Appendix A

Current MSW Management in King County (Part of Task 2 – WTE Existing Conditions Memorandum)

Memorandum

To: *Pat McLaughlin, Project Sponsor*
King County Solid Waste Department

From: *Paul Hauck, P.E.*

Date: *August 2, 2017*

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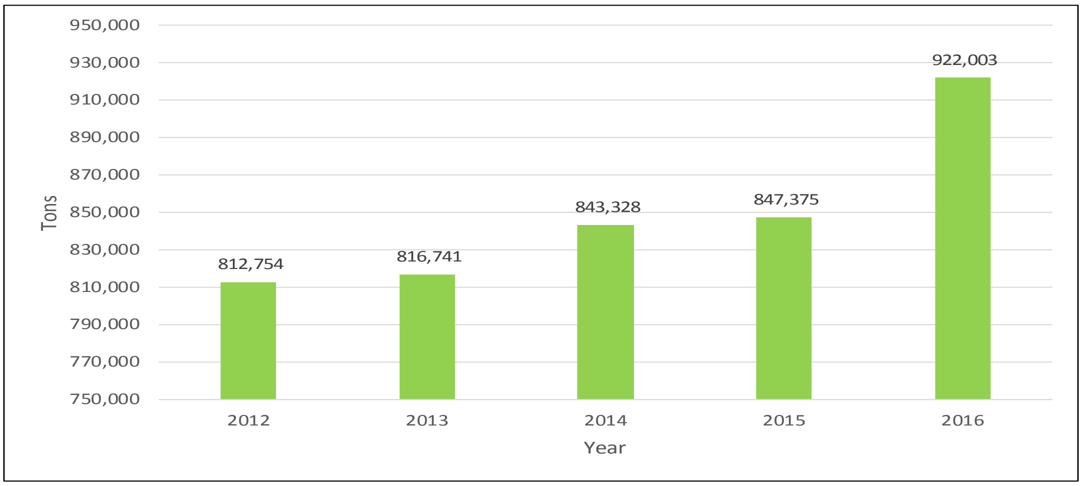
Subject: *Current MSW Management in King County*
(part of Task 2 – WTE Existing Conditions Memorandum)

1. Introduction

In accordance with the final Scope of Work for the King County (County) Waste-to-Energy (WTE) Study, CDM Smith has been tasked with summarizing the current MSW management practices employed in the County. The following discussion addresses the services provided by the County and the private sector as well as descriptions of current solid waste facilities.

2. Service Area

The County's Department of Natural Resources and Parks – Solid Waste Division (SWD)'s service area consists of residential and commercial customers in the unincorporated areas of the County and 37 of the 39 cities in the County (Seattle is serviced by City of Seattle and Milton is serviced by Pierce County). As of 2015, the average disposal rate per resident was 0.6 tons per year (3.3 lb/day/person). **Figure 1** shows the past five years of waste disposal at the County's Cedar Hills Landfill, the sole landfill in operation during the period shown (2012-



2016).

Figure 1. Total Annual Waste Disposal at the Cedar Hills Regional Landfill (2012-2016)

3. Services and Facilities

The SWD offers drop-off and disposal services for MSW – separated into bins for garbage, recyclables, and yard waste. **Figure 2** shows the facilities that the SWD oversees and indicates the portions of the MSW processing which are provided by organizations outside of the County government.

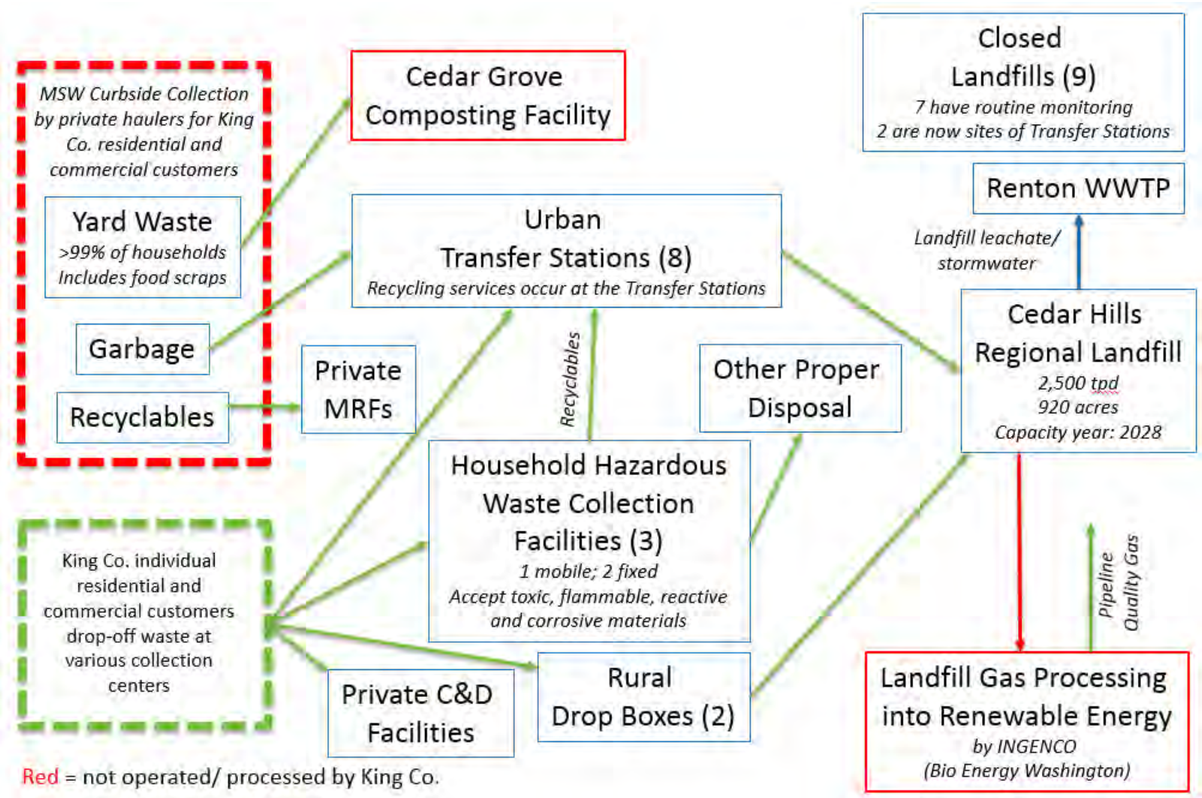


Figure 2. King County Solid Waste Division Facilities and MSW Process Flow Schematic

The County's use of eight Transfer Stations and two drop boxes has resulted in a solid waste program that provides convenience to its users, while reducing the number of "windshield miles" for the collection firms and truck traffic/emissions associated with the system. The County also allows self-haulers to bring waste to any of the Transfer Stations and drop box locations. Details about each SWD facility and related sites are shown in **Table 1;** locations of these and other facilities throughout the County are shown in **Figure 3**.

Table 1. King County SWD Sites and Facilities - Detailed Information

SWD Site/ Facility Name	Location	Recycling Services?	Acres	Total Solid Waste Disposed (tpy in 2016)	% of Total at all TS	Distance to Cedar Hills Landfill (mi)
Algona Transfer Station	Algona	No	4.4	155,722	18%	20
Algona-Future South Recycling and Transfer Station (Scheduled to Open in 2020)	Algona	Yes	16.49	N/A	N/A	20
Bow Lake Recycling and Transfer Station	Tukwila	Yes	20.04	271,202	30%	17
Bow Lake Closed Landfill	Tukwila	No				
Cedar Falls Drop Box (and Closed Landfill)	North Bend	Yes	7 (84.25ac total if closed LF is included)	3,880	0.40%	22
Cedar Hills Regional Landfill	Maple Valley		920	922,003		
Corliss Closed Landfill	Shoreline	No				
Duvall Closed Landfill	Duval	No	75.38			
Enumclaw Recycling and Transfer Station (and Closed Landfill)	Enumclaw	Yes	25.67	21,434	2%	21
Factoria Transfer Station	Bellevue	No (but Scheduled for Dec. 2017)	25.41	131,976	15%	18
Harbor Island	Seattle	No	2.79			
Harbor Island	Seattle	No	9.61			
Harbor Island	Seattle	No	1.28			
Hobart Closed Landfill	Maple Valley	No	72.85			
Houghton Recycling and Transfer Station (and Closed Landfill)	Kirkland	Yes	8.4 (25.94ac total if closed LF is included)	157,743	18%	24
Puyallup/ Kit Corner Closed Landfill	Federal Way/ Puyallup	No	38.14			
Renton Recycling and Transfer Station	Renton	Yes	5.3 (constructed on 13ac of land)	68,654	8%	12
Shoreline Recycling and Transfer Station	Shoreline	Yes	13.14	70,983	8%	36
Skykomish Drop Box	Skykomish	Yes	3.54 (constructed on a 7 ac property)	1,484	<1%	
Vashon Recycling and Transfer Station (and Closed Landfill)	Vashon	Yes	9.4 (59.19ac total if closed LF is included)	7,413	1%	45

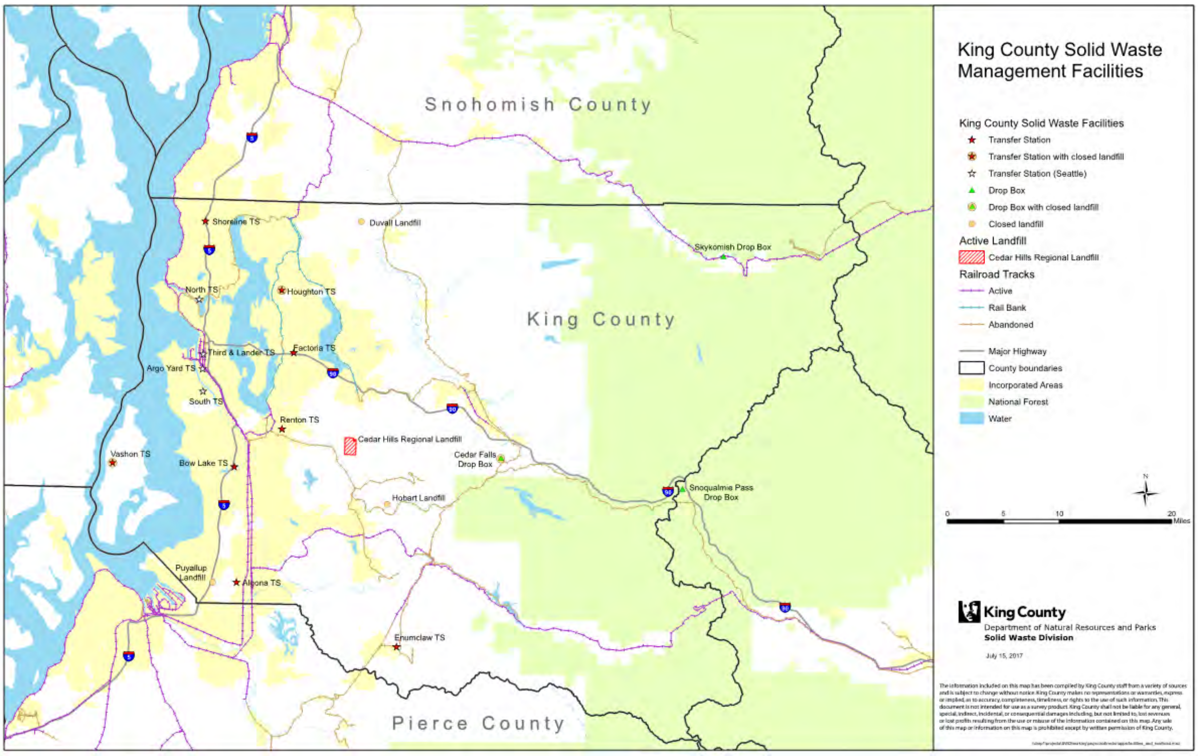


Figure 3. King County Solid Waste Management Facilities
Source: King County Department of Natural Resources and Parks, Solid Waste Division (2017)

Private solid waste management companies ("haulers") collect MSW in the County, except in Enumclaw and Skykomish (in-house collection system operation). The four parent company private haulers are Republic Services (formerly Allied Waste), Recology CleanScapes, Waste Connections, Inc., and Waste Management, Inc. Combined, there is a fleet of over 100 recycling trucks for curbside pickup in neighborhoods. Around 90 percent of County residents use their recycle bins to recycle newspaper, mixed paper, cardboard, plastic, tin cans and aluminum cans. Yard waste collection at the curb is available to nearly 100 percent of the customers as part of their MSW collection service, for an additional fee.

It is estimated that seventy percent of what is sent to the landfill still has recyclable value, however the County does not recover recyclables from mixed waste at the transfer stations due to concerns over poor quality, which affects the marketability and price paid by recycling markets. This appears to be a sound strategy, as recent observations in China support:

> *China has been applying restrictions on imported paper via their "Green Fence" and more recently their "National Swords" initiatives. These have stalled shipments of some recovered materials from the U.S. and led to substantial import fee increases for shipments that do clear customs. Many materials recovery facilities (MRFs) are unequipped to produce the high grade of paper China is now demanding, and as a result, it leaves few downstream markets for the material.*

4. Commitment to Sustainability

In addition to the services described above, the SWD's robust MSW management program also includes community events, a detailed and user-friendly website, guidance videos, facility tours, educational materials (English and Spanish), list of what should/should not be disposed of in the various collection containers, list of acceptable materials at collection centers, statistics, fees, social media, WasteWise goals, Zero Waste by 2030 goal, "Rethink-Reduce-Reuse-Recycle" mantra, "Compost More. Waste Less." pledge, and "Food: Too Good To Waste" campaign. The SWD and the County as a whole have received numerous awards for their strong commitment to sustainability.

5. Waste Composition

Every five years, waste characterization studies are performed to identify the composition of what is being thrown away. County residents and businesses currently recycle 52% of all solid waste generated. **Figure 4** displays the waste composition for the County.

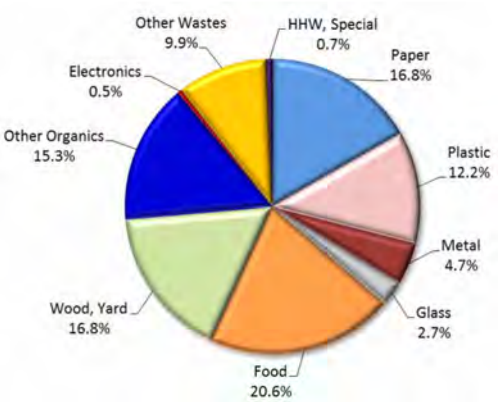


Figure 4. King County Overall Waste Composition for 2015
Source: 2015 King County Waste Characterization and Customer Survey Report by Cascadia Consulting Group (September 2016)

6 Long-Term Planning

The SWD released the *2013 Comprehensive Solid Waste Management Plan* where they outlined the vision and long-term planning for solid waste generated in the County. The only open and operating landfill in the County (Cedar Hills Regional Landfill) is estimated to reach capacity and close in 2028. The SWD recognizes that landfilling may not always be the most economical method for waste disposal so is continuing to explore other viable disposal options, such as waste export to an out-of-county landfill, waste-to-energy (WTE), and other emerging conversion technologies. Sites of existing Transfer Stations could become sites for future WTE facility(ies), as could many other locations, both in- and out-of-region subject to a host of site-specific project development and operations parameters. There are currently no plans to develop additional landfills as the current policy is for either out-of-county disposal (waste export) or waste conversion. The purpose of this *2017 King County WTE Study* is to determine the feasibility of currently-available WTE technologies. The *2017 King County WTE Study* should be used as a tool to aid the SWD in their decision-making process for the future of solid waste in the County.

Appendix B

Approach to Evaluating Waste Conversion Technologies

Appendix B - Approach to Evaluating Waste Conversion Technologies

Challenges exist with the evaluation and implementation of WTE technologies, especially for those which lack an extensive operating track record. For many of the alternate and emerging technologies, it is difficult to quantify their "non-quantifiable" contribution towards achieving policy goals and objectives for the sustainable management of municipal solid wastes.

Evaluation of proven and emerging waste conversion technologies requires a rigorous analysis. The analysis is often compared with the current baseline waste processing systems, which in the case of the King County system, is the modern Subtitle D landfill. There are a significant number of technical, environmental, economic, financial, and other important challenges which affect the outcome of any proposed waste conversion technology. The following is a summary and brief discussion of the more important criteria and challenges to overcome:

B.1 Technical Criteria

B.1.1 State of Technology

The state of technology review addresses the documented track record of the vendor with both pilot and commercial facilities. The operational history of all process steps, from waste receipt through energy conversion to management of material side streams and residuals are considered under the state of the technology. Specific factors assessed include waste types and quantities processed, demonstrated operational reliability, and existence of operational facilities as noted below:

- Existing operational plants (location, start date, daily capacity, processing availability)
- Waste types and quantities actually processed (this includes potential restrictions on the composition of wastes accepted that would apply to future deliveries from local municipal sources)
- Demonstrated operational reliability of the complete system
- Identified problem areas and freedom from high risk failure modes
- Degree to which the entire system has been demonstrated (from receipt through processing, environmental control, and residue processing)

B.2 Technical Performance

This criterion addresses the ability of the proposed waste conversion process to address the full spectrum of the potential needs of the users and rate payers of the solid waste management system. Also addressed is whether the proposed process can safely and efficiently process the types of wastes which are generated by the system users. The need for source separation and/or pre-treatment (removal of items, sorting and size reduction) and the percentage of waste by-passed to the landfill or other waste disposal options is also of importance.

- Compatibility with full spectrum of community waste disposal needs (capacity for processing municipal solid waste, household hazardous, commercial, institutional and medical waste, E-waste, wastewater treatment plant biosolids, etc.)
- Need for source separation and/or pre-treatment (sorting, size reduction, drying, etc.)
- Percent of waste that is bypassed to landfill or other waste conversion process

B.3 Technical Support

The vendor must demonstrate that its organization has the local resources (on a continuing basis) to provide technical support to the project, including a key project leader with a track record of conducting similar assignments. Emerging technologies often will have one "key project leader" without whom the project will fall apart, whereas the preferred case would be for the vendor to have a broader team that can sustain the project if one or more of the project leaders leave. Some of the key questions when evaluation technical support are as follows:

- Does the proposing contractor have experience in all aspects of waste processing that is necessary for successful project execution (permitting, design, construction, operation (waste receipt, storage, handling, and processing), and maintenance?
- Does the vendor organization have local resources (on a continuing basis) to provide technical support to the operation?
- Is there one "key project leader" without whom the project will fall apart or does a broader team exists that can sustain the project if one or more of the project leaders leave?

B.4 Facility Siting and Public Acceptance

This criterion addresses the compatibility of the proposed facilities with the proposed site. Siting characteristics of significance include the extent of grading required to implement the facility and the need for additional utilities; water, power, natural gas, and sewage.

- Is the proposed process adaptable to the proposed facility site without major retrofit such as grading activities?
- Does the proposed process take advantage of the adjacent activities on the site in a synergistic way?
- Does the existing site meet all of the needed utility services, or will new or increased capacity be required?
- Is the proposed system better suited for an alternate location on the proposed site or another location altogether?
- Is the proposed facility within a distance that minimizes the cost of waste and residue transportation?

- Does the potential electrical generation (if any) by the process require new switchgear and/or transmission line changes by the local utility to accept its output?
- Can the existing adjacent facilities take advantage of any potential heat (steam, hot water), electrical power, or other forms of energy generation in lieu of exporting the power to the bulk electric grid?
- Is the technology attractive from the public's perspective, including civic groups, environmental groups, and residents?
- Will the process / project create well-paying construction jobs, high quality operation and maintenance jobs, and have a significant annual economic ripple effect on the local / regional economy?

B.5 Environmental Criteria

B.5.1 Environmental - Emissions

All waste conversion technologies will generate emissions in solid, liquid, and gaseous phase that represent some impact on the environment. The intent of this criterion is to assess the nature of this impact. Specific information evaluated includes the quantity and types of emissions with specific consideration of the technology contributions to greenhouse gases.

- Is there data that demonstrate the uncontrolled and controlled emissions of air pollutants, water pollutants, noise, odor, and residue?
- Is the net emission of greenhouse gases reduced, kept the same, or increased versus the "base case" of landfilling?
- Are there proven control technologies to mitigate environmental impacts?

B.5.2 Environmental - Sustainability

The intent in applying the sustainability criterion is to assess the proposed technologies contribution to the local community's overall environmental policy and goals. Factors considered include conformance with local community waste objectives, economic development through the creation of "Clean Tech" jobs, and promotion of healthy natural habitats and communities.

- Does the implementation of the technology act to maximize recycling, minimize potable water usage and fossil fuel based energy usage and otherwise contribute to a minimization of impacts on limited resources?
- Are there any significant or potential issues (positive or negative) on the neighboring community or downstream habitat?
- Does the proposed process fully meet all of the local community's environmental goals?
- Does the proposed process fully meet the local waste reduction goal?
- Does the proposed process provide long-term economic benefit to the community?

B.5.3 Institutional Criteria

B.5.3.1 Financial Resources

The primary aspect of this criterion is whether the vendor has the financial resources to continue to input capital and operating expenses to resolve technical and O&M problems in order to fully achieve performance goals for the project. Other components of the financial resources criterion relate to the vendor's financial capability to make the municipal project sponsor whole from any investments made by the municipality and the resources to dismantle and remove the facilities in the event of a "failure" to meet performance standards.

- Does the vendor have the financial resources to continue to input capital and operating expense to resolve technical and O&M problems in order to fully achieve performance goals?
- Does the vendor have the financial resources to make local municipality whole from investments made by the municipality in the technology if the technology fails? Can the definition of "failure" be clearly spelled out in any proposed contract or other expressed or implied contractual relationship?
- Does the vendor have the financial resources to escrow funds to dismantle and remove their facilities in the event of a "failure?"

B.5.3.2 Project Economics

The economic analysis incorporates the operating expenses associated with a technology (labor, power, chemicals, etc.) and estimate revenues obtained from sale of power and byproducts. In addition, the economics of a given technology is significantly influenced by the municipality's requirement to commit to participation in capital investment and commitment of the feedstock delivery at a specified price.

- Required commitment of local municipality to participate in capital investment
- Required commitment of municipality for delivery of waste (tons-per-day, contract years) at specified price, and associated escalation methodology and benchmarks
- Realism of assumptions used to develop estimates of income from the sale of power and byproducts, or processing of special wastes, etc. (generation rate, quality, and pricing).
- Realism regarding operating expenses (labor forces and unit wages, power use, costs for chemicals, and fuels).
- Does process provide long-term revenue potential for local municipality, and/or low cost renewable energy to the municipality and/or residents and businesses located within the local service area?
- Are there additional funding mechanisms and energy and tax credits available for the technology?

B.6 Overall Project Risks

- Economic Realities - What is the process cost differential compared to landfill disposal and other competing technologies? Will the process help stabilize solid waste disposal rates over the long-term, or be subject to uncertain escalation?
- Technical Risk – Is there a limited history of technology and/or limited history of the service provider?
- Procurement Issues – Is there a lack of qualified competition due to the uniqueness or state of technology development?
- Fatal Flaws – Is the project dependent on uncertain factors or conditions, such as the acceptance of a by-product by an industry that could leave the local community or income from a byproduct whose price or market is not reliable?
- Contractual Risk – Can the definition of "failure" be clearly described or expressed in a contract?
- Contract Terms – Is the developer willing to include an "escape clause" if the technology fails to achieve benchmark performance goals or guarantees?

Appendix C

Detail Description of Leading WTE Candidates

Appendix C – Detail Description of Leading WTE Candidates

C.1 Massburn WTE

Massburn WTE is the thermal treatment of waste in oxygen rich conditions, with little to no preprocessing of the waste required.

C.1.1 Technology Issues

The most common combustion technology used in U.S., and world-wide are massburn waterwall units, which account for approximately 83 percent of the operating facilities in North America, and the majority of operating facilities in Europe and Asia. This technology is regarded by most experts as the most tried and proven method of combusting municipal solid waste for recovering its energy and other recyclable materials, including metals and minerals. These combustors are field erected units consisting of a stoker grate and integral waterwall boiler. Other types of technologies currently in use in North America, but to a much less extent, include mass burn rotary units, mass burn refractory units, and mass burn modular units.

Massburn technology is compatible with the full spectrum of municipal wastes, and only requires minimal pre-processing, primarily the removal of large bulky items which could plug the waste feed chute or ash residue dischargers, along with hazardous or undesirable wastes such as auto batteries, medical and mercury containing devices. Some WTE facilities have incorporated bulky waste shredders into their facilities to reduce the amount of non-processible wastes which must be disposed of by other means. Combustion liberates many ferrous and non-ferrous metals which are recyclable, and most massburn WTE facilities employ metal recovery systems to generate revenue from the sale of these recyclable metals removed from the ash residue. Within the past ten years, numerous WTE facilities world-wide have upgraded their metal recovery systems with high strength magnets for ferrous metals and eddy current separators for non-ferrous metals.

Mass burning of MSW on grates in a boiler furnace is the technology with the most extensive experience base worldwide (hundreds of plants throughout the US, Asia and Europe) and available from several highly experienced and financially sound vendor firms. There are several operation, maintenance, and management contractors which offer their proprietary massburn WTE technology in the United States.

- **Covanta Energy -** The leading WTE service provider in the U.S. is Covanta Energy, located in Fairfield, New Jersey. Covanta is the licensed contractor of the Martin GmbH Reverse Acting Stoker Grate technology, which is provided by Martin GmbH of Germany. The list of Martin plants world-wide is quite impressive, and includes several hundreds of plants with combustion units ranging in size from 100 to 1,000 TPD. Covanta currently operates approximately 41 WTE facilities in fifteen states within the U.S. Most of these facilities employ the Martin Reverse Acting Stoker Grate technology, along with other waste combustion technologies which have been acquired from other vendors.

- **Hitachi Zosen Inova (HZI AG)** – Wheelabrator Technologies Inc. (WTI) was the North American licensee since 1968 for the Von Roll Industries combustion grate technology which has been implemented at more than 390 facilities worldwide (Wei/Phillip to update). The Von Roll technology was later acquired by Austrian Energy and Environment Inova, which eventually was purchased by Hitachi Zosen to form Hitachi Zosen Inova. HZI AG is located in Zurich, Switzerland and maintains North American offices in Norcross, Georgia. WTI currently operates 17 massburn WTE facilities in the U.S. ranging in size from 225 TPD to 750 TPD units.

- **Babcock & Wilcox Volund A/S** - One of Europe's leading waste combustion technology is offered by B&W Volund, headquartered in Esbjerg, Denmark. Volund has supplied more than 500 waste-to-energy processing lines over the past 70 years in Europe and Asia. Volund currently offers both air and water cooled grates that are capable of processing both municipal solid waste along with the possibility of co-firing biomass. Volund offers waste combustion systems in the size range of 50 – 1,000 TPD units. B&W Volund provided the combustion grate technology for the most recently constructed WTE facility in the U.S. in Palm Beach County, FL. They are also providing the same combustion technology system for the world's largest WTE facility to be constructed (2000) in Shenzhen, China.

Other WTE vendors offering WTE technology in North America include:

- Foster Wheeler
- Riley Power
- Segher Keppel

The designers of grate-fired massburn systems have responded to the heterogeneous nature of the waste with robust, reliable and flexible mechanical concepts and control systems that routinely meet contract requirements and which have a strong track record in moving quickly through plant start-up to stable operation to process waste at or above their nominal capacity.

There is a wide range of massburn waterwall WTE facilities which have been constructed around the world over the past 50 years, ranging in overall plant size from small units at 100 tons per day (tpd) to much larger units of 3,000 tpd. The technical and financial success of a WTE facility depends on whether it can consistently achieve certain expected performance levels; primarily waste throughput and energy production. Most of the massburn waterwall facilities currently operating in North America were constructed in the late 1980s and early 1990s. However, there have been several new Massburn WTE facilities constructed in the past 20 years, including:

- City of Tampa, Florida (1,000 tpd massburn retrofit) in 2000
- Lee County, Florida (636 tpd massburn expansion) in 2006
- Hillsborough County, Florida (600 tpd massburn expansion) in 2007
- Honolulu Hawaii (1,000 tpd massburn addition to existing RDF WTE facility) in 2013

- Palm Beach County Florida (3,000 tpd new massburn addition to existing RDF WTE facility) in 2015
- Durham-York, Canada (488 tpd new massburn WTE) in 2015

C.1.2 Environmental Issues

Massburn furnace designs and flue gas cleaning technology have evolved over the years to cope with increasingly stringent environmental regulations. Modern plants routinely exceed the most stringent federal and state requirements for stack emissions and residue quality.

According to the U.S. EPA, modern WTE facilities are one of the cleanest sources of renewable electricity, with an emission profile considerably better than coal based electric power. Recent trends in flue gas cleaning technology have demonstrated the ability to reduce NOx emissions by more than 75 percent.

The advent of modern flue gas cleaning systems has evolved with the WTE industry standard which incorporates the following control technology:

- Advanced combustion controls and flue gas recirculation for carbon monoxide control
- Ammonia or urea injection into boiler for improved NOx control
- Activated powder carbon injections for mercury and dioxin/furan controls
- Atomized slaked lime injection in spray dryer absorber for control of acid gasses
- Fabric filter for removal of particulate
- Fly ash residue recirculation for maximized acid gas control

A summary of the significant reduction of WTE emissions since the advent of the modern era from large and small municipal waste combustor flue gas emissions is illustrated below:

Table C1 Emission Comparison

Pollutant	1990 Emissions (TPY)	2005 Emissions (TPY)	Percent Reduction (%)
CDD / CDF TEQ Basis*	44	15	99+%
Mercury	57	2.3	96+%
Cadmium	9.6	0.4	96%
Lead	170	5.5	97%
Particulate Matter	18,600	780	96%
HCL	57,400	3,200	94%
SO2	38,300	4,600	88%
NOx	64,900	49,500	24%

Source: EPA, August 2007
*Dioxin / furan emissions are in units of grams per year toxic equivalent quantity (TEQ), using 1989 NATO toxicity factors, and all other pollutant emissions are in units of tons per year.

Recent advancements in combustion air controls have reduced NOx emissions by up to 50% of the current generation of WTE facilities. Even greater reductions of NOx emissions can be achieved with use of Selective Catalytic Reduction (SCR) technology which can achieve NOx emissions in the range of 45 - 50 ppm, representing approximately a 75% reduction compared to the current generation of operating WTE facilities. The use of SCR technology has recently been applied in the U.S. on the new 3,000 tpd massburn waterwall WTE facility in Palm Beach County, Florida. There is also one WTE facility in Canada which has added SCR control technology.

In summary, proven WTE technology deployed in the U.S. continues to evolve with reduced air emissions that continue to exceed the regulatory requirements.

C.1.3 Financial / Economic Issues

Massburn WTE technology is commercially proven and provides the following advantages to the purchaser of the renewable electricity:

- Base loaded, reliable renewable electricity with greater than 90% capacity factor
- Support for proper operating voltages on the local electrical grid
- Alleviate strain on challenged transmission and existing distribution infrastructure
- Reduce reliability risks associated with increased system load
- Potentially delay or eliminate the need to permit new base load units and transmission upgrades
- Avoids need to use higher cost peak power plants, independent of the natural gas grid,

- Provide (regional) power during storm events due to adequate supply of MSW "fuel" from storm debris, and
- Improves local fuel diversity to local electrical grid for reliability during interruptions in fossil fuel supply during extreme weather events, or as a result of sabotage and terrorism.

Revenues from the sale of renewable energy are stable and predictable due to long-term power purchase agreements with electric power providers. In some regions of the country, additional revenues may be generated from the sale of Renewable Energy Credits (RECs). Future federal legislation may mandate a national Renewable Energy Standard, and the adoption of a REC trading system on a national basis. Several voluntary markets for trading of REC and Verified Carbon Units (VCUs) also currently exist in the U.S.

The capital and operation/maintenance cost of massburn WTE facilities varies with facility size. For the project size envisioned for King County, the capital cost may range between $210,000 and $250,000 per ton of daily capacity, and are typically financed over 20 – 25 years. The operation and maintenance cost for massburn WTE facility ranges between $21 and $40 per ton of daily capacity, depending upon the size of the facility, revenue sharing arrangements, and other terms and conditions in the operation and management agreement.

One of the key advantages of WTE technology is its ability to stabilize solid waste disposal rates over the long term, especially after the capital debt service is retired. A typical massburn WTE facility has a service life of 45 - 50 years with periodic capital required for major equipment refurbishment. At the end of the construction financing period, the capital cost component will no longer remain, reducing the annual cost of WTE by 30-40 percent.

C.1.4 Overall Project Risk

The overall project risk associated with massburn WTE facilities is low. There are approximately 85 WTE facilities currently in operation in North America, along with hundreds of commercially successful projects in Europe and Asia. Over the past 35 years, advanced grate combustion technology has demonstrated its ability to process the wide variations in municipal solid waste and is considered to be the leading proven waste conversion technology. CDM Smith recommends massburn WTE as the best fit WTE technology for this study.

C.2 Refuse Derived Fuel (RDF) Waste-to-Energy

At the time of development approximately 25 years ago, RDF WTE facilities were perceived as a means to produce a cleaner fuel which would result in higher thermal efficiencies and lower boiler corrosion rates due to the extraction of recyclable and non-processible materials (wet organic materials) and inert materials (glass, rocks, sand, and dirt). However, the perceived benefits of RDF WTE technology did not result in lower boiler corrosion rates as expected, and the quantity and quality of the recovered recyclables was not sufficient to produce significant revenues to offset the increased cost of RDF processing. Additionally, there is approximately 30% of non-processible residuals which are removed from solid waste in the preparation of RDF, which requires disposal by other means.

C.2.1 Technology Issues

RDF processing is well developed with a variety of high and low speed shredders that can reduce raw waste to a specified material size with acceptable reliability. Also, a variety of conveyance systems are available (clamshells or grapples; front-end loaders; belt, pan, apron and pneumatic conveyors) to handle and move waste from storage, to and from processing components, and to the combustion system. Around the world, and especially in the United States, there are a number of operating RDF processing facilities that can be reviewed and considered as potential models for a new plant.

History has shown that few, if any, RDF WTE plants where the RDF processing and handling system (from waste acceptance to the firing face of the combustor) is the same as that originally installed. Indeed, re-work of the RDF system has often required substantial new capital (as much as 30 percent) of the total plant investment) and has frequently delayed start-up. Often, irregular feeding brought about by the challenges of handling the shredded waste have produced significant upsets and continuing problems in achieving acceptable operations at rated capacity. Many of these problems have arisen due to unanticipated effects of difference in the actual composition of the local waste stream.

RDF technology is not compatible with the full spectrum of municipal waste. The removal of the smaller inert fraction of wastes (typically minus 2" in size), results in a significant percentage of biodegradable and inert materials (typically in the range of 30 percent) that must be disposed of in the landfill, or by alternate processes.

RDF WTE facilities typically require a greater amount of real estate for a similarly sized massburn WTE facility, due to the need for a larger waste receiving area, RDF processing, and RDF fuel storage.

C.2.2 Environmental Issues

RDF combustion and flue gas cleaning technology have evolved over the years to cope with increasingly stringent environmental regulations. Modern RDF plants routinely exceed the most stringent federal and state requirements for stack emissions and residue quality. The emission profile of RDF combustion technology is similar to massburn WTE technology.

C.2.3 Financial / Economic Issues

The capital cost for constructing a modern RDF WTE facility is comparable to a massburn WTE facility, although there is a significant (~ 35 – 50 percent) increase in the cost of the operation and maintenance of RDF WTE facilities due to the high level of pre-processing that is employed to manufacture the RDF, along with a significant higher number of operating staff. Additionally, there is a greater volume of wastes (non-processible wastes and ash residue) that still require landfill disposal than massburn WTE facilities.

C.2.4 Overall Project Risk

The overall project risk associated with RDF WTE facilities is low to medium. However, explosions in the RDF processing system are not uncommon, and can disrupt the daily processing of RDF fuel. Personnel injury and occasional deaths have resulted at some RDF facilities due to explosions in the shredders.

C.3 Advanced Thermal Recycling Technologies

Advanced Thermal Recycling (ATR) Systems are a third-generation European advancement of waste combustion and pollution control technology which is very similar to massburn combustion technology. The improvements developed in WTE technology during the past decades is simply a technical response by the industry to requirements made by environmental regulators, politicians, EU and national legislation. The industry is continuously improving, primarily for WTE based on mass burn technology. Every new WTE project can enjoy significant benefits by employing demonstrated improvements from the previous generation to make them unique and serve the special needs of the local community, including environmental aspects, sustainability, energy and material recover. A recent example of ATR could be made for the Palm Beach County WTE facility, which incorporates many advancements which were first developed and commercially proven in Europe.

The primary focus of ATR has been on resource management, improving energy and material recovery efficiency. This focus started with the ban on landfill disposal of untreated household waste or general waste similar to MSW from industry on June 1, 2005. The corner stone of this approach is to moving towards a circular economy, via the integration of ATR (only as the last resort of waste management as a resource for energy recovery under certain standards for efficiency, R1 criterion) with other resource management technologies, while making WTE work as efficiently as possible. The legal basis in Germany are embodied in the Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal and the Federal Emission Control Act. The renewed Closed Cycle Management Act, adopted in 2012, aims to improve the contribution of waste (resource) management for maximizing efforts at environmental and climate protection, as well as the increase of resource management efficiency, in conjunction with strengthening waste prevention and recycling. Landfill disposal of unprocessed and untreated wastes is considered the least sustainable, most environmentally damaging and costly approach. (All of this is the national implementation of European legislation).

ATR employs advanced combustion controls as part of the normal progress or enhancement due to developments mainly in computer technology, which can be found anywhere, for example in airplanes manufactured by Boing, along with an advanced emission control systems that can include a number technologies, from electrostatic precipitators, to wet and dry scrubbers, dry lime injection, fabric filters, including high efficiency ePTFE membrane filter bags (catalytic filtration for improved destruction of dioxins (90%). Other advanced control technologies may include processes designed to capture and recover recyclable components in the flue gas, converting them to marketable byproducts such as gypsum (e.g., for wallboard manufacture) and hydrochloric acid (used for water treatment) via the use of wet scrubbers.

The bottom ash and fly ash are typically segregated (this is a requirement of European, and world-wide regulations agreements or standards forbidding mixing of wastes. Separation of fly ash from bottom ash helps improves the quantity and quality of metals (ferrous, non-ferrous, and in some cases, precious metals) recovered from the bottom ash. Improvements in eddy-current technology has have also significantly helped to recover more non-ferrous metals. Further improvements can be achieved if the fraction of very fine particles in the bottom ash is reduced, for example by washing. This extensive treatment process facilitates the use of the bottom ash as a road base and or construction aggregates, provided such materials meet local and national regulatory requirements. An improved bottom ash treatment system will cost more, but this will be easily compensated by higher returns for the recovered metals.

Feedstocks for ATR systems can be unprocessed municipal solid waste or RDF, with an overall waste diversion from landfill disposal varying from 80 percent to over 95 percent. ATR technology has been proven in two full-scale, commercial facilities in Hamburg, Germany. The Muellverwertung Rugenberger Damm (MVR) facility has reportedly operated at over 90 percent annual availability since 1999, with a net energy generation rate of approximately 550 kWh per ton of waste processed. Each combustion unit at MVR unit has a throughput capacity of 21.5 tph, max 23 tph (metric tons). Larger units of the size suitable for King County can be designed. Based on this size, significant scale-up of this technology for application in the U.S. is not necessary. A new ATR facility recently constructed in Berlin, Germany employs a steam reheat cycle, which results in a much higher net energy generation rate of approximately 850 kWh per ton.

The ATR combustion process is essentially identical to massburn technology, with minor differences in the emission control systems, but only if you wet scrubbers are employed, otherwise the technology in principle is comparable to what is done in the U.S. Although there are no facilities employing the ATR Technology currently in operation in the U.S., technically ATR technology meets the intent of the WTE evaluation criteria for projects with a minimum of three years of commercial operating experience. The combustion system is practically the same and it is not possible to buy a WTE boiler with an outdated combustion control system. Even in case where it was decided to employ a technology to improve power production, the necessary technology has been applied in coal fired power plants for a long time. With current prices of natural gas low in the U.S., some consideration could be given for a process that combines a gas turbine generator with a WTE process. This in turn will raise power production considerably because the waste heat of the gas turbine generator can be utilized to improve the efficiency of the WTE steam-water cycle from about 25% to more than 40%. This technology has been applied in coal fired plants and in WTE plants as well (Spain, and Finland). An item of note, ATR technology was proposed for the City of Los Angeles' waste conversion project in 2006 as one of the highest ranked technologies of the ten qualified waste conversion processes which were deemed to meet the City's RFP Criteria. Unfortunately, none of the qualified waste conversion projects were implemented.

CDM Smith is of the opinion that ATR is simply an advanced form of massburn, and is a qualified technology for consideration in King County. Unit capacities of more than 1,200 tpd have been realized in Europe, while the combustion process and flue gas treatment systems are in operation as well, including in the U.S., although referred to as dry or semi-dry systems. Hence, the only real difference between ATR and massburn is the treatment of bottom ash, and the use of wet scrubbers for enhanced flue gas treatment with the recovery of gypsum and hydrochloric acids.

CDM Smith and Neomer both recommend ATR for King County's consideration at this time due to proven European commercial experience in the size ranges suitable for King County's waste stream and composition.

C.4 Other Emerging Thermal Processes

Although proven waste combustion technology has continued to advance over the past decades, various alternate thermal technologies are being promoted by many developers today. These emerging thermal processes include pyrolysis and several forms of gasification (thermal and plasma, with or without vitrification and direct melting). A brief introduction to several of the emerging WTE gasification technologies follows, although none of these processes are currently processing MSW have been commercially deployed in the Unites States to date.

Gasification is a process by which any carbon-based material, including municipal solid waste, is heated to temperatures of over 1,000 degrees Fahrenheit in a vessel with limited amounts of oxygen (or air) to create a mixture of combustible gases called synthesis gas (or syngas), which includes hydrogen, carbon monoxide, carbon dioxide, and other trace compounds. Syngas typically has a heating value of 200 to 500 Btu per cubic foot and can be used as a fuel to produce thermal energy as heat, steam, hot water, or electricity; or be further processed into a variety of other chemical compounds. Although several small scale gasification facilities exist in the U.S., the technology has achieved commercial success in Japan, South Korea, and parts of Europe in locations where landfill space faces substantial constraints. Four types, or variations of gasification technology are being promoted today.

Gasification and Chemical Synthesis – This process usually consists of a four-step thermochemical process. First solid waste is pre-sorted to remove recyclable materials (e.g., glass, metal, paper, and certain plastics) and non-processible materials (bulky wastes, inert materials and prohibited materials). The pre-sorted MSW may also need to be processed for size reduction to meet the limits of the waste delivery system. The pre-sorted MSW is then transferred into a gasification reactor which converts the MSW into syngas. The syngas is further cleaned and conditioned before the last step – chemical synthesis – which converts the syngas into methanol, ethanol, or other types of fuel and/or chemicals. This final step is typically completed with catalysts.

Plasma Gasification (also known as plasma-assisted gasification) combines gasification with plasma technology (e.g., plasma torches and high temperature electric arcs) to heat MSW to extremely high temperatures (e.g., greater than 2,000 to 3,000 degrees Fahrenheit). At these intense temperatures, the rate of gasification reactions increase, thereby improving the efficiency of the gasification process. The output of this process consists primarily of carbon monoxide and hydrogen. The efficiency of plasma gasification offers greater feedstock flexibility, including hazardous wastes, with minimal air emissions. Plasma gasification plants are currently operating in Japan, Canada, and India.

Gasification/Direct Melt is a common form of gasification in operation throughout Japan and South Korea. Also known as direct melting systems, such operations typically consist of a gasifier, combustion chamber, a boiler, and a flue gas cleaning system. This type of high-temperature gasification converts waste into syngas and recyclable outputs such as slag and metal. In Japan, current generation of direct melting systems offer greater waste feedstock flexibility, including WWTP biosolids, medical waste, waste tires, asbestos, and incinerator bottom ash (for additional conversion into an inert slag).

Gasification/Pyrolysis - involves the gasification of waste, in some cases a feedstock consisting of vegetation and other forms of biomass, MSW, and construction and demolition debris – in an environment deprived of oxygen. This process results in the separation of volatile gases from the waste feedstock. The remaining pyrolyzed material is known as char, which may then be combusted in a separate char combustor to generate energy. Additional markets for char produced from biomass as soil amendments are being developed in the U.S., however, this beneficial use may be limited this to biochars produced primarily from biomass. Thermal gasification processes are typically performed at high temperatures with a controlled amount of oxygen and/or steam, whereas pyrolysis is typically performed at lower temperatures. Gasification and pyrolysis involve the application of heat or partial oxidation (with air or oxygen) to convert organic matter to a "synthesis gas" (syngas) which consists primarily of carbon monoxide (CO) and hydrogen (H2). Like gasification, advantages to this process are due to the fact that multiple opportunities exist for use of produced syngas to generate heat, power, pipeline quality gas, or a wide variety of chemicals and liquid fuels. However, in an era of low cost natural gas and other forms of petroleum based energy, there are few economic opportunities to deploy these technologies in the near future.

C.4.1 Technology Issues

Unfortunately, there are also significant disadvantages of gasification and pyrolysis processed, including:

- Most gasification technologies cannot process the entire MSW stream, and require select wastes requiring source separation or pre-processing that rejects a significant fraction of the waste as residue and non-processible material which requires disposal in a landfill (25 – 40 percent).
- Materials with high moisture affects the composition of syngas (reduces overall energy content) and as a result, materials which contain less than 20 percent moisture are preferred. In some cases, drying of the feedstock may be required.
- The process is often complex with implications of steep learning curves, high cost, sophisticated process controls, and lower on-line availability.
- To date, few major and credible development firms have appeared, with unit costs and capacities less than conventional combustion technologies. Numerous gasification projects have been abandoned in the past ten years, most in the project development stage, but several after pilot and commercial scale testing.

On a positive note, Thermoselect is one of the more promising gasification technologies developed in Europe in the 1990s, and has been implemented at 7 facilities in Japan and Italy. Thermoselect is marketed in the U.S. by Interstate Wastes Technologies (IWT), and they continue to promote projects in Caguas, Puerto Rico, and Massachusetts. Each of the above projects is proposed to integrate five gasification units rated at 354 TPD each for a total capacity of 1,770 TPD. Thermoselect was also been selected to develop a 1,770 TPD project in Los Angeles County as part of their Phase IV Alternate Technologies Evaluation in 2007. However, this project has not materialized since it was first selected by the County almost ten years ago.

C.4.2 Environmental Issues

Data submitted by Thermoselect on several recent U.S. proposals suggests that most of the air emissions will be significantly less than the U.S. EPA limits for regulated air pollutants required of modern combustion technology. This claim must be taken with a cautionary note, since there are no large scale commercial gasification plants operating in the U.S. Compounding the air emission permitting process, many states do not have rules in place for gasification technology, which complicates and potentially lengthens the permitting process.

In addition to the main components of CO, CO_2, H_2, and H_2O, the raw syngas also contains HCL, HF, H_2S, particulate and metal compounds as impurities. Environmental air emissions from the typical gasification / pyrolysis process are minimized by use of a sophisticated syngas scrubbing process which is designed to address:

- Quenching of the hot syngas
- Acid gas scrubbing
- Dust and particulate removal (coarse and fine particles)
- Desulphurization
- Gas reheating

In the case of gasification technology integrated with vitirfication process, the inorganic waste components are converted by means of the melting process into potentially usable mineral substances and metals. This feature offers promise to maximize the diversion of wastes from the landfill, however, marketing of the vitrified slag to local markets will require significant time and effort as the beneficial reuse opportunities are typically in low value applications.

C.4.3 Financial / Economic Issues

Gasification technologies may also provide opportunities for sale of syngas to the natural gas markets or "across the fence" opportunities to local industries. The syngas can be used in a variety of industrial applications as a gaseous fuel for combustion and steam generation, or as substitute / supplemental natural gas type fuel used for electric power production via gas turbine engines and fuel cells in the near future.

While there is promise of higher revenues from the production of liquid and gaseous fuels compared to electricity, there are numerous hurdles to clear in securing the necessary long-term contracts for sale of renewable fuels at favorable economic terms and conditions. The liquid and gaseous fuel markets are heavily regulated with strict specifications for all potential suppliers before long-term favorable contracts would be negotiated. Additionally, the costs of production for biofuels from the conversion of syngas have yet to be determined, thereby complicating the potential for private financing of large multi-million dollar projects. The U.S. DOE awarded almost $600M in grants and loan guarantees to 19 emerging Bioenergy producers in December of 2009, in attempt to kick start a new Bioenergy industry. Without federal grants and loan guarantees, few investors will be willing to commit to loans for unproven technology. To date, few of the above noted 19 bioenergy projects are still operational and able to provide data on the technical and economic success of the various waste conversion technologies, many of which propose to use gasification technology for the production of syngas.

C.4.4 Overall Project Risk

There is a significant overall project risk associated with technologies for converting lingo-cellulosic feedstocks into useful energy products via gasification / pyrolysis, in spite of the fact that these technologies have been the subject of substantial research and development since the energy shocks of the 1970's. Most of this research has been completed with conventional homogeneous feedstocks, such as wood chips and saw dust. In response to the emerging paradigms of the past decade, including energy security, economic development, environmental sustainability, and climate change initiatives, there has been an acceleration of R&D programs in pursuit of waste conversion technologies on both the domestic and international front. This has incentivized some of the early developers to promote gasification and pyrolysis technologies for conversion of municipal solid waste at this time.

History has shown that solid waste is a stern taskmaster that presents an aggressive, corrosive, abrasive, and complex challenge to developers of innovative processing systems. Even sophisticated and well-funded developers have, repeatedly, failed to meet these challenges in ways that adequately address the severe economic, environmental, operability, maintainability, and flexibility demands of practical waste management systems. In most cases, this failure has led to the total collapse of the development effort at great economic and political cost. In addition, the time lost while facilities embodying the new technology were constructed, tested, modified or re-designed, retested etc. and, ultimately abandoned has had a serious adverse impact on the reliable delivery of waste management services within the host community.

The rewards of such risks are significant and tend to enhance the fortunes of the developer, while the impacts of failure sit heavily on the shoulders of the host. As a result, new or emerging technologies must be approached cautiously. The rate at which technologies penetrate the market segment varies. However, historical data suggests that major classes of technology can vary between five and forty years. CDM does not recommend gasification and pyrolysis waste conversion technologies at this time due to their lack of proven commercial experience with municipal solid waste in the United States.

In summary, advanced WTE technologies are high-risk and difficult to “scale”. CDM Smith does not recommend that this family of technologies be considered as best fit WTE processes for King County’s waste projection and composition.

Appendix D

Renewable Energy Certificates (RECs) and Verified Carbon Units (VCUs) (Part of Task 2 of the King County WTE Study)

Appendix D - Renewable Energy Certificates (RECs) and Verified Carbon Units (VCUs) (Part of Task 2 of the King County WTE Study)

D.1. Introduction

In accordance with the Scope of Work for the King County (County) Waste-to-Energy (WTE) Study, CDM Smith has been tasked with summarizing Renewable Energy Certificates (RECs) and Verified Carbon Units(VCUs) as they pertain to the subject project. The purpose of this memorandum is to describe how each of these “non-power attributes” or “environmental attributes” of WTE can be monetized, in the State of Washington and in other locations.

D.2. RECs

D.2.1 Background on RECs

RECs, also known as Green Tags, Renewable Energy Credits, Renewable Electricity Credits and Tradable Renewable Certificates (TRCs) are tradable, sellable energy commodities which prove that electricity was generated from a renewable source. One REC is equal to 1 MWh of electricity fed into the grid. Renewable Portfolio Standards (RPS, also referred to as Renewable Energy Standards) are state-regulated policies which require that a percentage of the electricity sold must come from renewable sources. Twenty-nine states have an RPS, as shown in **Figure D-1**.

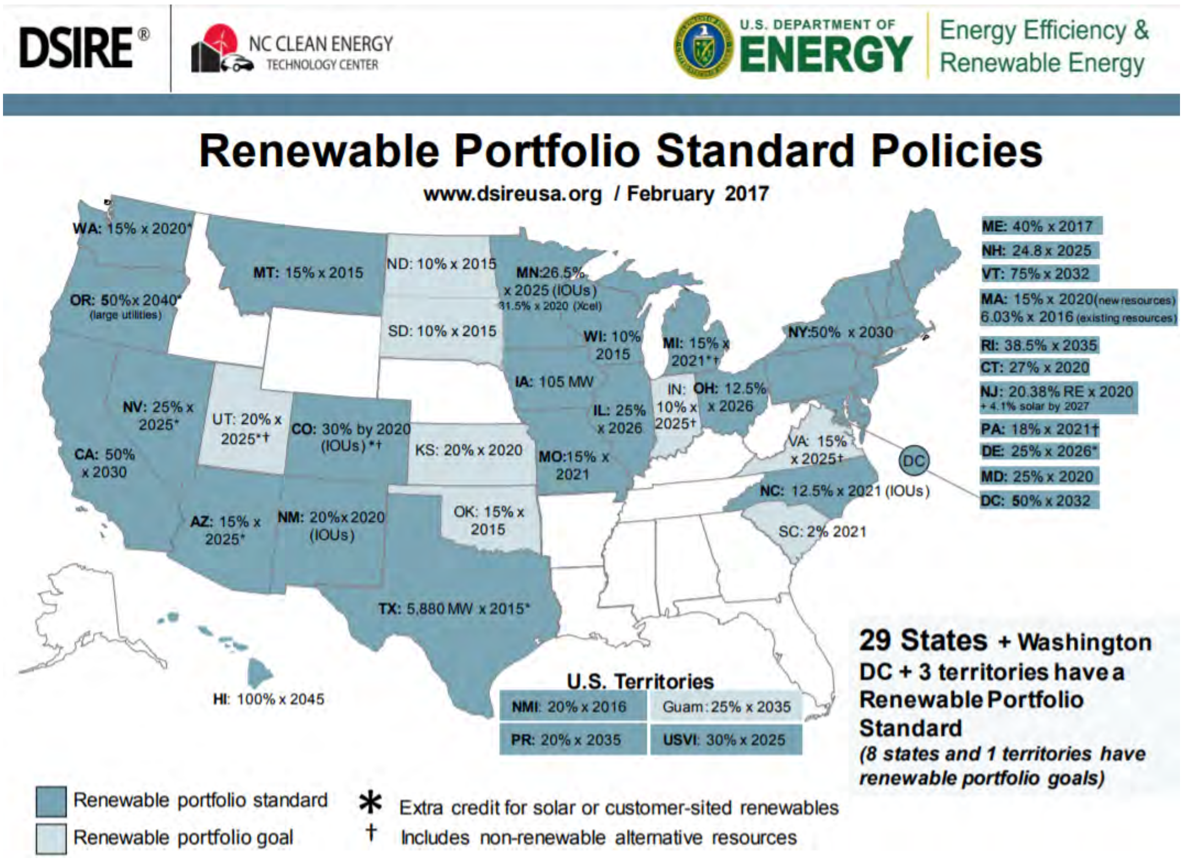


Figure D-1
Renewable Portfolio Standard (RPS) Policies in the U.S.
Source: US Department of Energy DSIRE; NC Clean Energy Technology Center

Washington's RPS states that utilities serving more than 25,000 customers must generate 15 percent of their sold electricity from renewable sources by 2020. By comparison, Oregon's RPS states that the largest utilities generate 20 percent of their electricity from renewable sources by 2020 and 25 percent by 2025. Utilities with less than 1.5 percent of the state load must generate 5 percent of their sold electricity from renewable sources by 2025. Utilities with 1.5 to 3 percent of the state load must generate 10 percent of the sold electricity from renewable sources by 2025. As of February 2017, Idaho did not have an RPS.

To meet the RPS, utilities may purchase RECs if they are not able to generate the electricity from a renewable source themselves, or if they do not have the planned capacity to do so. Oftentimes the physical location of the renewable energy generated is not located within close proximity to renewable energy buyers, however some RPSs stipulate that RECs be from regional RECs generators. Current state regulations state that Washington's RPS requirement be verified and managed through the Western Renewable Energy Generation Information System (WREGIS), a regional REC tracking system. Each REC is assigned a serial number to avoid double-counting. The process of RECs from registration to sale is displayed in **Figure D-2**.

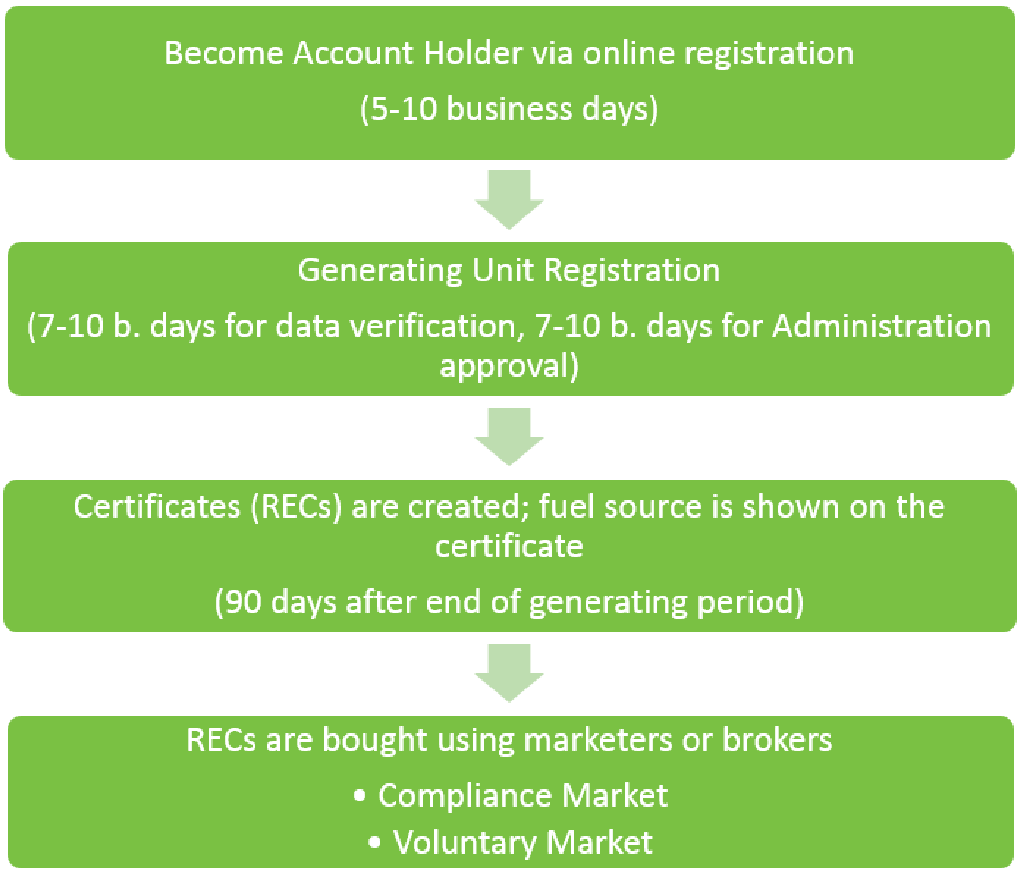


Figure D-2
RECs Process Flow Diagram

If the County were to construct a WTE facility, WREGIS would be able to create RECs from the electricity that the facility generates, because by WREGIS's Operating Rules, MSW combustion and MSW conversion are considered approved fuel sources for REC generation. However, the

State of Washington (as with many other states) does not recognize WTE as a qualified technology for generating renewable energy and therefore those RECs would have a difficult time being sold in the compliance market. If they cannot be easily sold (due to lack of demand or acceptability), the question becomes what is the value of generating the RECs in the first place? The convincing argument for moving forward with the construction of a King Co. WTE facility must then be for other reasons (e.g. landfill diversion, better electricity rates, increase material recovery, etc.) and not count on revenue from RECs. Under present circumstances, the best course for the County would be to sell its WTE power where the power is better appreciated (e.g. Idaho) and provide for the County to retain the corresponding RECs as part of the transaction (to be sold, used, or traded later if the acceptability of WTE RECs changes). Another idea would be for the County to sell the power from a County-owned WTE facility back to the County itself for use as the County determines (that could require "wheeling," and Puget Sound Energy (PSE) may have some resistance to).

D.2.2 Washington State Regulations on Renewable Resources

For further clarification, the following was excerpted from the Revised Code of Washington (RCW) 19.285.030:

(12) "Eligible renewable resource" means:

(a) Electricity from a generation facility powered by a renewable resource other than freshwater that commences operation after March 31, 1999, where: (i) The facility is located in the Pacific Northwest; or (ii) the electricity from the facility is delivered into Washington state on a real-time basis without shaping, storage, or integration services;

(b) Incremental electricity produced as a result of efficiency improvements completed after March 31, 1999, to hydroelectric generation projects owned by a qualifying utility and located in the Pacific Northwest where the additional generation does not result in new water diversions or impoundments;

(c) Hydroelectric generation from a project completed after March 31, 1999, where the generation facility is located in irrigation pipes, irrigation canals, water pipes whose primary purpose is for conveyance of water for municipal use, and wastewater pipes located in Washington where the generation does not result in new water diversions or impoundments;

(d) Qualified biomass energy; or

(e) For a qualifying utility that serves customers in other states, electricity from a generation facility powered by a renewable resource other than freshwater that commences operation after March 31, 1999, where: (i) The facility is located within a state in which the qualifying utility serves retail electrical customers; and (ii) the qualifying utility owns the facility in whole or in part or has a long-term contract with the facility of at least twelve months or more.

The RCW also defines:

(15)(a) "Nonpower attributes" means all environmentally related characteristics, exclusive of energy, capacity reliability, and other electrical power service attributes, that are associated with the generation of electricity from a renewable resource, including but not limited to the facility's fuel type, geographic location, vintage, qualification as an eligible renewable resource, and avoided emissions of pollutants to the air, soil, or water, and avoided emissions of carbon dioxide and other greenhouse gases.

(b) "Nonpower attributes" does not include any aspects, claims, characteristics, and benefits associated with the on-site capture and destruction of methane or other greenhouse gases at a facility through a digester system, landfill gas collection system, or other mechanism, which may be separately marketable as greenhouse gas emission reduction credits, offsets, or similar tradable commodities. However, these separate avoided emissions may not result in or otherwise have the effect of attributing greenhouse gas emissions to the electricity.

The RCW also defines:

(20) "Renewable energy credit" means a tradable certificate of proof of at least one megawatt-hour of an eligible renewable resource where the generation facility is not powered by freshwater. The certificate includes all of the nonpower attributes associated with that one megawatt-hour of electricity, and the certificate is verified by a renewable energy credit tracking system selected by the department.

(21) "Renewable resource" means: (a) Water; (b) wind; (c) solar energy; (d) geothermal energy; (e) landfill gas; (f) wave, ocean, or tidal power; (g) gas from sewage treatment facilities; (h) biodiesel fuel as defined in RCW ***82.29A.135*** that is not derived from crops raised on land cleared from old growth or first-growth forests where the clearing occurred after December 7, 2006; or (i) biomass energy.

The Washington Administrative Code (WAC) 480-109-060 discusses RECs and renewables as well:

(3) "Certificate" means proof of ownership, registered in WREGIS, of the nonpower attributes associated with a megawatt-hour of generation from an eligible renewable resource.

The WAC also defines:

(25) "Renewable resource" means:

(a) Water;

(b) Wind;

(c) Solar energy;

(d) Geothermal energy;

(e) Landfill gas;

(f) Wave, ocean, or tidal power;

(g) Gas from sewage treatment facilities;

(h) Biodiesel fuel as defined in RCW 82.29A.135 that is not derived from crops raised on land cleared from old growth or first-growth forests where the clearing occurred after December 7, 2006;

(i) Generation facilities in which fossil and combustible renewable resources are cofired in one generating unit that is located in the Pacific Northwest and in which the cofiring commenced after March 31, 1999. These facilities produce eligible renewable resources in direct proportion to the percentage of the total heat value represented by the heat value of the renewable resources; or

(j) Biomass energy, where the eligible renewable energy produced by biomass facilities is based on the portion of the fuel supply that is made up of eligible biomass fuels.

Figure D-3 shows the states which consider WTE to be a renewable source of energy.

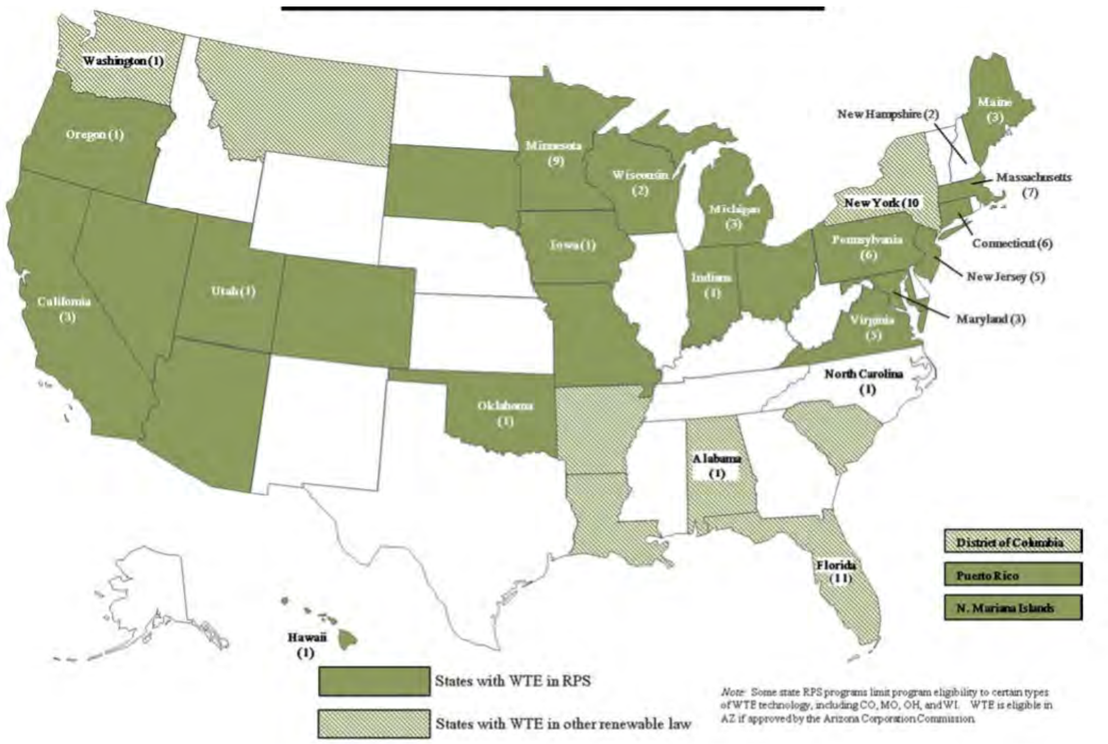


Figure D-3
States Defining WTE as Renewable
Source: http://energyrecoverycouncil.org/wp-content/uploads/2016/01/ERC_2014_Directory.pdf

California may consider WTE as a valid renewable technology, but only with special approval for those RECs. The fuel source is indicated on the REC and therefore not all RECs have equal value to the states attempting to meet their RPS requirements. To compare WTE to other energy sources, wind and solar are almost always acceptable RECs (highly successful on the voluntary market) while there is no consensus on the acceptability of hydropower RECs. Landfill gas is generally an acceptable REC, and it has more success on the compliance market than on the voluntary market. The "nonpower attributes" or "environmental attributes" of the renewable energy are unbundled from the energy itself and can therefore be traded/bought/sold independently of the electricity. Green-e is considered by some as the "marketplace for RECs" for non-RPS states.

D.2.3 WTE Facilities in the Pacific Northwest

Following is a list of the WTE facilities located in the Pacific Northwest.

- Washington - Wheelabrator Spokane Inc. (Spokane).
- Idaho – none.
- Montana – none.
- California – Commerce Refuse-to-Energy Facility (Commerce); Southeast Resource Recovery Facility (Long Beach); Stanislaus County Resource Recovery Facility (Crows Landing)
- Oregon - Marion County Solid Waste-to-Energy Facility (Brooks)
- Washington borders British Columbia, Canada, however, that region was beyond the scope of our investigation for this memorandum.

D.2.4 Project Example – Hillsborough County, Florida

Credits for elimination of carbon dioxide emissions from Hillsborough County's Resource Recovery Facility's (RRF) Unit 4 expansion are eligible for sale on U.S. voluntary markets. The credits for each year must be verified by a qualified independent third party prior to being offered for sale at market prices. Covanta coordinated this program for Hillsborough County after successfully performing a similar arrangement for Lee County, Florida (see next section). The first sale of 2010 vintage carbon credits occurred in February 2014. Approximately $6,000 was received by Hillsborough County for this initial transaction. Two additional sale transactions occurred in FY15 with the sale of 5,000 credits in January and 4,000 credits in March that resulted in a total of $3,500 received by Hillsborough County. In FY16, Hillsborough County decided to internally administer the sale of the carbon credits. There was no sale of carbon credits in FY16. Covanta and Hillsborough County are in negotiation to amend the Agreement to reinitiate Covanta's coordinate of the sale of carbon credits. Covanta, who happens to be the operator of Hillsborough County's RRF, sells RECs from many of their privately-owned WTE facilities.

D.2.5 Project Example Case Study – Lee County, Florida

D.3. VCUs

D.3.1 Background on VCUs

Verified Carbon Units (VCUs) are a completely different metric, tracking system, and currency from the RECs. VCUs are generated from GHG emission reductions at projects that meet the requirements of the Verified Carbon Standard (VCS) Program and approved GHG accounting methodologies. Changes in emissions from waste management due to WTE facilities are very site-dependent. The VCS Program, in their own words,

"…allows vetted projects to turn their greenhouse gas (GHG) emissions reductions into tradable carbon credits. Since its launch in 2006, the VCS Program has grown into the world's largest voluntary carbon credit market. The program has registered more than 1,300 carbon reduction projects worldwide that have reduced or removed more than 185 million tonnes of CO2 equivalent from the atmosphere. ***The VCS Program is the world's most widely used voluntary GHG program.*** *Projects developed under the VCS Program must follow a rigorous assessment process in order to be certified. VCS projects cover a diverse range of sectors, including renewable energy (such as wind and hydroelectric projects), forestry (including the avoidance of deforestation), and others. Emission reductions certified by our program are eligible to be issued as VCUs, with one VCU representing one metric tonne of greenhouse gas emissions reduced or removed from the atmosphere."*

(http://www.v-c-s.org/about-vcs/who-we-are/)

"Once projects have been certified against the VCS Program's rigorous set of rules and requirements, project developers can be issued tradable GHG credits that we call Verified Carbon Units (VCUs). Those VCUs can then be sold on the open market and retired by individuals and companies as a means to offset their own emissions."

(http://www.v-c-s.org/project/vcs-program/)

D.4. Monitizing Benefits

In 2016, the National Renewable Energy Laboratory (NREL, part of the U.S. Department of Energy) published a study of the cost, benefits and impacts of renewables used to meet U.S. RPSs by looking at two scenarios for 2015-2050: 1) Existing RPS Scenario and 2) High Renewable Energy (RE) Scenario in which most states adopt relatively aggressive targets. Health and environmental benefits are estimated on a cent per kilowatt-hour of renewable energy (kWh-RE) basis. GHG benefits are presented on a metric tons of carbon dioxide equivalent (CO_2e) basis. Their findings are shown in **Figures D-4 and D-5**.

"When comparing the costs and monetized benefits, we find that the benefits exceed the costs, even when considering the highest cost and lowest benefit outcomes… Under the Existing RPS scenario, the high end costs are 0.75¢/kWh-RE, while air pollution and health benefits total at least 1.2¢/kWh-RE and GHG benefits total at least 0.9¢/kWh-RE. Under the High RE scenario, the high end costs are 1.5¢/kWh-RE while air pollution and health benefits total at least 2.7¢/kWh-RE and GHG benefits total at least 1.2¢/kWh-RE. The figures here are presented on a national basis and reflect levelized 2015-2050 values. These cost ranges reflect varying assumptions about future natural gas prices and renewable technology costs."

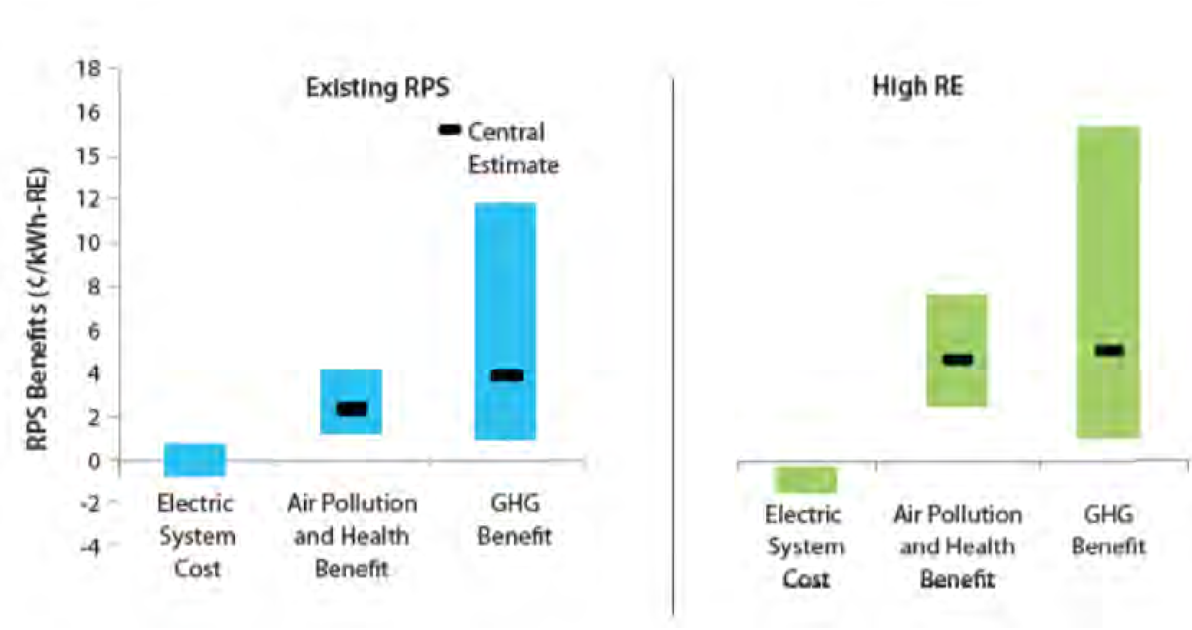


Figure D-4
Comparison of costs, benefits, and impacts under the Existing RPS and High RE scenarios
Source: ***http://www.nrel.gov/docs/fy17osti/67561.pdf***

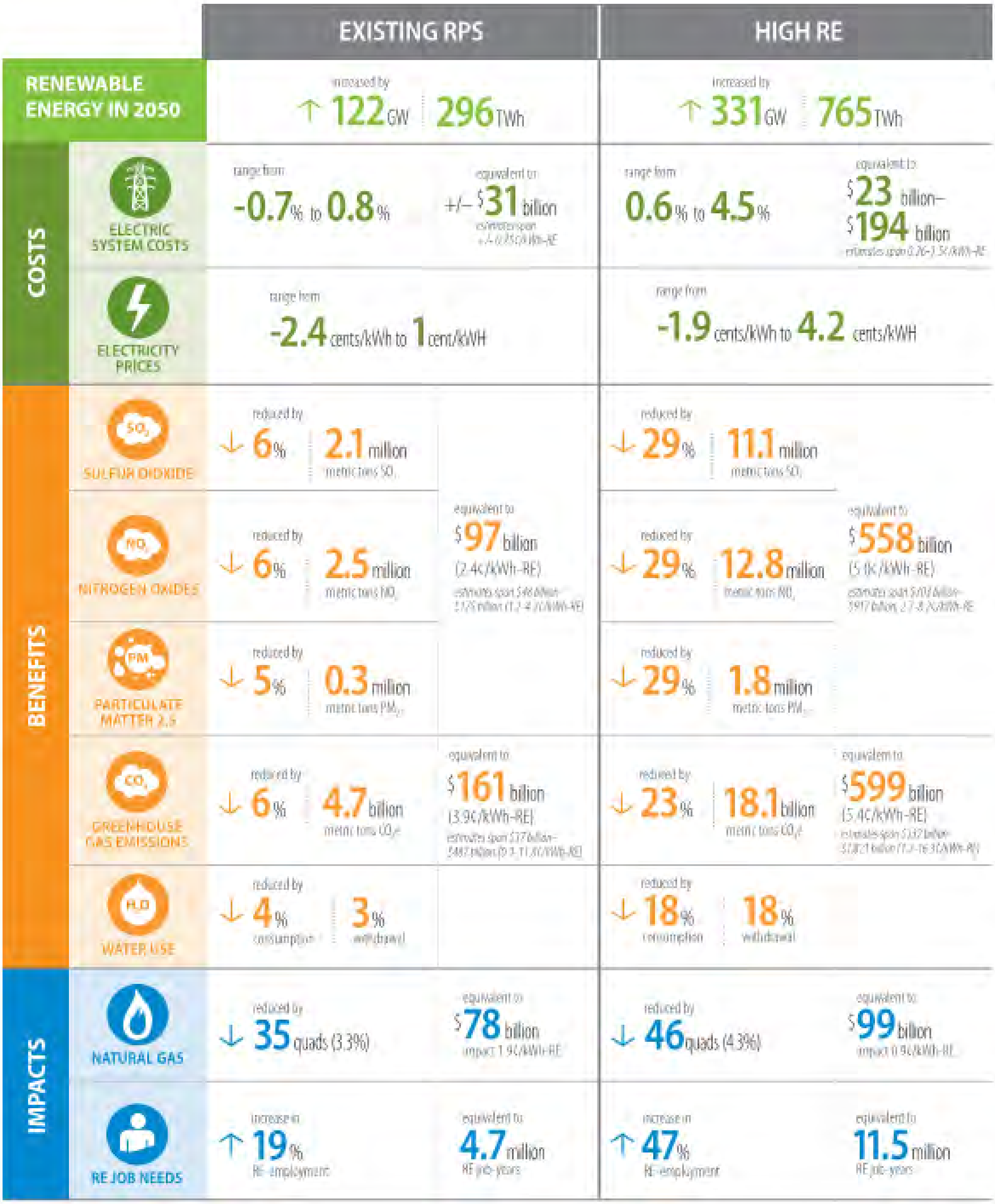


Figure D-5
Cost, benefits, and impacts of the Existing RPS and High RE scenario relative to the No RPS Scenario, 2015-2050
***Source:* http://www.nrel.gov/docs/fy17osti/67561.pdf**

Should the County decide to sell their WTE RECs in the marketplace, there may be costs associated with:

- Registration of the WTE facility in the WREGIS tracking system

- Reporting, data submission/ validation for proof for REC generation
- Independent Consultant qualifying the WTE facility as a renewable generator, (e.g. every 5-10 years), and perhaps periodically re-qualifying the WTE
- Third party verification of RECs for sale on annual basis (estimated up to $9,000)
- REC broker fees
- Extensive convincing for acceptance of WTE RECs to meet state RPS requirements

Fees may be in the form of one-time fees (e.g. registration, account setup, etc.) recurring fees (e.g. $/year/account), and volumetric fees ($/REC or $/transaction). The fees associated specifically with the use of the WREGIS RECs accounting system include annual, volumetric (Issuance, Transfer, Retire, Reserve, and Export), and reports. Other service fees may be charged where applicable. The WREGIS Fee Matrix is displayed in **Figure D-6**.

Annual and Volumetric Fees

	Account Holder Types	Total GU Size Per WREGIS Account	Annual	Issuance	Transfer	Retire, Reserve, or Export
1	**GU Micro** *(Generating Unit Owner / Representative Only)*	30 KW or Less	$50.00	None	None	None
1	**GU Small** *(Generating Unit Owner / Representative Only)*	30 KW - 1 MW	$75.00	None	None	None
1	**GU Medium** *(Generating Unit Owner / Representative Only)*	1 MW - 10 MW	$100.00	None	None	None
	One or more types below may be selected - the annual fee will remain $125.00 per account					
1	**GU Large** *(Generating Unit Owner / Representative Only)*	10 MW or More	$125.00	$0.005 / Certificate	$0.005 / Certificate	$0.005 / Certificate
2	**Load Serving Entities** *(Municipal Utility, Irrigation District, Joint Power Authority, Investor-Owned Utility, Rural Electric Cooperative, Electric Service Provider)*		$125.00	$0.005 / Certificate	$0.005 / Certificate	$0.005 / Certificate
3	**Retail Marketers** *(Federal Marketer / Power Administrator)*		$125.00	$0.005 / Certificate	$0.005 / Certificate	$0.005 / Certificate
4	**Wholesale Marketers** *(Federal Marketer / Power Administrator)*		$125.00	$0.005 / Certificate	$0.005 / Certificate	$0.005 / Certificate
5	**Utility Aggregators**		$125.00	$0.005 / Certificate	$0.005 / Certificate	$0.005 / Certificate
6	**Generating Unit Aggregators** *(Community Choice Aggregator)*		$125.00	$0.005 / Certificate	$0.005 / Certificate	$0.005 / Certificate
7	**Account Holder Other** *(Broker, Public Interest Organization, Tribal Organization)*		$125.00	$0.005 / Certificate	$0.005 / Certificate	$0.005 / Certificate

Reports and Other Service Fees

Report / Service Type	Email	Hardcopy	Monthly	Per Transaction
Authorized Report	$25.00	$50.00		
WREGIS Deliverability (e-Tag) User			$212.00	
Change Control				Variable
International Wire Transfer				$20.00
Fuel and/or Aggregated Meter Modifications (per generator and vintage)				$75.00
Failure to complete Generating Unit Annual Review (per generator)				$50.00

Effective January 1, 2017

Figure D-6
WREGIS Fee Matrix
Source: **https://www.wecc.biz/Administrative/WREGIS%20Fee%20Matrix%20and%20Definitions.pdf**

Green-e is a clean energy certification and verification program for products such as RECs and Carbon Offsets in the form of VCUs. The Green-e fee structure is shown in **Figure D-7**.

Table 1.A - Base Fees per Product

Base Fee for First Renewable Energy ("RE") or First Offset Product[1]	Additional RE Product or additional Offset Product	Base Fee for Non-profit (RE products only; details below)	Fee per Third-Party Distributor (offsets only; details below)	Base Fee for Federal Option product with Concurrent Green-e Energy Product[2]
$5,000	$4,000	$1,100	$250	Waived

Table 1.B - Volumetric Fees

MWh (RE products) or Tons (Offsets)	Retail ($ / MWh or Ton)	Wholesale ($ / MWh or Ton)
1 - 250,000	$0.031	$0.03
250,001 - 2,000,000	$0.018	$0.0025
2,000,001 – 5,000,000	$0.013	$0.0005
>5,000,000	$0.012	$0.0005

Examples

1. A Green-e Energy Participant with two certified REC products and 300,000 MWh of retail REC sales and 25,000 MWh of wholesale REC sales in 2016 would be invoiced for 2018 program participation a total of $18,400:

   Base fees: $5,000 for the first product, plus $4,000 for the second product = $9,000
   Retail volumetric fees: (250,000 x $0.031) + (50,000 x $0.018) = $8,650
   Wholesale volumetric fees: 25,000 * $.03 = $750

2. A Participant selling one Green-e Climate certified offset product with 200,000 tons of certified retail sales and one Green-e Energy certified competitive electricity product with 100,000 MWh of certified retail sales in 2016 would be invoiced for 2018 program participation a total of $19,300:

   Base fees: $5,000 for the first Climate product, plus $5,000 for the first Energy product = $10,000
   Retail offset volumetric fees: 200,000 x $0.031 = $6,200
   Retail renewable electricity volumetric fees: 100,000 * $0.031 = $3,100

Figure D-7
Green-e Fee Tables and Examples
Source: Michael Leschke; Green-e Verification Manager and Senior Analyst; Center for Resource Solutions

In the most simple scenario, a party can sell a certified product for a flat $5,000 a year along with a volumetric fee of $.031/MWh sold. That doesn't tell you the price the RECs are actually selling for on the wholesale market, but it does at least demonstrate that would be a premium on supply that is used for Green-e purposes as people will want to make up for the cost of certification.

Appendix E

WARM Model Categorization Table

Appendix E - WARM Model Categorization Table

Cascadia 2015 Waste Composition Study		WARM Model Material Input	
Material	**Cascadia Definition**	**Material**	**WARM Model Definition**
Paper			
Newspaper (ONP)	Printed groundwood newsprint and other minimally bleached groundwood. This category also includes some glossy paper typically used in newspaper insert advertisements, unless found separately.	Newspaper	Newspaper represents uncoated paper made from 70% mechanical pulp and 30% chemical pulp. For the carbon sequestration portion of the factor, it was assumed that the paper was all mechanical
Plain Corrugated Cardboard (OCC)	Kraft linerboard, containerboard cartons, and shipping boxes with corrugated paper medium (unwaxed). This category also includes Kraft (brown) paper bags. Excludes waxed and plastic-coated cardboard, solid boxboard, and bags that are not	Corrugated Containers	Corrugated cardboard boxes made from containerboard (liner and corrugating medium) used in packaging applications.
Waved Corrugated Cardboard (OCC)	Kraft linerboard, containerboard, cartons, and other boxes with a wax coating. Examples include commercial produce boxes.	Corrugated Containers	Corrugated cardboard boxes made from containerboard (liner and corrugating medium) used in packaging applications.
Low grade Recyclable Paper	All recyclable paper other than that listed in another category. This list includes magazines, phone books, junk mail, used envelopes, other material with sticky labels, construction paper, blueprint and thermal copy paper (NCR paper), fax paper, bright-dyed paper (fiesta or neon colors), paperback books, colored manila envelopes, and groundwood catalogues. This category also includes polycoated paperboard, aseptic packaging and other low-grade recyclable papers used in packaging, including polycoated or aseptic milk, ice cream, or juice containers, chipboard and other solid boxboard such as for beer, cereal, and soda	Magazines/Third-class Mail	Third Class Mail is now called Standard Mail by the U.S. Postal Service and includes catalogs and other direct bulk mailings such as magazines, which are made of coated, shiny paper. This category represents coated paper produced from mechanical pulp.
High Grade Paper	White and lightly colored bond, rag, or stationary grade paper. This category is composed of high-grade paper, which includes white ledger, colored ledger, computer cards, bond, copy machine paper, manila envelopes and continuous-feed computer printouts and forms of various types. Excludes glossy coated paper such as magazines, bright papers, groundwood publications such as catalogs.	Office Paper	Office paper represents paper made from uncoated bleached chemical pulp.
Single Use Food Service Compotable Paper	Includes paper soiled with food that was used in a “single-use” capacity. Examples include, paper plates, pizza boxes, french-fry containers. Does not include napkins or paper towels.	Phonebooks	Phonebooks represent telephone books that are made from paper produced from mechanical pulp.
Other Compostable Paper	Includes paper soiled with food that was not used in a “single-use” capacity. Examples include napkins, and paper towels.	Phonebooks	Phonebooks represent telephone books that are made from paper produced from mechanical pulp.
Other Paper	Includes materials that are primarily paper but combined with other materials that are not easily recyclable. Examples include frozen juice cans, oil cans, paper with foil laminates, foil-lined paper, spiral-bound notebooks, carbon paper, photographs, poly-lined chipboard, microwave containers, gift wrapping paper, and hardcover	Textbooks	Textbooks represent books made from paper produced from chemical pulp.
Plastic			
PET Bottles	All bottles made from polyethylene terephthalate (PET), consisting of pop, oil, liquor, and other types of bottles (SPI code 1).	PET	PET (Polyethylene terephthalate) is typically labeled plastic code #1 on the bottom of the container. PET is often used for soft drink and disposable water bottles, but can also include
Other PET Containers	PET containers other than bottles.	PET	PET (Polyethylene terephthalate) is typically labeled plastic code #1 on the bottom of the container. PET is often used for soft drink and disposable water bottles, but can also include
HDPE Bottles	All bottles made of high-density polyethylene (HDPE), such as milk, juice, detergent, and other bottles (SPI code 2).	HDPE	HDPE (high-density polyethylene) is usually labeled plastic code #2 on the bottom of the container, and refers to a plastic often used to make bottles for milk, juice, water and laundry products. It is also used to make plastic grocery bags.

Appendix E - WARM Model Categorization Table

Cascadia 2015 Waste Composition Study		WARM Model Material Input	
Material	**Cascadia Definition**	**Material**	**WARM Model Definition**
Paper			
Other HDPE Containers	HDPE containers other than bottles.	HDPE	HDPE (high-density polyethylene) is usually labeled plastic code #2 on the bottom of the container, and refers to a plastic often used to make bottles for milk, juice, water and laundry products. It is also used to make plastic grocery bags.
Other #3-#7 packaging	All other rigid bottles and containers with SPI codes 3 through 7.	LDPE	LDPE (Low-density polyethylene), usually labeled plastic code #4, is often used to manufacture plastic dry cleaning bags. LDPE is also used to manufacture some flexible lids and bottles.
Compostable Plastics	All items made from compostable materials such as corn or potatoes with the words “compostable” on the product.	PLA	Polylactic acid or PLA is a thermoplastic biopolymer constructed entirely from annually renewable agricultural products, e.g., corn, and used in manufacturing fresh food packaging and food service ware such as rigid packaging, food containers, disposable plastic cups, cutlery, and
Expanded Polystyrene Single-serve Food Packaging	Expanded polystyrene packaging used for carrying food. Examples include food trays, cups, plates, clamshells, egg cartons, and other packaging.	PS	GPPS (general purpose polystyrene) has applications in a range of products, primarily domestic appliances, construction, electronics, toys, and food packaging such as containers, produce baskets, and fast food containers (ICIS, 2011d).
Other Expanded Polystyrene Packaging	Any expanded polystyrene packaging not used for food service, such as molded packing blocks and Styrofoam peanuts.	PS	GPPS (general purpose polystyrene) has applications in a range of products, primarily domestic appliances, construction, electronics, toys, and food packaging such as containers, produce baskets, and fast food containers (ICIS, 2011d).
Expanded Polystyrene Products	Expanded polystyrene products such as some ice-chests, floatation devices, and EPS wig forms. This does not include EPS insulation, which is categorized in Construction/Demolition.	PS	GPPS (general purpose polystyrene) has applications in a range of products, primarily domestic appliances, construction, electronics, toys, and food packaging such as containers, produce baskets, and fast food containers (ICIS, 2011d).
Recyclable Plastic Bags	Plastic shopping bags used to contain merchandise to transport from the place of purchase, given out by the store with the purchase. This type includes dry cleaning bags and newspaper bags intended for one-time use. Does not include produce bags.	LLDPE	LLDPE (linear low-density polyethylene) is used in high-strength film applications. Compared to LDPE, LLDPE's chemical structure contains branches that are much straighter and closely aligned, providing it with a higher tensile strength and making it more resistant to puncturing or shearing.
Non-industrial Packaging Film Plastic	All film used as food packaging or in another non-industrial capacity. Include produce bags, zip-lock bags, frozen vegetable bags, bread bags, food wrappers such as candy bar wrappers, deli bags, and other film packaging with a label or sticker.	LLDPE	LLDPE (linear low-density polyethylene) is used in high-strength film applications. Compared to LDPE, LLDPE's chemical structure contains branches that are much straighter and closely aligned, providing it with a higher tensile strength and making it more resistant to puncturing or shearing.
Industrial Packaging Film Plastic	Film plastic used for large-scale packaging or transport packaging. Examples include shrink-wrap, mattress bags, furniture wrap, and film bubble wrap.	LLDPE	LLDPE (linear low-density polyethylene) is used in high-strength film applications. Compared to LDPE, LLDPE's chemical structure contains branches that are much straighter and closely aligned, providing it with a higher tensile strength and making it more resistant to puncturing or shearing.
Plastic Garbage Bags	Plastic bags sold for use as trash bags, for both residential and commercial use. This type includes garbage, kitchen, compactor, can-liner, yard, lawn, leaf, and recycling bags. This type does not include other plastic bags, like shopping bags, that might have been used to contain trash.	LLDPE	LLDPE (linear low-density polyethylene) is used in high-strength film applications. Compared to LDPE, LLDPE's chemical structure contains branches that are much straighter and closely aligned, providing it with a higher tensile strength and making it more resistant to puncturing or shearing.
Plastic Film Products	Items made of film plastic not intended for a single use, such as shower curtains, kid’s pools, and utility tarps.	LLDPE	LLDPE (linear low-density polyethylene) is used in high-strength film applications. Compared to LDPE, LLDPE's chemical structure contains branches that are much straighter and closely aligned, providing it with a higher tensile strength and making it more resistant to puncturing or shearing.

Appendix E - WARM Model Categorization Table

Cascadia 2015 Waste Composition Study		WARM Model Material Input	
Material	**Cascadia Definition**	**Material**	**WARM Model Definition**
Paper			
Other Plastic Packaging	All other non-film packaging that does not fit into the above categories including caps, closures, rigid bubble packaging, and other miscellaneous non-film packaging items.	PP	PP (Polypropylene) is used in packaging, automotive parts, or made into synthetic fibres. It can be extruded for use in pipe, conduit, wire, and cable applications. PP's advantages are a high impact strength, high softening point, low density, and resistance to scratching and stress cracking. A drawback is its brittleness at low temperatures
Single Resin Plastic Products	Primarily rigid or solid consumer items made from a single resin type. Examples include dishware, utensils and other household items, vinyl products, plastic furniture and toys, car parts, and hangers. Also includes thermoset plastics such as Formica, fiberglass, and other related products.	PP	PP (Polypropylene) is used in packaging, automotive parts, or made into synthetic fibres. It can be extruded for use in pipe, conduit, wire, and cable applications. PP's advantages are a high impact strength, high softening point, low density, and resistance to scratching and stress cracking. A drawback is its brittleness at low temperatures
Mixed Resin Plastic Products	Primarily rigid or solid consumer items made from more than one type of plastic resin. Examples include hair brushes, toothbrushes, and pens.	Mixed Plastics	Mixed plastics are made up of 39% HDPE and 61% PET plastic.
Foam Rubber and Padding	Foam materials, consisting primarily of polyurethane, such as foam mattress pads.	PVC	PVC (Polyvinyl Chloride) is produced as both rigid and flexible resins. Rigid PVC is used for pipe, conduit, and roofing tiles, whereas flexible PVC has applications in wire and cable coating, flooring, coated fabrics, and shower curtains.
Carpet Padding	Foam material used for carpet padding.	PVC	PVC (Polyvinyl Chloride) is produced as both rigid and flexible resins. Rigid PVC is used for pipe, conduit, and roofing tiles, whereas flexible PVC has applications in wire and cable coating, flooring, coated fabrics, and shower curtains.
Plastic and Other Materials	Items that are predominantly made of plastic, but are combined with other material, such as three-ring binders, some toys, razors, some kitchenware and car parts with wood or metal components.	PVC	PVC (Polyvinyl Chloride) is produced as both rigid and flexible resins. Rigid PVC is used for pipe, conduit, and roofing tiles, whereas flexible PVC has applications in wire and cable coating, flooring, coated fabrics, and shower curtains.
Food			
Packaged Vegetative Food	Any vegetative food item such as pasta, grains, baked goods, beans, fruits, vegetables, sauces, soda, tea, juice and water where the package has remained intact. In the sorter's judgment, packaged vegetative food items could have been donated to a food bank or similar organization, rather than disposed. This category may include fresh fruits and vegetables (packaged in waxed boxes, for example) if, in the sorter's judgment, the food was not	Food Waste	Food waste consists of uneaten food and wasted, prepared food from residences, commercial establishments such as grocery stores and restaurants, institutional sources such as school cafeterias, and industrial sources such as factory lunchrooms. This emission factor contains a weighted average of all food types in the waste stream currently modeled in WARM, including beef, poultry, grains, fruits and vegetables, and dairy products. The mix is assumed to be 9% beef, 11% poultry, 13% grains, 49% fruits and vegetables, and 18% dairy products.
Unpackaged/Scrap Vegetative Food	Any vegetative food item such as pasta, grains, backed goods, beans, fruits, vegetables, sauces, soda, tea, juice, water, and ice where the package has been opened or broken, the item is unpackaged, or where the vegetative food is found in scraps or pieces. In the sorter's judgment, theses food items would not have been acceptable for		
Packaged Non-vegetative Food	Any non-vegetative food item such as fresh or canned meat or fish, cheeses, eggs, dairy items, and chili or soup containing meat, where the package has remained intact. In the sorter's judgment, packaged non-vegetative food items could have been donated to a food bank or similar		
UnPackaged/Scrap Non-Vegetative Food	Any non-vegetative food item such fresh or canned meat or fish, cheeses, eggs, dairy items, and chili or soup containing meat, where the package has been opened or broken, the item is unpackaged, or where the food is found in scraps or pieces. In the sorter's judgment, theses food items would not	Food Waste	(see previous page for definition)
Wood/Yard			

Appendix E - WARM Model Categorization Table

Cascadia 2015 Waste Composition Study		WARM Model Material Input	
Material	**Cascadia Definition**	**Material**	**WARM Model Definition**
Paper			
Dimensional Lumber	Both clean and painted wood commonly used in construction for framing and related uses, including 2 x 4's, 2 x 6's, and sheets of plywood, strandboard, and particle board. Includes pallets and crates.	Dimensional Lumber	Lumber includes wood used for containers, packaging, and building and includes crates, pallets, furniture and dimensional lumber like two by fours.
Treated Wood	Wood treated with preservatives such as creosote, including dimensional lumber. This category may also include some treated plywood, strandboard, chemically treated wood, and other wood.	Dimensional Lumber	Lumber includes wood used for containers, packaging, and building and includes crates, pallets, furniture and dimensional lumber like two by fours.
Contaminated Wood	Wood contaminated with other wastes in such a way that they cannot easily be separated, but consisting primarily (over 50 percent) of wood. Examples include wood with sheetrock attached.	Dimensional Lumber	Lumber includes wood used for containers, packaging, and building and includes crates, pallets, furniture and dimensional lumber like two by fours.
Roofing and Siding Wood	Painted or unpainted wood from demolition or construction waste that is commonly used for siding or roofing of buildings. This category includes only wood products, such as cedar shingles or shakes.	Dimensional Lumber	Lumber includes wood used for containers, packaging, and building and includes crates, pallets, furniture and dimensional lumber like two by fours.
Stumps	Stumps of trees and shrubs, with any adhering soil.	Yard Trimmings	Yard trimmings are assumed to be 50% grass, 25% leaves, and 25% tree and brush trimmings from residential, institutional, and commercial sources.
Large Prunings	Other natural woods, such as logs and branches in excess of four inches in diameter (Prunings less than four inches in diameter are categorized as	Yard Trimmings	Yard trimmings are assumed to be 50% grass, 25% leaves, and 25% tree and brush trimmings from residential, institutional, and commercial sources.
Yard Waste	Leaves, grass clippings, garden wastes, and brush up to four inches in diameter.	Yard Trimmings	Yard trimmings are assumed to be 50% grass, 25% leaves, and 25% tree and brush trimmings from residential, institutional, and commercial sources.
Other Wood	Other types of wood including wood products that do not fit into the above categories.	Yard Trimmings	Yard trimmings are assumed to be 50% grass, 25% leaves, and 25% tree and brush trimmings from residential, institutional, and commercial sources.
Other Organics			
Textiles: Clothes	Fabric materials including natural and man-made textile materials such as cottons, wools, silks, woven nylon, rayon, polyesters and other materials. This category includes clothing, rags, curtains, and other fabrics.	Textbooks	Textbooks represent books made from paper produced from chemical pulp.
Other Textiles	Upholstery, shoes, and other non-recyclable products including leather products.	Textbooks	Textbooks represent books made from paper produced from chemical pulp.
Disposable Diapers	Diapers and similar products made from a combination of fibers, synthetic, and/or natural, and made for the purpose of a single use. Diapers that are all cloth and not originally intended for single use will be classified as a textile. This category includes fecal matter contained within, sanitary napkins and tampons, and adult	Textbooks	Textbooks represent books made from paper produced from chemical pulp.
Rubber Products	Items made of natural and synthetic rubber, including door mats, car parts, hoses, rubber toys, and other products. This material type does not include tires or foam rubber.	Tires	Tires represent scrap tires that have been disposed of by consumers and have several end uses in the U.S. market including as a fuel, in civil engineering, and in various ground rubber applications such as running tracks and molded products.
Tires	Whole tires from automobiles, trucks, motorcycles, bicycles, and other vehicles.	Tires	Tires represent scrap tires that have been disposed of by consumers and have several end uses in the U.S. market including as a fuel, in civil engineering, and in various ground rubber applications such as running tracks and molded products.
Animal Carcasses	Carcasses of small animals and pieces of larger animals, unless the waste is the result of food storage or preparation.	Food Waste (meat only)	Food Waste (meat only) is a weighted average category representing meat waste in the U.S. waste stream, based on the share of poultry and beef in USDA's loss-adjusted food availability survey. The mix is assumed to be 46 percent beef and 54
Animal Feces	Feces from animals including kitty litter and bedding.	Food Waste (meat only)	Food Waste (meat only) is a weighted average category representing meat waste in the U.S. waste stream, based on the share of poultry and beef in USDA's loss-adjusted food availability survey. The mix is assumed to be 46 percent beef and 54

Appendix E - WARM Model Categorization Table

Cascadia 2015 Waste Composition Study		WARM Model Material Input	
Material	**Cascadia Definition**	**Material**	**WARM Model Definition**
Paper			
Miscellaneous Organics	Hair, wax, soap, and other organics not otherwise classified.	Food Waste (meat only)	Food Waste (meat only) is a weighted average category representing meat waste in the U.S. waste stream, based on the share of poultry and beef in USDA's loss-adjusted food availability survey. The mix is assumed to be 46 percent beef and 54
Metals			
Aluminum Cans	Beverage cans composed of aluminum only.	Aluminum Cans	Aluminum cans represent cans produced out of sheet rolled aluminum ingot.
Other Aluminum	Other types of aluminum containers such as pans and trays; includes foil and foil products or packages and all other aluminum materials including furniture, house siding, cookware, and scrap.	Aluminum Ingot	Aluminum ingot is processed from molten aluminum in the form of a sheet ingot suitable for rolling, extruding, or shape casting. Thus, it serves as a pre-cursor to manufacture of aluminum products such as aluminum cans. It can serve as a proxy for certain aluminum materials such as electrical transmission and distribution wires, other electrical conductors, some extruded aluminum products, aluminum product cuttings, joinings and weldings, and consumer durable
Tinned Food Cans	Tin-plated steel cans (food cans), does not include other bi-metals, paint cans, or other types of steel cans.	Steel Cans	Steel cans represent three-piece welded cans produced from sheet steel which is made in a blast furnace and basic oxygen furnace (for virgin cans) or electric arc furnace (for recycled cans).
Other Ferrous	Ferrous and alloyed ferrous scrap materials, without non-metal contaminants, including household, industrial, and commercial products such as other cans and containers. This category includes scrap iron and steel to which a magnet can	Steel Cans	Steel cans represent three-piece welded cans produced from sheet steel which is made in a blast furnace and basic oxygen furnace (for virgin cans) or electric arc furnace (for recycled cans).
Other Non-Ferrous	Metals that are not materials derived from iron, including copper, brass, bronze, aluminum bronze, lead, pewter, zinc, and other metals to which a magnet will not adhere. Examples include brass door knobs and copper pipes. Metals that are significantly contaminated are not included.	Mixed Metals	Mixed metals are made up of 35% aluminum cans and 65% steel cans.
Mixed Metals (Items <20% non-metal)	Composite, multi-metal products such as engines and electric motors with minor non-metal contaminants. The metal content must be more than 80% by weight of the material.	Mixed Metals	Mixed metals are made up of 35% aluminum cans and 65% steel cans.
Other Mixed Metals (Items >20% non-metal)	Metals combined with significant amounts of other materials, such as umbrellas and coated wire. The non-metal content of the item must be greater than 20% by weight.	Mixed Metals	Mixed metals are made up of 35% aluminum cans and 65% steel cans.
Compressed Gas Cylinders	Metal gas tanks and cylinders most often used to contain propane or butane.	Mixed Metals	Mixed metals are made up of 35% aluminum cans and 65% steel cans.

Appendix E - WARM Model Categorization Table

Cascadia 2015 Waste Composition Study		WARM Model Material Input	
Material	**Cascadia Definition**	**Material**	**WARM Model Definition**
Paper			
Glass			
Clear Glass Containers	Bottles and jars that are clear in color; used for food, soft drinks, beer, and wine.	Glass	Glass represents glass containers (e.g., soft drink bottles and wine bottles)
Green Glass Containers	Bottles and jars that are green in color; used for food, soft drinks, beer, and wine.		
Brown Glass Containers	Bottles and jars that are brown in color; used for food, soft drinks, beer, and wine. This category also includes blue glass containers.		
Kitchenware/Ceramics	Glass or ceramic cooking ware, dishware, and other products.		
Other Glass	Window glass, automotive glass, glass table-tops, mirrors, light bulbs, and any other glass item that does not fit into a category above.		
Electronics			
Small Household Appliances	Small household appliances such as toasters, broilers, can openers, microwaves, coffee	Personal Computers	See next page for definition
A/V Equipment	Stereos, VCRs, DVD players, large radios, gaming systems, cable or satellite television control boxes, and audio/visual equipment. This category does not include televisions or monitors.	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
Printers/Copiers/Fax Machines	Computer printers (both inkjet and laser), facsimile machines, and photocopying machines.		
CPU	Such as computer hard drives when the CPU is a separate component in the system.		
Computer Peripherals	Computer peripherals including keyboards, gaming controllers, and mice.		
CRT Computer Monitors & Televisions	Computer monitors and televisions containing a cathode ray tube (CRT). Includes items with built in optical drives or other processors.		
Other Computer Monitors & Televisions	All non-CRT monitors and televisions (LCD, plasma, OLED, etc.). Includes items with built-in optical drives or other processors such as an iMac or personal DVD player. Control of the content viewed on the item must be performed by an external control device such as a keyboard, mouse, or remote. Does not include "tablets" or other small		
Laptops	All laptop and notebook computers. Must have a permanently attached, physical keyboard.		
Cell Phones	Personal electronic devices primarily intended for mobile voice communication over a cellular network. This includes both smartphones and traditional cell phones.		
Tablets	Personal computing and entertainment devices with a screen greater than 4". Examples include video display devices, e-readers, and touch screen portable computers. This type includes products like the iPad, Kindle Fire, Nook, Surface, and Galaxy		
Other Electronics	Includes scanners, personal digital assistants (PDAs), portable music players, answering machines, electronic toys, and any other electronic item with some circuitry not categorized elsewhere and with displays less than 4" when the item	Personal Computers	See previous page for definition

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Cascadia 2015 Waste Composition Study		WARM Model Material Input	
Material	**Cascadia Definition**	**Material**	**WARM Model Definition**
Paper			
Other Wastes			
C&D Wastes	Construction, demolition, or land clearing waste that cannot be placed into one of the above categories, such as concrete, plaster, rocks, gravel, bricks, non-wood roofing materials, and insulation of various types (including foam, fiberglass etc.).	Wood Flooring	Virgin hardwood flooring is produced from lumber. Coatings and sealants can be applied to wood flooring in "pre-finishing" that occurs at the manufacturing facility, or on-site.
		Clay Bricks	Bricks are produced by firing materials such as clay, kaolin, fire clay, bentonite, or common clay and shale. The majority of the bricks produced in the US are clay. In WARM, clay brick source reduction is considered to be the reuse of full bricks rather than the grinding and reusing of broken or damaged
		Concrete	Concrete is a high-volume building material produced by mixing cement, water, and coarse and fine aggregates. In WARM, concrete is assumed to be recycled into aggregate, so the GHG benefits are associated with the avoided emissions associated with mining and processing aggregate.
Asphalt Shingles	Roofing material composed of fiberglass or organic felts saturated with asphalt and covered with asphalt and inert aggregates. Commonly known as three-tab roofing shingles.	Asphalt Shingles	Asphalt concrete is composed primarily of aggregate, which consists of hard, graduated fragments of sand, gravel, crushed stone, slag, rock dust, or powder.
Ash	Material remaining after the combustion process, present in the waste stream as ash from fireplaces and wood stoves, used charcoal from grills, and	Fly Ash	Fly ash is a byproduct of coal combustion that is used as a cement replacement in concrete.
Nondistict Fines	Soil, sand, dirt, and similar nondistinct materials.	Fly Ash	Fly ash is a byproduct of coal combustion that is used as a cement replacement in concrete.
Gypsum Wallboard	Calcium sulfate dihydrate sandwiched between heavy layers of Kraft-type paper.	Drywall	Drywall, also known as wallboard, gypsum board, or plaster board, is manufactured from gypsum plaster and a paper covering.
Furniture	Furniture made of mixed materials and in any condition.	Medium-density Fiberboard	Fiberboard is a panel product that consists of wood chips pressed and bonded with a resin. Fiberboard is used primarily to make furniture.
Mattresses	Mattresses made of mixed materials and in any condition.	Carpet	Carpet represents broadloom residential carpet containing a mix of nylon, PET and PP components within the face fiber, primary and secondary backing, and latex used for attaching the backings.
Carpet	General category of flooring applications consisting of various natural or synthetic fibers bonded to some type of backing material.	Carpet	Carpet represents broadloom residential carpet containing a mix of nylon, PET and PP components within the face fiber, primary and secondary backing, and latex used for attaching the backings.
Miscellaneous Inorganics	Other non-combustible, inorganic material not classified elsewhere. Also includes non-C&D plaster and concrete statuary, or other products.	Fiberglass Insulation	Fiberglass insulation is produced from a blend of sand, limestone, soda ash, and recycled glass cullet, which accounts for about 40 percent of the
		Vinyl Flooring	All vinyl flooring is comprised of polyvinyl chloride (PVC) resin along with additives such as plasticizers, stabilizers, pigments, and fillers.
HHW/Special			
Used Oil	Used lubricating oils, primarily used in cars but including other types with similar characteristics	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals. NOTE: This category was selected as Personal Computers would have been managed as household hazardous waste.
Vehicle Batteries	Car, motorcycle, and other lead-acid batteries used for motorized vehicles.		
Household Batteries	Batteries of various sizes and types, as commonly used in households, excluding alkaline and button cell batteries.		
Latex Paint	Water-based paints and similar products.		
Oil-based Paint	Solvent-based paints, varnishes, and similar		
Solvents and Thinners	Various solvents, including chlorinated and flammable solvents, paint strippers, solvents contaminated with other products such as paints, degreasers and some other cleaners if the primary ingredient is (or was) a solvent, and alcohols such		

Appendix E - WARM Model Categorization Table

Cascadia 2015 Waste Composition Study		WARM Model Material Input	
Material	**Cascadia Definition**	**Material**	**WARM Model Definition**
Paper			
Adhesives and Glue	Glues and adhesives of various sorts, including rubber cement, wood putty, glazing and spackling compounds, caulking compounds, grout, and joint and auto body fillers.	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals. NOTE: This category was selected as Personal Computers would have been managed as household hazardous waste.
Cleaners and Corrosives	Various acids and bases whose primary purpose is to clean surfaces, unclog drains, or perform other		
Pesticides and Herbicides	Variety of chemicals whose purpose is to discourage or kill pests, weeds, or microorganisms. Fungicides and wood preservatives, such as pentachlorophenol, are also included.		
Gasoline and Fuel	Gasoline, diesel fuel, and fuel oils.		
Antifreeze/Brake Fluid	Automobile and other antifreeze mixtures based on ethylene or propylene glycol; also brake and other automotive fluids (except motor oil).		
Medical Waste	Wastes related to medical activities, including syringes, intravenous (I.V.) tubing, bandages, and		
Pharmaceuticals and Vitamins	Means both prescription and over-the-counter medications and supplements in all forms, including pills, liquid medications, creams, and ointments. Does not include containers for these items, except for tubes for creams and ointments and other containers that cannot be easily separated from the product they contain.		
Compact Florescent Bulbs	All compact fluorescent bulbs.		
Other Fluorescent Bulbs/Tubes	Includes other fluorescent lighting and fluorescent tube lighting.		
Other Hazardous Waste	Asbestos-containing wastes if this is the primary hazard associated with the waste; gunpowder, unspent ammunition, picric acid and other potentially explosive chemicals; radioactive materials (but smoke alarms are classified as "other plastic"); items that contain mercury, such as thermometers, thermostats, jewelry, and mercury switches (alkaline and button cell batteries, which also contain mercury, are covered as a separate category of “Household Batteries”); and other	Personal Computers	See previous page for definition

Table 44 - Detailed Composition, Overall Disposed Waste, 2015 Annual Tons

Material	Estimated I
Paper	**16.8%**
Plastic	**11.8%**
Food	**20.5%**
Wood/Yard	**16.4%**
Other Organics	**15.3%**
Metals	**4.7%**
Glass	**2.6%**
Electronics	**0.4%**
Other wastes	**9.9%**
HHW/Special	**0.6%**
Total	99.1%

Notes:

1.) The total calculated tonnage on this spreadsheet (842,957) is different from the CASCADIA

+/-	Estimated Tons
	141,366
	102,944
	173,237
	141,429
	129,182
	39,280
	22,380
	4,097
	83,484
	5,558
	842,957

A report of (842,953). The difference is neglible.

Row Labels	Sum of Estimated Tons
Aluminum Cans	2582
Aluminum Ingot	1647
Asphalt Shingles	3002
Carpet	22081
Clay Bricks	7395
Concrete	7395
Corrugated Containers	27909
Dimensional Lumber	95019
Drywall	14797
Fiberglass Insulation	1788.5
Fly Ash	5054
Food Waste	173237
Food Waste (meat only)	51023
Glass	22380
HDPE	4379
LDPE	2655
LLDPE	54487
Magazines/Third-class Mail	31132
Medium-density Fiberboard	12788
Mixed Metals	21304
Mixed Plastics	2726
Newspaper	12962
Office Paper	6726
Personal Computers	9655
PET	7088
Phonebooks	44200
PLA	151
PP	11030
PS	5327
PVC	15101
Steel Cans	13747
Textbooks	91386
Tires	5210
Vinyl Flooring	1788.5
Wood Flooring	7395
Yard Trimmings	46410
(blank)	
Grand Total	**842957**

Table 44 - Detailed Composition, Overall Disposed Waste, 2015 Annual Tons

Material	Definition	Estimated Percent
Paper		**16.8%**
Newspaper (ONP)	Printed groundwood newsprint and other minimally bleached groundwood. This category also includes some glossy paper typically used in newspaper insert advertisements, unless found separately.	1.5%
Plain Corrugated Cardboard (OCC)	Kraft linerboard, containerboard cartons, and shipping boxes with corrugated paper medium (unwaxed). This category also includes Kraft (brown) paper bags. Excludes waxed and plastic-coated cardboard, solid boxboard, and bags that are not pure unbleached Kraft.	3.1%
Waved Corrugated Cardboard (OCC)	Kraft linerboard, containerboard, cartons, and other boxes with a wax coating. Examples include commercial produce boxes.	0.2%
Low grade Recyclable Paper	all recyclable paper other than that listed in another category. This list includes magazines, phone books, junk mail, used envelopes, other material with sticky labels, construction paper, blueprint and thermal copy paper (NCR paper), fax paper, bright-dyed paper (fiesta or neon colors), paperback books, colored manila envelopes, and groundwood catalogues. This category also includes polycoated paperboard, aseptic packaging and other low-grade recyclable papers used in packaging, including polycoated or aseptic milk, ice cream, or juice containers, chipboard and other solid boxboard such as for beer, cereal, and soda cans, clothing forms, egg cartons (molded pulp), and other boxes.	3.7%
High Grade Paper	white and lightly colored bond, rag, or stationary grade paper. This category is composed of high-grade paper, which includes white ledger, colored ledger, computer cards, bond, copy machine paper, manila envelopes and continuous-feed computer printouts and forms of various types. Excludes glossy coated paper such as magazines, bright papers, groundwood publications such as catalogs.	0.8%
Single Use Food Service Compotable Paper	includes paper soiled with food that was used in a “single-use” capacity. Examples include, paper plates, pizza boxes, french-fry containers. Does not include napkins or paper towels.	1.3%
Other Compostable Paper	includes paper soiled with food that was not used in a “single-use” capacity. Examples include napkins, and paper towels.	4.0%

Other Paper	includes materials that are primarily paper but combined with other materials that are not easily recyclable. Examples include frozen juice cans, oil cans, paper with foil laminates, foil-lined paper, spiral-bound notebooks, carbon paper, photographs, poly-lined chipboard, microwave containers, gift wrapping paper, and hardcover books.	2.2%
Plastic		**11.8%**
PET Bottles	all bottles made from polyethylene terephthalate (PET), consisting of pop, oil, liquor, and other types of bottles (SPI code 1).	0.5%
Other PET Containers	PET containers other than bottles.	0.4%
HDPE Bottles	all bottles made of high-density polyethylene (HDPE), such as milk, juice, detergent, and other bottles (SPI code 2).	0.3%
Other HDPE Containers	HDPE containers other than bottles.	0.2%
Other #3-#7 packaging	all other rigid bottles and containers with SPI codes 3 through 7.	0.3%
Compostable Plastics	all items made from compostable materials such as corn or potatoes with the words “compostable” on the product.	0.0%

Expanded Polystyrene Single-serve Food Packaging	expanded polystyrene packaging used for carrying food. Examples include food trays, cups, plates, clamshells, egg cartons, and other packaging.	0.3%
Other Expanded Polystyrene Packaging	any expanded polystyrene packaging not used for food service, such as molded packing blocks and Styrofoam peanuts.	0.2%
Expanded Polystyrene Products	expanded polystyrene products such as some ice-chests, floatation devices, and EPS wig forms. This does not include EPS insulation, which is categorized in Construction/Demolition.	0.1%
Recyclable Plastic Bags	plastic shopping bags used to contain merchandise to transport from the place of purchase, given out by the store with the purchase. This type includes dry cleaning bags and newspaper bags intended for one-time use. Does not include produce bags.	0.5%
Non-industrial Packaging Film Plastic	all film used as food packaging or in another non-industrial capacity. Include produce bags, zip-lock bags, frozen vegetable bags, bread bags, food wrappers such as candy bar wrappers, deli bags, and other film packaging with a label or sticker.	2.1%
Industrial Packaging Film Plastic	film plastic used for large-scale packaging or transport packaging. Examples include shrink-wrap, mattress bags, furniture wrap, and film bubble wrap.	1.5%

Plastic Garbage Bags	plastic bags sold for use as trash bags, for both residential and commercial use. This type includes garbage, kitchen, compactor, can-liner, yard, lawn, leaf, and recycling bags. This type does not include other plastic bags, like shopping bags, that might have been used to contain trash.	2.2%
Plastic Film Products	items made of film plastic not intended for a single use, such as shower curtains, kid's pools, and utility tarps.	0.0%
Other Plastic Packaging	all other non-film packaging that does not fit into the above categories including caps, closures, rigid bubble packaging, and other miscellaneous non-film packaging items.	0.0%
Single Resin Plastic Products	primarily rigid or solid consumer items made from a single resin type. Examples include dishware, utensils and other household items, vinyl products, plastic furniture and toys, car parts, and hangers. Also includes thermoset plastics such as Formica, fiberglass, and other related products.	1.1%
Mixed Resin Plastic Products	primarily rigid or solid consumer items made from more than one type of plastic resin. Examples include hair brushes, toothbrushes, and pens.	0.3%
Foam Rubber and Padding	foam materials, consisting primarily of polyurethane, such as foam mattress pads.	0.1%

Carpet Padding	foam material used for carpet padding.	0.5%
Plastic and Other Materials	items that are predominantly made of plastic, but are combined with other material, such as three-ring binders, some toys, razors, some kitchenware and car parts with wood or metal components.	1.2%
Food		**20.5%**
Packaged Vegetative Food	any vegetative food item such as pasta, grains, baked goods, beans, fruits, vegetables, sauces, soda, tea, juice and water where the package has remained intact. In the sorter's judgment, packaged vegetative food items could have been donated to a food bank or similar organization, rather than disposed. This category may include fresh fruits and vegetables (packaged in waxed boxes, for example) if, in the sorter's judgment, the food was not spoiled at the time of disposal.	5.1%
Unpackaged/Scrap Vegetative Food	any vegetative food item such as pasta, grains, backed goods, beans, fruits, vegetables, sauces, soda, tea, juice, water, and ice where the package has been opened or broken, the item is unpackaged, or where the vegetative food is found in scraps or pieces. In the sorter's judgment, theses food items would not have been acceptable for donation.	7.7%

Packaged Non-vegetative Food	any non-vegetative food item such as fresh or canned meat or fish, cheeses, eggs, dairy items, and chili or soup containing meat, where the package has remained intact. In the sorter's judgment, packaged non-vegetative food items could have been donated to a food bank or similar organization, rather than disposed.	3.3%
UnPackaged/Scrap Non-Vegetative Food	any non-vegetative food item such fresh or canned meat or fish, cheeses, eggs, dairy items, and chili or soup containing meat, where the package has been opened or broken, the item is unpackaged, or where the food is found in scraps or pieces. In the sorter's judgment, theses food items would not have been acceptable for donation.	4.4%
Wood/Yard		**16.4%**
Dimensional Lumber	both clean and painted wood commonly used in construction for framing and related uses, including 2 x 4's, 2 x 6's, and sheets of plywood, strandboard, and particle board. Includes pallets and crates.	6.0%
Treated Wood	wood treated with preservatives such as creosote, including dimensional lumber. This category may also include some treated plywood, strandboard, chemically treated wood, and other wood.	2.0%
Contaminated Wood	wood contaminated with other wastes in such a way that they cannot easily be separated, but consisting primarily (over 50 percent) of wood. Examples include wood with sheetrock attached.	3.0%
Roofing and Siding Wood	painted or unpainted wood from demolition or construction waste that is commonly used for siding or roofing of buildings. This category includes only wood products, such as cedar shingles or shakes.	0.0%

Stumps	stumps of trees and shrubs, with any adhering soil.	0.0%
Large Prunings	other natural woods, such as logs and branches in excess of four inches in diameter (Prunings less than four inches in diameter are categorized as yard wastes).	0.3%
Yard Waste	leaves, grass clippings, garden wastes, and brush up to four inches in diameter.	4.1%
Other Wood	other types of wood including wood products that do not fit into the above categories.	1.0%
Other Organics		**15.3%**
Textiles: Clothes	fabric materials including natural and man-made textile materials such as cottons, wools, silks, woven nylon, rayon, polyesters and other materials. This category includes clothing, rags, curtains, and other fabrics.	2.2%
Other Textiles	upholstery, shoes, and other non-recyclable products including leather products.	0.9%
Disposable Diapers	diapers and similar products made from a combination of fibers, synthetic, and/or natural, and made for the purpose of a single use. Diapers that are all cloth and not originally intended for single use will be classified as a textile. This category includes fecal matter contained within, sanitary napkins and tampons, and adult disposable protective undergarments.	5.6%
Rubber Products	items made of natural and synthetic rubber, including door mats, car parts, hoses, rubber toys, and other products. This material type does not include tires or foam rubber.	0.5%
Tires	whole tires from automobiles, trucks, motorcycles, bicycles, and other vehicles.	0.1%

Animal Carcasses	carcasses of small animals and pieces of larger animals, unless the waste is the result of food storage or preparation.	0.5%
Animal Feces	feces from animals including kitty litter and bedding.	4.9%
Miscellaneous Organics	hair, wax, soap, and other organics not otherwise classified.	0.6%
Metals		**4.7%**
Aluminum Cans	beverage cans composed of aluminum only.	0.3%
Other Aluminum	other types of aluminum containers such as pans and trays; includes foil and foil products or packages and all other aluminum materials including furniture, house siding, cookware, and scrap.	0.2%
Tinned Food Cans	tin-plated steel cans (food cans), does not include other bi-metals, paint cans, or other types of steel cans.	0.5%

Other Ferrous	ferrous and alloyed ferrous scrap materials, without non-metal contaminants, including household, industrial, and commercial products such as other cans and containers. This category includes scrap iron and steel to which a magnet can adhere.	1.2%
Other Non-Ferrous	metals that are not materials derived from iron, including copper, brass, bronze, aluminum bronze, lead, pewter, zinc, and other metals to which a magnet will not adhere. Examples include brass door knobs and copper pipes. Metals that are significantly contaminated are not included.	0.8%
Mixed Metals (Items <20% non-metal)	composite, multi-metal products such as engines and electric motors with minor non-metal contaminants. The metal content must be more than 80% by weight of the material.	0.7%
Other Mixed Metals (Items >20% non-metal)	metals combined with significant amounts of other materials, such as umbrellas and coated wire. The non-metal content of the item must be greater than 20% by weight.	1.0%
Compressed Gas Cylinders	metal gas tanks and cylinders most often used to contain propane or butane.	0.0%
Glass		**2.6%**
Clear Glass Containers	bottles and jars that are clear in color; used for food, soft drinks, beer, and wine.	0.8%
Green Glass Containers	bottles and jars that are green in color; used for food, soft drinks, beer, and wine.	0.4%
Brown Glass Containers	bottles and jars that are brown in color; used for food, soft drinks, beer, and wine. This category also includes blue glass containers.	0.6%
Kitchenware/Ceramics	glass or ceramic cooking ware, dishware, and other products.	0.2%
Other Glass	ndow glass, automotive glass, glass table-tops, mirrors, light bulbs, and any other glass item that does not fit into a category above.	0.6%
Electronics		**0.4%**
Small Household Appliances	small household appliances such as toasters, broilers, can openers, microwaves, coffee machines, and blenders.	0.2%

A/V Equipment	stereos, VCRs, DVD players, large radios, gaming systems, cable or satellite television control boxes, and audio/visual equipment. This category does not include televisions or monitors.	0.0%
Printers/Copiers/Fax Machines	computer printers (both inkjet and laser), facsimile machines, and photocopying machines.	0.1%
CPU	such as computer hard drives when the CPU is a separate component in the system.	0.0%
Computer Peripherals	computer peripherals including keyboards, gaming controllers, and mice.	0.0%

CRT Computer Monitors & Televisions	computer monitors and televisions containing a cathode ray tube (CRT). Includes items with built in optical drives or other processors.	0.0%
Other Computer Monitors & Televisions	all non-CRT monitors and televisions (LCD, plasma, OLED, etc.). Includes items with built-in optical drives or other processors such as an iMac or personal DVD player. Control of the content viewed on the item must be performed by an external control device such as a keyboard, mouse, or remote. Does not include "tablets" or other small touch screen personal computing devices.	0.0%
Laptops	all laptop and notebook computers. Must have a permanently attached, physical keyboard.	0.0%
Cell Phones	personal electronic devices primarily intended for mobile voice communication over a cellular network. This includes both smartphones and traditional cell phones.	0.0%

Tablets	personal computing and entertainment devices with a screen greater than 4”. Examples include video display devices, e-readers, and touch screen portable computers. This type includes products like the iPad, Kindle Fire, Nook, Surface, and Galaxy tab.	0.0%
Other Electronics	includes scanners, personal digital assistants (PDAs), portable music players, answering machines, electronic toys, and any other electronic item with some circuitry not categorized elsewhere and with displays less than 4” when the item includes a display.	0.1%
Other wastes		**9.9%**
C&D Wastes	construction, demolition, or land clearing waste that cannot be placed into one of the above categories, such as concrete, plaster, rocks, gravel, bricks, non-wood roofing materials, and insulation of various types (including foam, fiberglass etc.).	2.6%
Asphalt Shingles	roofing material composed of fiberglass or organic felts saturated with asphalt and covered with asphalt and inert aggregates. Commonly known as three-tab roofing shingles.	0.4%

Ash	material remaining after the combustion process, present in the waste stream as ash from fireplaces and wood stoves, used charcoal from grills, and similar materials.	0.0%
Nondistict Fines	soil, sand, dirt, and similar nondistinct materials.	0.6%
Gypsum Wallboard	calcium sulfate dihydrate sandwiched between heavy layers of Kraft-type paper.	1.8%
Furniture	furniture made of mixed materials and in any condition.	1.5%
Mattresses	mattresses made of mixed materials and in any condition.	1.0%
Carpet	general category of flooring applications consisting of various natural or synthetic fibers bonded to some type of backing material.	1.6%
Miscellaneous Inorganics	other non-combustible, inorganic material not classified elsewhere. Also includes non-C&D plaster and concrete statuary, or other products.	0.4%
HHW/Special		**0.6%**
Used Oil	used lubricating oils, primarily used in cars but including other types with similar characteristics and oil filters.	0.0%

Vehicle Batteries	car, motorcycle, and other lead-acid batteries used for motorized vehicles.	0.0%
Household Batteries	batteries of various sizes and types, as commonly used in households, excluding alkaline and button cell batteries.	0.0%
Latex Paint	water-based paints and similar products.	0.1%
Oil-based Paint	solvent-based paints, varnishes, and similar products.	0.0%

Solvents and Thinners	various solvents, including chlorinated and flammable solvents, paint strippers, solvents contaminated with other products such as paints, degreasers and some other cleaners if the primary ingredient is (or was) a solvent, and alcohols such as methanol and isopropanol.	0.0%
Adhesives and Glue	glues and adhesives of various sorts, including rubber cement, wood putty, glazing and spackling compounds, caulking compounds, grout, and joint and auto body fillers.	0.1%
Cleaners and Corrosives	various acids and bases whose primary purpose is to clean surfaces, unclog drains, or perform other actions.	0.0%
Pesticides and Herbicides	variety of chemicals whose purpose is to discourage or kill pests, weeds, or microorganisms. Fungicides and wood preservatives, such as pentachlorophenol, are also included.	0.0%

Gasoline and Fuel Oil	gasoline, diesel fuel, and fuel oils.	0.0%
Antifreeze/Brake Fluid	automobile and other antifreeze mixtures based on ethylene or propylene glycol; also brake and other automotive fluids (except motor oil).	0.0%
Medical Waste	wastes related to medical activities, including syringes, intravenous (I.V.) tubing, bandages, and other wastes.	0.4%
Pharmaceuticals and Vitamins	means both prescription and over-the-counter medications and supplements in all forms, including pills, liquid medications, creams, and ointments. Does not include containers for these items, except for tubes for creams and ointments and other containers that cannot be easily separated from the product they contain.	0.0%

Compact Florescent Bulbs	all compact fluorescent bulbs.	0.0%
Other Fluorescent Bulbs/Tubes	includes other fluorescent lighting and fluorescent tube lighting.	0.0%
Other Hazardous Waste	asbestos-containing wastes if this is the primary hazard associated with the waste; gunpowder, unspent ammunition, picric acid and other potentially explosive chemicals; radioactive materials (but smoke alarms are classified as "other plastic"); items that contain mercury, such as thermometers, thermostats, jewelry, and mercury switches (alkaline and button cell batteries, which also contain mercury, are covered as a separate category of “Household Batteries”); and other hazardous wastes that do not fit into the above categories.	0.0%
Total		99.1%

+/-	Estimated Tons		
	141,366	**Material**	
0.2%	12,962	Newspaper	Newspaper represents uncoated paper made from 70% mechanical pulp and 30% chemical pulp. For the carbon sequestration portion of the factor, it was assumed that the paper was all mechanical pulp.
0.3%	26,112	Corrugated Containers	Corrugated cardboard boxes made from containerboard (liner and corrugating medium) used in packaging applications.
0.1%	1,797	Corrugated Containers	Corrugated cardboard boxes made from containerboard (liner and corrugating medium) used in packaging applications.
0.4%	31,132	Magazines/Third-class Mail	Third Class Mail is now called Standard Mail by the U.S. Postal Service and includes catalogs and other direct bulk mailings such as magazines, which are made of coated, shiny paper. This category represents coated paper produced from mechanical pulp.
0.1%	6,726	Office Paper	Office paper represents paper made from uncoated bleached chemical pulp.
0.1%	10,670	Phonebooks	Phonebooks represent telephone books that are made from paper produced from mechanical pulp.
0.4%	33,530	Phonebooks	Phonebooks represent telephone books that are made from paper produced from mechanical pulp.

0.4%	18,437	Textbooks	Textbooks represent books made from paper produced from chemical pulp.
	102,944		
0.0%	4,045	PET	PET (Polyethylene terephthalate) is typically labeled plastic code #1 on the bottom of the container. PET is often used for soft drink and disposable water bottles, but can also include other containers or packaging.
0.1%	3,043	PET	PET (Polyethylene terephthalate) is typically labeled plastic code #1 on the bottom of the container. PET is often used for soft drink and disposable water bottles, but can also include other containers or packaging.
0.0%	2,449	HDPE	HDPE (high-density polyethylene) is usually labeled plastic code #2 on the bottom of the container, and refers to a plastic often used to make bottles for milk, juice, water and laundry products. It is also used to make plastic grocery bags.
0.1%	1,930	HDPE	HDPE (high-density polyethylene) is usually labeled plastic code #2 on the bottom of the container, and refers to a plastic often used to make bottles for milk, juice, water and laundry products. It is also used to make plastic grocery bags.
0.0%	2,655	LDPE	LDPE (Low-density polyethylene), usually labeled plastic code #4, is often used to manufacture plastic dry cleaning bags. LDPE is also used to manufacture some flexible lids and bottles.
0.0%	151	PLA	Polylactic acid or PLA is a thermoplastic biopolymer constructed entirely from annually renewable agricultural products, e.g., corn, and used in manufacturing fresh food packaging and food service ware such as rigid packaging, food containers, disposable plastic cups, cutlery, and plates.

0.1%	2,832	PS	GPPS (general purpose polystyrene) has applications in a range of products, primarily domestic appliances, construction, electronics, toys, and food packaging such as containers, produce baskets, and fast food containers (ICIS, 2011d).
0.1%	1,771	PS	GPPS (general purpose polystyrene) has applications in a range of products, primarily domestic appliances, construction, electronics, toys, and food packaging such as containers, produce baskets, and fast food containers (ICIS, 2011d).
0.1%	724	PS	GPPS (general purpose polystyrene) has applications in a range of products, primarily domestic appliances, construction, electronics, toys, and food packaging such as containers, produce baskets, and fast food containers (ICIS, 2011d).
0.1%	4,169	LLDPE	LLDPE (linear low-density polyethylene) is used in high-strength film applications. Compared to LDPE, LLDPE's chemical structure contains branches that are much straighter and closely aligned, providing it with a higher tensile strength and making it more resistant to puncturing or shearing
0.2%	18,082	LLDPE	LLDPE (linear low-density polyethylene) is used in high-strength film applications. Compared to LDPE, LLDPE's chemical structure contains branches that are much straighter and closely aligned, providing it with a higher tensile strength and making it more resistant to puncturing or shearing
0.6%	12,602	LLDPE	LLDPE (linear low-density polyethylene) is used in high-strength film applications. Compared to LDPE, LLDPE's chemical structure contains branches that are much straighter and closely aligned, providing it with a higher tensile strength and making it more resistant to puncturing or shearing

0.2%	18,413	LLDPE	LLDPE (linear low-density polyethylene) is used in high-strength film applications. Compared to LDPE, LLDPE's chemical structure contains branches that are much straighter and closely aligned, providing it with a higher tensile strength and making it more resistant to puncturing or shearing.
0.1%	1,221	LLDPE	LLDPE (linear low-density polyethylene) is used in high-strength film applications. Compared to LDPE, LLDPE's chemical structure contains branches that are much straighter and closely aligned, providing it with a higher tensile strength and making it more resistant to puncturing or shearing.
0.1%	2,143	PP	PP (Polypropylene) is used in packaging, automotive parts, or made into synthetic fibres. It can be extruded for use in pipe, conduit, wire, and cable applications. PP's advantages are a high impact strength, high softening point, low density, and resistance to scratching and stress cracking. A drawback is its brittleness at low temperatures.
0.2%	8,887	PP	PP (Polypropylene) is used in packaging, automotive parts, or made into synthetic fibres. It can be extruded for use in pipe, conduit, wire, and cable applications. PP's advantages are a high impact strength, high softening point, low density, and resistance to scratching and stress cracking. A drawback is its brittleness at low temperatures.
0.2%	2,726	Mixed Plastics	Mixed plastics are made up of 39% HDPE and 61% PET plastic.
0.1%	1,182	PVC	PVC (Polyvinyl Chloride) is produced as both rigid and flexible resins. Rigid PVC is used for pipe, conduit, and roofing tiles, whereas flexible PVC has applications in wire and cable coating, flooring, coated fabrics, and shower curtains.

0.3%	3,948	PVC	PVC (Polyvinyl Chloride) is produced as both rigid and flexible resins. Rigid PVC is used for pipe, conduit, and roofing tiles, whereas flexible PVC has applications in wire and cable coating, flooring, coated fabrics, and shower curtains.
0.2%	9,971	PVC	PVC (Polyvinyl Chloride) is produced as both rigid and flexible resins. Rigid PVC is used for pipe, conduit, and roofing tiles, whereas flexible PVC has applications in wire and cable coating, flooring, coated fabrics, and shower curtains.
	173,237		
0.4%	42,906	Food Waste	Food waste consists of uneaten food and wasted, prepared food from residences, commercial establishments such as grocery stores and restaurants, institutional sources such as school cafeterias, and industrial sources such as factory lunchrooms. This emission factor contains a weighted average of all food types in the waste stream currently modeled in WARM, including beef, poultry, grains, fruits and vegetables, and dairy products. The mix is assumed to be 9% beef, 11% poultry, 13% grains, 49% fruits and vegetables, and 18% dairy products.
0.6%	65,055	Food Waste	Food waste consists of uneaten food and wasted, prepared food from residences, commercial establishments such as grocery stores and restaurants, institutional sources such as school cafeterias, and industrial sources such as factory lunchrooms. This emission factor contains a weighted average of all food types in the waste stream currently modeled in WARM, including beef, poultry, grains, fruits and vegetables, and dairy products. The mix is assumed to be 9% beef, 11% poultry, 13% grains, 49% fruits and vegetables, and 18% dairy products.

0.4%	28,098	Food Waste	Food waste consists of uneaten food and wasted, prepared food from residences, commercial establishments such as grocery stores and restaurants, institutional sources such as school cafeterias, and industrial sources such as factory lunchrooms. This emission factor contains a weighted average of all food types in the waste stream currently modeled in WARM, including beef, poultry, grains, fruits and vegetables, and dairy products. The mix is assumed to be 9% beef, 11% poultry, 13% grains, 49% fruits and vegetables, and 18% dairy products.
0.5%	37,178	Food Waste	Food waste consists of uneaten food and wasted, prepared food from residences, commercial establishments such as grocery stores and restaurants, institutional sources such as school cafeterias, and industrial sources such as factory lunchrooms. This emission factor contains a weighted average of all food types in the waste stream currently modeled in WARM, including beef, poultry, grains, fruits and vegetables, and dairy products. The mix is assumed to be 9% beef, 11% poultry, 13% grains, 49% fruits and vegetables, and 18% dairy products.
	141,429		
1.0%	50,389	Dimensional Lumber	Lumber includes wood used for containers, packaging, and building and includes crates, pallets, furniture and dimensional lumber like two by fours.
0.8%	16,440	Dimensional Lumber	Lumber includes wood used for containers, packaging, and building and includes crates, pallets, furniture and dimensional lumber like two by fours.
0.8%	24,900	Dimensional Lumber	Lumber includes wood used for containers, packaging, and building and includes crates, pallets, furniture and dimensional lumber like two by fours.
0.4%	3,290	Dimensional Lumber	Lumber includes wood used for containers, packaging, and building and includes crates, pallets, furniture and dimensional lumber like two by fours.

0.0%	374	Yard Trimmings	Yard trimmings are assumed to be 50% grass, 25% leaves, and 25% tree and brush trimmings from residential, institutional, and commercial sources.
0.3%	2,408	Yard Trimmings	Yard trimmings are assumed to be 50% grass, 25% leaves, and 25% tree and brush trimmings from residential, institutional, and commercial sources.
0.9%	34,801	Yard Trimmings	Yard trimmings are assumed to be 50% grass, 25% leaves, and 25% tree and brush trimmings from residential, institutional, and commercial sources.
0.5%	8,827	Yard Trimmings	Yard trimmings are assumed to be 50% grass, 25% leaves, and 25% tree and brush trimmings from residential, institutional, and commercial sources.
	129,182		
0.3%	18,376	Textbooks	Textbooks represent books made from paper produced from chemical pulp.
0.2%	7,490	Textbooks	Textbooks represent books made from paper produced from chemical pulp.
0.6%	47,083	Textbooks	Textbooks represent books made from paper produced from chemical pulp.
0.2%	4,543	Tires	Tires represent scrap tires that have been disposed of by consumers and have several end uses in the U.S. market including as a fuel, in civil engineering, and in various ground rubber applications such as running tracks and molded products.
0.1%	667	Tires	Tires represent scrap tires that have been disposed of by consumers and have several end uses in the U.S. market including as a fuel, in civil engineering, and in various ground rubber applications such as running tracks and molded products.

0.3%	4,280	Food Waste (meat only)	Food Waste (meat only) is a weighted average category representing meat waste in the U.S. waste stream, based on the share of poultry and beef in USDA's loss-adjusted food availability survey. The mix is assumed to be 46 percent beef and 54 percent poultry
0.6%	41,555	Food Waste (meat only)	Food Waste (meat only) is a weighted average category representing meat waste in the U.S. waste stream, based on the share of poultry and beef in USDA's loss-adjusted food availability survey. The mix is assumed to be 46 percent beef and 54 percent poultry
0.1%	5,188	Food Waste (meat only)	Food Waste (meat only) is a weighted average category representing meat waste in the U.S. waste stream, based on the share of poultry and beef in USDA's loss-adjusted food availability survey. The mix is assumed to be 46 percent beef and 54 percent poultry
	39,280		
0.0%	2,582	Aluminum Cans	Aluminum cans represent cans produced out of sheet rolled aluminum ingot.
0.0%	1,647	Aluminum Ingot	Aluminum ingot is processed from molten aluminum in the form of a sheet ingot suitable for rolling, extruding, or shape casting. Thus, it serves as a pre-cursor to manufacture of aluminum products such as aluminum cans. It can serve as a proxy for certain aluminum materials such as electrical transmission and distribution wires, other electrical conductors, some extruded aluminum products, aluminum product cuttings, joinings and weldings, and consumer durable products such as home appliances, computers, and electronics
0.1%	4,002	Steel Cans	Steel cans represent three-piece welded cans produced from sheet steel which is made in a blast furnace and basic oxygen furnace (for virgin cans) or electric arc furnace (for recycled cans).

0.3%	9,745	Steel Cans	Steel cans represent three-piece welded cans produced from sheet steel which is made in a blast furnace and basic oxygen furnace (for virgin cans) or electric arc furnace (for recycled cans).
0.3%	7,134	Mixed Metals	Mixed metals are made up of 35% aluminum cans and 65% steel cans.
0.2%	5,744	Mixed Metals	Mixed metals are made up of 35% aluminum cans and 65% steel cans.
0.5%	8,248	Mixed Metals	Mixed metals are made up of 35% aluminum cans and 65% steel cans.
0.0%	178	Mixed Metals	Mixed metals are made up of 35% aluminum cans and 65% steel cans.
	22,380		
0.1%	6,820	Glass	Glass represents glass containers (e.g., soft drink bottles and wine bottles)
0.1%	3,523	Glass	Glass represents glass containers (e.g., soft drink bottles and wine bottles)
0.1%	5,108	Glass	Glass represents glass containers (e.g., soft drink bottles and wine bottles)
0.1%	1,786	Glass	Glass represents glass containers (e.g., soft drink bottles and wine bottles)
0.2%	5,143	Glass	Glass represents glass containers (e.g., soft drink bottles and wine bottles)
	4,097		
0.2%	2,008	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.

0.0%	194	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.1%	530	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.0%	123	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.0%	66	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.

0.0%	407	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.0%	0	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.0%	169	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.0%	10	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.

0.0%	0	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.0%	590	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
	83,484		
0.7%	22,185	Wood Flooring	Virgin hardwood flooring is produced from lumber. Coatings and sealants can be applied to wood flooring in “pre-finishing” that occurs at the manufacturing facility, or on-site.
		Clay Bricks	Bricks are produced by firing materials such as clay, kaolin, fire clay, bentonite, or common clay and shale. The majority of the bricks produced in the US are clay. In WARM, clay brick source reduction is considered to be the reuse of full bricks rather than the grinding and reusing of broken or damaged brick.
		Concrete	Concrete is a high-volume building material produced by mixing cement, water, and coarse and fine aggregates. In WARM, concrete is assumed to be recycled into aggregate, so the GHG benefits are associated with the avoided emissions associated with mining and processing aggregate.
0.3%	3,002	Asphalt Shingles	Asphalt concrete is composed primarily of aggregate, which consists of hard, graduated fragments of sand, gravel, crushed stone, slag, rock dust, or powder.

0.0%	49	Fly Ash	Fly ash is a byproduct of coal combustion that is used as a cement replacement in concrete.
0.4%	5,005	Fly Ash	Fly ash is a byproduct of coal combustion that is used as a cement replacement in concrete.
0.6%	14,797	Drywall	Drywall, also known as wallboard, gypsum board, or plaster board, is manufactured from gypsum plaster and a paper covering.
0.7%	12,788	Medium-density Fiberboard	Fiberboard is a panel product that consists of wood chips pressed and bonded with a resin. Fiberboard is used primarily to make furniture.
0.5%	8,251	Carpet	Carpet represents broadloom residential carpet containing a mix of nylon, PET and PP components within the face fiber, primary and secondary backing, and latex used for attaching the backings.
0.7%	13,830	Carpet	Carpet represents broadloom residential carpet containing a mix of nylon, PET and PP components within the face fiber, primary and secondary backing, and latex used for attaching the backings.
0.3%	3,577	Fiberglass Insulation	Fiberglass insulation is produced from a blend of sand, limestone, soda ash, and recycled glass cullet, which accounts for about 40 percent of the raw material inputs.
		Vinyl Flooring	All vinyl flooring is comprised of polyvinyl chloride (PVC) resin along with additives such as plasticizers, stabilizers, pigments, and fillers.
	5,558		
0.0%	23	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.

0.0%	1	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.0%	138	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.1%	965	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.0%	56	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.

0.0%	20	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.1%	541	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.0%	103	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.0%	224	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.

0.0%	2	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.0%	0	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.2%	2,974	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.0%	117	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.

0.0%	40	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.0%	14	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
0.0%	340	Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
	842,957		

WARM Material	WARM Data Source Definition
Aluminum Cans	Aluminum cans represent cans produced out of sheet rolled aluminum ingot.
Aluminum Ingot	Aluminum ingot is processed from molten aluminum in the form of a sheet ingot suitable for rolling, extruding, or shape casting. Thus, it serves as a pre-cursor to manufacture of aluminum products such as aluminum cans. It can serve as a proxy for certain aluminum
Steel Cans	Steel cans represent three-piece welded cans produced from sheet steel which is made in a blast furnace and basic oxygen furnace (for virgin cans) or electric arc furnace (for recycled cans).
Copper Wire	Copper wire is used in various applications including power transmission and generation lines, building wiring, telecommunication, and electrical and electronic products.
Glass	Glass represents glass containers (e.g., soft drink bottles and wine bottles)
HDPE	HDPE (high-density polyethylene) is usually labeled plastic code #2 on the bottom of the container, and refers to a plastic often used to make bottles for milk, juice, water and laundry products. It is also used to make plastic grocery bags.
LDPE	LDPE (Low-density polyethylene), usually labeled plastic code #4, is often used to manufacture plastic dry cleaning bags. LDPE is also used to manufacture some flexible lids and bottles.

PET	PET (Polyethylene terephthalate) is typically labeled plastic code #1 on the bottom of the container. PET is often used for soft drink and disposable water bottles, but can also include other containers or packaging.
LLDPE	LLDPE (linear low-density polyethylene) is used in high-strength film applications. Compared to LDPE, LLDPE's chemical structure contains branches that are much straighter and closely aligned, providing it with a higher tensile strength and making it more resistant to puncturing or shearing.
PP	PP (Polypropylene) is used in packaging, automotive parts, or made into synthetic fibres. It can be extruded for use in pipe, conduit, wire, and cable applications. PP's advantages are a high impact strength, high softening point, low density, and resistance to scratching and stress cracking. A drawback is its brittleness at low temperatures
PS (polystyrene)	GPPS (general purpose polystyrene) has applications in a range of products, primarily domestic appliances, construction, electronics, toys, and food packaging such as containers, produce baskets, and fast food containers (ICIS, 2011d).
PVC	PVC (Polyvinyl Chloride) is produced as both rigid and flexible resins. Rigid PVC is used for pipe, conduit, and roofing tiles, whereas flexible PVC has applications in wire and cable coating, flooring, coated fabrics, and shower curtains.

PLA	Polylactic acid or PLA is a thermoplastic biopolymer constructed entirely from annually renewable agricultural products, e.g., corn, and
Corrugated Containers	Corrugated cardboard boxes made from containerboard (liner and corrugating medium) used in packaging applications.
Magazines/Third-class Mail	Third Class Mail is now called Standard Mail by the U.S. Postal Service and includes catalogs and other direct bulk mailings such as magazines, which are made of coated, shiny paper. This category represents coated paper produced from mechanical pulp.
Newspaper	Newspaper represents uncoated paper made from 70% mechanical pulp and 30% chemical pulp. For the carbon sequestration portion of the factor, it was assumed that the paper was all mechanical pulp.
Office Paper	Office paper represents paper made from uncoated bleached chemical pulp.
Phonebooks	Phonebooks represent telephone books that are made from paper produced from mechanical pulp.
Textbooks	Textbooks represent books made from paper produced from chemical pulp.
Dimensional Lumber	Lumber includes wood used for containers, packaging, and building and includes crates, pallets, furniture and dimensional lumber like two by fours.
Medium-density Fiberboard	Fiberboard is a panel product that consists of wood chips pressed and bonded with a resin. Fiberboard is used primarily to make furniture.

Food Waste (non-meat)	Food Waste (non-meat) is a weighted average category representing non-meat food waste in the U.S. waste stream, based on the share of grains, fruits and vegetables, and dairy products in USDA's loss-adjusted food availability survey. The mix is assumed to be 22 percent dairy products, 61 percent fruits and vegetables, and 16 percent grains.
Food Waste (meat only)	Food Waste (meat only) is a weighted average category representing meat waste in the U.S. waste stream, based on the share of poultry and beef in USDA's loss-adjusted food availability survey. The mix is assumed to be 46 percent beef and 54 percent poultry.
Beef	Beef includes the upstream emissions and energy associated with the production of beef cattle in the United States, including the energy and emissions associated with feed production.
Poultry	Poultry includes the upstream emissions and energy associated with the production of broiler chicken (i.e., domesticated chickens raised specifically for meat production), including the energy and emissions associated with feed production.
Grains	The Grains emission factor consists of a weighted average of the relative amounts of grain products in the municipal waste stream, consisting of wheat flour, corn and rice.
Bread	The bread emission factor consists of the upstream emissions and energy associated with wheat flour

Fruits and Vegetables		Fruits and vegetables represents the average fresh fruits and vegetable components of food waste. It consists of a weighted average of the six most common fruits and vegetables in the municipal waste stream, including apples, bananas, melons, oranges, potatoes, and tomatoes.
Dairy Products		Dairy products consists of a weighted average of the emissions associated with nearly the entire dairy product waste stream, including milk, cheese, ice cream, and yogurt.
Yard Trimmings		Yard trimmings are assumed to be 50% grass, 25% leaves, and 25% tree and brush trimmings from residential, institutional, and commercial sources.
Grass		Grass consists of grass clippings from residential, institutional and commercial sources.
Leaves		Leaves consist of fallen leaves from deciduous trees recovered from residential, institutional and commercial sources.
Branches		Branches are assumed to be the woody clippings from trees and brush from residential, intuitional and commercial sources.
Mixed Paper - General		Mixed paper is assumed to be 24% newspaper, 48% corrugated cardboard, 8% magazines, and 20% office paper.
Mixed Paper - Residential		Residential mixed paper is assumed to be 23% newspaper, 53% corrugated cardboard, 10% magazines, and 14% office paper.

Mixed paper - Office Paper		Office mixed paper is assumed to be 21% newspaper, 5% corrugated cardboard, 36% magazines, and 38% office paper.
Mixed Metals		Mixed metals are made up of 35% aluminum cans and 65% steel cans.
Mixed Plastics		Mixed plastics are made up of 39% HDPE and 61% PET plastic.
Mixed Recyclables		Mixed Recyclables are made up of approximately 1% aluminum cans, 3% steel cans, 6% glass, 1% HDPE, 2% PET, 54% corrugated cardboard, 7% magazines/third-class mail, 11% newspaper, 8% office papers, <1% phonebooks, <1% textbooks, and 5% dimensional lumber. See those definitions for details.
Food Waste		Food waste consists of uneaten food and wasted, prepared food from residences, commercial establishments such as grocery stores and restaurants, institutional sources such as school cafeterias, and industrial sources such as factory lunchrooms. This emission factor contains a weighted average of all food types in the waste stream currently modeled in WARM, including beef, poultry, grains, fruits and vegetables, and dairy products. The mix is assumed to be 9% beef, 11% poultry, 13% grains, 49% fruits and vegetables, and 18% dairy products.
Mixed Organics		Mixed organics are made up of 52% food waste and 48% yard trimmings. See those definitions for details.

Mixed MSW	Mixed MSW (municipal solid waste) comprises the waste materials typically discarded by households and collected by curbside collection vehicles; it does not include white goods (e.g., refrigerators, toasters) or industrial waste.
Carpet	Carpet represents broadloom residential carpet containing a mix of nylon, PET and PP components within the face fiber, primary and secondary backing, and latex used for attaching the backings.
Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
Clay Bricks	Bricks are produced by firing materials such as clay, kaolin, fire clay, bentonite, or common clay and shale. The majority of the bricks produced in the US are clay. In WARM, clay brick source reduction is considered to be the reuse of full bricks rather than the grinding and reusing of broken or damaged brick.

Concrete	Concrete is a high-volume building material produced by mixing cement, water, and coarse and fine aggregates. In WARM, concrete is assumed to be recycled into aggregate, so the GHG benefits are associated with the avoided emissions associated with mining and processing aggregate.
Fly Ash	Fly ash is a byproduct of coal combustion that is used as a cement replacement in concrete.
Tires	Tires represent scrap tires that have been disposed of by consumers and have several end uses in the U.S. market including as a fuel, in civil engineering, and in various ground rubber applications such as running tracks and molded products.
Asphalt Concrete	Asphalt concrete is composed primarily of aggregate, which consists of hard, graduated fragments of sand, gravel, crushed stone, slag, rock dust, or powder.
	Asphalt shingles are typically made of a felt mat saturated with asphalt.

Asphalt Shingles	Fiberglass shingles are composed of asphalt cement (36 percent by weight), a mineral stabilizer like limestone or dolomite (40 percent), sand-sized mineral granules (38 percent), in addition to the organic or fiberglass felt backing (15 percent).
Drywall	Drywall, also known as wallboard, gypsum board, or plasterboard, is manufactured from gypsum plaster and a paper covering.
Fiberglass Insulation	Fiberglass insulation is produced from a blend of sand, limestone, soda ash, and recycled glass cullet, which accounts for about 40 percent of the
Vinyl Flooring	All vinyl flooring is comprised of polyvinyl chloride (PVC) resin along with additives such as plasticizers, stabilizers, pigments, and fillers.
Wood Flooring	Virgin hardwood flooring is produced from lumber. Coatings and sealants can be applied to wood flooring in “pre-finishing” that occurs at the manufacturing facility, or on-site.

Primary Data Source	Data Source Year
PE Americas	2010
Aluminum Association	2011
PE Americas	2010
Franklin Associates	1998
Franklin Associates	2002
EPA	2015
Franklin Associates, American Chemistry Council	2010
Franklin Associates, American Chemistry Council	2010

Franklin Associates, American Chemistry Council	2010
Franklin Associates, American Chemistry Council	2010
Franklin Associates, American Chemistry Council.	2010
Franklin Associates, American Chemistry Council	2010
Franklin Associates, American Chemistry Council	2010

Natureworks, LLC	2010
U.S. Life Cycle Inventory Database	2010
EPA	2006
EPA	2006
Franklin Associates	1998
Franklin Associates	1998
EPA	2006
EPA	2006
EPA	2015
EPA	1995

USDA	2012
USDA	2012
Battagliese et al.	2013
Pelletier	2008
USDA	2000-2009
USDA	2004-2009
Espinoza-Orias et al.	2011

Ecoinvent Centre	2007
Luske, B.	2010
UC Davis	2009
Innovation Center for U.S. Dairy	2010
EPA	2006
EPA	2006
EPA	2006
EPA	2006
EPA	2006
EPA	2006

EPA	2006
EPA	2006
EPA	2006
EPA	2006
USDA	2012
EPA	2006

EPA	2006
Plastics Europe	2005
Realff, M.	2011
Franklin Associates	2002
EPA	2003

EPA	2003
EPA	2003
Atech Group	2001
EIA	2009
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Census Bureau	2001
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WARM Material	WARM Data Source Definition
Aluminum Cans	Aluminum cans represent cans produced out of sheet rolled aluminum ingot.
Aluminum Ingot	Aluminum ingot is processed from molten aluminum in the form of a sheet ingot suitable for rolling, extruding, or shape casting. Thus, it serves as a pre-cursor to manufacture of aluminum products such as aluminum cans. It can serve as a proxy for certain aluminum
Steel Cans	Steel cans represent three-piece welded cans produced from sheet steel which is made in a blast furnace and basic oxygen furnace (for virgin cans) or electric arc furnace (for recycled cans).
Copper Wire	Copper wire is used in various applications including power transmission and generation lines, building wiring, telecommunication, and electrical and electronic products.
Glass	Glass represents glass containers (e.g., soft drink bottles and wine bottles)
HDPE	HDPE (high-density polyethylene) is usually labeled plastic code #2 on the bottom of the container, and refers to a plastic often used to make bottles for milk, juice, water and laundry products. It is also used to make plastic grocery bags.
LDPE	LDPE (Low-density polyethylene), usually labeled plastic code #4, is often used to manufacture plastic dry cleaning bags. LDPE is also used to manufacture some flexible lids and bottles.

PET	PET (Polyethylene terephthalate) is typically labeled plastic code #1 on the bottom of the container. PET is often used for soft drink and disposable water bottles, but can also include other containers or packaging.
LLDPE	LLDPE (linear low-density polyethylene) is used in high-strength film applications. Compared to LDPE, LLDPE's chemical structure contains branches that are much straighter and closely aligned, providing it with a higher tensile strength and making it more resistant to puncturing or shearing.
PP	PP (Polypropylene) is used in packaging, automotive parts, or made into synthetic fibres. It can be extruded for use in pipe, conduit, wire, and cable applications. PP's advantages are a high impact strength, high softening point, low density, and resistance to scratching and stress cracking. A drawback is its brittleness at low temperatures
PS (polystyrene)	GPPS (general purpose polystyrene) has applications in a range of products, primarily domestic appliances, construction, electronics, toys, and food packaging such as containers, produce baskets, and fast food containers (ICIS, 2011d).
PVC	PVC (Polyvinyl Chloride) is produced as both rigid and flexible resins. Rigid PVC is used for pipe, conduit, and roofing tiles, whereas flexible PVC has applications in wire and cable coating, flooring, coated fabrics, and shower curtains.

PLA	Polylactic acid or PLA is a thermoplastic biopolymer constructed entirely from annually renewable agricultural products, e.g., corn, and
Corrugated Containers	Corrugated cardboard boxes made from containerboard (liner and corrugating medium) used in packaging applications.
Magazines/Third-class Mail	Third Class Mail is now called Standard Mail by the U.S. Postal Service and includes catalogs and other direct bulk mailings such as magazines, which are made of coated, shiny paper. This category represents coated paper produced from mechanical pulp.
Newspaper	Newspaper represents uncoated paper made from 70% mechanical pulp and 30% chemical pulp. For the carbon sequestration portion of the factor, it was assumed that the paper was all mechanical pulp.
Office Paper	Office paper represents paper made from uncoated bleached chemical pulp.
Phonebooks	Phonebooks represent telephone books that are made from paper produced from mechanical pulp.
Textbooks	Textbooks represent books made from paper produced from chemical pulp.
Dimensional Lumber	Lumber includes wood used for containers, packaging, and building and includes crates, pallets, furniture and dimensional lumber like two by fours.
Medium-density Fiberboard	Fiberboard is a panel product that consists of wood chips pressed and bonded with a resin. Fiberboard is used primarily to make furniture.

Food Waste (non-meat)	Food Waste (non-meat) is a weighted average category representing non-meat food waste in the U.S. waste stream, based on the share of grains, fruits and vegetables, and dairy products in USDA's loss-adjusted food availability survey. The mix is assumed to be 22 percent dairy products, 61 percent fruits and vegetables, and 16 percent grains.
Food Waste (meat only)	Food Waste (meat only) is a weighted average category representing meat waste in the U.S. waste stream, based on the share of poultry and beef in USDA's loss-adjusted food availability survey. The mix is assumed to be 46 percent beef and 54 percent poultry.
Beef	Beef includes the upstream emissions and energy associated with the production of beef cattle in the United States, including the energy and emissions associated with feed production.
Poultry	Poultry includes the upstream emissions and energy associated with the production of broiler chicken (i.e., domesticated chickens raised specifically for meat production), including the energy and emissions associated with feed production.
Grains	The Grains emission factor consists of a weighted average of the relative amounts of grain products in the municipal waste stream, consisting of wheat flour, corn and rice.
Bread	The bread emission factor consists of the upstream emissions and energy associated with wheat flour

Fruits and Vegetables		Fruits and vegetables represents the average fresh fruits and vegetable components of food waste. It consists of a weighted average of the six most common fruits and vegetables in the municipal waste stream, including apples, bananas, melons, oranges, potatoes, and tomatoes.
Dairy Products		Dairy products consists of a weighted average of the emissions associated with nearly the entire dairy product waste stream, including milk, cheese, ice cream, and yogurt.
Yard Trimmings		Yard trimmings are assumed to be 50% grass, 25% leaves, and 25% tree and brush trimmings from residential, institutional, and commercial sources.
Grass		Grass consists of grass clippings from residential, institutional and commercial sources.
Leaves		Leaves consist of fallen leaves from deciduous trees recovered from residential, institutional and commercial sources.
Branches		Branches are assumed to be the woody clippings from trees and brush from residential, intuitional and commercial sources.
Mixed Paper - General		Mixed paper is assumed to be 24% newspaper, 48% corrugated cardboard, 8% magazines, and 20% office paper.
Mixed Paper - Residential		Residential mixed paper is assumed to be 23% newspaper, 53% corrugated cardboard, 10% magazines, and 14% office paper.

Mixed paper - Office Paper		Office mixed paper is assumed to be 21% newspaper, 5% corrugated cardboard, 36% magazines, and 38% office paper.
Mixed Metals		Mixed metals are made up of 35% aluminum cans and 65% steel cans.
Mixed Plastics		Mixed plastics are made up of 39% HDPE and 61% PET plastic.
Mixed Recyclables		Mixed Recyclables are made up of approximately 1% aluminum cans, 3% steel cans, 6% glass, 1% HDPE, 2% PET, 54% corrugated cardboard, 7% magazines/third-class mail, 11% newspaper, 8% office papers, <1% phonebooks, <1% textbooks, and 5% dimensional lumber. See those definitions for details.
Food Waste		Food waste consists of uneaten food and wasted, prepared food from residences, commercial establishments such as grocery stores and restaurants, institutional sources such as school cafeterias, and industrial sources such as factory lunchrooms. This emission factor contains a weighted average of all food types in the waste stream currently modeled in WARM, including beef, poultry, grains, fruits and vegetables, and dairy products. The mix is assumed to be 9% beef, 11% poultry, 13% grains, 49% fruits and vegetables, and 18% dairy products.
Mixed Organics		Mixed organics are made up of 52% food waste and 48% yard trimmings. See those definitions for details.

Mixed MSW	Mixed MSW (municipal solid waste) comprises the waste materials typically discarded by households and collected by curbside collection vehicles; it does not include white goods (e.g., refrigerators, toasters) or industrial waste.
Carpet	Carpet represents broadloom residential carpet containing a mix of nylon, PET and PP components within the face fiber, primary and secondary backing, and latex used for attaching the backings.
Personal Computers	PCs are made up of a central processing unit (CPU) and a cathode ray tube (CRT) monitor. The components of the CPU and monitor include steel housing, internal electric components, the CRT, plastic casing, and circuit boards. In addition to these valuable components, PCs contain lead, brominated flame retardants and other potentially hazardous chemicals.
Clay Bricks	Bricks are produced by firing materials such as clay, kaolin, fire clay, bentonite, or common clay and shale. The majority of the bricks produced in the US are clay. In WARM, clay brick source reduction is considered to be the reuse of full bricks rather than the grinding and reusing of broken or damaged brick.

Concrete	Concrete is a high-volume building material produced by mixing cement, water, and coarse and fine aggregates. In WARM, concrete is assumed to be recycled into aggregate, so the GHG benefits are associated with the avoided emissions associated with mining and processing aggregate.
Fly Ash	Fly ash is a byproduct of coal combustion that is used as a cement replacement in concrete.
Tires	Tires represent scrap tires that have been disposed of by consumers and have several end uses in the U.S. market including as a fuel, in civil engineering, and in various ground rubber applications such as running tracks and molded products.
Asphalt Concrete	Asphalt concrete is composed primarily of aggregate, which consists of hard, graduated fragments of sand, gravel, crushed stone, slag, rock dust, or powder.
	Asphalt shingles are typically made of a felt mat saturated with asphalt.

Asphalt Shingles	Fiberglass shingles are composed of asphalt cement (36 percent by weight), a mineral stabilizer like limestone or dolomite (40 percent), sand-sized mineral granules (38 percent), in addition to the organic or fiberglass felt backing (15 percent).
Drywall	Drywall, also known as wallboard, gypsum board, or plasterboard, is manufactured from gypsum plaster and a paper covering.
Fiberglass Insulation	Fiberglass insulation is produced from a blend of sand, limestone, soda ash, and recycled glass cullet, which accounts for about 40 percent of the
Vinyl Flooring	All vinyl flooring is comprised of polyvinyl chloride (PVC) resin along with additives such as plasticizers, stabilizers, pigments, and fillers.
Wood Flooring	Virgin hardwood flooring is produced from lumber. Coatings and sealants can be applied to wood flooring in “pre-finishing” that occurs at the manufacturing facility, or on-site.

Primary Data Source	Data Source Year
PE Americas	2010
Aluminum Association	2011
PE Americas	2010
Franklin Associates	1998
Franklin Associates	2002
EPA	2015
Franklin Associates, American Chemistry Council	2010
Franklin Associates, American Chemistry Council	2010

Franklin Associates, American Chemistry Council	2010
Franklin Associates, American Chemistry Council	2010
Franklin Associates, American Chemistry Council.	2010
Franklin Associates, American Chemistry Council	2010
Franklin Associates, American Chemistry Council	2010

Natureworks, LLC	2010
U.S. Life Cycle Inventory Database	2010
EPA	2006
EPA	2006
Franklin Associates	1998
Franklin Associates	1998
EPA	2006
EPA	2006
EPA	2015
EPA	1995

USDA	2012
USDA	2012
Battagliese et al.	2013
Pelletier	2008
USDA	2000-2009
USDA	2004-2009
Espinoza-Orias et al.	2011

Ecoinvent Centre	2007
Luske, B.	2010
UC Davis	2009
Innovation Center for U.S. Dairy	2010
EPA	2006
EPA	2006
EPA	2006
EPA	2006
EPA	2006
EPA	2006

EPA	2006
EPA	2006
EPA	2006
EPA	2006
USDA	2012
EPA	2006

EPA	2006
Plastics Europe	2005
Realff, M.	2011
Franklin Associates	2002
EPA	2003

EPA	2003
EPA	2003
Atech Group	2001
EIA	2009
Corti, A. and Lombardi, L.	2004
Athena Institute	2000
Census Bureau	2001
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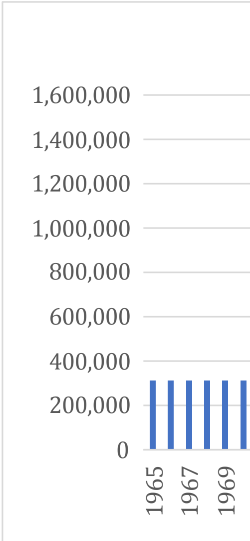
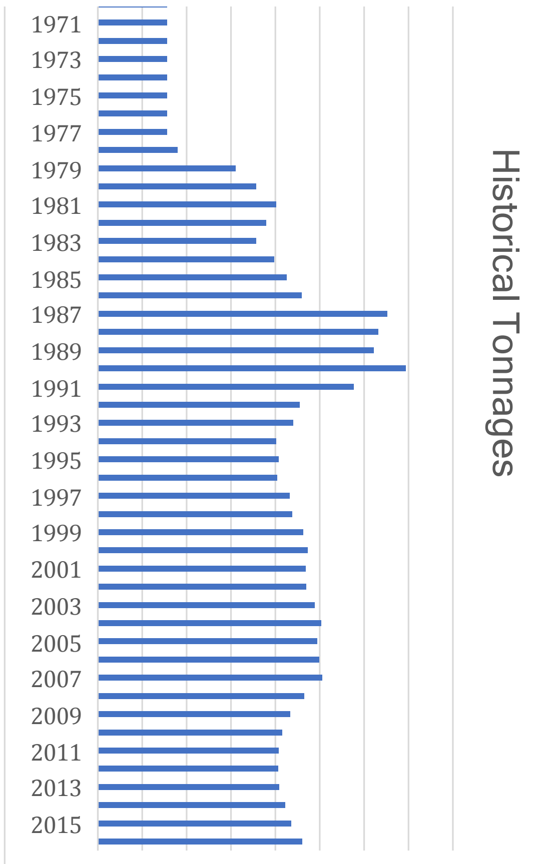
Model	Parameter	Model Comparison
		Waste processed
WARM	Categorization of only "Mixed MSW"	Landfill Only
WARM	Categorization of only "Mixed MSW"	Combustion
WARM	Reduction of 97 materials and tonnages to the 54	Landfill Only
WARM	Reduction of 97 materials and tonnages to the 54	Combustion
MRR		

	Current Year	20	30
	2016		
Output	922,002		
MTCO2E	147,040		
MTCO2E	92,701		

Year	Disposed (metric tons)	Disposed (short ton)
1965	283,858	312,900
1966	283,858	312,900
1967	283,858	312,900
1968	283,858	312,900
1969	283,858	312,900
1970	283,858	312,900
1971	283,858	312,900
1972	283,858	312,900
1973	283,858	312,900
1974	283,858	312,900
1975	283,858	312,900
1976	283,858	312,900
1977	283,858	312,900
1978	327,357	360,849
1979	563,437	621,082
1980	648,540	714,892
1981	730,149	804,851
1982	688,180	758,588
1983	648,546	714,899
1984	720,752	794,492
1985	771,768	850,728
1986	833,773	919,076
1987	1,183,599	1,304,693
1988	1,146,547	1,263,850
1989	1,128,738	1,244,219
1990	1,259,605	1,388,475
1991	1,046,361	1,153,414
1992	825,388	909,833
1993	798,133	879,790
1994	729,465	804,097
1995	739,534	815,196
1996	734,672	809,836
1997	784,168	864,396
1998	794,234	875,492
1999	839,470	925,356
2000	859,262	947,173
2001	849,406	936,309
2002	852,290	939,488
2003	887,986	978,836
2004	912,776	1,006,162
2005	897,074	988,854
2006	905,558	998,206
2007	916,646	1,010,428
2008	844,241	930,615
2009	786,965	867,479
2010	753,791	830,911
2011	740,755	816,542
2012	737,319	812,754
2013	740,936	816,741
2014	765,655	843,989
2015	790,729	871,628
2016	836,427	922,002




Historical Tonnages
1971
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2015

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