2011 China only produced 74TWh of electricity (Schuman and Lin, 2012). This is roughly a 22% capacity factor, which means this is 22% of the total potential capacity, if the wind producing generators were to run at full capacity (Schuman and Lin, 2012). The main obstacle keeping China from achieving their full wind-powered potential at this point in time is their rush for implementation without adequate infrastructure preparation. For instance, according to the 2005 REL, companies operating China's power grids are required to purchase all energy supplied by renewable sources in their districts (Schuman and Lin, 2012). The truth is that it simply didn't happen and enforcement of this provision was never strict due to the concerns of the grid operators that the inconsistency of the wind-generated power would destabilize the grid (Schuman and Lin, 2012). In 2010 there were 80 instances of wind farms suddenly going off-line causing major grid disruptions, in 2011 there were 163 occurrences before the end September (Schuman and Lin, 2012)[5]. In July of 2011 the Chinese government took action to mitigate the stability problems its wind farms had been having by mandating that all turbines be retrofitted with the Low Voltage Ride Through (LVRT) technology, a requirement that had already been in place for on-the-grid turbines in the United States and Germany (Schuman and Lin, 2012). This technology allows the turbines to remain on-line during periods of low voltage which would otherwise have caused disturbances in the grid. However, this does not solve all the problems related with connecting the energy generating wind farms with the grid system. According to Sahu et al, the wind farms in China are located in areas that do not have high electrical capacity infrastructures, and therefore the Chinese electrical grid cannot support the influx of wind generated energy (2013). Because of these obstacles in implementing the REL, China revisited the law in 2009 and amended it in certain ways; one amendment was to the mandatory purchase clause. In 2009 the law was changed so that grid operators were only required to purchase energy from renewable sources that met

[5] Schuman and Lin obtained their data from: State Electricity Regulatory Commission, 2011. Wind Power Safety Regulatory Report. November, 2011.

"certain technical requirements for connection," to be established by the State Council standardization body (Schuman and Lin, 2012). This amendment made the wind-power generators equally responsible for the stability of the grid as the grid operators themselves, and provided them incentives to make their units more reliable.

The way China has financed its massive wind farm expansion is partially through feed-in tariffs, which were also used in part in Germany, and a national surcharge on electricity use (Schuman and Lin, 2012). However, the surcharge levied on the population has proven to be a slippery slope, starting at .001RMB/kWh for commercial and industrial users, .004RMB/kWh for residential users; in 2006 the surcharge for commercial and industrial consumers increased to .002RMB/kWh, while the charge for residential customers stayed constant; then in 2009 it increased again for commercial and industrial consumers to .004RMB/kWh; the most recent increase at the end of 2011 was for both commercial/industrial and residential users making the surcharge now .008RMB/kWh (Schuman and Lin, 2012)[6]. Though, as technology improves, increasing the reliability of non-hydro sources of renewable energy, the amount of financial support that the Chinese government has to provide its wind farms may actually decrease, as they become more competitive with traditional sources of power.

Another important factor of China's renewable energy industry is the amount of manufacturing it provides. For instance, China produces approximately half of the world's supply of completed solar photovoltaic (PV) panels (Liu and Goldstein, 2013). The majority of which are exported to other countries in the world, like the U.S. and Germany who have significantly higher rates of solar PV usage. This creates a large source of income for Chinese manufacturers which in turn creates jobs for Chinese citizens, and a significant boost for the Chinese economy. A similar occurrence is happening in the wind turbine manufacturing industry. In the early 2000s the world's most prominent wind turbine manufacturers were

[6] Schuman and Lin cite: Bloomberg New Energy Finance, 2012b. Will China be Able to Afford its Renewable Energy Incentives? May 11, 2012.

based in Europe and the U.S. (Liu and Goldstein, 2013). However, the expansion route China's wind turbine industry has taken is markedly different from that of its solar PV industry. China's internal demand for wind energy has been the driving factor behind its wind turbine manufacturing, which has only in recent years been strong enough to enter the global market, though not quite strong enough to completely knock out the top competitors from Europe and U.S. (Liu and Goldstein, 2013). These industries in 2007 employed approximately 1 million people according to an interview that Worldwatch Institute did with Li Junfeng, Deputy Director General of the Energy Research Institute of the National Development and Reform Commission in Beijing, and General Secretary of the Chinese Renewable Energy Industries Association (*Jobs in Renewable Energy Expanding*).

Brazil

The Brazilian approach to renewable energy has had a much different focus than the Chinese approach. For instance, Brazil has put a much heavier emphasis on biofuel use within their automotive market, requiring that all gasoline be at least 25% anhydrous alcohol, most often from ethanol generated from sugarcane (Pereira et al, 2012). In fact, vehicles powered by biofuel in Brazil outnumber vehicles powered by gasoline and almost all new cars in Brazil have flex fuel engines (Pereira et al, 2012; Filho and Horridge, 2013). During the time of the great oil crisis of the 1970s, the Brazilian government enacted a policy called the Brazilian Ethanol Program, or in Proácool in Portuguese. This law required mixing gasoline with between 1.1% and 25% ethanol for over 10 million automobiles which reduced the amount of foreign oil Brazil had to import by approximately 550 million barrels saving them about $11.5 billion (Pereira et al, 2012). Brazil is actually second only to the U.S. in world ethanol production, the U.S. makes up 49.9% of the world market, producing 50.4 billion liters in 2012, and Brazil makes up 32.5%, producing 21.6 billion liters in 2012 (Pereira et al, 2012; REN21, 2013).

Though the use of biofuels in flex fuel motor vehicles is an effective means of reducing CO_2 emissions, the problem presented in Brazil is whether or not Brazil can produce enough ethanol to meet domestic and export demands without encroaching on the Amazon rainforest. According to Pereira et al, Brazil can do just this, by making use of other arable land, thereby reducing even further the already few negative environmental side effects associated with the production of ethanol (2012)[7], unlike the American corn based equivalent, which requires more land and more fossil fuels to create the same amount of ethanol (*The Economist*, 2012). Supporting his assertion, the Brazilian government has recently passed laws intended to limit and restrict Amazonian deforestation (Filho and Horridge, 2014). However, according to Filho and Horridge, tracking land use change is difficult due in part to the semantics of the Brazilian Agriculture Census, which groups Amazonian rainforest and other natural forests, urban areas, lakes, and roads as simply "Unused" land (2013). However, Filho and Horridge also go on to say that since urban areas, lakes, and roads "are expected to change much less" than natural forests, therefore decreases in "Unused land" can be attributed to decreases in natural forest (2013). They also note, however, that when there is a decrease in "Unused" land and an increase in "Crop" land there is no way of knowing which crop is being expanded, and therefore calculating the exact impact of ethanol production expansion on deforestation is very difficult (Filho and Horridge, 2013). Filho and Horridge designed a model to estimate the effect of an expansion in ethanol production on land use change in Brazil and concluded that there would be a decline in "Unsued" land, natural forests, however there would be a larger decline in pasture land (2013). They conclude that deforestation can be minimized through this use of pasture land and increases in productivity, thereby minimizing the negative environmental effects associated with ethanol production. Gregory Manuel, the International Energy Coordinator for the U.S. State Department, confirms that due to the climate of the rainforest, which is unsuitable for sugarcane cultivation, the likelihood of ethanol production causing Amazonian deforestation is unlikely (Ethanol and Biodiesel News, 2007).

[7] Such negative side effects are mostly associated with the burning of fossil fuels and emission of greenhouse gasses associated with the cultivation process of sugarcane.

In addition to Brazil's ethanol production and use, in 2009 approximately 80% of their electricity came from renewable sources, between the domestic hydroelectricity and other renewable sources and imported electricity from renewables (Pereira et al, 2012). The most prevalent source of renewable energy in Brazil is their mature hydroelectricity market; in fact, Brazil ranks second only to China in total energy produced from hydroelectric sources and contributed 8.5% of the world's hydroelectric energy in 2012 (REN21, 2013). Brazil has over 400 large and medium scale hydroelectric plants that produced approximately 441TWh of energy in 2012 (REN21, 2013), on average accounting for approximately 70% of the country's total electricity (Pereira et al, 2012). However, in recent years Brazil has been investing in alternatives to hydro-generated electricity to make supplement their main source of electricity during the yearly dry season (Filgueiras and Silva, 2003), and to account for their increased demand for electricity. According to Pereira et al, 12 million Brazilian residents gained access to electricity between 2005 and 2009 (2012). Solar PV and wind-generated technologies have been on the rise in Brazil. In 2010 Brazil's total installed solar PV capacity was 20MWp, most of which was installed as part of a government program called the Program for Energy Development of States and Municipalities or PRODEEM, initiated in 1994 with over $37.25 million being used to fund approximately 8956 renewable energy projects (Pereira et al, 2012).

In addition to the use of solar PV in Brazil, massive wind farm projects have been investigated for the northeast region near Brazil's Sao Francisco River (Filgueiras and Silva, 2003). According to Filgueiras and Silva this area has the greatest potential for wind power in Brazil and the potential to have an addition positive environmental impact in that it will provide much needed relief to the water system of the Sao Francisco River since the windiest time of the year coincides with the rivers' driest (2003). According to the Global Wind Energy Council (GWEC), Brazil had a total installed wind-generated capacity of 2,508MW at the end of 2012, almost double what it was in 2011 at 1,431MW. The expansion of the Brazilian wind-generated energy industry has been facilitated by certain actions of the Brazilian government. For instance, the government reorganized their energy sector into three agencies: the National Electrical Energy Agency (ANEEL), the National Operator System (ONS), and the Wholesale Market of Energy (MAE) (Filgueiras and Silva, 2003). The majority of Brazilian energy generation systems are still state owned, though there are also some thermal-generation and wind-generation facilities that are privately owned, drawing in foreign investments and learning opportunities for Brazilian industries (Filgueiras and Silva, 2003).

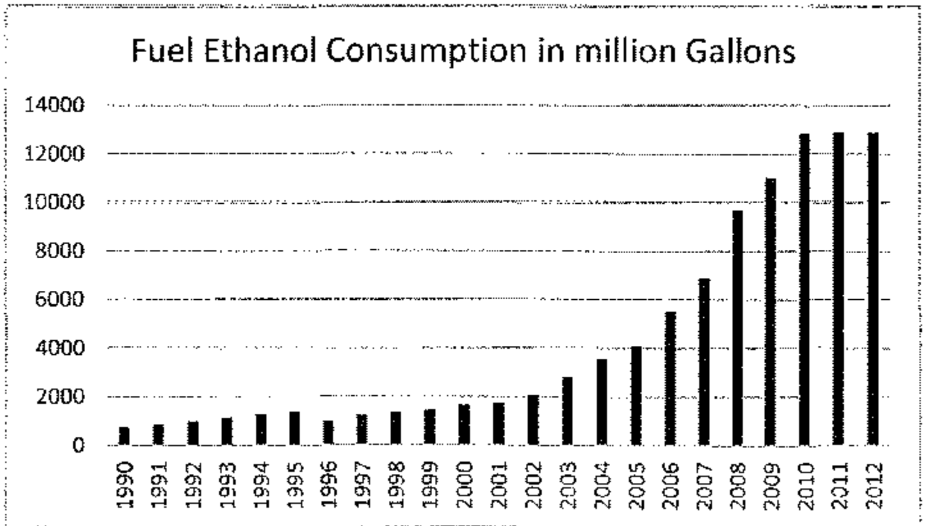
In recent years many wind turbine manufacturing facilities have begun to open in Brazil to feed the new demand for alternative energy sources. One such company is Wobben Wind Power based in Sorocaba, a Brazilian subsidiary of the German company Enercon (Filgueiras and Silva, 2003). There is another manufacturing unit in Ceara that, until 2004, only made rotors for wind turbines and currently produces approximately 300 turbines a year, most of them intended for export to Europe after first meeting the combined internal demand and demand from the rest of South America (Filgueiras and Silva, 2003). Other examples of foreign investment in Brazil's wind industry are Enerbrasil a subsidiary of Iberdrola of Spain, Electricite of France, and another German company Fhurlander (Filgueiras and Silva, 2003). However, foreign investors are not the only ones taking advantage of the expanding investment opportunity; CL Participacoes is Brazilian group that also manufactures wind turbines in Brazil (Filgueiras and Silva, 2003). According to Simas and Pacca there were almost 12 jobs created for megawatt produced by wind turbines in Brazil in 2011 (2013). The areas included in these jobs are in construction of manufacturing facilities and wind farms themselves, manufacturing employees, and operation and maintenance. Simas and Pacca also estimate that 90,000 jobs could be created every year in Brazil between 2012 and 2016 because of the expanding wind industry (2013).

The United States

In the mature energy market of the United States the majority of the energy is generated by coal, renewable sources only make up approximately 12% of total energy generation, according to the U.S.

Energy Information Administration in March of 2013. Of that 12%, more than half comes from hydroelectric plants, 28% from wind-generation, biomass sources like wood and waste make up a combined 12% of total renewable sources, and geothermal and solar sources are a combined 4%. According to the Interstate Renewable Energy Council, only 13 U.S. states lack either Renewable Portfolio Standards or Renewable Portfolio Goals, as of early 2013. Renewable Portfolio Standards and Goals require state energy providers to obtain certain amounts of energy from renewable sources. Wind-generated energy has experienced the largest growth rate in the U.S. In the last decade, it increased from only about 6 billion KWh in 2000 to over 140 billion in 2012, though it is not evenly distributed over the entire country (EIA, 2013). According to the Global Wind Energy Council, despite this lack of national cohesion, the U.S. is second only to China in total installed capacity for wind-generated energy, making up about 21.2% of the total world share (2013).

As was stated in the previous section on Brazil, the U.S. is the world's largest producer of ethanol, though made from corn and not sugarcane. Almost all gasoline in the U.S. now has an ethanol content per volume of 10% (EIA, 2013), which is considerably less than the Brazilian minimum of 25%. Though, 15%



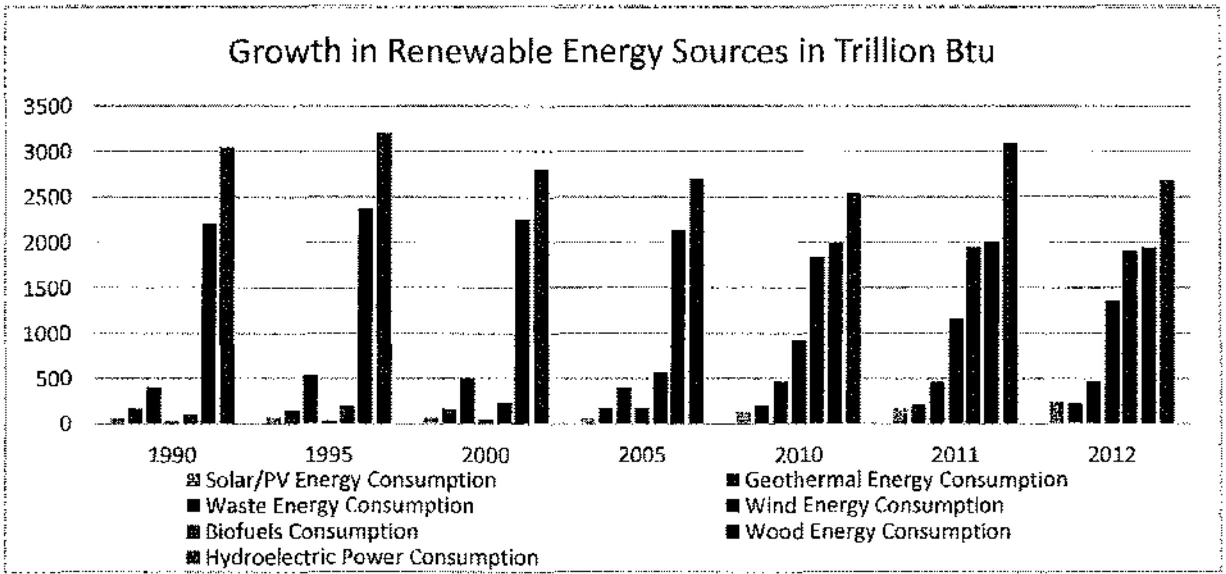
ethanol by volume has been approved by the Environmental Protection Agency, concerns over how ethanol will effect engines keeps the mixture below this amount for the majority of the U.S. (Healey, 2012). According to Healey, ethanol can cause corrosion in engines due to the fact that alcohol attracts moisture (2012), concerns like these keep the integration of ethanol into American gasoline low. Though the Department of Energy estimates that the U.S. could see gasoline with

30% ethanol by volume by 2030 (2013). According to the Energy Information Administration (EIA) the American ethanol export industry experienced significant growth of 200% in 2011, due to increased export markets and a poor Brazilian sugarcane crop (2012). Despite the recent growth, the U.S. ethanol producers also suffered a minor set-back recently, when the tariffs and tax cuts that had been working in their favor were allowed to expire (*The Economist*, 2012), meaning that American and Brazilian ethanol producers are now competing at market price.

National incentive programs supporting renewable sources of energy have not been consistently implemented or supported in the U.S. There was a large initial push during the oil crisis of the 1970s, which spurred Germany in the direction of renewables as well, during which time the U.S. created the Department of Energy, and increased government spending on research and development of renewables from $15.4 million in 1975 to $542 in 1980 (Laird and Stefes, 2009)[8]. The U.S. government also initiated tax incentive programs in 1970 to encourage the expansion of large turbine wind farms and solar energy generation, mostly solar heat and water heating systems, in personal households and small businesses (Laird and Stefes, 2009). Unfortunately the wind industry suffered from then unresolved technical problems, which caused the U.S. wind turbine industry to fall behind that international contemporaries (Laird and Stefes, 2009). However, in recent years wind energy has been the most quickly expanding renewable energy source in the U.S. (Ferrell and DeVuyst, 2013). The expansion of the wind energy industry in the U.S. started in the 1990s due to deregulation of the energy industry (Ferrel and DeVuyst, 2013). The Department of Energy estimates that wind generated power could supply 20% of the U.S. electrical demand by 2030 (Ferrell and DeVuyst, 2013). However, that would require an installed capacity of more than 300,000MW (Ferrell and DeVuyst, 2013), and current installed capacity is roughly just 39,135MW (EIA, 2011). Though, the EIA states that there are planned expansions of the wind generated

[8] These amounts are in current dollars, (Laird and Stefes, 2009).

capacity of 15,043MW for before 2015 (2011). President Obama's administration has set an integration goal of clean energy into the total energy supply of 80% by 2035 (Ferrel and DeVuyst, 2013), providing an opportunity for wind generated energy production to continue expanding.



Despite the failure of the federal government to provide renewable energy programs or incentives, individual states have established programs to support the use of renewable energy in their regions. However, not all states have stated goals for renewable energy integration into the grid, and some are pushing renewable energy much harder than others. For instance, Washington and California are the two leading states in regards to renewable energy production and use in the U.S. According to the U.S. EIA, Washington produced 74.905GWh in 2010, more than half of which came from conventional hydroelectric sources, and California produced 58.881GWh, only 16.4% of which came from conventional hydroelectricity. Both states have several incentive plans for encouraging renewable energy use, as well as their own Renewable Portfolio Goals and Standards.

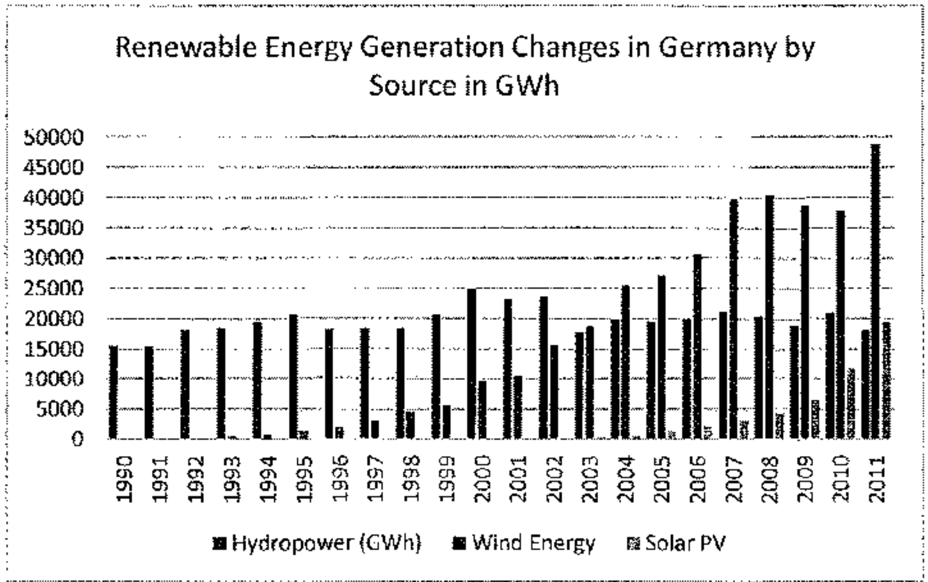
Germany

According to Laird and Stefes, the U.S. and Germany started their renewable energy initiatives around the same time and in similar ways, however when the U.S. stopped supporting the renewables industry, Germany continued to forge ahead (2009). There have been several factors that have contributed to the divergence in actions taken, where Germany has kept renewable energy sources as a priority and the U.S. has let renewables fall lower on its list. One driving force behind the advancement of renewable energy sources in Germany is their Green party, which was founded in the 1980s and gradually gained momentum in the decades following[9]. It now has 68 elected members within the German parliament, the largest number of representatives from an environmental party in the world[10]. It comes as no great surprise, then, that Germany has one of the highest integration rates of renewable energy into their national energy supply, and is Europe's largest producer of non-hydro renewable energy (Eurostat Commission, 2013).

Germany has been increasing the use of renewables within their total energy supply for many years. Since 2004 the share of renewables in their total energy consumption has more than doubled, from 5.2% in 2004 to 12.3% at the end of 2011 (Euro Stat, 2013). That percent includes the amount of electricity and heat generated from renewables, and the amount of fuel from renewable sources consumed. According to the Euro Stat Commission, Germany's production of energy from renewable resources grew at an average annual rate of 13.7% between 2000 and 2010, a clear illustration of the success of the policies that Germany has enacted (2013). The vast majority of German renewable energy (including heat) in 2010 came from biomass and waste, which accounted for 78.7% of their total renewable energy production (Euro Stat, 2012). Wind energy made up for just below 10% in 2010, solar 4.4%, geothermal accounted for 1.6%, and surprisingly hydroelectric generation only accounted for 5.4%, less than what was provided by wind generation (Euro Stat, 2012). According to the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (Bürominísterium für Umwelt, Naturschutz, und Reaktorsicherheit, shortened BMU), renewable energy sources provided 20.3% of the electricity

[9] According to the official Green Party website: http://www.gruene-bundestag.de/service-navigation/english_ID_2000025.html
[10] According to the official Green Party website.

consumer in Germany in 2011, 11% of total heat supplied, and only 5.5% of the total fuel consumed (Böhme, 2012). The trend in Germany is that energy generation is gradually moving away from conventional sources, like hydroelectricity. According to Dieter Böhme at the BMU, the amount of electricity generated by hydro plants in Germany in 1990 was 15,580GWh, this number gradually increased over a period of five years to 20,747GWh, and then declined to just above 18,300GWh where it held roughly constant for three years before increasing again, then decreasing (2012). This fluctuation left the amount of hydro-generated electricity in 2011 at 18,074GWh, an amount lower than what it was in 1996 by 300GWh (Böhme, 2012). Whereas wind generated electricity has experienced a consistent and almost constant growth since 1990, and now provides more than twice as much electricity as the mature hydro-generated systems (Böhme, 2012). Even the solar PVs provide more electricity in Germany than do their hydroelectric plants at 19,340GWh vs 18,074 GWh for 2011 (Böhme, 2012). The target they have set for renewable energy integration into total energy consumption is 35% by 2020 (Böhme, 2012).



While the Germans have been very successful at implementing and integrating their renewable energy sources into their total energy consumption, it has not come without a cost. The Renewable Energy Law (Erneuerbare Energie Gesetz, EEG), initiated in 2000 and revised in 2004 and 2009, accounts for approximately €0.05/kWh of the €0.25/kWh that German households are charged; that cost also accounts for electricity tax, sales tax, costs for production, distribution, and transport, the latter of which makes up the largest portion (Böhme, 2012).

The increased use of renewable energy sources in Germany has led to a 138% increase in employment in this area since 2004 (Böhme, 2012). There are approximately 378,000 people employed in Germany in their renewable energy sector, both directly and indirectly, though there was a shift from employment in solar PV toward wind generation in 2012 due to a loss of 23000 jobs and an addition of 17000, respectively (REN21, 2013). The two largest areas of employment in the German renewable energy sector in 2011 were in the solar energy industry and biomass industry, providing 32.8% and 32.6% of the total respectively (Böhme, 2012). The large number of jobs provided by the solar industry in 2011 coincides with the large amount of investment in construction of solar PV installations in 2011 which was €15,000 million, roughly $20,054 million (using the 2011 average exchange rate posted on IRS website). While Germany's biomass industry, combined heat and electricity, made the most money in 2011 within the renewable energy sector, making €6,500 million ($8,690 million) in revenues (Böhme, 2012).

The steps the German government has taken to get its national energy supply more sustainable throughout the years has not always been as consistent and steady as the recent growth in renewables would imply. For Germany it began during the global oil crisis of 1973, when the German government increased federal funding for research and development for new domestic energy sources (Laird and Stefes, 2009; Wüstenhagen and Bilharz, 2006). Though, at this time the majority of the funding went into nuclear and coal sources, and not renewables (Laird and Stefes, 2009). In 1989 the German government introduced two plans to promote the expansion of wind-generated and solar PV sources, a wind production incentive that guaranteed investors €0.03/kWh and a subsidy for solar PV panels that would cover 70% of the installation costs, which lasted from 1991 until 1995 (Laird and Stefes, 2009; Wüstenhagen and Bilharz, 2006). Also in the 1990s Germany introduced the feed-in tariff system, which China has modified and implemented more recently, and created the BMU (Büroministerium für Umwelt, Naturschutz, und Reaktorsicherheit) (Laird and Stefes, 2009). The German feed-in tariff law required grid operators to purchase energy from renewable sources at rates that were between 65-90% of the average rate charged to end consumers for solar and wind generated energy, and 80% for small hydro-, gases produced from waste materials, and biomass generated (Laird and Stefes, 2009; Wüstenhagen and Bilharz, 2006). According to Laird and Stefes, this feed-in tariff initially benefitted small hydro plants and medium sized wind farms, but when used in conjunction with the production incentive already implemented for wind-generated energy, Germany experienced a large increase in its wind-generation capacity from 68MW in 1990 to more than 6000MW in 2000 (2009). Then in 2000 the coalition government between the Social Democratic party and the Green Party drafted and passed the Renewable Energy Law (EEG) (Laird and Stefes, 2009). The EEG was partially a revision to the feed-in tariff law to make it more predictable for investors. One way they did this was to change the compensation rates of the feed-in tariff from percentages of the average end user rate to a fixed rate that would be consistent for 20 years (Laird and St , 2009). Though there is still opposition to the expansion of renewable energy industries in Germany, mostly from the coal industry which is still very strong in Germany and provides approximately one third of their energy in 2011 (Euro Stat, 2013), their trend of increasing use of renewable sources of energy is not likely to slow as they move ahead with their integration goals for the future.

China, Brazil, U.S., Germany Comparison

Between these four countries the biggest surprises came from the developing nations. Though China cannot fully utilize the total installed capacity for wind power that they have, they have do have it. As technology improves in the future, and their grid system also improves, China will likely become the world's leader in green energy. However, Brazil is also using a surprising amount of renewable energy, though it is from mature technology in the hydro-electric market. I was surprised at the small percentage of total energy consumption renewables contributed in Germany, just 12.3% in 2011, roughly the same as the U.S. Though, Germany does utilize significantly more modern renewables in comparison to the other countries, which all rely heavily on hydro-electric sources for the bulk of their renewable energy. Hydro-generated energy, however, is not considered as green an energy source as wind, solar, or geothermal due to the negative environmental impacts it can have: greenhouse gas emissions, loss of land and biodiversity, and potential negative impacts on aquatic ecosystems. I had expected the share of energy produced by coal in Germany to much lower than it is in reality, approximately 37%[11] in 2011 (Euro Stat, 2013). However, their use of coal and its derivatives as a source of energy has been declining since 2004 (Euro Stat, 2013) (graph presented below in the section on Coal Burning Power Plants). While in the U.S. coal contributes the lion's share of the energy consumed. Although individual states have started initiatives to increase renewables' of energy consumption, without an overall national plan to organize and guide them, significant improvements seem unlikely in the near future.

Waste Management Industry Changes

Global Overview

"I think the economic logic behind dumping a load of toxic waste in the lowest wage country is impeccable and we should face up to that . . . I've always thought that under-populated countries in Africa are vastly under-polluted," said Lawrence Summers, who was then chief economist for the World Bank, in a memo that was reprinted in *The Economist* in 1992. Municipal solid waste (MSW) and hazardous waste is traded between nations on a massive scale, and has become a multi-million dollar industry. In 1988 Guinea-Bissau signed a contract with the U.S. and some European countries to store millions of tons of waste for an estimated $600million. However, the country was persuaded by its neighbors to withdraw from the deal (McKee, 1996).

[11] Total energy consumed from hard coal and derivatives divided by total energy consumed.

There are two general hypotheses discussed by economists in regards to the movement of wastes between nations: 1) the pollution haven hypothesis, which states that industries will move production to lesser developed nations because the costs of treating and disposing of the hazardous waste generated during the production process will be cheaper; and 2) the waste haven hypothesis that states that richer countries with high waste storage costs and higher environmentally conscious citizens will export their waste, both hazardous and non-hazardous, to countries with less stringent environmental regulations. According to Jen Baggs, evidence for the pollution haven hypothesis has been inconsistent with regards to high toxic waste producing industries, using evidence from the years between 1989 and 1997 (Baggs, 2009). However, in 2007 a total of 191 million tons of waste were traded globally, this represents a 67% growth in total weight of waste traded per year over 5 a year period (Kellenberg, 2012). According to Kellenberg's study on effects of environmental regulation and amount of wastes imported, a 1% decrease in environmental regulation stringency relative to the trading partner leads to a .32% increase in total waste imported into that country (2012). According to Kellenberg's environmental regulation stringency index[12], the average developing nation has an index rating 39% lower than that of the average developed nation (2012). Policy makers have finally begun to see the international waste trade as a threat to the global environment and have begun to try to restrict the transnational trade in waste, beginning with the Basel Convention of 1989.

[12] Kellenberg's environmental regulation stringency index "...is constructed using data from the 2003–2004 Global Competitiveness Report. The report is based on survey responses from 7741 company executives across 102 countries (which account for 97.8% of the world's GDP). The environmental regulation index used in this paper is constructed using data from five of the survey questions in the report. Company executives in each country are asked to rank the stringency of the country's air, water, chemical, and toxic waste regulations relative to other countries in the world. In addition, they are asked a question on how well the country enforces its environmental regulations...with answers based on a 1–7 scale. The country level environmental regulation index is calculated as the sum of the mean of the five answers reported for each country. The scale of the index ranges from 0 to 35 with Germany having the highest observed environmental regulation index of 32.5 and Guatemala and Paraguay having the lowest ranking at 11.5." (2012).

The Basel Convention was initiated by the United Nations Environment Program (UNEP) in 1981 after evidence was found that developed nations had been exporting and storing hazardous wastes in countries in Africa, Eastern Europe, and other nations in developing world where environmental regulations were less strict making storage and disposal of such waste products less expensive. The three main goals of the Convention were to reduce the amount of hazardous waste generated and its toxicity, to have it disposed of as close to the source of generation as possible, and to minimize the movement of hazardous waste (Baggs, 2009). According to the Convention's official website[13], the UNEP drafted the resolution in March 1989 and it was adopted later that month. The Convention and 8 resolutions for its implementation were signed by 53 nations and the European Economic Community (EEC). The United States signed the treaty during its initial adoption, but did not ratify it and still has not ratified it. Germany signed and ratified the treaty with the declaration that the government of Germany did not recognize, under Article 4 paragraph 12 of the Convention, any obligation to notify a country that hazardous waste is being transported through their borders as was in accordance with the "right of innocent passage" established in international law. By 2008 170 countries had signed the convention, though not all of them have ratified it domestically yet (Baggs, 2009). Some challenges left unresolved by the Basel Convention are the fact that it relies on the member countries to self-report on the hazardousness of the waste there are exporting, which allows signatories to circumvent the convention by not reporting some forms of waste that are themselves not hazardous but contain hazardous components, for instance electronic wastes that contain heavy metals (Kellenberg, 2012).

Though international trade of all kinds of wastes is a large environmental and ethical problem; it is not the only problem the waste management industry is facing. Poor countries progressing in their

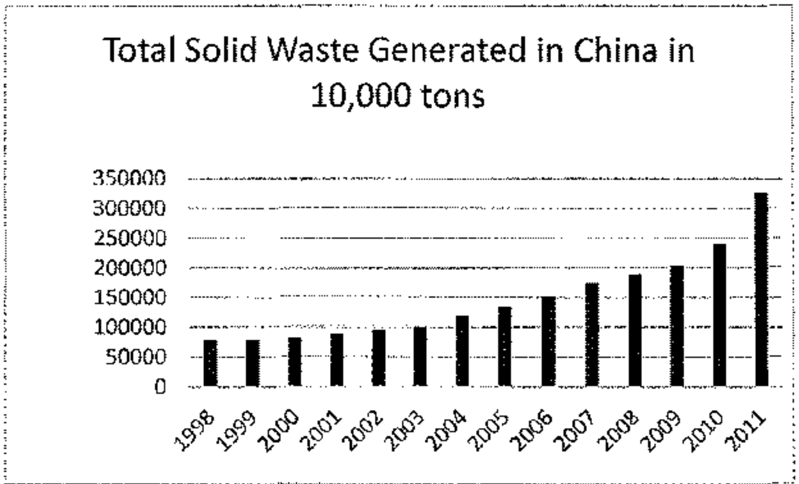
[13] Basel Convention official website:
http://www.basel.int/Home/tabid/2202/mctl/ViewDetails/EventModID/8295/EventID/443/xmid/8052/Default.aspx

development and urbanization create more waste themselves, and need to develop environmentally and economically sound means of recycling and disposing of their waste. According to Nikolas Themelis (2009), worldwide waste production should double by 2030, with the majority of that production coming from the developing world.

The rest of this section details the approaches to waste management and trade for the four countries observed in this paper: China, Brazil, the United States, and Germany.

China

The rapid economic and population growth that China has experienced in recent decades has been accompanied by an increase in the amount of garbage. Between 1976 and 2006 the amount of waste discarded increased by 7.1% yearly (Chen, 2010). China, as of 2004, is the world's largest total waste producer, combining both MSW and industrial waste, surpassing the even the U.S. (Chen, 2010, Dorn, 2010). In fact, 660 cities in China account for 7.5% of the world's total municipal solid waste (MSW) production (Dorn, 2010). In 2004 China produced 190 million tons of municipal solid waste (Chen, 2010)[14]. This increase in waste produced has led the Chinese government to reform their waste disposal methods and to invest more money into cleaner waste treatment processes. In 1996, the Chinese government passed a law titled the Law for the Prevention of Environmental Pollution from Solid Waste, which assigns legal responsibilities in case of an accident, establishes measures of care and storage that will be taken in handling the waste, and sets up the management,

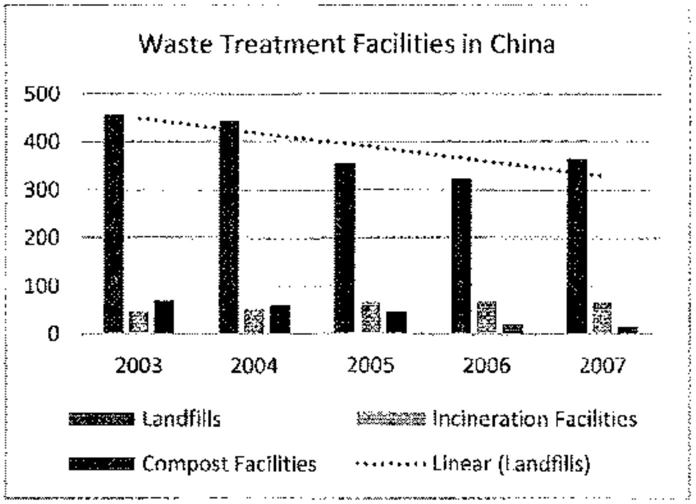


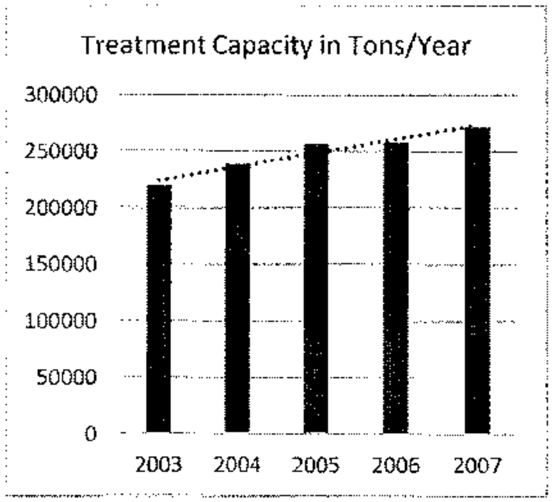
[14] Official Chinese government statistics of total MSW generated are only for municipalities, and do not include rural populations which account for 54% of the total Chinese population, approximately 721 million people, do actual MSW amounts are higher (Dorn, 2010).

supervisions, and administration of waste handling (Chen, 2010). The law was amended in 2004 to increase producer responsibility of the unnecessary materials used in end consumer goods, also called extended producer responsibility (Chen, 2010). This law makes the producer responsible for the waste generated by their products throughout the lifetime of the product, a view held in Germany as well as throughout Europe and recently Brazil as well, though not in the United States. Despite their efforts, clean waste disposal was still an issue in 2006 when only 53% of the waste that generated was disposed of in way that would be classified as safe by the Chinese State Environmental Protection Association (SEPA), which changed to the Ministry of Environmental Protection in 1998 (Chen, 2010). China's vast rural population is partially to blame for the low safe disposal rate of MSW. In 2008 the amount of rural-generated MSW was estimated to be between 40-70 million tons, which was disposed of in uncovered "unsecured" pits (Dorn, 2010). Despite the fact that municipal agencies in China achieved a safe disposal rate of approximately 73.5%, of which 82% was sent to landfills, 15% was incinerated, and 3% was composted (Dorn, 2010). According to Dorn in a 2008 "best case scenario" the Chinese would be able to achieve just 52% safe disposal rate in 2008, which would actually be a decrease from two years prior, due to the large amounts of rural waste not officially collected, treated, and disposed (2010).

There are two government agencies that were created under the Law for the Prevention of Environmental Pollution by Solid Waste that monitor the cleanliness of the waste industry in China: the Ministry of Construction (MOC) and the Ministry of Environmental Protection (MOEP) (Chen, 2010). The MOC handles the collection, cleaning, transportation, storage, and final disposal of MSW in China, whereas the MOEP handles the collection, treatment, and final disposal of hazardous waste. In addition, they are responsible for monitoring China's waste trade and the amount of pollution emitted by disposal facilities and by the construction process of building new ones (Chen, 2010). In 2008 China had 495 waste treating facilities which could handle a yearly maximum capacity of 115 million tons, assuming the facility ran 365 days year (Dorn, 2010). Compare this to actual amount of MSW produce: 154.4 million tons reported by the Chinese plus the estimated 40-70 million tons produced in rural areas, totaling an estimated amount between 194.4-224.4 million tons of MSW (Dorn, 2010). This shows that their safe disposal capacity lags far behind their rate of production. Though many new facilities for hazardous and medical waste treatment and disposal have been constructed in recent years, in 2011 a total of 334 such facilities were either opened for operation or completely constructed (Chinese Ministry of Environmental Protection, 2011). This represents a commitment by the Chinese government to take steps to ensure safe disposal of potentially dangerous wastes.

Their commitment to protecting the environment from designated hazardous wastes is clear, however it is the MSW in China's landfills that has the greatest potential for causing global harm. Landfills are the primary method of waste disposal in China, because of their inexpensive convenience, particularly local dumps in rural areas (Chen, 2010). China's landfills are composed predominantly of food and high water content products, which make up approximately 78% of the nation's total MSW (Dorn, 2010). The rest is made up of 10% dry organic material, like wood, paper, and grass clippings; 12% non-biodegradable refuse like plastic, metal, glass, and ash (Dorn, 2010). Despite the seemingly benign composition of China's landfills, the large amounts of decomposing materials in landfills creates a large problem in terms of Greenhouse Gas (GHG) emissions. China's landfills reclaim only 20% of the GHG they create, compared to the average for an industrialized nation which is 60% (Dorn, 2010). Methane (CH_4) is the primary emission





that countries attempt to control and reclaim because its effects on the atmosphere are 21 times stronger than CO_2 (Dorn, 2010). In 2007 there were approximately 366 official landfills operating in China, though this number is fewer than the 457 landfills that were in operation in 2003 the landfill capacity had increased by 52,184 tons per year (Zhang, 2010). In addition to the landfills there were 78 composting sites in 2007 (Zhang, 2010). According to Zhang et al., only 30% of the MSW generated in China was collected in 2007, of that amount only 62% was treated before disposal (2010). This is a mountainous challenge for the Chinese government and solving it will not be easy, cheap, or quick. Improvements must be made in the construction of their landfills, particularly the rural landfills that are predominantly open pits with no treatment facilities, no GHG reclamation, and leachate containment. In fact, a study conducted by Xue et al. (2006) discovered that 47% of China's landfills do not treat leachate, 10% release the leachate into the sewage system, 20% treat it with bio-chemicals, 3% use membrane liners underneath the landfill, and 20% report to use "other methods" (Dorn, 2010).

However, waste provides a valuable resource for China and the country has long been an international importer of MSW. In 2004, the Chinese government approved the import of up to 23.42 million tons of "restricted" waste that could be used as raw materials and the total amount of waste actually imported for this purpose was 10.53 million tons, an amount 17.9% higher than the previous year (Chinese Ministry of Environmental Protection, 2004). China also approved under their automatic permission up to 57.82 million tons of waste for reuse in manufacturing, the total that was actually imported in this category was 22.55 million tons (Chinese Ministry of Environmental Protection, 2004). This amount increased to 54.12 million tons of approved imported waste in 2011, to be recycled and used as raw materials in the manufacturing process (Chinese Ministry of Environmental Protection, 2011). However, more recently, China has been threatening to reduce the amount of waste it imports from abroad. Called "Operation Green Fence," China is looking to enforce strict environmental regulations on all waste coming into the country, which could mean financial hardship for the waste exporters. For instance, in 2011 the total value of waste exported from the U.S. to China was approximately $11.3 billion (Earley, 2013). One reason that China has to import recyclables instead of collecting them internally is their high rate of scavenging. Scavengers are typically poor citizens who sift through the garbage to pull out the valuable recyclable materials and then sell them back to manufacturers at lower prices than the official recyclable collecting agencies (Chen, 2010, Dorn, 2010). There are also city scavengers who operate as private waste collectors, who gather recyclables door to door and sell them to manufacturers (Dorn, 2010). In 2005 the World Bank estimated that there were approximately 2 million active scavengers in China (Chen, 2010). Chinese authorities have taken different kinds of actions against these scavengers, some municipalities sought to legalize them through a local registrar and still some other sought to expel them from the cities altogether (Chen, 2010). Neither approach has proved very successful: most scavengers are too poor to afford the registration fees, and effective governmental monitoring to keep them out is costly, especially when their only source of income comes from selling the recyclables (Chen, 2010). This compounds the municipalities structural problem in that it robs them of revenues they could be making off of the sale of recyclable materials, which could then be used to improve and expand the system.

Brazil

The rate of growth of the Brazilian economy in recent years has vastly outpaced their ability to manage their waste effectively with environmentally sound and sustainable methods. According to Bianchini of the Brazilian Association of Public Cleaning and Waste Management Companies, also known as ABRELPE, the cost of implementing a nationwide waste management system is presently the largest inhibitor of their progress in this area (2007). However, improvements have been made on the regional and national level. This section looks at the status as it is now with a look at policy development for the future. One development in Brazil that has aided in its waste management problems was the creation of ABRELPE in 1976. ABRELPE works with public and private sectors to improve information sharing within the MSW industry in Brazil. It is the Brazilian representative association of the International Solid Waste Association (ISWA) and has assembled and released an annual status report on the Brazilian MSW industry, called the Panorama, for the past ten years[15].

According to the ABRELPE Panorama Report of 2012 Brazil's total MSW generated increased 1.3% from the previous year, while their population only increased by .9% (ABRELPE Panorama, 2012). During this time Brazil also experienced a growth in rate of MSW collected, up 1.9% from 2011 (ABRELPE Panorama, 2012). Despite the increase in collection, the amount generated still exceeded the amount collected, which means there was an actual increase of improperly disposed of MSW of 6% (ABRELPE Panorama, 2012). Approximately 58% of MSW was disposed of "properly," according to the ABRELPE Panorama report, however 24 million tons, about 41.9% of the national total, of MSW were sent to "controlled" dumpsites, which have limited security measures against air pollution or groundwater contamination and are, essentially, open dumps (ABRELPE, 2012; Pacheco, 2012). Of the waste produced in Brazil, approximately 52.5% is organic material like food products and 24.5% is paper products and cardboard (Lino, 2012). This creates the same problem in Brazil that it does in China, where large amounts of biodegradable materials are disposed of in open dumps without treatment, GHG recovery, or leachate prevention. These trends will hopefully be changing in the near future, after the effects of the 2010 National Policy on Solid Waste begin to be seen.

The National Plan for Solid Waste, a law that former President Lula da Silva signed in 2010, establishes the priorities of the Brazilian government for waste management: 1) avoidance, 2) reduction, 3) reuse, 4) recycling, 5) treatment, and lastly 6) disposal (ABRELPE: *Solid Waste*, 2012). It also addresses three principles for further attention: implementation of solid waste plans, shared responsibility of waste generation between the public, the government, and companies, and addressing the informal recycling

[15] ABRELPE official website: http://www.abrelpe.org.br/_eng/abrelpe_quemsomos.cfm

sector of MSW scavengers (ABRELPE: *Solid Waste*, 2012). According to the law firm Beveridge and Diamond PC[16], which specializes in environmental law, the solid waste plans are plans that must be developed by "industrial facilities, mining operations, health service providers, public sanitation services, construction companies, and transportation terminals" for management of their waste with regular reports sent to the newly developed national waste management information service. The concept of shared responsibility for waste generation in Brazil is known as Reverse Logistics, and has the same extended producer responsibility that new laws in China have, and that mature laws in Germany and the European Union have. In Brazil, like in Germany, it applies to certain products like packaging materials, batteries, oil, tires, pesticides, electronic equipment, and others (de Oliveira, 2010). The third principle of the National Solid Waste Policy is the integration of scavengers into the official recycling system. Like in China, Brazilian waste management companies suffer losses of income from recyclable materials due to individual scavengers that either collect the materials at the source or fish them out of dump sites and resell them for lower than market value. This law legitimizes these scavengers by organizing them in to cooperatives and makes them part of the waste management system. According to de Oliveira, the law allows for organizations of scavengers or individual scavengers to be hired in the attempt to increase recycling rates (2010). This provision may have a significant impact on recycling rates in Brazil, considering ABRELPE estimated that there were over a million scavengers in 2012 (ABRELPE: *Solid Waste*, 2012), and it was estimated the 60%-70% of recyclable plastics in Brazil were collected by these scavenging cooperatives (Pacheco, 2012).

Despite the scavengers, or perhaps because of them, recycling programs in Brazil have been relatively successful. Four materials in which Brazil's recycling rates are high are glass, metal, plastic, and paper (ABRELPE Panorama, 23). For aluminum the rate of recycling has stayed relatively constant from

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[16] Beveridge and Diamond, PC. 2010. <http://www.bdlaw.com/news-834.html>.

2009 to 2011 at approximately 98%, which is one of the highest aluminum recycling rates in the world (Do Carmo, 2010); the rate of recycling for paper, however, has gradually decreased from 46% in 2009 to 44% in 2011; the rate of recycling for glass is only given for 2009 when it was 47%; and recycling of plastics has been gradually increasing from 55.6% in 2009 to 57.1% in 2011 (ABRELPE Panorama, 2012). In 2012 60% of Brazil's municipalities had at least some form of recyclables collection system, however several of the collection systems do not cover the entire municipality or region and rely on voluntary delivery of recyclables, thus reducing their efficiency (ABRELPE Panorama, 2012). In the coming year this may change as the Solid Waste Plans are developed and implemented.

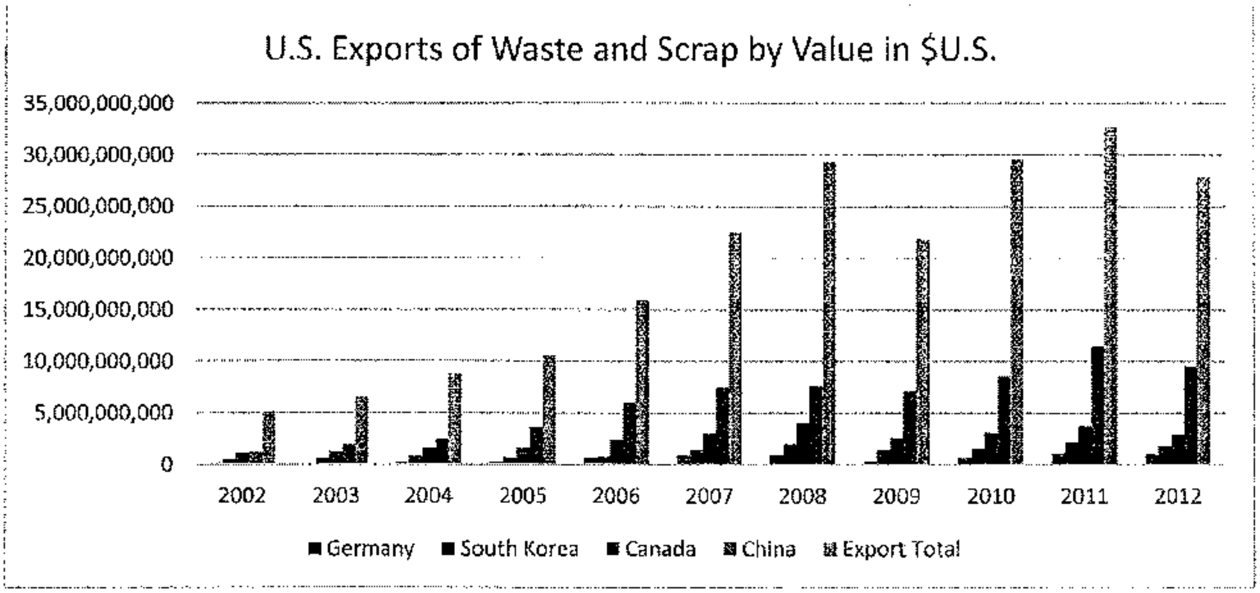
A study conducted on the recycling sector of Rio de Janeiro, Brazil's second largest city, shows some of the problems that all cities in Brazil face. One such problem regarding the quality of their plastic recyclables is contamination (Pacheco, 2012). Because Brazil has not established a separate collection system for recyclables, they are collected with the rest of the public refuse: food leftovers, used disposable diapers, and everything else (Pacheco, 2012). Most often this waste is simply sent to unsanitary landfills, according to Pacheco, 36% of the waste collected by the company of urban sanitation was sent to a sanitary landfill (2012). In Rio de Janeiro in 2006 waste was divided between two controlled dump sites, which were estimated to be closed in 2011 when they were expected to reach their maximum capacities (Pacheco, 2012). The minimal separation services offered in Brazil are done most often manually, where garbage is placed on a conveyor belt and the recyclables are separated by hand (Pacheco, 2012). However, there has been an increase in curbside collection programs where the recyclables are separated at the source which allows for lower recycling costs, due to the lower amounts of contamination (Pacheco, 2012). In 2007 the total plastic recycling capacity of Rio de Janeiro state was only 16% based on the plastic content of the two controlled dumps (Pacheco, 2012). However, this capacity on a national scale is likely higher, particularly now that Brazil has implemented a closed cycle waste management system for plastic packaging, their reverse logistics system.

Information on Brazil's waste management programs is still difficult to find, particularly in English, though there is no denying the potential for the industry is high. Brazil has in its MSW a resource for raw materials and energy production. Through modern technology assistance, government support, and determination the recent policy changes in waste management will likely improve the waste management and recycling processes in the near future.

The United States

The U.S. for many years was the world's largest waste producer and was only in the recent decade surpassed by China (Chen, 2010; Dorn, 2010). Waste in the U.S. is managed locally, state wide, and nationally. Some municipalities run their waste collection, treatment, and disposal facilities while others are sourced out to private waste management firms. On a national scale the U.S. Environmental Protection Agency (EPA) sets safety standards, waste management regulations, and waste reduction/recycling rate goals. Each state, however, can set further goals of its own. Another aspect of the waste management industry in the U.S. is the trade of waste between states, which is considered interstate commerce and controlled by the U.S. Department of Commerce. Waste generated in the U.S. is also trade on a global scale, with the largest export destinations being China, Canada, South Korea, and Germany[17] (graph on next page). Though the U.S. has stringent collection, treatment, and disposal regulations and an expansive network of collection, transportation, storage, treatment, and disposal resources, there are still some challenges that the its waste management industry faces. For example, Americans in rural areas who choose not to utilize the many waste management resources available to them. These few residents choose to burn their refuse privately, most often in a burn barrel or pit (EPA: *Backyard Burning*)[18]. The amount of MSW generated by these individuals is not account for in the national

[17] Data collected from the New National Trade Report from the U.S. International Trade Association.
[18] EPA Website 2013: http://www.epa.gov/wastes/nonhaz/municipal/backyard/



statistics, however it comprises a very small proportion. Trash burning in rural areas of the U.S. is difficult to monitor and prevent, and laws governing the activity vary between states. This, however, is just one small challenge face by the U.S. waste management industry and the EPA.

The EPA tracks and reports the amount of MSW produced nationally, how it is treated, and how it is disposed. According to the EPA the U.S. generated approximately 250 million tons of MSW in 2011 (EPA 2011). This represents a steady decline in total MSW generated over a 4 year period. In 2007 MSW production in the U.S. peaked at 256 million tons (EPA 2010). Of the materials discarded by U.S. residents product packaging made up approximately 70% (by weight) of the total MSW generated (EPA 2011). However, approximately 34.7% of the total MSW generated in 2011 was recycled, 11.7% was combusted for energy generation, and the total amount ultimately sent to landfills for disposal was approximately 134,260,000 tons. This was a decrease from the previous year of about 1.9 million tons and a decrease of about 8 million tons over a period of 6 years (EPA 2011). In 1993, the environmental safety standards and regulations on landfill operation changed and many had to close because of the cost of upgrading to newer technology that provides greater contaminant security (Macauley, 2009). Some of the new regulations included having a "flexible membrane" lining the landfill to prevent leachate from entering nearby water systems; mandating that the landfill be covered daily, primarily with soil, to prevent stench, littering, and fires; landfills also had to monitor and control the amount of methane they released (Macauley, 2009). Another requirement created in 1993 had to do with how landfills close. According to Macauley, the EPA mandates that closing procedures commence 30 days prior to the close date, and that the company or municipality operating the landfill monitor the landfill for an additional 30 years after closure (2009).

Particular to the waste management industry in the U.S. is the occurrence of interstate trade in waste products. States will ship MSW across state lines in order to dispose of it in a less expensive way. For instance, the Chicago area has a high population density and creates a substantial amount of MSW yearly, which it exports to nearby states. Southern Illinois, however, has much more land available and can potentially import waste from large cities like St. Louis (Macauley, 2009). In 2003 states traded approximately 39 million tons of MSW, approximately 16% of the total national waste generated for that year (Macauley, 2009)[19]. The privatization of the waste management industry was an additional motivatior for moving MSW between states: a waste management company with disposal facilities out of state could move the waste collected across state lines to their facility instead of taking it to that of a competitor (Macauley, 2009). The differences in waste disposal fees between states makes this strategy financially feasible, counteracting the costs of transportation (Macauley, 2009). In fact, Macauley cites a study by Ley et al in 2002 that affirms that, due to the differences in tip fees (the fees a waste carrier is charged to leave MSW at the landfill site), there was an overall public savings caused by interstate MSW transport and disposal (2009). According to the U.S. Census Bureau, there were 17,349 firms operating within the waste management and remediation industry in the U.S. in 2010. They conducted operations for hazardous and non-hazardous wastes that include waste collection, separation, treatment, transport, and disposal by compost, incineration, landfill, recycling, and other (*Statistics of Businesses: U.S., all*

[19] Macauley cites Repa 2005, whose figures were generated from McCarthy 2004.

Industries). These firms employed approximately 349,953 people nationwide (U.S. Census Bureau: *Statistics of Businesses: U.S., all industries*).

Waste products generated in the U.S. are not traded between states alone, but also internationally on a large scale. For the past decade China has been the largest export market for American waste and scrap (International Trade Administration). The U.S. also imports waste and scrap from other countries, though not nearly in as large of quantities. The U.S. imports the most amount of waste from Canada. The trade of hazardous and non-hazardous waste between Canada and the U.S. has been an important part American/Canadian relations since 1986 when they formed a bilateral agreement on the transboundary movement of hazardous waste (EPA: *US - Canada Municipal Waste Import/Export Issues*)[20]. According to the EPA, the agreement was modified in 1992 to include the trade of MSW as well as hazardous waste. The U.S. also has bilateral hazardous waste import agreements with Mexico, Costa Rica, Malaysia, and the Philippines (EPA: *International Waste Agreements*)[21]. In addition to the individual bilateral agreements that the U.S. has, it is also part of the OECD, which makes it a party to the 2001 Decision of the Council Concerning the Revision of Decision C(92)39/Final on the Control of Transboundary Movements of Wastes Destined for Recovery Operations. This agreement, in addition to the international environmental treaties signed and ratified by the U.S. government, guides the waste

[20] EPA website 2012: http://www.epa.gov/wastes/hazard/international/us-can.htm
[21] EPA website 2012: http://www.epa.gov/wastes/hazard/international/agree.htm

trade between the U.S. and all other countries and international groups, with which it does not have a bilateral agreement.

The U.S faces many challenges with regards to its waste generation and recovery rates. As was stated earlier, the small number rural individuals who burn their household waste privately is a challenge, but not the only one. The sheer amount of waste generated is in itself a challenge, and the EPA is working to reduce the initial amount of MSW created in the U.S. through various programs that it sponsors. On such program is the Reduce, Reuse, Recycle (RRR) campaign for which President Obama declared November 15th, 2013 to be "America Recycles Day" (EPA: *Reduce, Reuse, Recycle*). The RRR program is part of a larger EPA program called "Sustainable Materials Management," in which the EPA has issued "challenges" to other Federal Departments and the general public (EPA: *Sustainable Materials Management*). The Federal Program is intended to inspire the general public through leadership by example. Other instances of EPA outreach are their educational resources students of various age groups, and teachers (EPA: *Education Materials*). These initiatives are examples of how the U.S. government is trying to raise awareness of the growing waste problems it faces, and its improvement process has been slow but promising. However, the global trend is towards extended producer responsibility, and it seems to be successful in Germany and other European Nations. Implementation of this kind of policy in the U.S. seems unlikely due to the financial burden it would place on businesses.

Germany

The evaluation of long term waste management techniques in Germany is very unique due to the separation of East and West Germany after WWII. Each country had a different way of reporting waste production as well different methods of treatment and disposal. The reunification of Germany did not occur until 1990, therefore all waste generation, treatment, and disposal estimates for the time period prior to 1990 and post 1945 must be considered as first estimates only (Vehlow, 1996). However, given that reunification occurred over 23 years ago, there is enough data available to observe new trends in German waste generation and management methods, which will be the focus of this section.

The German government puts very strong emphasis on waste reduction at the source, similar to China (BMU, 2012). The 1996 Closed Substance Cycle and Waste Management Act (Kreislaufwirtschaftsgesetz) sets the priority of waste management in the order of reduction/avoidance, recycling, and lastly disposal, according to the BMU official website[22]. The primary impact this law had was in changing the German perspective on waste materials: instead of being viewed as materials for disposal, it is now looked at as a resource for raw materials (BMU, para 1). According to the BMU, Germany's goal is to eliminate the need to send MSW to landfills through this reduction and recycling process by the year 2020 (para 2). They've been close to this goal since 2006 when the percentage of German MSW sent to landfills reached 1%, and this proportion has not increased since then, though it did decrease to under 1% in 2009 and 2010, to go back up to an estimated 1% in 2011 (Euro Stat). This rate is despite the fact that MSW generation in Germany for the year 2011 was up 1 million tons from the previous year, from 49.237million tons to 50.237million tons (Euro Stat). Overall, these differences are relatively small, especially when one considers how much MSW is reclaimed through recycling and energy generating combustion. Clearly, there some lessons that the U.S. and other developing nations could learn from Germany in waste reduction and utilization.

One lesson that would be highly effective in increasing waste recovery and recycling, however difficult for American citizens to swallow, would be the Mülltrennung or garbage separation that takes place on individual basis in Germany. This is the process through which average Germans dispose of their household refuse. In front of almost every house in Germany, as well in several public areas, are the garbage containers: yellow for plastic and metal packaging, green or brown for food and organic material,

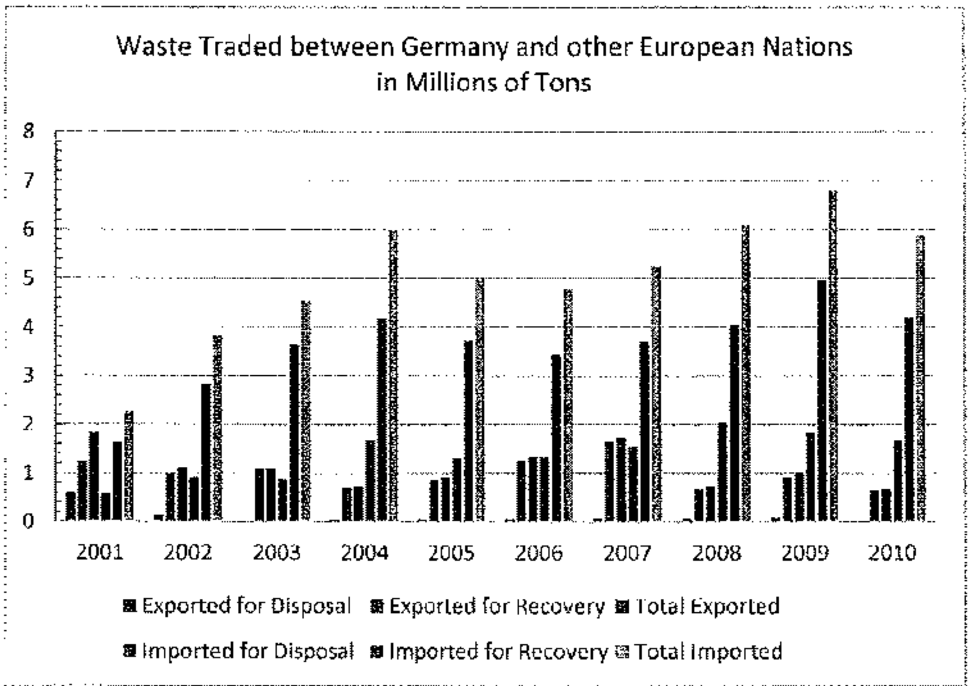
[22] BMU official website 2013: http://www.bmu.de/en/topics/water-waste-soil/waste-management/general-information/

blue for paper products, and black or grey for the materials that don't quite fit in any of the other categories (Cui and Schmaus, 2013). The dedication of the German citizens as well as that of the German waste collection companies keeps this complicated system running, however confusingly, considering not all German citizens even understand what should go in which bin (Cui and Schmaus, 2013). In the German newspaper Deutsche Welle, a representative of the German waste collection company Remondis in Bonn explains that many citizens in Bonn believe that all plastic products can be thrown away in the yellow container, despite the fact that its intended contents are exclusively packaging materials. He goes on to state that, in fact, half of the contents of the yellow bins are the wrong materials (Cui and Schmaus, 2013). This creates an expensive problem for the collection company, who then has to separate and dispose of the material, most of which is incinerated for energy generation; incineration costs are approximately 100-200 Euro per ton (Cui, 2013). However, this common problem has already been addressed by the German government, and in 2015 a new law allowing all plastic materials to be recycled in the yellow bin will take effect (Cui, 2013).

The garbage separation (Mülltrennung) was introduced in Germany as part of the Packaging Ordinance (Verpackungsverordnung), which makes certain manufacturers and retailers responsible for the waste generated over the life cycle of their products (Vehlow, 1996). The products included in this law are plastic and metal packaging material, electrical and electronic devices waste (E-waste), vehicles, solvents, oil, and batteries (Fischer, 2013). After the initial implementation of this law in 1991 the German packaging industry entered into a voluntary agreement with the German government, and created the Duales System of Germany AG (DSD) which collects, sorts, and recycles the waste from the packaging industry (Neumayer, 2000). This way the industry can retain waste management autonomy while following the governmental regulations, instead of being governmentally micromanaged. On a national scale the recycling rate for Germany in 2011 was approximately 60% for MSW, 60% for commercial waste, and 90% for construction and demolition waste (BMU, 2012).

Incineration of MSW for energy production in Germany has increased in recent years as well, despite its slow start due to negative public opinion of the perceived environmental impact of incineration (Vehlow, 1996). In 2010 Germany incinerated 37% of the MSW it collected, which was an increase from 2001 when they incinerated only 22% (Fischer, 2013). Public opinion has changed recently due to the increase efficiency of the exhaust cleaning process of incineration facilities (Vehlow, 1996). In 2010 Germany had 799 incineration facilities operating, all of which were equipped with energy recovering systems, and they processed approximately 25.8 million tons of non-hazardous waste that year (Euro Stat, 2013). Germany also produced 25.759 million tons of oil equivalent (TOE) of energy from biomass and renewable wastes (Euro Stat, 2013). One TOE produces approximately 11.63MWh, so this would have produced 299.577 million megawatt hours.

Germany does not dispose of all its waste internally, nor does it treat and dispose of exclusively domestic waste, but rather trades wastes with other European countries. In 2010 Germany imported 19.8 million tons of waste from various countries, according to the BMU, and exported 20.5 million tons of waste (BMU: *Cross Border Waste Shipments*). Within the European Community, Germany is a large importer of wastes, mostly hazardous wastes intended for recycling and resource recovery, though other non-hazardous wastes are included as well. Germany also exports waste to its neighboring European nations, though not on as a large a scale. Germany is clearly a



waste management innovator and world leader in waste-to-resource conversion, these methods can be used by other countries as guiding resources in how to lower the environmental impact of their domestic waste management industries.

China, Brazil, U.S., Germany Comparison

I found a few similarities in the waste management systems of Brazil and China, which is not surprising since they are both developing nations. They share an inconsistency in residential waste collection, recyclable collection, treatment of waste, and safe final disposal of waste. Both countries have partially implemented environmental protection standards in and near the larger cities, however lack standardization and protection measures in their vast rural populations. They have taken similar approaches to solving the issues of scavengers in the recyclables collection sector. Though, China has not managed to effectively integrate the scavengers into their waste management sector, Brazil has incorporated them into the waste management system through local cooperatives with reasonable success, according to Pacheco (2012). Perhaps this is a method that China could also implement, to increase the amount of domestically recycled materials and decrease the need to import those recyclables from other nations.

Germany and the U.S., while both having highly devolved waste management systems, have markedly different perspectives on what waste really is and, therefore, how they approach managing it is very different. The Germans don't actually view waste as waste, according to the government agency in charge of the waste management systems. Solid municipal waste in Germany is viewed as natural resource, and they reuse as much of it as possible to eliminate the need for landfills. It all starts at the individual level, which is another point of comparison between Germany and the U.S. The residents of Germany are required to separate their household garbage themselves by law. This pre-collection separation makes recycling and treatment much easier for the waste management companies, allowing them to utilize their waste-resources more efficiently. As an American, I find it difficult to imagine my neighbors, let alone residents in other states across the country, accepting this as a legally mandated requirement to garbage pick-up. However, the additional effort on the individual level is, in my opinion, small compared to the impact it would have on the efficiency of the waste management process in the U.S. Such differences are where the U.S. could really improve by looking to Europe as a role model: to obtain ideas and methods for improved environmental sustainability and adapt them to function within the U.S.

Industries in Decline

Incandescent Light Bulb

Advances in technology have always lead to creative destruction, out with old in with the new. Similarly, in the case of environmental motivation, the incandescent light bulb is not only being passed over in favor of more efficient alternatives; it is being governmentally phased out. The United States and the European Union have both passed laws mandating the manufacturing and sales of incandescent light bulbs be phased over the years between 2012 and 2014, mandated in the U.S. Energy Independence and Security Act of 2007 and the European Commission Regulation 244/2009 (Frondel, 2011). Though the phase out is not specifically directed at incandescent bulbs in themselves, the regulations mandate that light bulbs meet higher efficiency standards, which the old incandescent bulbs of Thomas Edison do not (Grunwald, 2013).

Thomas Edison invented the light bulb at the end of 1800s and remarkably it hadn't changed a lot until the 1970s, when the first compact fluorescent light bulbs were manufactured. The brand new higher efficiency technology was at first prohibitively expensive, each bulb costing approximately $30-35 at the check-out register (in 2012 inflation adjusted dollars) (Miller, 2012). Though prices for higher energy efficient alternatives have come down significantly since then, and are most cost efficient in the long run in terms of reduced energy costs, they are still considerably more expensive than incandescents.

Despite the undeniably better energy efficiency, many people still choose the cheaper less efficient incandescent light bulbs, though it may not be in their best interests. The more efficient bulbs are available on the market, and have been for years. The problem is that consumers are not buying the high efficiency bulbs in large enough numbers to really have an impact on energy use. Therefore, the governments of Europe and the U.S. have stepped in to increase their dispersion, and hopefully lower energy demand. In the European Community the resolution hopes to save 40 billion kilowatt hours (kWh) per year, 7.5 billion kWh in Germany alone, an amount that is equivalent to 1 coal burning power plant (Frondel, 2011). Another justification for the requiring higher efficiency light bulbs is the amount of GHG emissions that could be avoided. The European Commission estimates that the light bulb mandate could save an annual 15 million tons of GHG emissions (Frondel, 2011). However, this amount is only .34% of total GHG emissions (in equivalent CO_2 tons) in 2011 (Euro Stat, 2013). According to Frondel (2011), the savings may not even by that high, because of the European Emissions Trading Scheme (ETS). Frondel (2011) asserts that the light bulb regulation will decrease electricity demand, and also CO_2 emissions, however this will also lower the price of CO_2 certificates, assuming that the ETS is "binding" and the price of CO_2 positive. This weakens the motivations for other sectors in the ETS to lower their CO_2 emissions and results in a shift of CO_2 production between sectors instead of an overall reduction (Frondel, 2011). A second reason the actual GHG emission reduction might not be as high as the European Commission has estimated is a behavioral response called the "rebound effect" (Frondel, 2011). This is the effect generated when people, knowing the increased energy efficiency of their lights, leave their lights on for longer periods of time. A survey of German families in 2007 found that 15% would, indeed, leave their lights on longer in response to lower energy costs (Frondel, 2011). According to Greening et al. (2000)[23], the rebound effect for household lighting is between 5-12%, meaning the higher efficiency bulbs would

[23] Frondel (2011) cites Greening et al (2000).

only create a decrease in energy consumption 88-95% of the ideal total. Though the impact of the light bulb regulation on CO_2 emissions and energy usage may not be as large as policy makers would like, there are still some cost benefits to consumers.

The Energy Independence and Security Act mandates that by 2020 all bulbs in the U.S. be 60% more efficient than current incandescent light bulbs, which will save $13 billion in total energy costs across the country and make 30 coal burning power plants obsolete (Grunwald, 2013). Despite a higher initial purchase cost, sometimes 6.5 times more than non-efficient incandescent bulbs, the energy efficient compact fluorescent light (CFL) bulbs last approximately 6 times as long and use less energy over their lifetime, which saves the consumer in utility costs (Frondel, 2011). Frondel shows the cost savings for an average European customer: a typical 60W incandescent light bulb has an estimated life of 1000 hours and their high efficiency counterpart lasts an estimated 6000 hours, therefore 6incandescent bulbs are needed to equal the life of one CFL (Frondel, 2011; di Maria, 2010). Frondel uses a purchase cost of 0.60€ per 60W incandescent bulb, making it a total purchase cost of 3.60€ for all 6, while the cost of one CFL is 4.60€ (2011). Frondel estimates an electricity charge of 0.20€ per kWh; the 15W CFL bulb only uses 90kWh over the span of its 6000 hour life, while the 60W incandescent light bulb will use 60kWh over its life of only 1000 hours (2011). So the total estimated cost for the incandescent light bulb would be the purchase price 0.60€ plus the electricity charge 0.20€/kWh times 60kWh, which comes to 12.60€ per light bulb, times 6 bulbs to equal 75.60€; compare this to the purchase cost of one CFL 4.60€ plus the electricity cost of 0.20€/kWh times the energy usage over the life of the CFL which is 90kWh, and the total consumer cost is estimated at 22.60€ (Frondel, 2011). The U.S. Department of Energy (DOE) has a slightly different chart on its website that shows similar savings in dollars for the U.S. market. It shows the relative increase in efficiency of other light bulb varieties against a 60W incandescent, for instance a more energy efficient incandescent light bulb called the 43W energy saving incandescent, which uses 25% less energy than a conventional incandescent and has an annual energy cost of approximately $3.50, based on an electricity charge of $0.11/kWh and an daily usage of 2 hours, this kind of improved efficiency incandescent also has the potential for a longer life, between 1000 and 3000 hours (DOE)[24]. The 15W CFL, however, uses 75% less energy than the conventional incandescent, saves the consumer $3.60 per year in energy costs alone, and lasts for 10,000 hours, according to the DOE. The CFL and other high efficiency light bulbs save end users money in the long run, and if used widely enough can decrease the need to invest in new power plants in the future. Despite their long lasting life and low energy demand, CFL bulbs bring with them potential hazards with regards to when they reach the end of the useful life span.

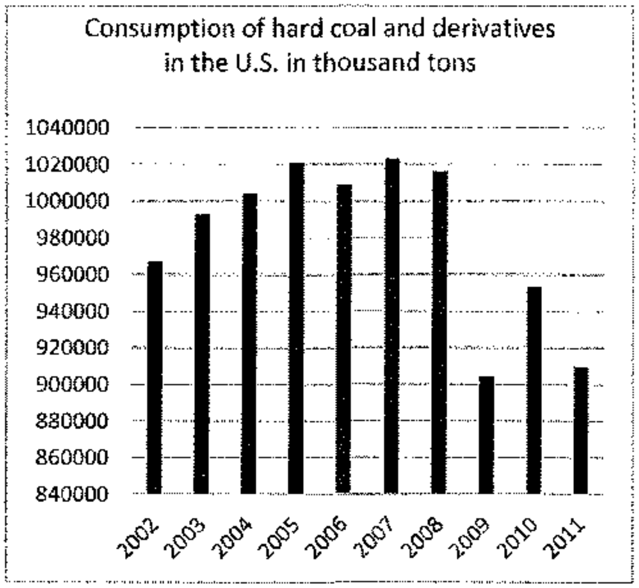
Compact fluorescent light bulbs contain mercury than can be inhaled or ingested if a person comes into contact with a broken CFL or can leak out into landfills if CFLs are not disposed of properly. This is a problem that the developed world must face if it wants to make CFLs the new standard in lighting, since mercury is a key component in all forms of CFLs. According to Sarigiannis et al. (2012), mercury exposure from broken CFL bulbs is most prevalent among children and infants 3 years or younger, because the mercury dispersion from a bulb dropped on the ground does is much more concentrated at lower heights. The U.S. EPA offers guidance and instruction on proper clean-up procedure in the case of a CFL breaking in a resident's home. The EPA also instructs U.S. residents on how to dispose of their burned out CFLs, since they cannot be thrown away in the normal municipal solid waste (MSW) stream due to their mercury content. According to the EPA, many MSW collectors will also collect the hazardous residential waste, like burned out CFLs, old paint, pesticides, and similar products. Several retailers also offer in-store recycling services for old CFLs: hardware stores like Lowes Home Improvement, Ace, and the Home Depot; furniture and home goods stores like IKEA, just to name a few. Providing a safe means of disposal is a key component to making CFL use on a large scale sustainable, without it their use could lead to dangerous levels of mercury contamination throughout the waste stream and the environment.

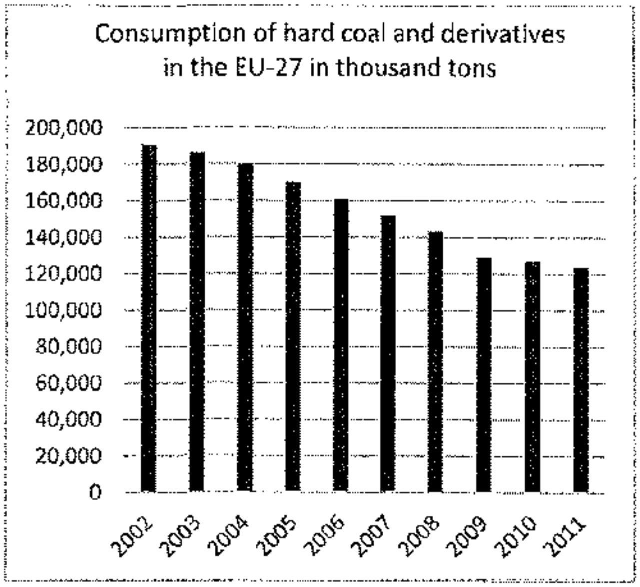
[24] U.S. Department of Energy website document: http://energy.gov/eere/energybasics/articles/lighting-basics

China in particular has expressed concern, as they attempt to increase their energy efficiency through CFLs as well, considering 10-13% of the energy consumption comes from lighting (Hu, 2012). China announced that it would also gradually phase out the old incandescent light bulb in favor of the more energy conscious CFL on November 1, 2011 (Hu, 2012). However, as was discussed earlier in this paper, the Chinese MSW management system is not prepared to treat and dispose of large amounts of CFLs containing mercury in a safe and sustainable way. In a study done by Hu and Cheng, it was estimated that approximately 20% of the mercury content of China's municipal solid waste came from CFLs in 2012 (Hu, 2012). But mercury vapor poses just as significant a threat as mercury contaminated leachate, and the majority of Chinese landfills do not have gas recovery systems to catch and filter contaminated GHGs (Hu, 2012). Despite the high risk for mercury contamination in the air and ground, the Chinese national government has issued no official policy or legislative plan to address the risk from CFLs (Hu, 2012). The Ministry of Housing and Urban and Rural Development, however, has announced that it intends to implement a separate collection system for wastes that contain mercury, like CFLs and old thermometers (Hu, 2012). This will hopefully lead to a reduction in the amount of mercury found in the MSW stream in China. Even if it doesn't, Hu (2012) argues, the amount of mercury taken out of the environment through reduced energy consumption (mostly produced by coal burning power plants in China), estimated at 3.76 tons of mercury emissions annually, more than compensates for the small amount put back into the environment from broken CFLs. It comes back to the need for China to address the short comings of its waste management system; that will be the only way to prevent mercury contamination from CFL disposal.

Coal Burning Power Plants

With increased focus on renewable energy sources, and their growth worldwide, one would expect there to be a decline in the older, "dirtier" sources of energy, like coal. Coal remains the primary source of energy in countries throughout the world for several decades, despite its high rates of carbon emissions and the dangers of coal mining. Though, this expected decline has not really been seen. The amount of electricity produced by coal burning power plants has decreased in Europe as they move towards cleaner and more sustainable sources of energy (Euro Stat, 2013), though their focus for the





future of coal is developing stronger exhaust filtration and carbon capture and storage systems to make coal a cleaner source of energy.

Though, the downward trend seen in Europe[25] has not been evidenced throughout the world. In the U.S., where coal mining and production are an important industry, there appears to be no consistent trend in either direction. Over the past decade the amount of energy produced by coal in the U.S. has neither decreased substantially nor increased substantially over a period of more than one year, but fluctuated from year to year. However, since 1990 coal's share in energy production has decreased from 53% to 43% in 2011 (IEA, 2013). There was also a significant decrease in the amount of energy produced from coal in 2009, which many have been caused by the economic recession, as the amount has been gradually increasing since then, presumably as the economy recovers. Coal remains the largest source of energy for the U.S. and China, and many other nations, and the U.S. Energy Information Administration

[25] Data for the EU-27 coal consumption graph was taken from Euro Stat (2013), and the data for the U.S. graph was taken from the Department of Energy *Annual Energy Review: Coal*, 2012.

(EIA) projects that coal consumption for energy production will increase in 2014 (EIA, 2013). While a press release earlier this year from the Chinese government said that they planned on closing 5,000 small coal mines this year (Rapoza, 2013). Though this mainly an attempt to get the Chinese coal industry to consolidate, encouraging firms to merge with smaller companies and improve safety standards (Rapoza, 2013). The OECD International Energy Agency (IEA) projects that China's demand for coal will decrease in future years only as their coal burning power plants increase in efficiency, and that soon India will take China's place as the second largest coal consumer in the world (2013).

Though the coal industry is not declining, it has not experienced significant growth in the past decade. As countries search for cleaner, more sustainable sources of energy, coal is used as a crutch to support the energy system while technology is made more stable. According to the IEA, under New Policy Scenario Projections, coal would still be the world's primary source of energy between 2011 and 2035, though coal consumption would be predominantly in non-OECD countries and make up only 33% of the energy production instead of 44% (2013). If, however, current policies remain constant, coal consumption in OECD would decrease only marginally, and coal demand would increase globally at double the rate it would under the New Policy Scenario (IEA, 2013). They have a third projection scenario that takes the perspective of intense GHG emission reduction, which estimates that coal demand could be cut by a third by 2035, and that coal fired power plants could make up just 14% of the world's total energy supply in 2035 (IEA, 2013). It is possible to achieve significant reductions in coal use within the energy sector by 2035, however the world and its population have to make clean, sustainable energy sources a priority over conventional sources that have been significant historically: out with the old, in with the new.

Summary

Renewable energy has become a priority for nations around the world, with developing nations like China and Brazil quickly implementing new technologies to provide much needed electricity to feed their growing demands. China now has the world's highest wind energy capacity, though the amount of actual electricity produced from new renewable technologies remains low due to grid and turbine efficiency and reliability problems. While in Brazil renewable energy is not a new concept, since Brazil gets the majority of its electricity from hydroelectric power plants. Though the Brazilian government has been investing in wind power due to the instability of some hydro plants during their annual dry season. While the U.S. trails behind other developed nations, like Germany, with regards to a national implementation plan for the future of renewable energy sources. Germany is without doubt a global leader in renewable energy technology implementation. China used a feed-in tariff system based on the German model to finance their new wind generated energy market. While Germany, like the U.S., still has a strong coal industry, unlike the U.S. they are not allowing it to disrupt their plans for an energy sector free of GHG emissions.

Whereas, it came as a surprise to discover that Brazil leads the world in renewable automobile fuel use. Second only the U.S. in ethanol production, it surpasses the U.S. in ethanol use for motor vehicles. Brazil is leading the world in sustainable automotive fuel use. The success of their flex fuel engines is something that the car-addicted U.S. should pay close attention to, since 28% of American GHG emissions comes from the transportation sector, which is predominantly composed of individual cars (EPA, 2013).

Waste management systems over the four countries examined vary widely in terms of environmental impact as well. In developing countries like China and Brazil the government struggles to combat growing municipal solid waste and the related GHG emissions, ground water contamination, and health hazards. As with many developing nations, waste management systems in the cities are far more advanced than those in rural areas, if those systems even exist in remote areas where frequently the only disposal option is the local unsecured dump. Waste is a resource and should be utilized to its full potential as a raw material for manufacturing, as a fuel for producing energy, and as compost that can be turned into fertilizer for agriculture. In addition to the domestic challenges faced by nations, there exists the international challenge of the waste trade and waste havens being addressed by international environmental agencies like the UNEP through treaties like the Basel Convention.

Though global efforts to reduce the negative environmental impacts of human innovation have led to the development of new industries like wind, solar, and geothermal generated energy and industry changes and expansions like the case of the waste management systems, there have also been casualties in the war for environmental sustainability. Though, the associated destruction is also linked with innovation, as was the case with the slow, inevitable death of the energy devouring incandescent light bulb in favor of the much more energy efficient compact fluorescent light bulbs and LED. Though it will not likely be in the coming decade, or perhaps not even the next few decades, the demise of the coal burning power plant is, in the opinion of the author, inevitable as newer energy producing technologies become less expensive and more efficient.

Conclusion and Recommendations

So as far as implementation for renewable energy as a primary source of power, as percentage of their total energy generated, the countries evaluated rank from most to least in order of Brazil, Germany, the United States, and China. Brazil was ranked first because of its extensive utilization of hydroelectric power. Though hydroelectric is a renewable source of energy, it has a larger impact on the environment than other forms due to loss of ecological diversity from flooding for reservoir building and the CO_2 emissions that are generated. Despite China's immense installed wind-power potential, it ranks last because of its inefficient integration of wind power into the total energy supply. As a percentage of total energy generation, the U.S. and Germany have similar integration rates hovering at 12% and 12.3% respectively. Though Germany has set up a stronger support system for further renewable energy integration than the U.S. has, by mandating that power companies buy the energy produced from renewable sources at a subsidized price funded by the feed-in tariff system. This seems like a reasonable approach that U.S. should consider adopting. With a population of working age adults (set at 25 and older) over 200 million people (201,542,000) (Census, 2011), if everyone paid $0.01 extra per month, or $0.12 per year, it would amount to over $24.2 million dollars a year, which could be used to make energy from renewable sources more affordable, efficient, and prevalent in the U.S. lowering the need for fossil fuels and reducing the emissions of GHGs.

As far as waste management systems go, the Germans have by far the most advanced, and complicated, system which amazes and confuses. However, there's no denying that it works, despite its short comings. The Germans recycle, incinerate for energy, and compost the vast majority of their municipal solid waste with a decidedly Prussian efficiency. The effort exerted by the average citizen is what makes the system truly successful, and is what is needed throughout the rest of the developed world to make waste reduction and recovery successful. Another aspect that makes the German system so successful is the idea that a manufacturer remains responsible for its product throughout the products life, even when it becomes waste. This gives the manufacturer an incentive to produce something that will generate little or no waste, or waste that can be reused as recyclable materials. China and Brazil have adopted this principle of extended producer responsibility as well. This kind of program would be particularly useful in the U.S. where a significant portion of our municipal solid waste is generated from product packaging. One simple example of how extended producer responsibility can reduce waste through packaging minimization is how toothpaste is packaged; in Germany toothpaste does not come in a box, it is simply sold in its tube, though in the U.S. the tube is in a box. Is the box really necessary? It is time that manufacturers in the U.S. be held accountable for the unnecessary materials they bundle into their products, and time U.S. citizens view waste as a renewable resource for both raw materials through recycling and energy through incineration. Perspective and policy changes in the U.S. are necessary to improve environmental sustainability, but with positive role models like Germany and other European countries, the change is entirely possible.

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