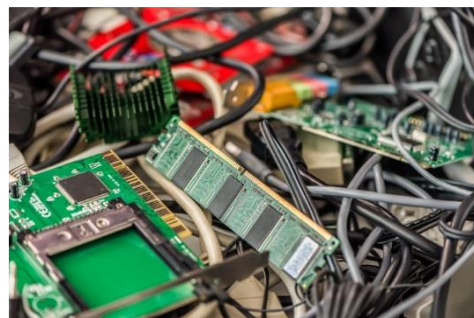
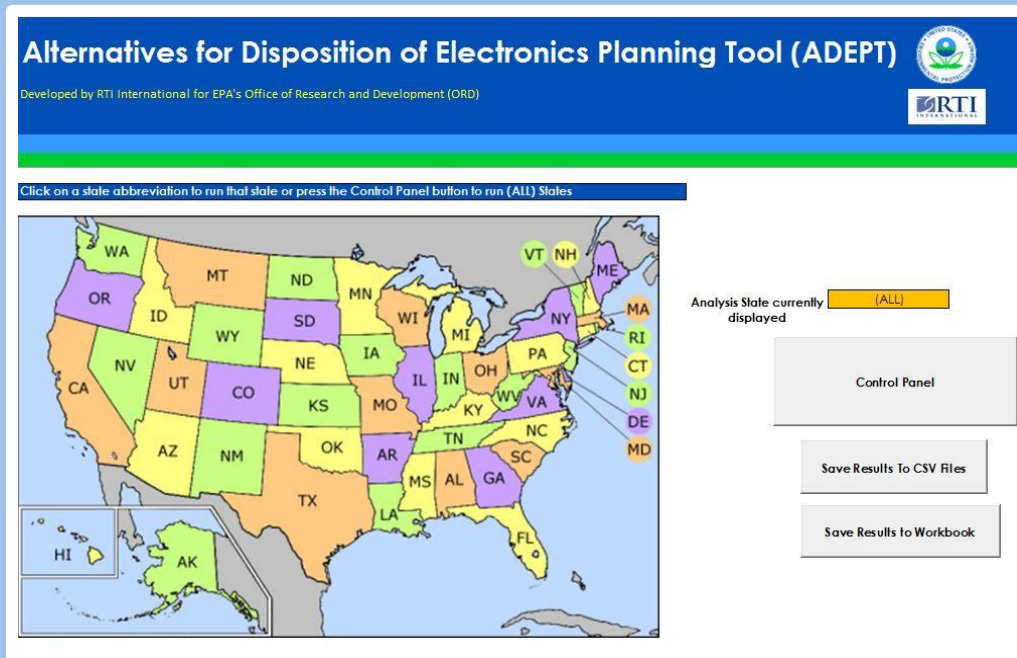


ADEPT: Alternatives for Disposition of Electronics Planning Tool

User Guide



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1 BACKGROUND AND INTRODUCTION

Increases in household income coupled with rapid technology development and falling prices have resulted in a significant increase in the sale and use of consumer electronics in the United States over the past two decades. The rapid growth in consumer electronics markets paired with the diversification of manufactured products has contributed to an equally rapid increase in the stock of obsolete equipment and devices ready for end-of-life (EOL) management.

In 2011, the White House established the Interagency Task Force on National Sustainable Electronics Stewardship, which devised a strategy for achieving the goals outlined in the 2009 Executive Order (EO) 13514, Federal Leadership in Environmental Energy and Economic Performance. The national strategy is based on the following four goals: (1) building incentives for designing greener electronics and enhancing science, research, and technology development in the United States; (2) ensuring that the federal government leads by example; (3) increasing safe and effective management and handling of used electronics in the United States; and (4) reducing harm from U.S. exports of e-waste and improving handling of used electronics in developing countries.

The U.S. Environmental Protection Agency's (EPA) Office of Research and Development, in support of the national strategy and Goals 3 and 4 specifically, is working to provide more information on the quantity and movement of electronic devices from initial purchase to final disposition. Understanding the pathways of used electronics from the consumer to their final disposition will provide insight to decision makers about their impacts and support efforts to encourage improvements in policy, technology, and beneficial use.

The EPA's effort includes three major activities. The first was an evaluation of information on state e-waste legislation, financing mechanisms, implementation challenges, and available data related to collected and recycled quantities of covered electronic devices. The second activity involved a general search for existing data, methods, and tools for estimating the number of electronic devices over their product life cycle. Through the first two activities, it was determined that a comprehensive and cost-effective mechanism was not available for tracking the flow and the reporting of used electronics and e-waste generation (coming out of use or post-use storage) and EOL management (domestically or elsewhere).

To address this information gap, the EPA has developed the Alternatives for Disposition of Electronics Planning Tool (ADEPT). This analytical tool provides stakeholders with an improved understanding of the generation of used electronics from consumer markets to the waste stream over time; however, ADEPT is based on a variety of assumptions and should not be used as the only source of information for making predictions about future generation and management of used electronics.

The geographic level of the tool is at both the state and national levels. Given the level of flexibility the tool provides, many users can find value in ADEPT's functionality to perform tasks such as:

- Policy makers using the tool to compare different disposition scenarios, such as low versus high recycling rates of used electronics from consumers.
- Private-sector firms throughout the recycling and waste stream using the tool in planning of future operations and facilities.

- States without recycling programs and/or without recycling data using the tool to provide a benchmark for policy and sustainability-based discussions.
- Manufacturing firms that use the recycled materials as an input using the tool to understand the potential quantity of a commodities resulting from the recycling of used electronics.

This user guide documents the underlying analytical methods and data used in the tool as well as provides instructions on how to use the tool.

2 TOOL OVERVIEW

ADEPT is built in an Excel workbook, with several supporting worksheets used in the calculation of waste generation at various stages in reuse, recycling, and end of life. Overview information is provided in this section and example runs of ADEPT are included in Section 4. This document concludes with some examples illustrating how to modify the default assumptions and generate and interpret results.

ADEPT starts with national sales data of electronics and disaggregates sales across states, based on each state's gross domestic product (GDP). These disaggregated sales are the starting point for estimating the movement of electronic products from usage to collection, recycling, and final EOL disposal. Following the end of useful life, the two final destinations for used electronic are the commodity market (for products broken down to their components) and final disposal, which is assumed to be landfilling in this tool.

Please note that if you require an adjusted screen contrast setting to use your personal computer, these adjustments to contrast may create unintended difficulties in reading some of the text throughout ADEPT, as certain buttons and cells are hard-coded to a certain color setting.

2.1 ADEPT Overview

ADEPT employs a combination of top-down data sources and bottom-up assumptions to track the generation of used electronics by state and estimate the material flows from generation to collection as well as processing and final disposition. Examples of top-down data sources include national statistics on population, GDP, and retail sales. Examples of bottom-up assumptions include average device weight per product based on the year of manufacturing, expected product lifetimes, and market share by consumer segment. ADEPT estimates material flows to three disposition pathways (i.e., reuse, recycling, and disposal).

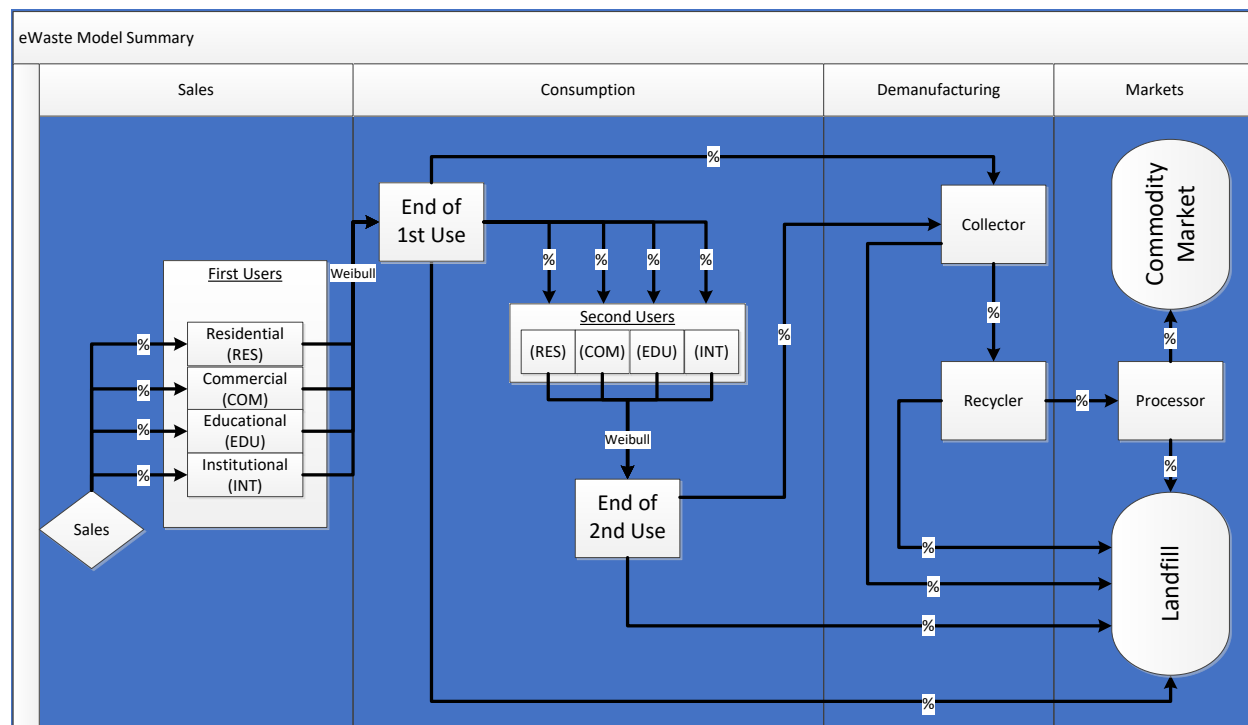
ADEPT produces national- and state-level results for the quantity of electronic products entering EOL management annually (during the years 1980 through 2040) as well as the subsequent volume of waste being landfilled at each stage of the EOL management process. Although the quality and availability of information on the markets and consumer behavior is improving, the rate of change in technology and market behavior is high, which makes these parameters hard to quantify. For this reason, ADEPT was designed to allow end users to easily update key parameters and data elements based on their own assumptions and better information in the future.

2.1.1 ADEPT Structure

The ADEPT structure is illustrated in Figure 1. Original equipment manufacturers (OEMs) make the products, which are sold to retailers, and then purchased by consumers. Following product use, consumers generate used electronics and e-waste. After the material is generated, it flows to one of the following places: storage (e.g., basement, attic, storage closet), a collection (drop-off) center, or disposal

(e.g., landfill). Materials that are gathered through a used electronics collection program are sent to a processing (e.g., recycling) facility, are sold or donated to another consumer for reuse, or are disposed of. Products that are reused will eventually go through the process of collection, reuse, recycling, or disposal again after some period. Materials collected for recycling will either be processed (dismantled, parts sent for reuse or recycled) or disposed. Recycled materials (e.g., metals) may be used to manufacture a new electronic device or other type of product, thus completing the cycle.

Figure 1: ADEPT summary diagram



ADEPT includes several data sources and assumptions that can be used to derive estimates of annual used electronics generation at the national, regional, and state level. The current version of ADEPT is limited in scope to three major categories of consumer electronics: televisions, cell phones, and personal computers (PCs) and related products, as shown in Table 1. Televisions are divided into five subcategories: color cathode ray tubes (CRTs) less than 19 inches, color CRTs greater than 19 inches, flat-panel TVs, color projection, and monochrome. PCs and related products include desktops, portables, hard copy peripherals (e.g., printers, scanners, fax machines), mice, keyboards, PC CRTs, and PC flat monitors. Other materials include items not already listed in the Table 1 such as wood paneling from old television sets, electrical cords, and similar materials.

Table 1: List of products and materials within ADEPT

Products		Materials	
• Cell Phones	• Keyboards	• Aluminum	• Flat Panel Display
• Color CRT <19"	• Mice	• Battery	Module LED
• Color CRT >19"	• Monochrome TVs	• Copper	• Other
• Color Projection TVs	• PC CRTs	• CRT Glass	• Other Metals
• Desktops	• PC Flat-Panel	• CRT Lead	• Printed Circuit Board
• Flat-Panel TVs	Monitors	• Ferrous Metal	Material
• Hard Copy	• Portables	• Flat Panel Display	• Plastics
Peripherals		Module CCFL	

2.1.2 ADEPT Capabilities (intended uses and limitations)

ADEPT is a tool that begins with static, nationally representative sales data. To disaggregate to the state-level, national sales are distributed via state shares of total GDP. This method does not account for specific state policies or actual state-level sales.

Flows of used electronics and waste between states are not accounted for. Accounting of generation is performed at the national-level and is then disaggregated to states. This may not reflect the true nature of how states manage used electronics or how these materials move between states.

Assumptions are based on literature, prior research, industry standards, and anecdotal evidence from stakeholder interviews and conversations. The user should adjust assumptions and parameters to appropriately match their information, assumptions, and specific needs.

Projections of future sales and sales growth are made via simple linear projections. These projections can be edited by the user.

2.2 Glossary

There are many terms used repeatedly throughout ADEPT to describe the various processes and characteristics used throughout the tool. The definitions of these common terms, as they apply to use in ADEPT, are detailed in the table below.

Table 2: ADEPT Glossary of Terms

Term	Definition
Behavior	Refers to the consumer or processor's choice for disposition of the electronic product or commodities embodied with in the product either through recycling, refurbishing for re-use, or landfilling. The Behavior tab in the tool shows the assumed percentage of all electronic devices considered which are expected to be either recycled, reused, or landfilled at each stage of handling.

Term	Definition
Collector	A person or entity who receives used electronic devices from households, schools, institutions, or businesses and completes initial sorting of electronic devices. This initial sorting is thought to incorporate the sorting of reusable electronics from electronics at their end of useful life (EOL), and the sorting of electronics into specific categories (e.g. laptops, LED televisions, etc.). The collector then delivers, or arranges the delivery of, those electronic devices proceeding downstream to a recycler.
Commodity	A raw material or product that can be bought and sold (e.g. plastics, glass, ICBs, metals, etc.).
Commodity Market	The market through which raw materials and products can be purchased and sold.
Composition	A distribution by weight of constituent commodities embodied in each electronic device that may include plastic, batteries, copper, etc. These values were derived from a mixture of publicly available data on material composition from state electronics recycling programs and published studies.
CRT Glass	The glass component of a cathode ray tube (CRT) video display component of an electronic device (usually a television or computer monitor).
CRT Lead	The lead component of a cathode ray tube (CRT) video display component of an electronic device (usually a television or computer monitor).
First Use	Defined as the period of use for an electronic device from point of purchase until the original owner/user deems the electronic device to be obsolete and discards of it.
Generation	Total of electronics (by weight) reaching the end of consumer life. Within ADEPT, there is generation from both the first-use consumer market and the second-use consumer market.
Hard Copy Peripherals	Common hardware that may be connected to a computer for a beneficial use, other than mouse and keyboard. For example, printers, scanners, and fax machines are hard copy peripherals.
Lifetime	See 'Weibull Distribution'
Market Segment	Groups of electronic device consumers displaying distinct consumption behavior with respect to duration of use. The market segments considered in ADEPT are Residential (single family homes, apartments, townhomes, etc.), Education (colleges, universities, primary education institutions), Commercial (businesses), and Institutional (local and national governments, healthcare systems, etc.).
Portables	Small electronic devices that are easy to carry, other than laptop computers. Portables may include personal digital assistants (PDAs), tablets, e-readers, etc.

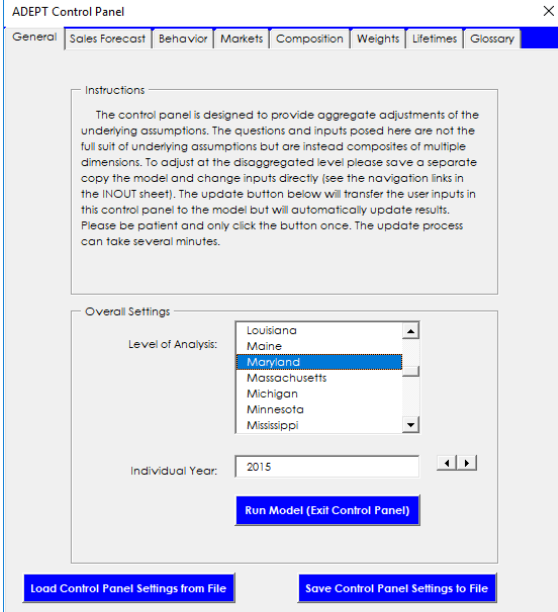
Term	Definition
Processor	A person or entity who accepts used electronic devices, or more commonly, specific parts of used electronic devices, for the purpose of breaking down these devices and their constituent parts into raw commodities than can be reused and sold in the commodity market (such as glass, plastic, copper, etc.). Processors can include smelters, secondary or tertiary recyclers, plastics shredders, glass crushers, etc.
Product Weights	The average weight of each type of electronic device considered ADEPT. The weights currently contained within the tool are derived from the 2008 EPA Waste Management Approach publication. Educated weight assumptions are made for years beyond the 2008 EPA publication
Recycler	A person or entity who accepts used electronic devices from households, schools, institutions, businesses, and electronic waste collectors for the purpose of recycling the valuable material contained within the devices they accept.
Second Use	Second Use Lifetimes contain the Weibull distributions for electronic products considered within ADEPT in their second use. Second use occurs when an original electronic device owner discards of their device to the used electronics waste stream, but a collector or recycler deems the electronic device to be in good condition and will choose to refurbish it and sell to a second user instead of dismantling and recycling it. The Second Use Lifetime accounts for this secondary owner's use of the electronic device. In general, ADEPT considers all Second Use Lifetimes to be approximately half the lifetime of a specific device's First Use Lifetime.
Weibull	A continuous probability distribution used to estimate the probable lifetime of various electronics. ADEPT uses Weibull Distributions as 'Lifetime Distributions' to visualize the probable end of useful life (EOL) times for different electronic devices. The peak of the Weibull distribution for any electronic device represents the most common lifetime of the device.

2.3 Quick Start Instructions

1. Download the Excel file and save it to a computer or a shared network folder.

2. Open the file and navigate to the sheet labeled **INOUT**. NOTE: The file may initially open in a non-editable mode and may cause features such as the **Control Panel** button to be non-responsive. If this is the case, click the **Enable Content** button.
3. Click the abbreviation for the desired state on the map. This opens the **General** tab on the Control Panel for the selected state, which is highlighted in the *Level of Analysis* list. For example, if the state of Maryland were selected from the map, the Control Panel would open to look like Figure 2. The user can then select the year to be evaluated, up to the year 2015.

Figure 2: ADEPT Control Panel interface



Alternatively, the user can click on the **Control Panel** button on the INOUT screen. This also opens the Control Panel **General** tab and the user can then select the state from the *Level of Analysis* list and select the year to be evaluated.

In addition, the Control Panel provides access to various tabs where the user can make changes to ADEPT assumptions (see Section 2.1.3). The user can use the toggle buttons provided to either increase or decrease assumption input values or enter a value directly in the data field.

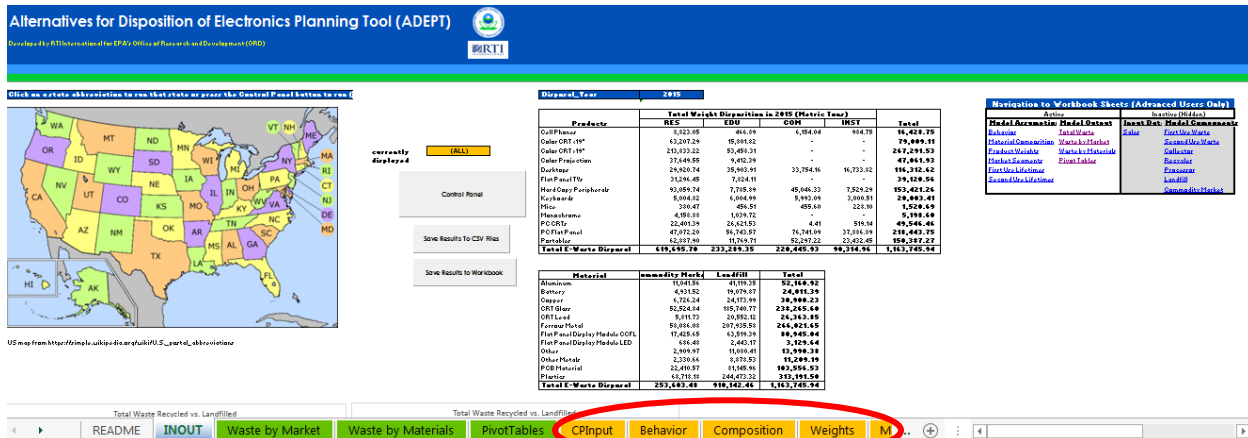
4. Once satisfied with the changes, click the blue button labeled **Run Model (Exit Control Panel)**.¹ ADEPT will update with any changes to the default parameters made within the Control Panel. The Control Panel will automatically close when finished. Note that the update process may take up to a minute to run. “Recalculating—Please Wait” will be displayed during this time. The user should see updated values appear in the summary tables on the right-hand side of the **INOUT** sheet.

Advanced Users: Advanced users are users familiar with the Excel environment and feel confident in their ability to directly manipulate spreadsheet data. If a user has very detailed, specific information they would like to include in their analysis within ADEPT (i.e. measured product weights, specific sales data), it would be worthwhile to act as an advanced user and directly manipulate the input spreadsheets feeding into the ADEPT runs. For the average user,

¹ There are **Run Model** buttons on the various assumptions tabs within the Control Panel. Clicking those buttons will run ADEPT with the updated assumptions but not close the Control Panel, allowing the user to make incremental changes to various assumptions without losing all assumption changes. To close the Control Panel after running ADEPT, use the red close button in the top right corner or use the **Run Model** button on the **General** tab.

simply manipulating inputs in the Control Panel will suffice for most scenarios. Advanced users can also modify data assumptions directly in the sheets with tabs highlighted in yellow. The hyperlinks listed in the Navigation box on the **INOUT** sheet will also take users directly to the data tables of assumptions. **Directly editing assumptions on the sheets with yellow tabs will break the link between the Control Panel and the rest of ADEPT.** This means that once the user opts to directly edit assumptions within the tabs of ADEPT itself, any assumptions further adjusted within the Control Panel will not be carried through in the run's calculations, as the directly edited sheet inputs will override the Control Panel adjustments. **Therefore, it is advisable to save a separate copy of the workbook if the user intends to directly edit individual parameters.**

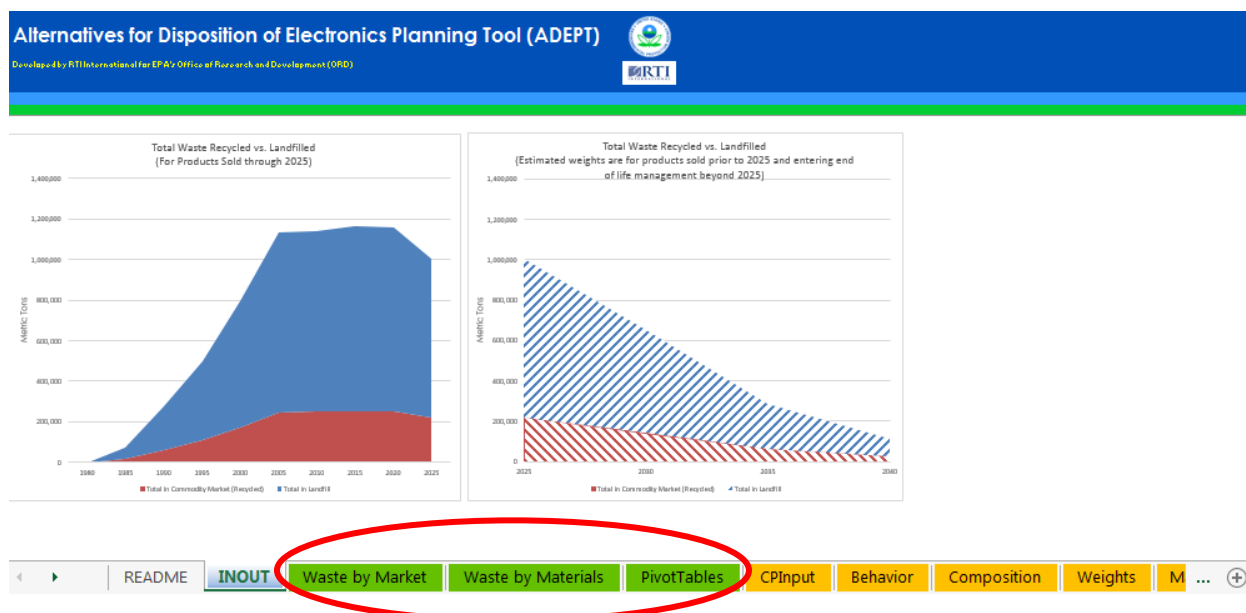
Figure 3: ADEPT Homescreen, highlighting tabs the user can edit



Values that can be modified by the user are on the sheets with tabs highlighted in yellow as shown in Figure 3.

- Explore ADEPT output in the data visualization sheets and summary pivot tables located on sheets with tabs highlighted in green (Figure 4). Graphical representations of the results tables in the INOUT tab can be found by scrolling down in the INOUT tab.

Figure 4: ADEPT Homescreen, highlighting data visualization and summary tabs



Notes:

- Waste may be sent directly to landfill during each stage in the flow or through the recycling chain. At each step in the recycling chain (i.e., collectors to recyclers), there is a fixed materials extraction efficiency applied to all products. For example, the default efficiency parameter from collectors to recyclers is 85%. This means that 85% of materials continue to recyclers and the remaining 15% goes to landfill. These efficiency parameters can be adjusted in the Control Panel's *Behavior* tab. These incremental movements of product and material weight to landfill is cumulative. The *Total E-Waste Disposal* for landfill is the cumulative waste disposed, for a given year, across each of these steps.
- Material composition for each product is static across years. This assumption is based on a laboratory study by the Rochester Institute of Technology (Babbitt et al., 2017).
- Changes to any ADEPT default assumptions are not made until ADEPT is run, by clicking the **Run Model** button within the Control Panel. Once the Control Panel is closed and the run results have been presented, the assumptions within ADEPT reset to defaults.
- Assumptions are designed to be changed within the Control Panel. Any assumption initially presented to the user in the Control Panel can be adjusted.
- The color coding within the map has no significance and is only for ease of use and aesthetics.

3 ADEPT WORKSHEET DESCRIPTIONS

ADEPT uses sales data in combination with time series datasets that provide average product weights and lifetimes. In addition, other assumptions are included with respect to market share across major consumer segments (i.e., residential, commercial, institutional, and education).

The tool relies primarily on spreadsheet calculations, with a few simple automation steps handled by an Excel VBA macro. The macro quickly refreshes a series of pivot tables to summarize the spreadsheet calculations in the file.

ADEPT consists of 30 worksheets—11 of which are directly visible to the user, and 7 can be manipulated—that can be categorized into three types (see Table 2). In addition to the user interface (INOUT), ADEPT includes data sheets and calculation sheets.

Table 3: ADEPT worksheets and description

Sheet Name	Sheet Type	Description	Data Sources
INOUT	Output	Provides interface for users and contains access to ADEPT Control Panel. Users select region or state of interest. ADEPT results table and figures presented at right.	N/A
Waste by Market	Output	Graphs waste generated by products, sold through 2025, and projected to the year 2040, for first use and second use markets.	EPA 2008 Waste Management Approach; Default assumptions developed from informal questionnaires completed by selected state program representatives regarding sales forecast beyond 2014.
Waste by Materials	Output	Graphs material breakdown for landfill and commodity market, for products sold through 2025, projected to the year 2040.	EPA 2008 Waste Management Approach; Default assumptions developed from informal questionnaires completed by selected state program representatives regarding sales forecasts beyond 2014.
PivotTables	Calculation	Pivot tables used to summarize the data for the selected region or state.	Pivot tables pulling in information from various sheets to characterize disposal quantities from the various processes in the management of used electronics.
CPInput	Input	Assumptions from the user Control Panel.	Assumptions pulled in from the user Control Panel.
Behavior	Input	Detailed assumptions for consumers, collectors, recyclers, and processors with respect to how they send products or materials to the next destination in the overall material flow.	Assumptions and feedback from questionnaires sent to U.S. e-waste collectors and recyclers.
Composition	Input	Detailed assumptions regarding the material composition of each consumer product. Additionally, efficiency extraction parameters are set, by product, in this sheet.	Babbitt et al., 2017.
Weights	Input	Data table provides annual average product weights for products sold between 1980 and 2007. Weights for years 2008 to 2014 are RTI-developed estimates.	1980 to 2007: Product weights from EPA, 2008. 2008 to 2014: Default assumptions developed from informal questionnaires completed by selected state program representatives and estimated by applying average growth rate between 2000 and 2007.
MarketShare	Input	Data table provides state market share allocation by consumer segment and product type.	Default assumptions developed from informal questionnaires completed by selected state program representatives.
Lifetimes	Input	Calculates the percentage of annual sales that are retired to EOL management for recycling/disposal, for the original purchaser of the product.	Commercial Segment: Adaptation of Lifetimes presented in EPA, 2011. All Other Segments: Wang et al., 2013; Balde et al., 2015.

Sheet Name	Sheet Type	Description	Data Sources
SecondLife (Refurbished Lifetime)	Input	Calculates the percentage of annual sales that are retired to EOL management for recycling/disposal, for the second (final) user of the product.	Commercial Segment: Adaptation of Lifetimes presented in EPA, 2011. All Other Segments: Wang et al., 2013; Balde et al., 2015.
FirstUse_Life	Calculation, hidden tab	Annual amount of waste generated by product type and consumer group, for the original purchaser of the product.	Default assumptions developed from informal questionnaires completed by selected state program representatives.
SecondUse_Life (Refurbished Lifetime)	Calculation, hidden tab	Annual amount of waste generated by product type and consumer group, for the second (final) user of the product.	Default assumptions developed from informal questionnaires completed by selected state program representatives.
Collector	Calculation, hidden tab	Annual amount of waste sent to collector by product, commodity, and source (e.g., first use market, second use market).	Default assumptions developed from informal questionnaires completed by selected state program representatives.
Recycler	Calculation, hidden tab	Annual amount of waste sent to recycler by product and commodity.	Default assumptions developed from informal questionnaires completed by selected state program representatives.
Processor	Calculation, hidden tab	Annual amount of waste sent to processor by product and commodity.	Default assumptions developed from informal questionnaires completed by selected state program representatives.
Commodity Market	Calculation, hidden tab	Annual amount of waste sent to commodity market by product and commodity.	Default assumptions developed from informal questionnaires completed by selected state program representatives.
Landfill-Total	Calculation, hidden tab	Total amount of waste sent to landfill, by year, product, and commodity.	Default assumptions developed from informal questionnaires completed by selected state program representatives.
Landfill-Consumers	Calculation, hidden tab	Annual amount of waste sent to landfill from consumers and separated by product and commodity.	Default assumptions developed from informal questionnaires completed by selected state program representatives.
Landfill-Collector	Calculation, hidden tab	Annual amount of waste sent to landfill from collectors and separated by product and commodity.	Default assumptions developed from informal questionnaires completed by selected state program representatives.
Landfill-Recycler	Calculation, hidden tab	Annual amount of waste sent to landfill from recyclers and separated by product and commodity.	Default assumptions developed from informal questionnaires completed by selected state program representatives.
Landfill-Processor	Calculation, hidden tab	Annual amount of waste sent to landfill from processors and separated by product and commodity.	Default assumptions developed from informal questionnaires completed by selected state program representatives.
Sales	Calculation, hidden tab	Data table of national product sales by year and product type. Values expressed in millions of product units.	1980 to 2019 Consumer Electronic Historical Sales: CTA, 2019 Historical Sales Data Electronics Sales Data.

Sheet Name	Sheet Type	Description	Data Sources
Region_Sales	Calculation, hidden tab	Data table breaks out national product sales by state using the states' shares of national GDP.	Default assumptions developed from informal questionnaires completed by selected state program representatives.
Region_SalesWeight	Calculation, hidden tab	Data table applies product weights from the Weights sheet to Regional Sales to estimate the weight of products sold each year.	Default assumptions developed from informal questionnaires completed by selected state program representatives.
RegSalesUnit_Consumer	Calculation, hidden tab	Data table breaks out regional sales to one of the four consumer segments (residential, commercial, institutional, or education).	Default assumptions developed from informal questionnaires completed by selected state program representatives.
RegSalesWeight_Consumer	Calculation, hidden tab	Data table breaks out regional sales weights to one of the four consumer segments (residential, commercial, institutional, and education).	Default assumptions developed from informal questionnaires completed by selected states program representatives.
%_GDP	Calculation, hidden tab	Data table provides individual state share of national GDP by year (1980–2014).	BEA, 2014. National Accounts, Interactive Tables.
LookUps	Descriptive	Provides lists of regional groupings by state.	
SheetList	Descriptive	Summary of sheets.	

3.1 INOUT Sheet

In addition to the Control Panel, the **INOUT** sheet serves as the main user interface to run ADEPT. Users may select a state for which to run ADEPT. To generate individual state results, users can open the Control Panel from the INOUT sheet and select a specific state on the **General** tab, then click on the button labeled **Run Model (Exit Control Panel)**. Alternatively, the user can simply click on a state within the map located on the **INOUT** sheet to begin an evaluation for that specific state.

To generate national results, select (All) in the level of analysis selection box within the **General** tab of the Control Panel and then click **Run Model (Exit Control Panel)**.

The **INOUT** sheet also displays summary tables of run results once completed. The results are tabulated both by the amount of electronic waste disposed of in the specified year by product and sector, and by component and final disposition (e.g. commodity market or landfill). Results are produced both in metric tons (first set of visible tables) and short tons (accessible by scrolling down on the **INOUT** sheet).

3.1.1 ADEPT Control Panel

To simplify the setup and operation of ADEPT, the **ADEPT Control Panel** user interface was developed. The ADEPT Control Panel simplifies the process of changing certain default assumptions within ADEPT. Users also can manipulate assumptions directly in the **CPIInput** tab of ADEPT as described in Section 3.3.

The Control Panel provides users with an easy reference point to quickly review and update key assumptions or quickly restore default parameter values and recalculate the waste flows and generate new results. The panel provides the following seven tabs where users can adjust run parameters:

- **Sales Forecast.** Change the default average annual rate of growth in sales projected for years between 2025 through the year 2040 by product type.
- **Behavior.** Adjust default assumptions regarding the disposition of an electronic device or its constituent parts.
- **Markets.** Adjust average market share for electronic device sales in the primary and secondary use markets. ADEPT considers four consumer segments that include residential, educational, commercial, and government/institutional.
- **Composition.** Change the average material composition of electronic devices. Users can also adjust the average material extraction efficiency on this tab.
- **Weights.** Adjust the average weight for each of the 13 device categories in ADEPT where weights are reported in grams.
- **Lifetimes.** Adjust the product lifetimes for primary and secondary uses. First-use lifetimes are derived from a Weibull distribution using specific parameters defined in the literature. Second-use lifetimes impose the same assumptions but allow for a percentage reduction in the average length of lifetimes. Currently the default is a 50% reduction in the second-use lifetimes.
- **Glossary.** Provides definitions for several key terms and concepts used in ADEPT.

3.2 Input Data

3.2.1 Sales

National sales data for 1980–2019 were obtained from product sales of electronics tabulated by the Consumer Technology Association (CTA). Sales are presented for the following 13 product categories:

- Desktops
- Portables
- Hard Copy Peripherals
- Mice
- Keyboards
- PC CRTs
- PC Flat Panel
- Color CRT <19"
- Color CRT >19"
- Flat Panel TVs
- Color Projection
- Monochrome
- Cell Phones

These specific product categories were chosen for this tool because these were product categories the EPA had previously used in its estimation of electronic waste. To forecast sales, annual growth rates are assumed. The user has the ability to adjust the average annual growth rates via the Control Panel or can adjust the year-over-year sales directly on the *Sales* tab (advanced users only).

3.2.2 %_GDP

To disaggregate the national sales data for consumer electronics, annual state-level GDP data is used. Each state's share of national GDP is then applied to the national sales data, resulting in state-level sales data. This sheet is hidden by default.

State share of GDP data was obtained from the Bureau of Economic Analysis (BEA) National Accounts Tables² for 1980–2014.

3.3 Assumptions

As previously described, all tabs within ADEPT that are colored yellow are editable. These tabs include default values and assumptions that are currently in ADEPT. Changes to **CPInput**, and within the **Control Panel**, will cause average changes to the rest of the assumptions sheets. Changes in any of the other assumptions sheets are as granular as ADEPT allows. Within each sheet, cells highlighted in yellow are editable while cells highlighted in gray are fixed.

3.3.1 CPInput

The Control Panel input sheet (**CPInput**) reads in the user-defined assumptions from the Control Panel. The assumptions defined here are averages or aggregates of the assumptions defined in the other assumptions sheets (e.g., Behavior, Consumption). The Source column refers to the input box in the Control Panel that the value is coming from. The Description column gives a short description of the assumption being defined.

3.3.2 Behavior

The **Behavior** sheet provides assumptions about the behavior of all the agents within ADEPT: consumers, collectors, recyclers, and processors. Each row represents the behavior for each agent within ADEPT with respect to a specific product.

Figure 5 shows an example for the first row for the sheet. The Waste Flows column refers to the stage where the used electronics are currently existing in its lifetime (e.g., first use, collection). Product is the electronic product category, which in the example is desktops. Recycled refers to the percentage of a product (by total weight) sent to the recycler. The 2nd Use column provides the default percentage of a product being sold (or donated) into the secondary use market and only applies to the original purchasers of the product. Landfill is the percentage of a product directly sent to landfill. The Expected

² BEA Interactive Tables available at <http://www.bea.gov/itable/index.cfm>.

Lifetime for Secondary Markets percentage located at the top of the spreadsheet is a single parameter that scales first-use lifetimes to the second-use lifetimes.

Assumptions made within this sheet can be easily adjusted via the *Behavior* tab of the **Control Panel**. However, **assumptions made within the Control Panel will only update the average values for each of the designated waste flows (i.e., 1st Use, 2nd Use, Collector, Recycler, Processor) as the Control Panel does not contain the specificity needed to input unique breakdowns for recycling, second use, and landfilling at each stage. If the user wishes to input this level of specificity into their run, the process for adjusting assumptions manually for advanced users is described in Section 4.2.**

In the example shown in Figure 5, the row is assuming that of all desktops sold and at the end of their useful life for the original purchaser, 55% will be recycled, 20% will be resold into a secondary market, and 25% will be diverted to landfill.

Figure 5: Example Behavior (update for Refurbished Lifetime)

Waste Flows	Product	Recycled	2nd Use	Landfill
1st Use	Desktops	55%	20%	25%

3.3.3 Composition

The **Composition** tab provides an estimate (by percentage) of the various materials that comprise each type of electronic device (Figure 6). The default materials compositions are intended to not be changed by the user; however, an advanced user is able to change the default materials compositions.³ The Stage column identifies where within the management stream the product is. The information in the Product column identifies the electronic product category. The compositional breakdowns are based on a presentation and subsequent report from the Rochester Institute of Technology (Babbitt et al., 2017).

³ Changing the default materials compositions should be performed with caution. It is suggested that the user save an alternative copy of the tool to modify if the user intends on changing the materials compositions.

Figure 6: Example Composition

Stage	Product	Battery	CRT Lead	CRT Glass	Flat Panel Display Module CCFL	Flat Panel Display Module LED
Starting	Cell Phones	18%	0%	0%	15%	0%
Starting	Color CRT <19"	0%	6%	54%	0%	0%
Starting	Color CRT >19"	0%	6%	54%	0%	0%
Starting	Color Projection	0%	5%	45%	0%	0%
Starting	Desktops	0%	0%	0%	0%	0%
Starting	Flat Panel TVs	0%	0%	0%	18%	8%
Starting	Hard Copy Peripherals	0%	0%	0%	0%	0%
Starting	Keyboards	0%	0%	0%	0%	0%
Starting	Mice	0%	0%	0%	0%	0%
Starting	Monochrome	0%	5%	45%	0%	0%
Starting	PC CRTs	0%	6%	56%	0%	0%
Starting	PC Flat Panel	0%	0%	0%	21%	0%
Starting	Portables	14%	0%	0%	17%	0%
Starting	Average	2%	2%	20%	5%	1%
Starting -> Collector		99%	85%	85%	85%	85%
Collector -> Recycler		99%	90%	90%	90%	90%
Recycler -> Processor		99%	95%	95%	95%	95%
Processor -> Commodity Market		99%	99%	99%	99%	99%

The user-editable fields in the Composition tab are the efficiency parameters. These represent the percentage of total weight that passes to the next destination in the recycling stream. For example, an efficiency parameter of 85% for batteries for “Starting -> Collector” means that 85% of the weight of all batteries contained in products moving from consumers to collectors will continue through the recycling stream while 15% of that weight will be diverted to landfill. Assumptions to this sheet can be easily changed via the Composition tab of the **Control Panel**.

The assumptions within the Composition tab differ from those within the Behavior tab. While the assumptions within the Behavior tab describe the total percentage of whole products that go directly to a landfill versus another step such as recycling, the extraction efficiencies in the Composition tab describe the fate of individual materials from each product that go on to landfill versus another step such as recycling.

3.3.4 Weights

The **Weights** sheet contains the average product weight in kilograms from 1980 to 2050 (Figure 7). From 1980 to 2007, product weights are derived from the 2008 EPA Waste Management report. From 2008 to 2050, the weights are linear forecasts based on previous years. Each row within the table represents a year while each column is a product category. Assumptions to this sheet can be easily changed via the **Weights** tab of the **Control Panel**.

Figure 7: Example Weights

Year	Desktops	Portables	Copy Periph	Mice	Keyboards	PC CRTs
2014	10.0	2.9	7.9	0.1	1.3	22.9
2015	10.0	2.9	7.9	0.1	1.3	22.9
2016	10.0	2.9	7.9	0.1	1.3	22.9
2017	10.0	2.9	7.9	0.1	1.3	22.9
2018	8.0	2.9	7.9	0.1	1.3	22.9
2019	8.0	2.9	7.9	0.1	1.3	22.9
2020	7.0	2.9	7.9	0.1	1.3	22.9
2021	7.0	2.9	7.9	0.1	1.3	22.9
2022	7.0	2.9	7.9	0.1	1.3	22.9
2023	7.0	2.9	7.9	0.1	1.3	22.9
2024	7.0	2.9	7.9	0.1	1.3	22.9
2025	7.0	2.9	7.9	0.1	1.3	22.9
2026	7.0	2.9	7.9	0.1	1.3	22.9
2027	7.0	2.9	7.9	0.1	1.3	22.9
2028	7.0	2.9	7.9	0.1	1.3	22.9
2029	7.0	2.9	7.9	0.1	1.3	22.9
2030	7.0	2.9	7.9	0.1	1.3	22.9
2031	7.0	2.9	7.9	0.1	1.3	22.9

3.3.5 MarketShare

The **MarketShare** sheet includes the table of assumed market shares by consumer segment and product type (Figure 8). The share of products sold to each consumer segment are held constant for all years. Assumptions to this sheet can be easily changed via the *Markets* tab of the **Control Panel**.

Figure 8: Example Market Share

First Use Market Shares

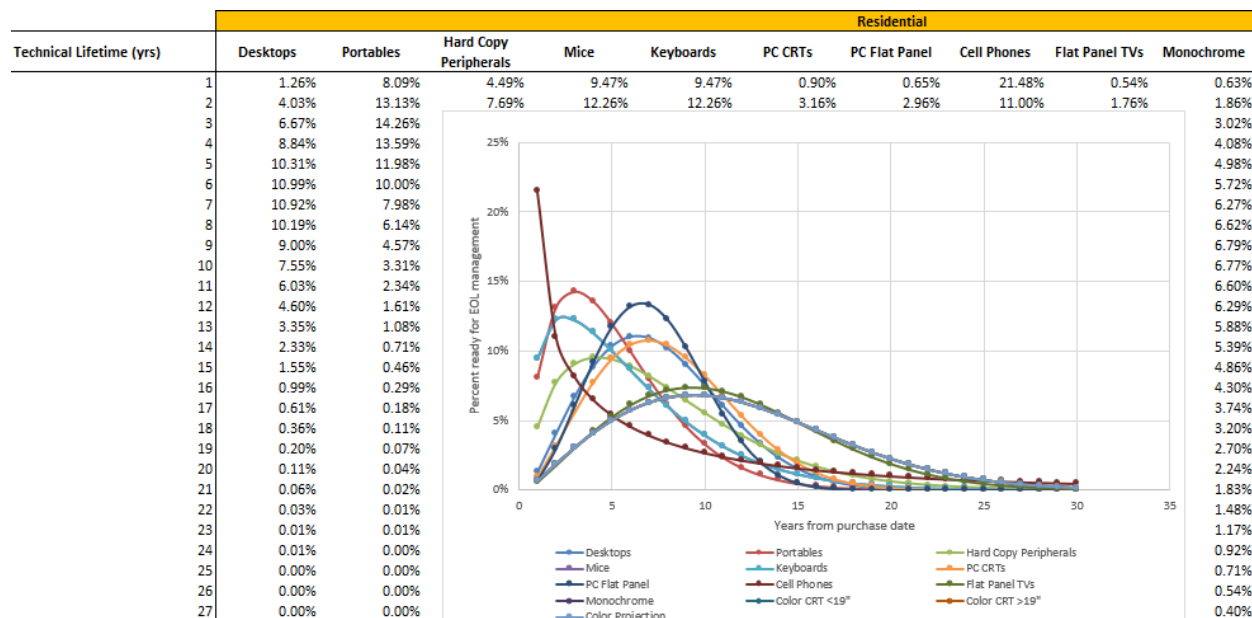
Market Segment	MrktSeg	Desktops	Portables	Hard Copy Peripherals	Mice
Residential	RES	25%	45%	60%	25%
Education	EDU	35%	10%	5%	30%
Commercial	COM	30%	30%	30%	30%
Institutional	INT	10%	15%	5%	15%
	Total	100%	100%	100%	100%

3.3.6 Lifetimes

Product lifetimes are presented in tables and graphs that provide estimates of the years of use for each product category (see Figure 9). ADEPT includes two distinct lifetime tables: one to capture product use for residential and education segments, and a second for commercial and institutional segments. The lifetime estimates for the residential and education segments were obtained from a 2015 report by the United Nations University (Balde et al., 2015). This study applied the Weibull distribution method to estimate a technical lifetime distribution for each product category. This report did not estimate

lifetimes for commercial and institutional market segments. For this reason, ADEPT estimates the Weibull distribution parameters that would most closely approximate the truncated lifetimes values assumed in EPA's 2008 Waste Management Approach document (EPA, 2008). The lifetimes assumed for the commercial and institutional segments are shorter compared to the residential estimates. Assumptions to this sheet can be easily changed via the *Lifetimes* tab of the **Control Panel**.

Figure 9: Example Lifetimes



3.3.7 SecondLife (Refurbished Lifetime)

The **SecondLife** sheet shows the lifetime distributions, by product category and market segment, for the second-use market (Figure 10). The lifetime distributions are based off the first-use lifetimes but with the β parameter scaled by the percentage from the **Behavior** sheet. Thus a 50% reduction in second-use lifetimes in the Behavior sheet translates to a 50% reduction in the β parameter, which leads to approximately a 50% reduction in the average second-use lifetime. Assumptions to this sheet can be easily changed via the *Lifetimes* tab of the **Control Panel**.

Figure 10: Example Second-use Life

Technical Lifetime (yrs)	Desktops	Portables	Hard Copy Peripherals	Mice	Keyboards
1	3.64%	21.22%	12.18%	21.73%	21.73%
2	11.06%	27.85%	18.56%	23.57%	23.57%
3	16.41%	21.98%	18.33%	18.71%	18.71%
4	18.32%	14.12%	15.54%	13.35%	13.35%
5	16.93%	7.89%	11.97%	8.91%	8.91%
6	13.40%	3.94%	8.58%	5.66%	5.66%
7	9.25%	1.80%	5.80%	3.45%	3.45%
8	5.61%	0.75%	3.73%	2.04%	2.04%
9	3.01%	0.29%	2.29%	1.17%	1.17%
10	1.43%	0.11%	1.36%	0.65%	0.65%

3.4 Calculation Worksheets

The Calculation worksheets described in this section are hidden by default within the tool and cannot be modified by the user. These worksheets are important intermediary steps required to calculate outputs from runs and should not be altered.

3.4.1 Region_Sales

Combining the national sales by product type from the **Sales** sheet with the state percentage of GDP by year, the tool allocates a proportion of the national sales to each state. The state share of GDP is a proxy chosen to quickly distribute national sales to each state. State shares of GDP data were obtained from the BEA National Accounts Tables for 1980–2014.

3.4.2 Reg_SalesWeight

This sheet multiplies the unit sales by the average product weight listed on the **Weights** sheet. The weight of products sold each year is expressed in metric tons. This data table is summarized using the Summary Table of Sales (Metric Tons) on the **PivotTables** sheet.

3.4.3 PivotTables

The pivot tables are used to filter ADEPT results by weight and number of units to the region or state selected using the **INOUT** sheet's drop-down boxes. The **PivotTables** sheet includes three pivot tables. Each has a filter field for EPA Region and state. Selecting (All) as the filter value for both EPA Region and state provides the national weight or number of units sold by product category over time.

The pivot table values are used on subsequent sheets to present estimates of the weights of used electronics by product category for each consumer segment.

3.4.4 RegSalesWeight_Consumer

This sheet distributes the filtered summary results from the **PivotTables** sheet to the four consumer segments using the table of assumed market shares presented in the **MarketShare** sheet.

3.4.5 FirstUse_Life

This sheet distributes the total weight of a product that has reached the end of its first-use life, purchased in a specific year by one of the four market segments (e.g., commercial), through the year 2041. Each row is identified by the following:

- **Market.** One of the four market segments (i.e., commercial, educational, institutional, or residential)
- **Product.** One of the 13 product categories (see Section 3.2.1 for a list of products)
- **Purchase_Year.** The year the product was purchased
- **Purchased_Weight.** The total weight of the product purchased.

3.4.6 SecondUse_Life (Refurbished Lifetime)

This sheet distributes the total weight of a product that has reached the end of its second-use life, purchased in a specific year by one of the four market segments (e.g., commercial), through the year 2041. Each row is identified by the following:

- **Market.** One of the four market segments (i.e., commercial, educational, institutional, or residential)
- **Product.** One of the 13 product categories (see Section 3.2.1 for a list of products)
- **Purchase_Year.** The year the product was purchased
- **Purchased_Weight.** The total weight of the product purchased.

3.4.7 Collector

This sheet contains a pivot table that distributes the total weight of commodities estimated to be arriving at collectors from products reaching the end of their useful first or second life.

The weights contained within the pivot table represent the components of used electronics that move through the processing chain and are not landfilled. However, via ADEPT structure described in Section 2.1.1, a portion of the used electronics received by collectors is assumed to be sent to landfill. This amount is captured in the **Landfill-Collector** sheet described later.

3.4.8 Recycler

This sheet distributes the total weight of commodities estimated to be arriving at recyclers from products reaching the end of their useful life, after being handled by collectors.

The weights contained within the sheet represent the components of used electronics that move through the processing chain and are not landfilled. However, as with collectors, a portion of the used electronics received by recyclers is assumed to be sent to landfill. This amount is captured in the **Landfill-Recycler** sheet.

For a list of commodities types whose weights are tracked across the 13 product categories, see Section 2.1.1.

3.4.9 Processor

This sheet distributes the total weight of commodities estimated to be arriving at processors from products reaching the end of their useful life, after being handled by recyclers.

The weights contained within the sheet represent the components of used electronics that move through the processing chain and are not landfilled. However, via the ADEPT structure described in

Section 2.1.1, a portion of the used electronics received by processors is assumed to be sent to landfill. This amount is captured in the **Landfill-Processor** sheet.

3.4.10 Landfill-Consumers

The **Landfill-Consumers** sheet estimates the weight of each commodity type that is expected to be landfilled. This is because in some states consumers can choose to simply dispose of their used electronics at the end of their useful life. The table breaks out the weight information into both first and second use disposal amounts across all 13 product categories.

3.4.11 Landfill-Collector

The **Landfill-Collector** sheet estimates the weight of each commodity type that is expected to be landfilled after collectors have processed the used electronics flowing to them from consumers. The table breaks out the weight information for each commodity type across all 13 product categories.

3.4.12 Landfill-Recycler

The **Landfill-Recycler** sheet estimates the weight of each commodity type that is expected to be landfilled after recyclers have processed the used electronics flowing to them from collectors. The table breaks out the weight information for each commodity type across all 13 product categories.

3.4.13 Landfill-Processor

This sheet estimates the weight of each commodity type that is expected to be landfilled after processors have processed the used electronic components flowing to them from recyclers. The table breaks out the weight information for each commodity type across all 13 product categories.

3.5 Output Data

The final destinations in ADEPT for consumer electronics are either the commodity market or the landfill. These two final destinations are the final output datasets. As product weight enters the tool via sales, the weight is distributed through the system and collects at either the **Commodity Market** sheet or the **Landfill-Total** sheet.

3.5.1 Commodity Market

The **Commodity Market** sheet is the ending destination of commodity materials from the recycling stream that are not landfilled after leaving the processor. Detailed data are provided that show estimates of the amounts of commodities entering the re-use market for a given year, by product.

3.5.2 Landfill-Total

The **Landfill-Total** sheet is the ending destination of waste that does not go into the commodity market. Waste enters the landfill from almost every step within the waste stream, thus this is the aggregate amount of waste entering a landfill in a given year. Detailed data are provided that show estimates of the amounts of commodities being landfilled for a given year, by product.

4 EXAMPLE ADEPT RUNS AND ANALYSIS

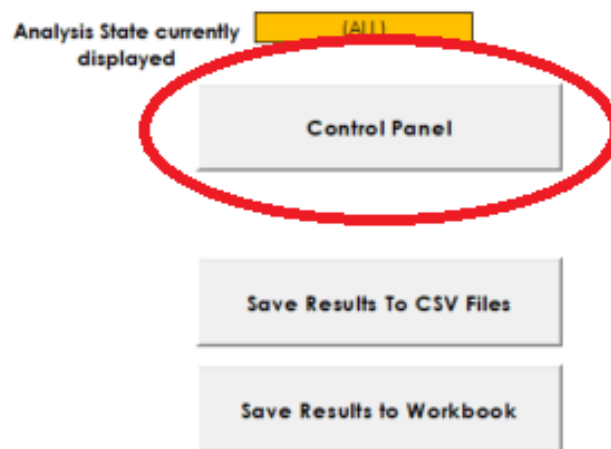
This section includes three case studies that illustrate how ADEPT can be used. Please note that ADEPT can be used in a variety of ways and is not limited to the three examples discussed below.

4.1 Adjusting Assumptions via Control Panel

This example walks users through the process of adjusting default parameters available in the Control Panel for a national calculation of electronic waste disposition in the year 2015.

Upon opening ADEPT, the front-facing tab is **INOUT**. Click the **Control Panel** button in the center of the tab to launch it (Figure 11).

Figure 11: Opening ADEPT Control Panel



Once the user launches the Control Panel, the dialog box should open (see Figure 12).

Because this example is for the entire United States, it is important to set the “Level of Analysis” field on the **General** tab to (ALL) (see red arrow below). This prepares for a calculation that includes all states.

For this example, the disposition of used electronics in the year 2015 will be analyzed. To do this, type in the year or use the arrows to the right of the “Individual Year” field to set the year to 2015.

After ensuring that the level of analysis is set to evaluate used electronics at the national scale, the user can move through the remaining tabs of the Control Panel and adjust parameters as needed.

Figure 12: ADEPT Control Panel 'General' tab

ADEPT Control Panel

General Sales Forecast Behavior Markets Composition Weights Lifetimes Glossary

Instructions

The control panel is designed to provide aggregate adjustments of the underlying assumptions. The questions and inputs posed here are not the full suit of underlying assumptions but are instead composites of multiple dimensions. To adjust at the disaggregated level please save a separate copy the model and change inputs directly (see the navigation links in the INOUT sheet). The update button below will transfer the user inputs in this control panel to the model but will automatically update results. Please be patient and only click the button once. The update process can take several minutes.

Overall Settings

Level of Analysis: (ALL) Alabama Alaska Arizona Arkansas California Colorado

Individual Year: 2015

Run Model (Exit Control Panel)

Load Control Panel Settings from File Save Control Panel Settings to File

Once all information on the **General** tab has been entered, select the next tab, **Sales Forecast**. This tab gives users the opportunity to provide input with respect to the annual growth rate of electronic sales (post-2019) for all product types incorporated into the tool (see Figure 13). Click **Restore Defaults** at the bottom of this page to reset the growth rates to the tool defaults.

Figure 13: ADEPT Control Panel 'Sales Forecast' tab

ADEPT Control Panel

General Sales Forecast Behavior Markets Composition Weights Lifetimes Glossary

Average Annual Growth Rate of Electronics Sales (Post-2014)

Cell Phones	-3	%	◀ ▶	Hard Copy Peripherals	-6	%	◀ ▶
CRT <19"	0	%	◀ ▶	Keyboards	-6	%	◀ ▶
CRT >19"	0	%	◀ ▶	Mice	-6	%	◀ ▶
Color Projection	0	%	◀ ▶	Monochrome	0	%	◀ ▶
Desktops	-6	%	◀ ▶	PC CRTs	0	%	◀ ▶
Flat Panel TVs	5	%	◀ ▶	PC Flat Panel	-3	%	◀ ▶
Portables	-4	%	◀ ▶				

Restore Defaults Ready to Run Model

For this example, an assumption will be made that the user has information suggesting that there should be an increase in the growth rate of portable electronics of 2% more than the Control Panel default. To incorporate this information and make a change to the default value, use the arrows to the right of the “Portables” field to increase the default percentage from -4% to -2% to accurately reflect this information (see Figure 14).

Figure 14: Making modifications to ADEPT Control Panel 'Sales Forecast' tab

The screenshot shows the 'ADEPT Control Panel' window with the 'Sales Forecast' tab selected. The window has a title bar with a maximize button and a tab bar with the following tabs: General, Sales Forecast, Behavior, Markets, Composition, Weights, Lifetimes, and Glossary. The 'Sales Forecast' tab is active and displays a section titled 'Average Annual Growth Rate of Electronics Sales (Post-2014)'. This section contains a grid of input fields for different product categories, each with a numerical value, a percentage sign, and a three-button spinner control. The categories and their values are: Cell Phones (-3%), Hard Copy Peripherals (-6%), CRT <19" (0%), Keyboards (-6%), CRT >19" (0%), Mice (-6%), Color Projection (0%), Monochrome (0%), Desktops (-6%), PC CRTs (0%), Flat Panel TVs (5%), PC Flat Panel (-3%), and Portables (-2%). At the bottom of the window, there are two buttons: 'Restore Defaults' and 'Ready to Run Model'.

Category	Growth Rate (%)
Cell Phones	-3
Hard Copy Peripherals	-6
CRT <19"	0
Keyboards	-6
CRT >19"	0
Mice	-6
Color Projection	0
Monochrome	0
Desktops	-6
PC CRTs	0
Flat Panel TVs	5
PC Flat Panel	-3
Portables	-2

Buttons: **Restore Defaults** **Ready to Run Model**

The next step in this example requires making changes to the **Behavior** tab. The Behavior tab contains high-level assumptions about how each segment of the used electronics management chain processes the materials that they receive. All segments have the option of either handling the used electronics sent to them and passing it to the next process segment or disposing of it. Consumers additionally have the option to donate or resell their used electronics if the product still has some value and usability. The defaults for the Behavior tab are shown in Figure 15. Clicking the **Restore Defaults** button on the bottom of the page will reset the behavior assumptions to the tool defaults.

Figure 15: ADEPT Control Panel 'Behavior' tab

The screenshot shows the 'ADEPT Control Panel' with the 'Behavior' tab selected. The panel contains four sections for different segments of the waste management chain, each with input fields for percentages and a 'Total' calculation.

Segment	Assumption	Value (%)	Total (%)
Consumers	How much waste is re-sold? (Second-use market):	16	100
	How much waste is recycled? (Goes to collector):	59	
	How much waste goes directly to landfill?:	25	
	Total (sum of percentages entered):	100	
Collectors	How much waste continues to recycler?:	75	100
	How much waste goes directly to landfill?:	25	
	Total (sum of percentages entered):	100	
Recyclers	How much waste continues to processor?:	75	100
	How much waste goes directly to landfill?:	25	
	Total (sum of percentages entered):	100	
Processors	How much waste continues to commodity market?:	75	100
	How much waste goes directly to landfill?:	25	
	Total (sum of percentages entered):	100	

At the bottom of the panel, there are two buttons: 'Restore Defaults' and 'Ready to Run Model'.

For this example, an assumption will be made that consumers will choose to recycle slightly less of their used electronics and landfill slightly more. First, decrease the percentage of used electronics that consumers will recycle by 1% by selecting the left (decreasing) arrow next to the “How much waste is recycled?” question (see Figure 16).

When the percentage of used electronics recycled is decreased, the box that sums the behavior percentages across the consumer segment turns red to alert the user that the totals for this segment currently are not equal to 100%, meaning that not all of the behavior of the consumer segment is accounted for (see Figure 16).

Figure 16: Making modifications to ADEPT Control Panel 'Behavior' tab, with out-of-range values

The screenshot shows the 'ADEPT Control Panel' with the 'Behavior' tab selected. The panel is divided into four sections: Consumers, Collectors, Recyclers, and Processors. Each section contains two input fields with percentage values and arrows for adjustment. The 'Total (sum of percentages entered)' for each section is displayed at the bottom of the section.

Segment	How much waste is re-sold? (Second-use market):	How much waste is recycled? (Goes to collector):	How much waste goes directly to landfill?:	Total (sum of percentages entered):
Consumers	16 %	58 %	25 %	99 %
Collectors	75 %	25 %	100 %	100 %
Recyclers	75 %	25 %	100 %	100 %
Processors	75 %	25 %	100 %	100 %

The 'Total' for the Consumers segment is highlighted in red, indicating it is out of range (not equal to 100%). A red arrow points to the right arrow next to the 'How much waste is recycled?' field for Consumers, indicating the adjustment made.

Buttons at the bottom: Restore Defaults, Ready to Run Model

After decreasing the percentage of used electronics that consumers will recycle, the amount landfilled needs to be increased for the 'Consumers' sum to equal 100%, assuming that the amount consumers resell remains constant. To do this, select the right (increasing) arrow next to the "How much waste goes directly to landfill?" question (see Figure 17) and increase the percentage by 1%.

Once the percentage of used electronics that goes directly to landfill is increased by 1 percentage point, the box that sums the behavior percentages across the consumer segment turns back to green, letting the user know that all percentages sum to 100% and that the user has accounted for the behavior of the entire consumer segment (see Figure 17).

Figure 17: Making changes to ADEPT Control Panel 'Behavior' tab

The screenshot shows the 'ADEPT Control Panel' with the 'Behavior' tab selected. The panel is divided into four sections: Consumers, Collectors, Recyclers, and Processors. Each section contains two input fields with percentage values and a 'Total (sum of percentages entered)' field. A red arrow points to the right arrow of the 'How much waste goes directly to landfill?' input for Consumers, which is currently 26%. The 'Total' field for Consumers is highlighted with a red circle and shows 100%.

Segment	How much waste is re-sold? (Second-use market):	How much waste is recycled? (Goes to collector):	How much waste goes directly to landfill?:	Total (sum of percentages entered):
Consumers	16 %	58 %	26 %	100 %
Collectors	75 %	25 %		100 %
Recyclers	75 %	25 %		100 %
Processors	75 %	25 %		100 %

Buttons at the bottom: Restore Defaults, Ready to Run Model

After adjusting parameters in the Behavior tab, move to the **Markets** tab. The Markets tab specifies the market share of the first- and second-uses of used electronics across all four consumer segments considered in the tool (residential, commercial, institutional, and educational). Clicking **Restore Defaults** at the bottom of this page will reset the market share values to the tool defaults (see Figure 18).

Figure 18: ADEPT Control Panel 'Markets' tab

The screenshot shows the 'ADEPT Control Panel' window with the 'Markets' tab selected. The window has a title bar with a close button (X) and a menu bar with tabs: General, Sales Forecast, Behavior, Markets (selected), Composition, Weights, Lifetimes, and Glossary. The main content area is divided into two sections: 'First Use Market' and 'Second Use Market'. Each section contains four input fields for market share percentages, each with a spin button to its right. The 'First Use Market' section shows: Residential market share: 53%, Educational market share: 21%, Commercial market share: 18%, and Institutional market share: 8%. The 'Total (sum of percentages entered):' is 100%. The 'Second Use Market' section shows: Residential market share: 62%, Educational market share: 30%, Commercial market share: 0%, and Institutional market share: 8%. The 'Total (sum of percentages entered):' is 100%. At the bottom of the window, there are two buttons: 'Restore Defaults' and 'Ready to Run Model'.

Market Type	Residential	Educational	Commercial	Institutional	Total
First Use Market	53%	21%	18%	8%	100%
Second Use Market	62%	30%	0%	8%	100%

For this example, assume that the educational consumer segment will take up a larger portion of the second-use (or refurbished) market than the residential segment. To reflect this change, decrease the residential second-use market share to 43% and increase the educational second-use market share to 49%. Use the left (decreasing) arrow to the right of the “Residential market share” statement in the Second Use Market box to decrease the value to 43%. Then, use the right (increasing) arrow to the right of the “Educational market share” statement in the Second Use Market box to increase the value to 49%. Double-check that the box to the right of the “Total (sum of percentages entered)” for the Second Use Market box is green and reads 100% (see Figure 19).

Figure 19: Making changes to ADEPT Control Panel 'Markets' tab

The screenshot shows the 'ADEPT Control Panel' with the 'Markets' tab selected. The panel is divided into two main sections: 'First Use Market' and 'Second Use Market'. Each section contains four market share inputs: Residential, Educational, Commercial, and Institutional, each with a text box and a percentage sign, followed by left and right arrow buttons for adjustment. The 'Total (sum of percentages entered)' is displayed in a green box at the bottom of each section.

Market	Residential	Educational	Commercial	Institutional	Total
First Use Market	53%	21%	18%	8%	100%
Second Use Market	43%	49%	0%	8%	100%

Red arrows indicate the adjustments made: a downward arrow on the Residential market share of the Second Use Market and an upward arrow on the Educational market share of the Second Use Market. The 'Total' for the Second Use Market is circled in red.

Buttons at the bottom: 'Restore Defaults' and 'Ready to Run Model'.

Next, move on to the **Composition** tab. The Composition tab contains assumptions about the total weight of used electronics for a given year, and how that weight can be categorized into one of 12 different commodity groups (see Section 2.1.1). As noted previously in Section 3.3.3, the composition values are static and not editable in this sheet. The tab also contains assumptions regarding the extraction efficiency of each processing step. The extraction efficiency is a measure of how effectively a processing step can separate used electronics (or components of used electronics) into their constituent commodities. An extraction efficiency of 85% means that 85% of materials from the used electronics are recovered and able to move through to the next processing step. The remaining percentage is considered lost (landfilled).

The Composition tab looks like the screenshot in Figure 20. Clicking the **Restore Defaults** button on the bottom of this tab will reset the extraction efficiency values to the tool defaults.

Figure 20: ADEPT Control Panel 'Composition' tab

ADEPT Control Panel

General | Sales Forecast | Behavior | Markets | **Composition** | Weights | Lifetimes | Glossary

Average Material Composition of Waste

Battery: 2 %	Other: 2 %
CRT Lead: 2 %	Copper: 2 %
CRT Glass: 20 %	Aluminum: 6 %
Flat Panel (CCFL): 5 %	Ferrous Metals: 20 %
Flat Panel (LED): 1 %	Other Metals: 1 %
PCB Material: 8 %	Plastics: 31 %

Total (sum of percentages entered): 100 %

Restore Defaults

Average Materials Extraction Efficiency

Consumer -> Collector	85 %
Collector -> Recycler	90 %
Recycler -> Processor	95 %
Processor -> Commodity Market	99 %

Restore Defaults

Ready to Run Model

For this example, an assumption is made that the percentage of aluminum in the used electronics for 2015 is higher than the default value of 6%, while the percentage of ferrous metal is lower than the default value of 20%.

To increase the percentage of aluminum in the total weight of the used electronics for this evaluation year, click on the right (increasing) arrow to the right of the “Aluminum” field in the *Average Material Composition of Waste* box on the tab until 11% is reached. After increasing this amount, decrease the percentage of ferrous metals by clicking the left (decreasing) arrow to the right of the “Ferrous Metals” field until 15% is reached (see below). Verify that the Total (sum of percentages entered) box is green, indicating 100% of the weight of the used electronics in the evaluation year is allocated (see Figure 21).

For this example, also assume that the extraction efficiency of materials moving from collectors to recyclers is higher than the default of 90%, possibly due to higher market prices for certain commodities that are driving collectors to be more efficient with their handling and extraction of materials from the used electronic components. Increase this extraction efficiency by selecting the right (increasing) arrow to the right of the “Collector → Recycler” field in the *Average Materials Extraction Efficiency* box until 95% is reached (see red arrow in Figure 21).

Figure 21: Making changes to ADEPT Control Panel 'Composition' tab

The screenshot shows the ADEPT Control Panel with the 'Composition' tab selected. The interface is divided into two main sections: 'Average Material Composition of Waste' and 'Average Materials Extraction Efficiency'.

Average Material Composition of Waste:

Material	Percentage (%)
Battery	2
CRT Lead	2
CRT Glass	20
Flat Panel (CCFL)	5
Flat Panel (LED)	1
PCB Material	8
Other	2
Copper	2
Aluminum	11
Ferrous Metals	15
Other Metals	1
Plastics	31
Total (sum of percentages entered)	100

The 'Total' box is highlighted in green, indicating 100% allocation. A 'Restore Defaults' button is located at the bottom right of this section.

Average Materials Extraction Efficiency:

Process	Efficiency (%)
Consumer -> Collector	85
Collector -> Recycler	95
Recycler -> Processor	95
Processor -> Commodity Market	99

A red arrow points to the right arrow of the 'Collector -> Recycler' field, indicating an increase in efficiency. A 'Restore Defaults' button is located at the bottom right of this section.

At the bottom of the panel, there is a 'Ready to Run Model' button.

The next tab in the Control Panel is the **Weights** tab (see Figure 22). This tab lists the average weight, in grams, of each of the used electronics product categories considered in the tool. Clicking the **Restore Defaults** button at the bottom of the page will reset the growth rates to the tool defaults.

Figure 22: ADEPT Control Panel 'Weights' tab

Average Weight of Electronics	
Cell Phones	300 g
CRT <19"	18600 g
CRT >19"	33200 g
Color Projection	72000 g
Desktops	10000 g
Flat Panel TVs	7700 g
Portables	2500 g
Hard Copy Peripherals	7900 g
Keyboards	1300 g
Mice	100 g
Monochrome	18600 g
PC CRTs	20200 g
PC Flat Panel	9200 g

Restore Defaults

Ready to Run Model

For this example, an assumption is made that portable electronics are on average lighter in weight than the tool default by 100 g. Within the *Average Weight of Electronics* box, enter the value 2400 in the field box next to “Portables” (see Figure 23).

Figure 23: Making changes to ADEPT Control Panel 'Weights' tab

The image shows the 'ADEPT Control Panel' window with the 'Weights' tab selected. The 'Average Weight of Electronics' section contains a grid of input fields for different electronic categories. The 'Portables' field is circled in red and contains the value 2400. A 'Restore Defaults' button is located below the grid, and a 'Ready to Run Model' button is at the bottom right of the window.

Average Weight of Electronics	
Cell Phones	300 g
CRT <19"	18600 g
CRT >19"	33200 g
Color Projection	72000 g
Desktops	10000 g
Flat Panel TVs	7700 g
Portables	2400 g
Hard Copy Peripherals	7900 g
Keyboards	1300 g
Mice	100 g
Monochrome	18600 g
PC CRTs	20200 g
PC Flat Panel	9200 g

Restore Defaults

Ready to Run Model

The next tab in the Control Panel is the **Lifetimes** tab (see Figure 24). The Lifetimes tab outlines assumptions on the average first- and second-use lifetimes of total used electronics. The user can increase or decrease the average lifetimes of used electronics coming from each of the four consumer segments on this page and can also modify assumptions regarding the length of second-use lifetimes. The default percentage of 50% for the “Second use lifetimes reduction” field means that the second-use lifetime for used electronics in this evaluation is assumed to be half of the first-use lifetime.

Figure 24: ADEPT Control Panel 'Lifetimes' tab

The screenshot shows the 'ADEPT Control Panel' window with the 'Lifetimes' tab selected. The window has a title bar with a close button (X). The 'Lifetimes' tab is highlighted in the top navigation bar, which also includes 'General', 'Sales Forecast', 'Behavior', 'Markets', 'Composition', 'Weights', and 'Glossary'.

First Use Lifetimes

Segment	Value (%)	Controls
Increase/Decrease Residential Lifetimes	0	Up/Down arrows
Increase/Decrease Educational Lifetimes	0	Up/Down arrows
Increase/Decrease Commercial Lifetimes	0	Up/Down arrows
Increase/Decrease Average Institutional Lifetimes	0	Up/Down arrows

Second Use Lifetimes

Field	Value (%)	Controls
Second use lifetimes reduction	50	Up/Down arrows

Buttons: 'Restore Defaults' (under First Use Lifetimes), 'Restore Defaults' (under Second Use Lifetimes), and 'Ready to Run Model' (bottom right).

In this example, an assumption is made that electronics being used by the commercial consumer segment, on average, have 10% longer lifetimes than the default lifetimes within the tool and above the other consumer segments. To make this adjustment, select the upwards (increasing) arrow to the right of the “Increase/Decrease Commercial Lifetimes” field until the value reaches 10% (see Figure 25).

An assumption is also made that the second-use lifetime for electronics is, on average, lower than half of the original first-use lifetime for the products considered within the tool. To adjust this second-use lifetime assumption, select the downwards (decreasing) arrow to the right of the “Second use lifetimes reduction” field in the Second Use Lifetimes box until the value reaches 45% (see Figure 25)

Figure 25: Making changes to ADEPT Control Panel 'Lifetimes' tab

The screenshot displays the 'ADEPT Control Panel' with the 'Lifetimes' tab selected. The panel is divided into two main sections: 'First Use Lifetimes' and 'Second Use Lifetimes'. In the 'First Use Lifetimes' section, there are four rows, each with a text label, a numerical input field, a percentage sign, and a pair of up/down arrows. The 'Increase/Decrease Commercial Lifetimes' row has the value '10' in the input field, and a red arrow points to the up arrow. The other rows (Residential, Educational, and Average Institutional) have the value '0'. Below this section is a 'Restore Defaults' button. The 'Second Use Lifetimes' section contains one row labeled 'Second use lifetimes reduction' with the value '45' in the input field and a red arrow pointing to the down arrow. Below this is another 'Restore Defaults' button. At the bottom right of the panel is a 'Ready to Run Model' button.

First Use Lifetimes			
Increase/Decrease Residential Lifetimes	0	%	▲▼
Increase/Decrease Educational Lifetimes	0	%	▲▼
Increase/Decrease Commercial Lifetimes	10	%	▲▼
Increase/Decrease Average Institutional Lifetimes	0	%	▲▼

Restore Defaults

Second Use Lifetimes	
Second use lifetimes reduction	45 % ▲▼

Restore Defaults

Ready to Run Model

Once adjustments have been made to the Lifetimes tab, all Control Panel tabs containing ADEPT assumptions that may adjusted have been reviewed and edited and the tool is now ready to run.

At the bottom of the Lifetimes tab, click the button labeled **Ready to Run Model** (see Figure 26).

Figure 26: Preparing to run ADEPT from the Control Panel

The screenshot displays the 'ADEPT Control Panel' window with the 'Lifetimes' tab selected. The window contains two main sections: 'First Use Lifetimes' and 'Second Use Lifetimes'. Each section has a 'Restore Defaults' button. The 'First Use Lifetimes' section includes four rows of settings, each with a text input field and a percentage sign, followed by up and down arrow buttons. The 'Second Use Lifetimes' section includes one row with a text input field and a percentage sign, followed by up and down arrow buttons. At the bottom right of the window, a blue button labeled 'Ready to Run Model' is circled in red.

Section	Parameter	Value	Unit
First Use Lifetimes	Increase/Decrease Residential Lifetimes	0	%
	Increase/Decrease Educational Lifetimes	0	%
	Increase/Decrease Commercial Lifetimes	10	%
	Increase/Decrease Average Institutional Lifetimes	0	%
Second Use Lifetimes	Second use lifetimes reduction	45	%

The **Ready to Run Model** button directs the user back to the **General** tab, or the first tab of the Control Panel.

Locate the button labeled **Run Model (Exit Control Panel)** towards the middle of the **General** tab (see Figure 27). Click this button once all assumptions have been entered and the tool is ready to run the scenario.

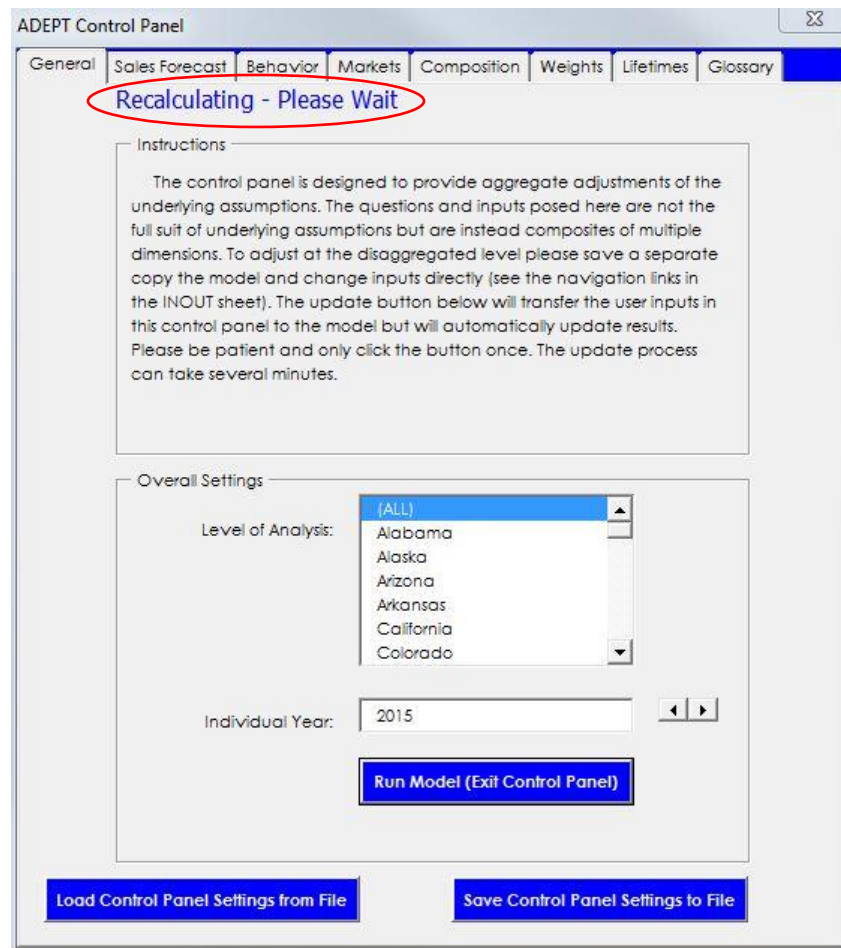
Figure 27: Running ADEPT from the Control Panel

The screenshot displays the ADEPT Control Panel interface. At the top, there is a tabbed menu with the following tabs: General, Sales Forecast, Behavior, Markets, Composition, Weights, Lifetimes, and Glossary. The 'General' tab is currently selected. Below the tabs, there is an 'Instructions' section with a text box explaining the control panel's purpose: 'The control panel is designed to provide aggregate adjustments of the underlying assumptions. The questions and inputs posed here are not the full suit of underlying assumptions but are instead composites of multiple dimensions. To adjust at the disaggregated level please save a separate copy the model and change inputs directly (see the navigation links in the INOUT sheet). The update button below will transfer the user inputs in this control panel to the model but will automatically update results. Please be patient and only click the button once. The update process can take several minutes.'

Below the instructions is the 'Overall Settings' section. It contains a 'Level of Analysis' dropdown menu with a list of states: Alabama, Alaska, Arizona, Arkansas, California, and Colorado. The 'Individual Year' is set to 2015. A red oval highlights the 'Run Model (Exit Control Panel)' button, which is located below the 'Individual Year' field. At the bottom of the panel, there are two buttons: 'Load Control Panel Settings from File' and 'Save Control Panel Settings to File'.

Once the **Run Model (Exit Control Panel)** button is selected, a message will appear at the top of the Control Panel that reads “Recalculating – Please Wait” (see Figure 28).

Figure 28: ADEPT Control Panel interface while performing a run



The Control Panel will remain visible until the tool has completed its calculation of the scenario described within the Control Panel. Once the tool has completed its calculation, the Control Panel will close and the outputs for the ADEPT run will be visible on the first tab (**INOUT**).

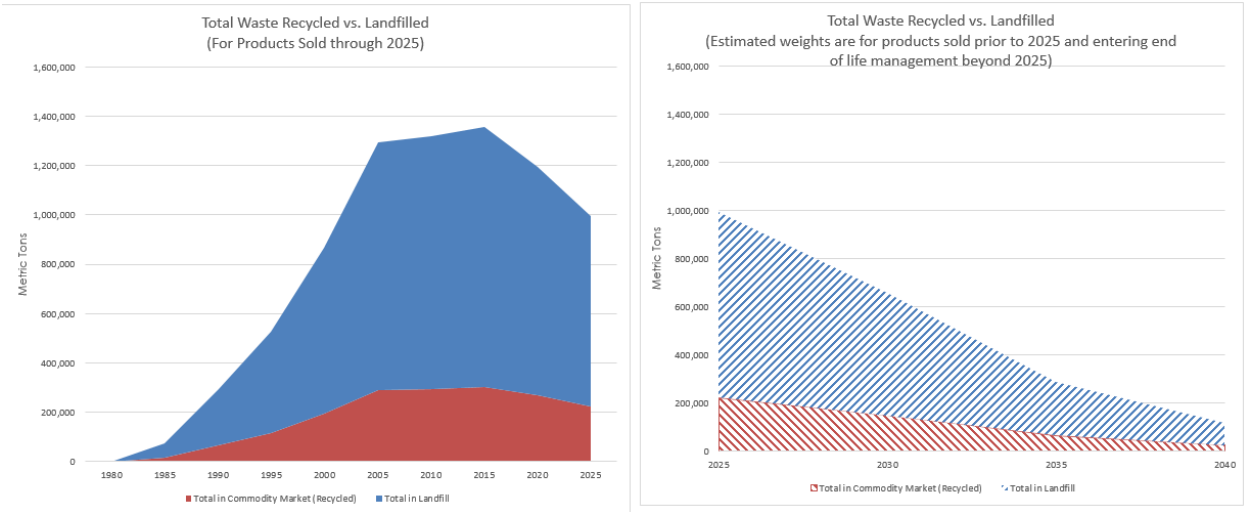
After ADEPT has completed running the scenario with the new inputs described above, the user will be brought back to the **INOUT** tab where numeric and graphical updates have occurred to reflect this specific run. The tables shown in Figure 29 provide the numerical output from this example run. The user can analyze the amount of e-waste disposed of in 2015 by product, market, and commodity type. Graphical representation of this output is shown in Figure 30.

Figure 29: ADEPT run results displayed on the homescreen, Metric tons only

Products	Total Weight Disposition in 2015 (Metric Tons)				Total
	RES	EDU	COM	INST	
Cell Phones	10,056.97	697.15	6,124.35	1,012.04	17,890.50
Color CRT <19"	63,745.36	17,426.46	-	-	81,171.82
Color CRT >19"	215,225.92	56,745.59	-	-	271,971.51
Color Projection	37,991.99	10,260.52	-	-	48,252.51
Desktops	68,096.22	82,879.15	72,118.24	36,192.65	259,286.25
Flat Panel TVs	30,757.87	6,334.64	-	-	37,092.51
Hard Copy Peripherals	93,355.67	8,064.45	45,479.38	7,644.78	154,544.28
Keyboards	4,993.52	5,990.89	6,033.59	3,016.28	20,034.28
Mice	379.61	455.44	458.68	229.30	1,523.04
Monochrome	4,199.57	1,357.75	-	-	5,557.32
PC CRTs	21,566.26	30,744.92	10.97	764.40	53,086.54
PC Flat Panel	47,852.86	52,536.27	77,604.84	38,069.72	216,063.69
Portables	78,087.15	12,237.97	67,075.92	31,561.25	188,962.29
Total E-Waste Disposal	676,308.96	285,731.18	274,905.98	118,490.42	1,355,436.54

Material	Commodity Market	Landfill	Total
Aluminum	31,542.20	109,166.92	140,709.12
Battery	6,621.87	23,053.14	29,675.01
Copper	8,434.07	29,164.46	37,598.54
CRT Glass	55,163.24	189,477.05	244,640.29
CRT Lead	6,102.38	20,961.90	27,064.28
Ferrous Metal	63,398.04	219,605.64	283,003.68
Flat Panel Display Module CCFL	19,384.79	67,472.40	86,857.19
Flat Panel Display Module LED	658.21	2,309.19	2,967.40
Other	3,986.72	13,824.58	17,811.30
Other Metals	3,045.28	10,590.54	13,635.82
PCB Material	29,198.23	100,925.67	130,123.90
Plastics	76,555.24	264,794.77	341,350.01
Total E-Waste Disposal	304,090.27	1,051,346.27	1,355,436.54

Figure 30: Total Waste by Market data for ADEPT run, located on ADEPT homescreen



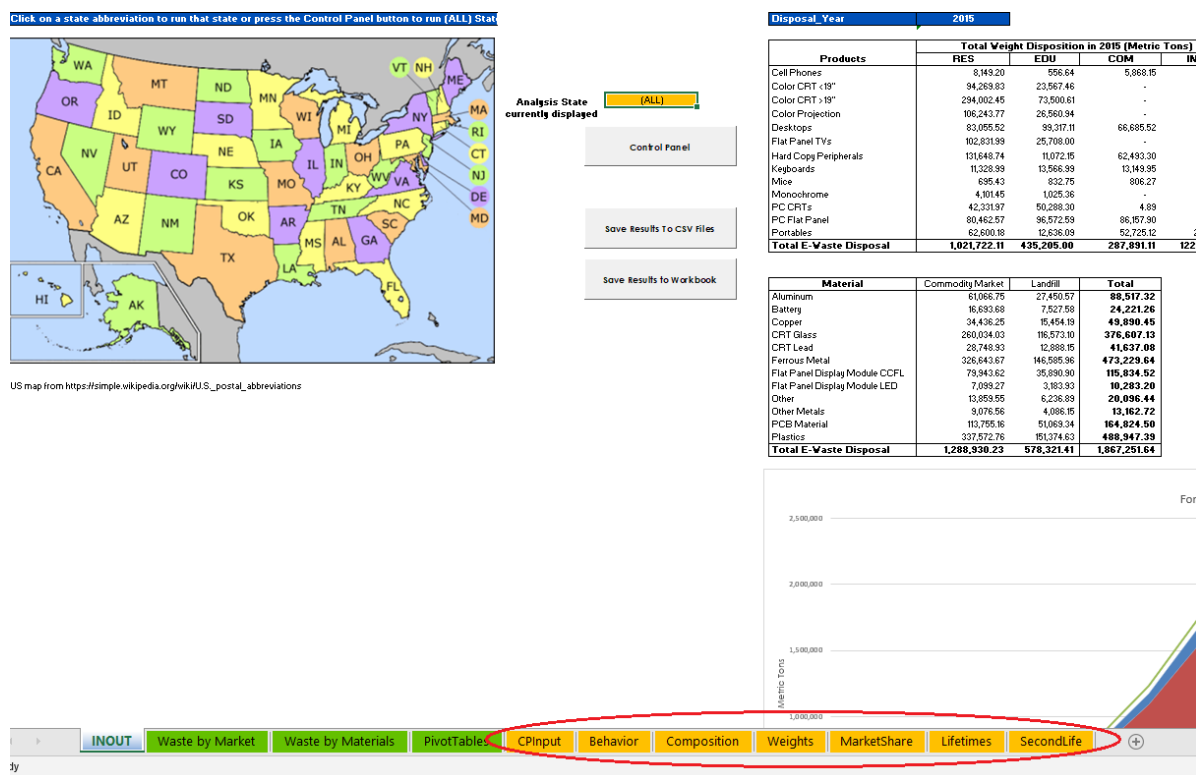
4.2 Adjusting Assumptions Manually (Advanced Users – Only)

This example showcases the ability of a user to manually adjust assumptions as well as narrow down the analysis to a specific state. In this scenario North Carolina is chosen as the analysis state.

For the advanced user, there is the option to manually adjust individual parameters and assumptions. Before proceeding, save ADEPT as a separate file to preserve the original version of the tool. Manually adjusting parameters will break certain links and formulas that cannot be reconstructed. Thus, each scenario or run of ADEPT should be done in a separate copy of the entire Excel workbook when manually adjusting parameters and assumptions.

After a separate copy of ADEPT is saved, find the orange/yellow tabs along the bottom of the workbook (see Figure 31). These tabs include the assumptions and parameters of ADEPT. For this example, assumptions about how users choose to manage their used electronics after their original use will be explored. Clicking on the **Behavior** tab brings up a table of assumptions by product for each step in the waste stream.

Figure 31: Indication of the sheets that are editable by the user in ADEPT



By default, the original consumers of desktops are assumed to recycle 55% of the time, sell to the secondary market 20% of the time, and dispose to a landfill 25% of the time (see Figure 32). Now assume original consumers send desktops to be recycled 45% of the time and to landfill 30% of the time. Manually enter the values 45 for 1st Use Desktops Recycled and 30 for 1st Use Desktops Landfill. Doing so will cause the value in the 2nd Use column for 1st Use Desktops to automatically update. Changing the percentage of desktops that go from the original consumer to recycling from 55% to 45% and from original consumer to landfill from 25% to 30%, the remainder will go to second use (see Figure 33). Note, second use is calculated as a remainder of total waste after recycling and landfill. Manually changing the second use value will clear the formula.

Figure 32: ADEPT Behavior tab data

[Home](#)

Expected Lifetime for Secondary Markets

Waste Flows	Product	Recycled	2nd Use	Landfill
1st Use	Desktops	55%	20%	25%
1st Use	Portables	55%	20%	25%
1st Use	Hard Copy Periph	70%	5%	25%
1st Use	Mice	65%	10%	25%
1st Use	Keyboards	65%	10%	25%
1st Use	PC CRTs	65%	10%	25%
1st Use	PC Flat Panel	65%	10%	25%
1st Use	Color CRT <19"	65%	10%	25%
1st Use	Color CRT >19"	65%	10%	25%
1st Use	Flat Panel TVs	65%	10%	25%
1st Use	Color Projection	65%	10%	25%
1st Use	Monochrome	65%	10%	25%
1st Use	Cell Phones	5%	70%	25%
2nd Use	Desktops	75%	N/A	25%
2nd Use	Portables	75%	N/A	25%
2nd Use	Hard Copy Periph	75%	N/A	25%

INOUT Waste by Market Waste by Materials PivotTables CPInput **Behavior**

Figure 33: Modifying Behavior assumptions for the Desktop product category, first use

Waste Flows	Product	Recycled	2nd Use	Landfill
1st Use	Desktops	45%	25%	30%
1st Use	Portables	55%	20%	25%
1st Use	Hard Copy Periph	70%	5%	25%
1st Use	Mice	65%	10%	25%
1st Use	Keyboards	65%	10%	25%
1st Use	PC CRTs	65%	10%	25%
1st Use	PC Flat Panel	65%	10%	25%
1st Use	Color CRT <19"	65%	10%	25%
1st Use	Color CRT >19"	65%	10%	25%
1st Use	Flat Panel TVs	65%	10%	25%
1st Use	Color Projection	65%	10%	25%
1st Use	Monochrome	65%	10%	25%
1st Use	Cell Phones	5%	70%	25%

In the **Composition** tab, the gray area represents the starting materials composition of each product. The gray table should not be adjusted. There are no constraints on the composition table, so if a row does not sum to 100%, then ADEPT will create additional “waste” as a product moves through the management stream. If a user wants to make changes to the composition values highlighted in gray, the user must confirm that the changes made result in a total value of 100%. Instead of making changes in the gray area, edit the efficiency parameters highlighted in orange (see Figure 34).

Figure 34: ADEPT Composition tab data

Stage	Product	CRT Lead	CRT Glass	Flat Panel Display Module CCFL	Flat Panel Display Module LED	PCB Material	Plastics	Other	Copper	Aluminum	Ferrous Metal	Other Metals
Starting	Cell Phones	0%	0%	15%	0%	10%	14%	15%	2%	20%	0%	6%
Starting	Color CRT <19"	6%	54%	0%	0%	10%	21%	0%	2%	1%	6%	0%
Starting	Color CRT >19"	6%	54%	0%	0%	10%	21%	0%	2%	1%	6%	0%
Starting	Color Projection	5%	45%	0%	0%	7%	20%	0%	2%	11%	9%	1%
Starting	Desktops	0%	0%	0%	0%	14%	12%	2%	4%	11%	57%	0%
Starting	Flat Panel TVs	0%	0%	18%	8%	5%	25%	0%	1%	4%	38%	1%
Starting	Hard Copy Peripherals	0%	0%	0%	0%	3%	58%	1%	1%	0%	37%	0%
Starting	Keyboards	0%	0%	0%	0%	4%	80%	0%	1%	0%	15%	0%
Starting	Mice	0%	0%	0%	0%	4%	90%	0%	1%	0%	5%	0%
Starting	Monochrome	5%	45%	0%	0%	7%	20%	0%	2%	11%	9%	1%
Starting	PC CRTs	6%	56%	0%	0%	12%	17%	0%	4%	1%	3%	1%
Starting	PC Flat Panel	0%	0%	21%	0%	6%	25%	2%	5%	3%	38%	0%
Starting	Portables	0%	0%	17%	0%	14%	23%	2%	2%	12%	10%	6%
Starting	Average	2%	20%	5%	1%	8%	31%	2%	2%	6%	20%	1%
Starting -> Collector		85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%
Collector -> Recycler		90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Recycler -> Processor		95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Processor -> Commodity Market		99%	99%	99%	99%	99%	99%	99%	99%	99%	99%	99%
Collector	Cell Phones	0%	0%	13%	0%	9%	12%	13%	2%	17%	0%	5%
Collector	Color CRT <19"	5%	46%	0%	0%	9%	18%	0%	2%	1%	5%	0%
Collector	Color CRT >19"	5%	46%	0%	0%	9%	18%	0%	2%	1%	5%	0%
Collector	Color Projection	4%	38%	0%	0%	6%	17%	0%	2%	10%	8%	1%
Collector	Desktops	0%	0%	0%	0%	12%	10%	2%	3%	9%	48%	0%
Collector	Flat Panel TVs	0%	0%	15%	7%	4%	21%	0%	1%	3%	32%	1%
Collector	Hard Copy Peripherals	0%	0%	0%	0%	3%	49%	1%	1%	0%	31%	0%
Collector	Keyboards	0%	0%	0%	0%	3%	68%	0%	1%	0%	13%	0%
Collector	Mice	0%	0%	0%	0%	3%	77%	0%	1%	0%	4%	0%
Collector	Monochrome	4%	38%	0%	0%	6%	17%	0%	2%	10%	8%	1%
Collector	PC CRTs	5%	48%	0%	0%	10%	14%	0%	3%	1%	3%	1%
<div> <div>◀ ▶</div> <div>README</div> <div>INOUT</div> <div>Waste by Market</div> <div>Waste by Materials</div> <div>PivotTables</div> <div>CPInput</div> <div>Behavior</div> <div>Composition</div> <div>Weights</div> <div>MarketShare</div> <div>Lifetimes</div> </div>												

For this example, change the extraction efficiency of batteries to 99% across all steps in the management stream (see Figure 35).

Figure 35: Modifying the extraction efficiencies of the Battery product category

Starting	Average	2007	2018
Starting -> Collector		99%	85%
Collector -> Recycler		99%	90%
Recycler -> Processor		99%	95%
Processor -> Commodity Market		99%	99%
Collector	Cell Phones	18%	0%

Next, move to the **Weights** tab (see Figure 36). The Weights tab contains the average weights, by product, for each historical and future year. The gray cells represent historical data. The yellow cells represent future average weights that are assumed, by default, to be the same as 2007 values for all product categories except for Flat Panel TVs.

Figure 36: ADEPT Weights tab data

2.20 lb/kg		Average Weight (kg)									
Year	Desktops	Portables	Copy Periph	Mice	Keyboards	PC CRTs	PC Flat Panel	Color CRT <19"	Color CRT >19"	Flat Panel TVs	Color Proj
1989	9.9	2.4	8.1	0.1	1.3	11.1	11.2	18.6	32.5	0.0	
1990	9.9	2.4	8.9	0.1	1.3	11.2	11.2	18.4	33.9	0.0	
1991	9.9	2.4	8.3	0.1	1.3	11.2	11.2	18.6	33.5	0.0	
1992	10.1	2.4	7.9	0.1	1.3	11.3	11.2	18.6	33.3	0.0	
1993	10.0	2.4	8.1	0.1	1.3	11.3	11.2	18.5	34.2	0.0	
1994	9.8	2.4	8.1	0.1	1.3	13.1	11.2	18.7	33.3	0.0	
1995	10.4	2.4	7.6	0.1	1.3	14.8	11.2	18.6	33.4	0.0	
1996	10.0	2.4	7.0	0.1	1.3	16.6	11.2	18.7	33.0	0.0	
1997	10.3	2.4	7.6	0.1	1.3	18.3	11.2	18.4	33.5	0.0	
1998	10.3	2.4	7.4	0.1	1.3	20.1	11.2	18.8	33.6	0.0	
1999	10.0	2.4	7.4	0.1	1.3	21.8	11.2	18.7	33.1	13.2	
2000	10.0	2.4	8.4	0.1	1.3	23.6	11.2	18.1	33.8	13.2	
2001	10.0	2.4	7.7	0.1	1.3	23.4	11.2	18.6	32.7	13.2	
2002	10.9	2.4	7.4	0.1	1.3	23.2	11.2	18.3	33.0	13.2	
2003	10.0	2.4	7.5	0.1	1.3	23.1	11.2	18.6	33.1	13.2	
2004	10.0	2.4	7.9	0.1	1.3	22.9	11.2	18.6	33.1	13.2	
2005	10.0	2.4	7.9	0.1	1.3	22.9	11.2	18.6	33.1	13.2	
2006	10.0	2.4	7.9	0.1	1.3	22.9	11.2	18.6	33.1	13.2	
2007	10.0	2.4	7.9	0.1	1.3	22.9	11.2	18.6	33.1	13.2	
2008	10.0	2.4	7.9	0.1	1.3	22.9	11.2	18.6	33.1	12.6	
2009	10.0	2.4	7.9	0.1	1.3	22.9	11.2	18.6	33.1	11.3	
2010	10.0	2.4	7.9	0.1	1.3	22.9	11.2	18.6	33.1	10.1	
2011	10.0	2.4	7.9	0.1	1.3	22.9	11.2	18.6	33.1	9.7	
2012	10.0	2.4	7.9	0.1	1.3	22.9	11.2	18.6	33.1	9.3	
2013	10.0	2.4	7.9	0.1	1.3	22.9	11.2	18.6	33.1	9.4	
2014	10.0	2.4	7.9	0.1	1.3	22.9	11.2	18.6	33.1	9.8	
2015	10.0	2.4	7.9	0.1	1.3	22.9	11.2	18.6	33.1	9.8	
2016	10.0	2.4	7.9	0.1	1.3	22.9	11.2	18.6	33.1	9.8	
2017	10.0	2.4	7.9	0.1	1.3	22.9	11.2	18.6	33.1	9.8	
2018	10.0	2.4	7.9	0.1	1.3	22.9	11.2	18.6	33.1	9.8	

For this example, assume that desktops will be getting lighter in the future. Enter 8.0 kg for 2018–2019 and 7.0 kg for 2020 and beyond (see Figure 37).

Figure 37: Modifying the weight assumptions for the Desktop product category

Year	Desktops	Portables
2014	10.0	2.9
2015	10.0	2.9
2016	10.0	2.9
2017	10.0	2.9
2018	8.0	2.9
2019	8.0	2.9
2020	7.0	2.9
2021	7.0	2.9
2022	7.0	2.9
2023	7.0	2.9
2024	7.0	2.9
2025	7.0	2.9
2026	7.0	2.9
2027	7.0	2.9
2028	7.0	2.9
2029	7.0	2.9
2030	7.0	2.9
2031	7.0	2.9
2032	7.0	2.9
2033	7.0	2.9
2034	7.0	2.9
2035	7.0	2.9
2036	7.0	2.9
2037	7.0	2.9
2038	7.0	2.9
2039	7.0	2.9
2040	7.0	2.9
2041	7.0	2.9
2042	7.0	2.9
2043	7.0	2.9
2044	7.0	2.9
2045	7.0	2.9
2046	7.0	2.9
2047	7.0	2.9
2048	7.0	2.9
2049	7.0	2.9
2050	7.0	2.9
Average	10.0	2.5

The next assumption tab is **MarketShare** (see Figure 38). This sheet allows the user to adjust how the market for each product is allocated across the four market segments: residential, educational, commercial, and institutional. For this example, change the market shares for the original consumers of desktops. Increase the education share to 35% and decrease the institutional share to 10%. In doing so, an assumption is being made that the education segment is the largest purchaser of desktops and is followed by the commercial segment, then the residential and institutional segments (see Figure 39).

Figure 38: ADEPT MarketShare tab data

First Use Market Shares															
Market Segment	MrktSeg	Desktops	Portables	Hard Copy Peripherals	Mice	Keyboards	PC CRTs	PC Flat Panel	Color CRT <19"	Color CRT >19"	Flat Panel TVs	Color Projection	Monochrome	Cell Phones	Average
Residential	RES	25%	45%	60%	25%	25%	25%	25%	80%	80%	80%	80%	80%	60%	53%
Education	EDU	30%	10%	5%	30%	30%	30%	30%	20%	20%	20%	20%	20%	5%	21%
Commercial	COM	30%	30%	30%	30%	30%	30%	30%	0%	0%	0%	0%	0%	30%	18%
Institutional	INT	15%	15%	5%	15%	15%	15%	15%	0%	0%	0%	0%	0%	5%	8%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Second Use Market Shares															
Market Segment	MrktSeg	Desktops	Portables	Hard Copy Peripherals	Mice	Keyboards	PC CRTs	PC Flat Panel	Color CRT <19"	Color CRT >19"	Flat Panel TVs	Color Projection	Monochrome	Cell Phones	Average
Residential	RES	21%	41%	56%	21%	21%	21%	21%	61%	61%	61%	61%	61%	56%	43%
Education	EDU	64%	44%	39%	64%	64%	64%	64%	39%	39%	39%	39%	39%	39%	49%
Commercial	COM	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Institutional	INT	15%	15%	5%	15%	15%	15%	15%	0%	0%	0%	0%	0%	5%	8%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

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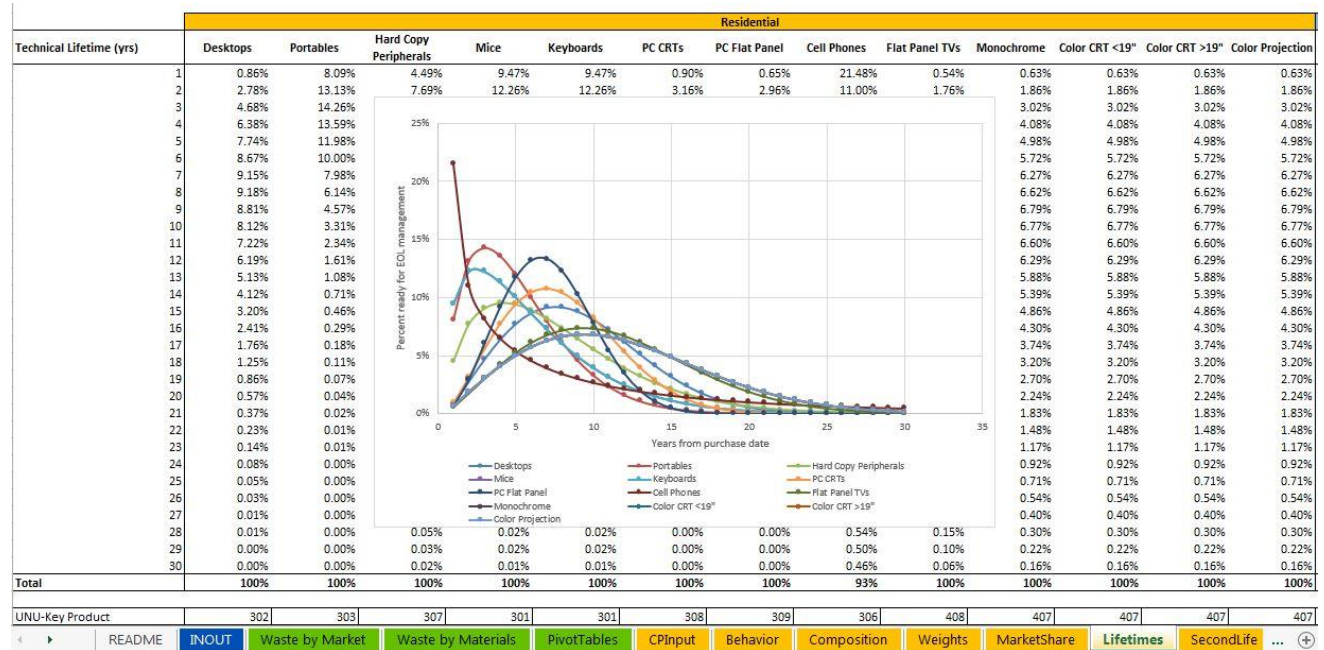
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Figure 39: Modifying the Market share of the Desktop product category

First Use Market Shares			
Market Segment	MrktSeg	Desktops	Portables
Residential	RES	25%	45%
Education	EDU	35%	10%
Commercial	COM	30%	30%
Institutional	INT	10%	15%
Total		100%	100%
Second Use Market Shares			
Market Segment	MrktSeg	Desktops	Portables
Residential	RES	40%	60%
Education	EDU	45%	25%
Commercial	COM	0%	0%
Institutional	INT	15%	15%
Total		100%	100%

The final user-editable assumptions are in the **Lifetimes** tab (see Figure 40). For each product category, by market segment, the alpha (α) and beta (β) parameters of the Weibull distribution are used to adjust the lifetimes of products. The α parameter dictates the shape of the distribution while the β parameter affects the scale. Perhaps the most relevant of the two parameters is the β , as this is the closest analog to the average lifetime. A higher β parameter translates to a longer average lifetime and vice versa. The α parameter correlates to the skewness of the distribution.

Figure 40: ADEPT Lifetimes tab data



For this example, decrease the average lifetime of desktops within the residential market segment by reducing the β parameter from 9.6 to 8 (see Figure 41). Notice that by making this change, a greater portion of desktops reach their end of life earlier than before.

Figure 41: Modifying the Lifetime assumptions for the Residential Desktop product category

Technical Lifetime (yrs)		Desktops
	1	1.26%
	2	4.03%
	3	6.67%
	4	8.84%
	5	10.31%
	6	10.99%
	7	10.92%
	8	10.19%
	9	9.00%
	10	7.55%
	11	6.03%
	12	4.60%
	13	3.35%
	14	2.33%
	15	1.55%
	16	0.99%
	17	0.61%
	18	0.36%
	19	0.20%
	20	0.11%
	21	0.06%
	22	0.03%
	23	0.01%
	24	0.01%
	25	0.00%
	26	0.00%
	27	0.00%
	28	0.00%
	29	0.00%
	30	0.00%
Total		100%
UNU-Key Product		302
α (shape)		2.1
β (scale)		8

With all changes made, go back to the Control Panel, select North Carolina as the analysis state, and Run Model (see Figure 42).

Figure 42: ADEPT Control Panel Homescreen, running the tool

ADEPT Control Panel

General | Sales Forecast | Behavior | Markets | Composition | Weights | Lifetimes | Glossary

Instructions

The control panel is designed to provide aggregate adjustments of the underlying assumptions. The questions and inputs posed here are not the full suit of underlying assumptions but are instead composites of multiple dimensions. To adjust at the disaggregated level please save a separate copy the model and change inputs directly (see the navigation links in the INOUT sheet). The update button below will transfer the user inputs in this control panel to the model but will automatically update results. Please be patient and only click the button once. The update process can take several minutes.

Overall Settings

Level of Analysis: New Jersey, New Mexico, New York, **North Carolina**, North Dakota, Ohio, Oklahoma

Individual Year: 2015

Run Model (Exit Control Panel)

Load Control Panel Settings from File | Save Control Panel Settings to File

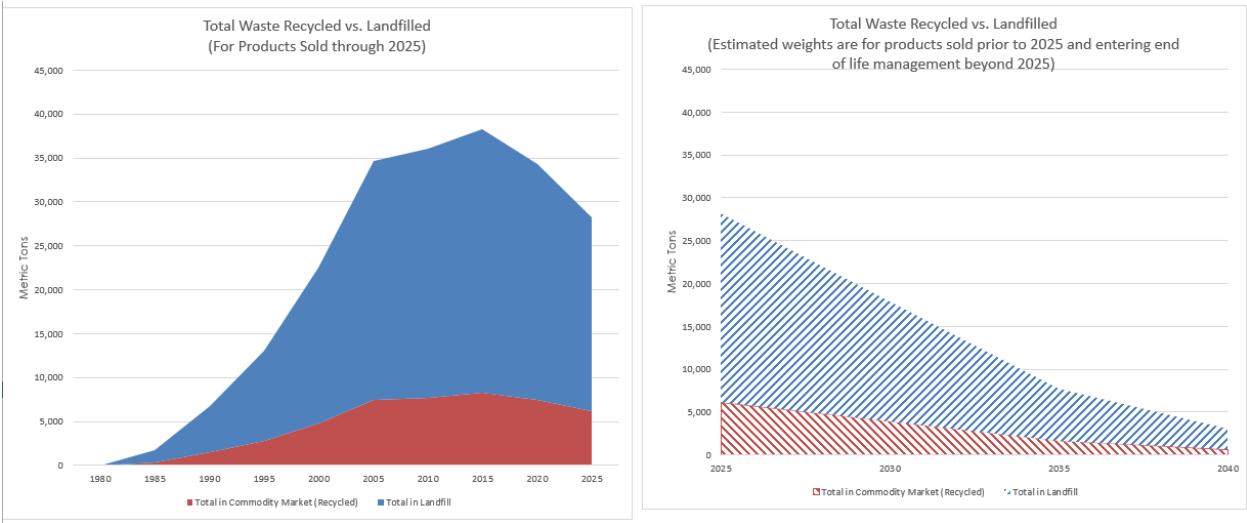
After ADEPT has completed running the scenario with the new inputs described above, the user will be brought back to the **INOUT** tab where numeric and graphical updates have occurred to reflect this specific run. The tables shown in Figure 43 provide the results from the run. Users can analyze the weight of used electronics being generated in 2015 by product, market, and commodity type in North Carolina. Graphical representation of this output can be seen in Figure 44.

Figure 43: Run results on ADEPT homescreen, Metric tons only

Products	Total Weight Disposition in 2015 (Metric Tons)				Total
	RES	EDU	COM	INST	
Cell Phones	242.87	12.46	171.82	27.54	454.69
Color CRT <19"	1,699.33	424.83	-	-	2,124.17
Color CRT >19"	5,778.66	1,444.67	-	-	7,223.33
Color Projection	1,018.02	254.51	-	-	1,272.53
Desktops	1,853.46	2,667.89	2,031.41	683.76	7,236.51
Flat Panel TVs	881.05	220.26	-	-	1,101.31
Hard Copy Peripherals	2,582.06	215.77	1,262.19	210.95	4,270.96
Keyboards	138.99	166.78	166.69	83.37	555.83
Mice	10.57	12.68	12.67	6.34	42.25
Monochrome	107.77	26.94	-	-	134.72
PC CRTs	611.52	726.75	0.12	14.17	1,352.56
PC Flat Panel	1,317.97	1,588.82	2,151.11	1,062.17	6,120.07
Portables	2,462.64	468.91	2,384.23	1,100.51	6,416.29
Total E-Waste Disposal	18,704.92	8,231.27	8,180.23	3,188.80	38,305.22

Material	Commodity Market	Landfill	Total
Aluminum	441.12	1,710.87	2,151.99
Battery	271.31	708.81	980.12
Copper	224.05	834.91	1,058.97
CRT Glass	1,419.21	5,019.13	6,438.34
CRT Lead	157.02	555.34	712.37
Ferrous Metal	2,071.74	7,832.65	9,904.39
Flat Panel Display Module CCFL	567.47	2,074.95	2,642.42
Flat Panel Display Module LED	19.33	68.78	88.11
Other	104.81	409.39	514.20
Other Metals	93.05	352.19	445.24
PCB Material	782.88	2,938.85	3,721.73
Plastics	2,093.26	7,554.08	9,647.34
Total E-Waste Disposal	8,245.26	30,059.96	38,305.22

Figure 44: Total Waste by Market run data displayed on ADEPT homescreen

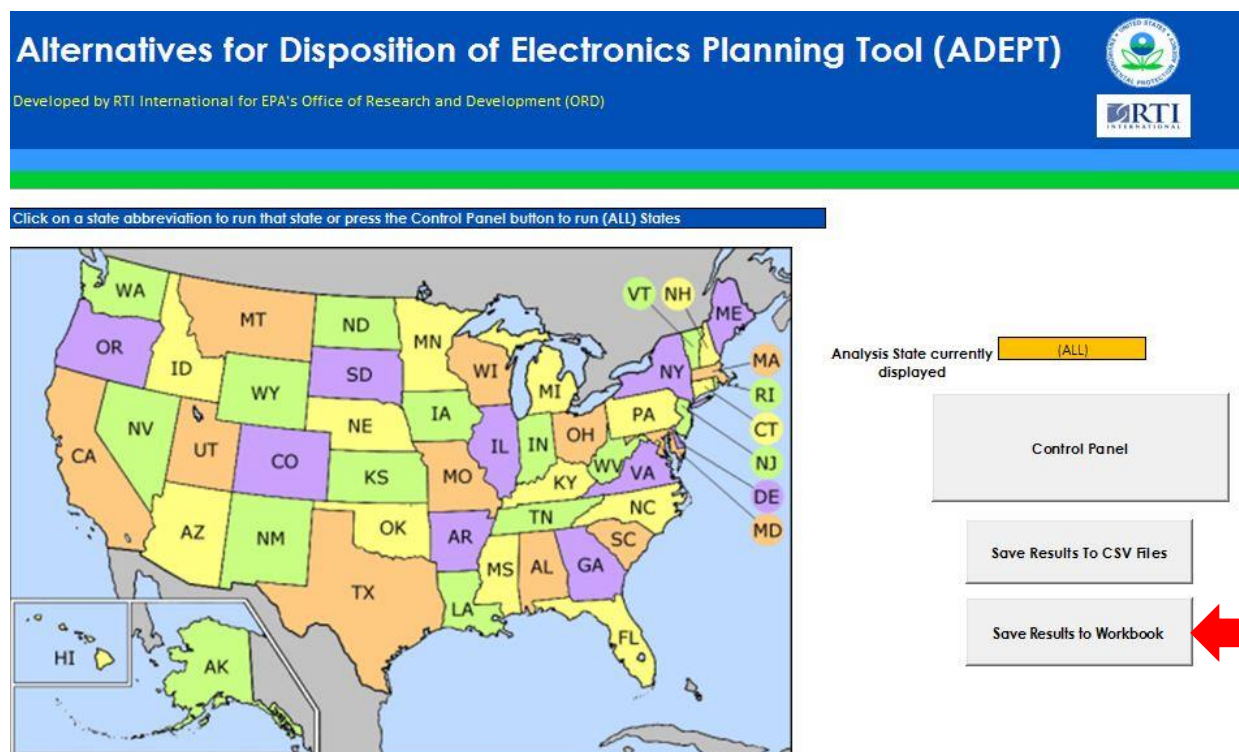


In addition to the predefined figures and tables of results, ADEPT allows the user to access the raw output data from each step in the tool's processing. This allows the user to analyze the data and generate customized graphs and tables to support specific information and decision-support needs. To access the raw output data, the user must first run ADEPT using the scenario of interest and then proceed through the following steps.

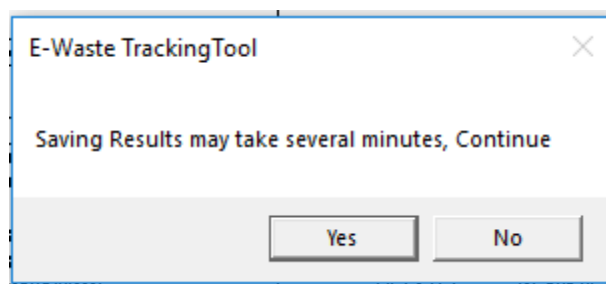
Following completion of the run, click **Save Results to Workbook**. Note that the user can save to a workbook or to separate CSV files. This example will explore the Save Results to Workbook option (see Figure 45).

Following completion of the run, click **Save Results to Workbook**. Note that the user can save to a workbook or to separate CSV files. This example will explore the Save Results to Workbook option (see Figure 45).

Figure 45: Saving run data from ADEPT homescreen

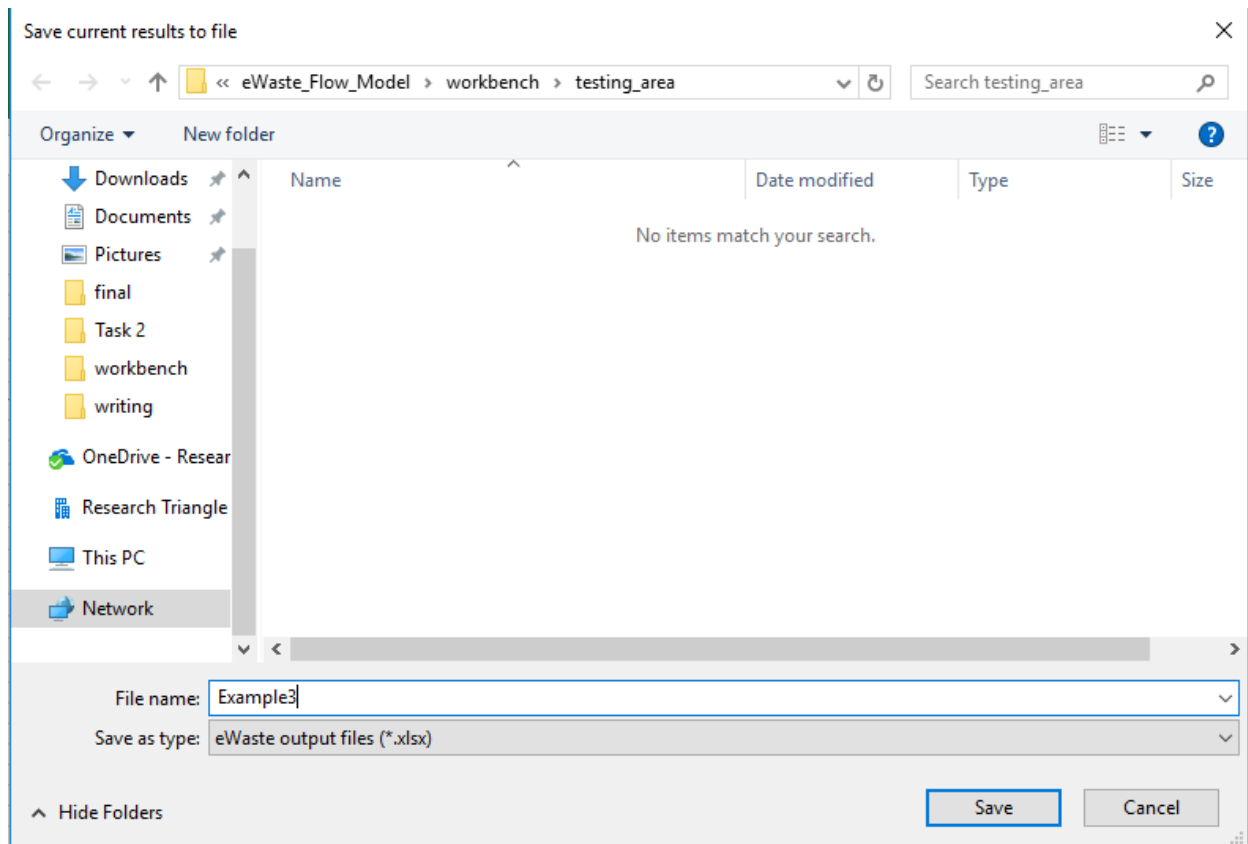


Click **Yes** when the window prompts to continue. Depending on a computer's processing power, this may take a few minutes.

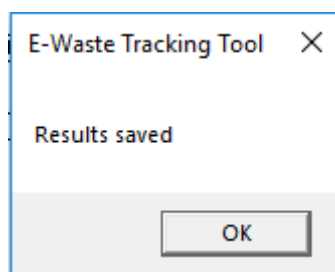


Choose a location on your computer to save the results to and provide a filename. In this example, the file is named *Example3* (Figure 46).

Figure 46: Saving ADEPT run data to a local machine



Once the data output process is complete, a window will pop up stating that the results are saved. In the interim, the Excel screen may flash multiple times as the program creates the results file. It is important to let the process complete before exiting Excel.



Next, navigate to the location on your computer where the results file has been saved and open the workbook. It is important to remember where you chose to save this file, as the file will not automatically open after it has been created. Once open, the file should open to the **CPInput** tab and look like Figure 47.

Figure 47: CPInput tab data inputs

A	B	C	D	E	F	G	H	I	J	K	L
Source	Value	Description									
StateList	(ALL)	Level of Analysis									
YearBox	2015	Analysis year									
ProductList		Analysis product									
resoldBox	16	Consumer % resold									
recycleBox	83	Consumer% recycled									
landfillBox	1	Consumer % landfilled									
ColrecycleBox	99	Collector % recycled									
CollandfillBox	1	Collector % landfilled									
RecrecycleBox	99	Recycler % recycled									
ReclandfillBox	1	Recycler % landfilled									
ProrecycleBox	99	Processor % recycled									
ProlandfillBox	1	Processor % landfilled									
FirstResMarketBox	53	First use residential market share									
FirstEduMarketBox	21	First use educational market share									
FirstComMarketBox	18	First use commercial market share									
FirstIntMarketBox	8	First use institutional market share									
SecResMarketBox	62	Second use residential market share									
SecEduMarketBox	30	Second use educational market share									
SecComMarketBox	0	Second use commercial market share									
SecIntMarketBox	8	Second use institutional market share									
BatteryBox	2	% battery									
CRTLeadBox	2	% crt lead									
CRTGlassBox	20	% crt glass									
CCFLBox	5	% ccfl flat panel									
LEDBox	1	% led flat panel									
PCBBox	8	% pcb									
OtherBox	2	% other									
CopperBox	2	% copper									
AlumBox	6	% aluminum									
FerBox	20	% ferrous metals									
OthMetBox	1	% other metals									
PlasticBox	31	% plastics									
ConColBox	85	Consumer to collector efficiency									
ColRecBox	90	Collector to recycler efficiency									
RecProBox	95	Recycler to processor efficiency									
ProComBox	99	Processor to commodity market efficiency									
cellBox	300	Cell phone weight									
smlCRTbox	18600	CRT < 19" weight									
bigCRTbox	33200	CRT > 19" weight									
projBox	72000	Color projection weight									
deskBox	10000	Desktop weight									
flatTVBox	7700	Flat panel TV weight									

The **CPInput** tab lists the assumptions used from the Control Panel. **Note that any manually adjusted assumptions (advanced users) will not be represented in the CPInput tab because the CPInput tab only shows values from the Control Panel.** The various red tabs represent all the raw output sheets used within ADEPT. For a more detailed discussion of the various calculation sheets, see Section 3.4.

Users also have the option to save run results to CSV files as opposed to a single Excel workbook, if they prefer. The CSV files contain the same information as the Excel workbook option; however, each tab in the Excel workbook option (Figure 47) is a separate CSV file with no formatting.

Use of the CSV files may be preferred over use of an Excel workbook if the user intends to import their run output directly into another piece of software (e.g., R, STATA). Users may prefer to generate their run output into an Excel workbook if they are looking to simply manipulate the output data within the Excel environment.

By having Excel sheets with data for a given, user-specified scenario, users can conduct different analyses and produce the customized tables and graphs most appropriate for a variety of individual policy analysis and decision-support needs.

5 REFERENCES

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