United States Environmental Protection Agency

EPA Tools and Resources Training Webinar

ADEPT: Alternatives for Disposition of Electronics Planning Tool

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Outline

- Motivation and Objectives
- Current status: Challenges and Opportunities
- Model development approaches for tracking flow of electronics
- Model parameters and assumptions
- Demonstration of ADEPT
- Examples of model output
- Comparison with selected state data and model validation
- Conclusion

Impetus

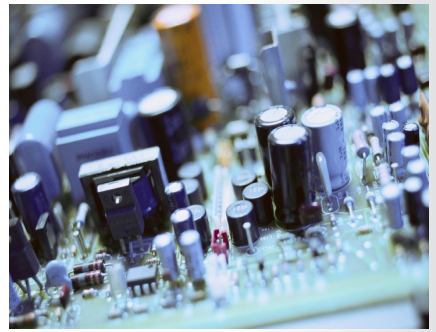
- Americans currently own more than 3 billion electronic products. The average American owns 24 units per household
- In 2016, the global e-waste average was 13.5 pounds (lb) per person, or for a family of four 54 lb
- Less than 30% of electronics is recycled; the rest is landfilled, incinerated, exported or disposed of indiscriminately
- For every 1 million cell phones that are recycled, 35,274 lb of copper, 772 lb of silver, 75 lb of gold, and 33 lb of palladium can be recovered

Total e-waste generated in 2016 = 4500 Eiffel Towers!

Global-E-waste Monitor 2017

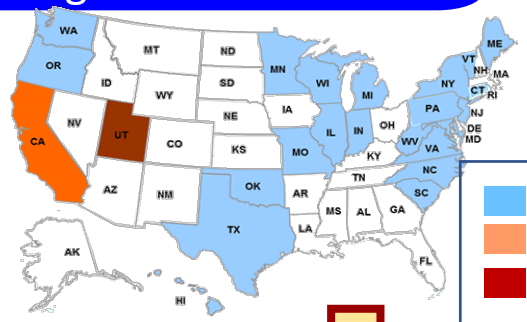
Objectives

- Assess the flow of historic, current and potential future quantities of used electronics and electronic waste
- Evaluate the existing methods for quantifying and tracking used electronics
- Develop an information-based method for estimating the flow of used electronics and electronic waste within the US
- Estimates are expected to inform formulation of e-waste policies, management of take-back programs, and policy implementation monitoring
- Enable the assessment of potential effects of the state-level electronics recycling requirements (e.g., benefits and drawbacks)

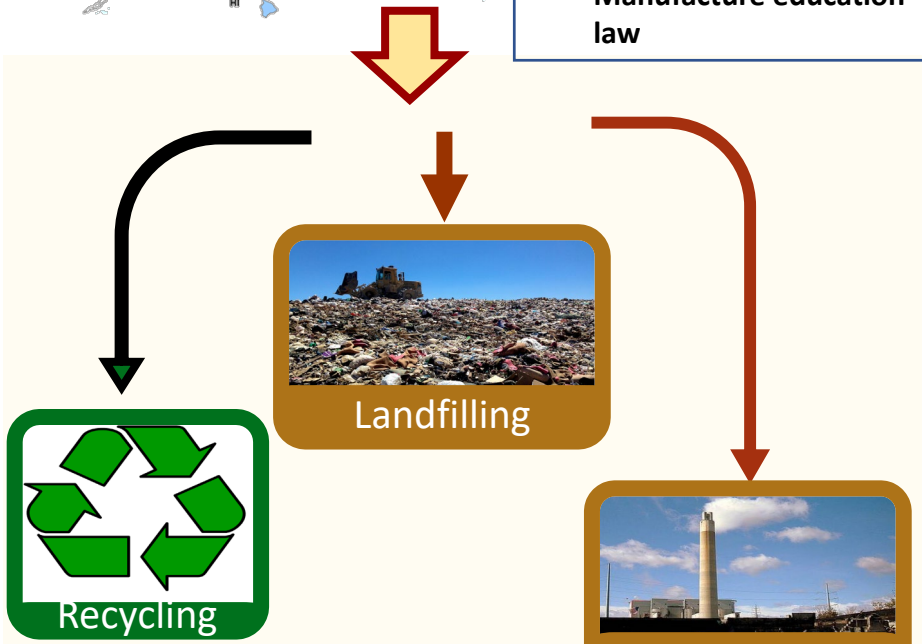


E-waste

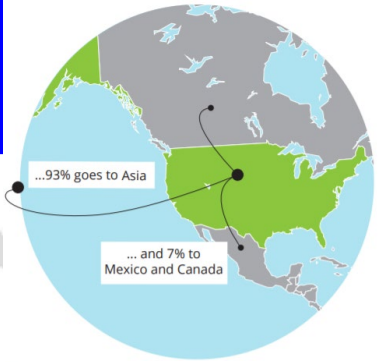
Domestic management
Treatment depends on state regulations

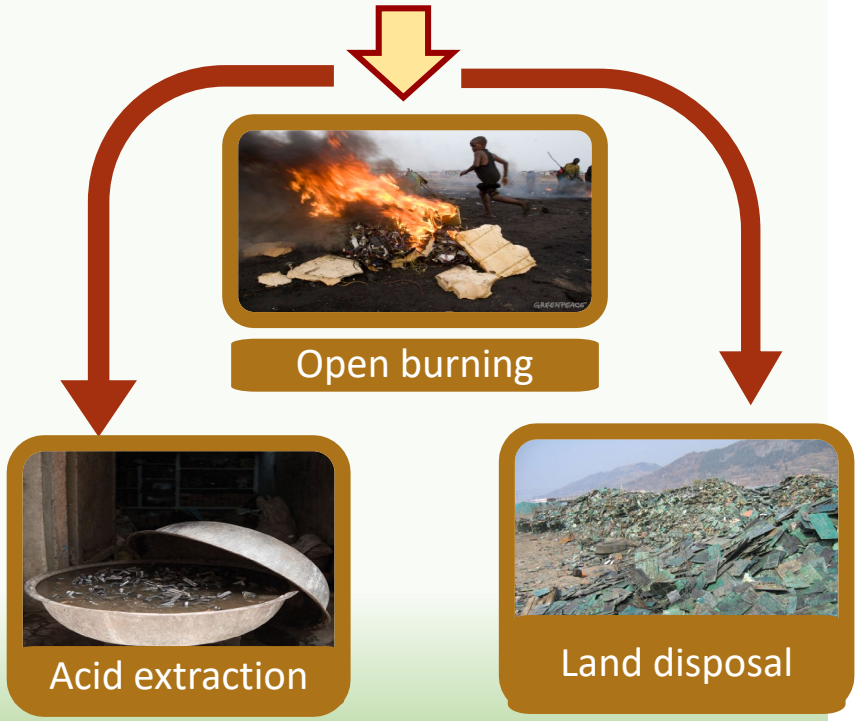


- Producer responsibility law
- Consumer law
- Manufacture education law



Export to developing countries

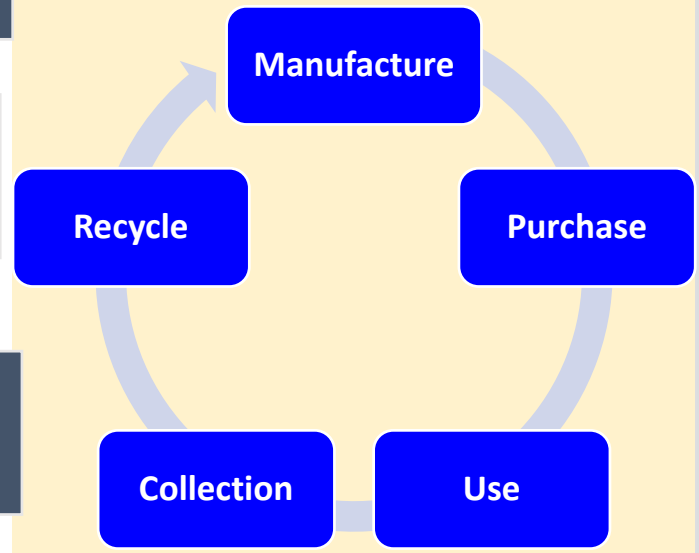




US doesn't have national legislation in effect on the management of e-waste.
However, some states have local legislation.

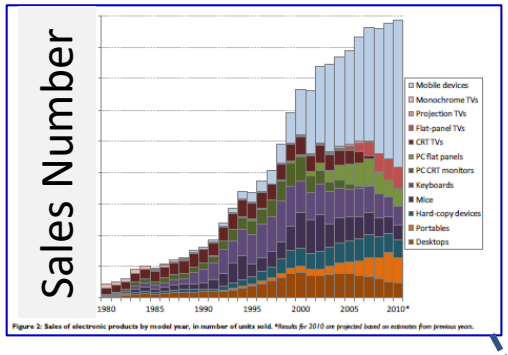
Approach

- Select a representative sampling of states that will serve as the proxy for assessing the practice of used electronics management across the US
- Assemble available information about the generation, recycling, export, recovery, reuse, and downstream flow of used electronics
- Develop a flow model, identify data gaps, and devise methods to estimate, or ascertain, unavailable data
- Assess environmental and economic impacts of the e-stewardship programs for the selected states

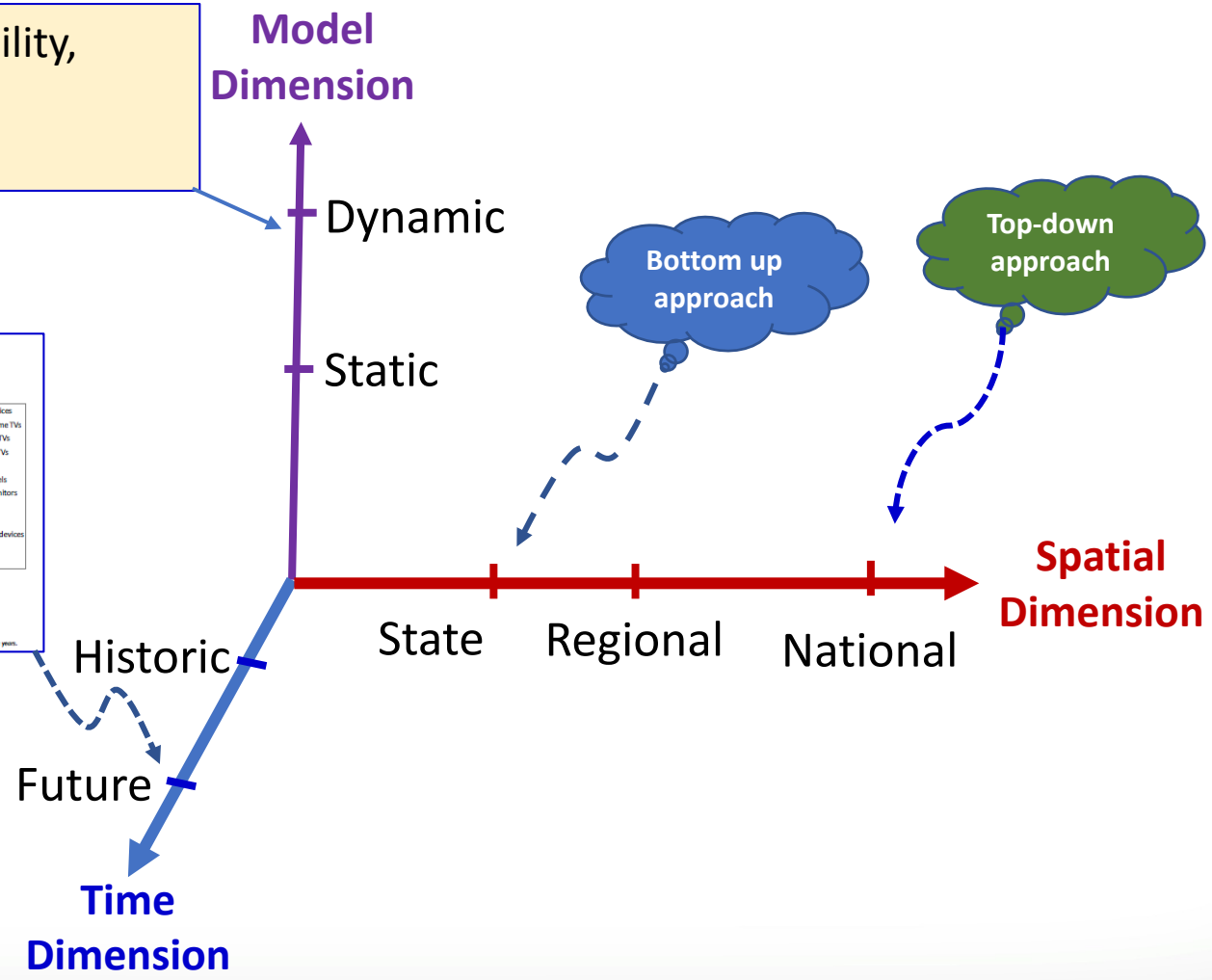


Dimensions of Characterizing Flow of Used and Waste Electronics

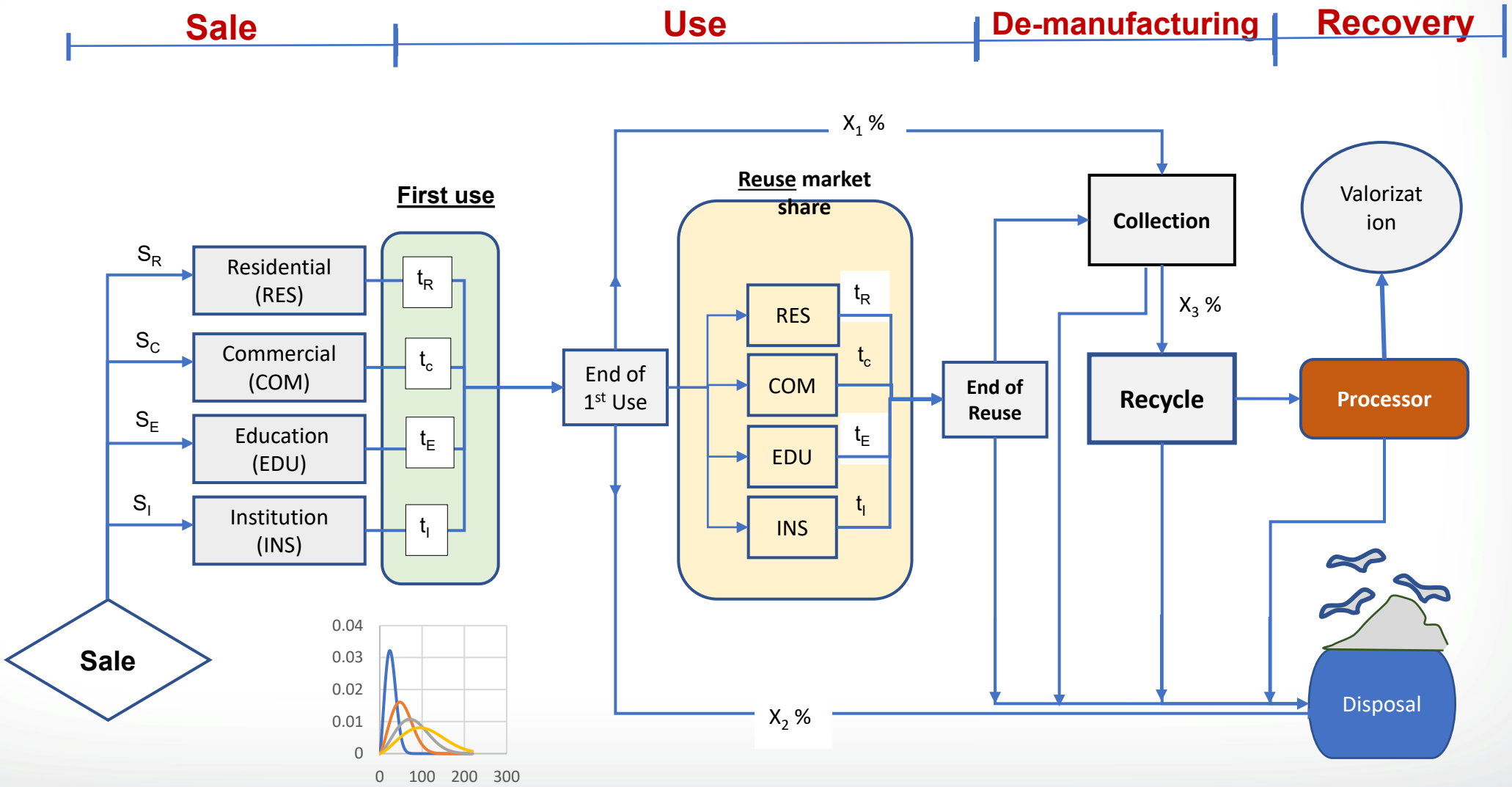
- Accounts for flow variability, delays, accumulation
- Forecasting possibilities



- **Products change**
- **Volatile demand-supply**



E-waste Stock – Flow – End-of-life Supply Chain Model



Goals of Material Flow Analysis – Model Development

- Estimate the flow of specific quantities of e-waste materials – CRT glass in storage – recycler or exported
- Estimate the future quantities of used electronics for which appropriate infrastructure is needed
- Identify data gaps for trade flows of used and scrap electronics, flows invisible to trade statistics
- Provide state policy makers a decision support tool with which to conduct scenario assessments
- Enable the comparison of different state practices

Basic Approach to Quantifying E-Waste

Sales

- Obtain historic sales data for products delineated by region and time
- Develop average weights for products in each year

Use

- Determine the typical distribution of product lifespans.

Disposition

- Calculate number and weight of products entering EOL* management annually
- Determine collection rates of products entering EOL management by region

***EOL – End of Life**

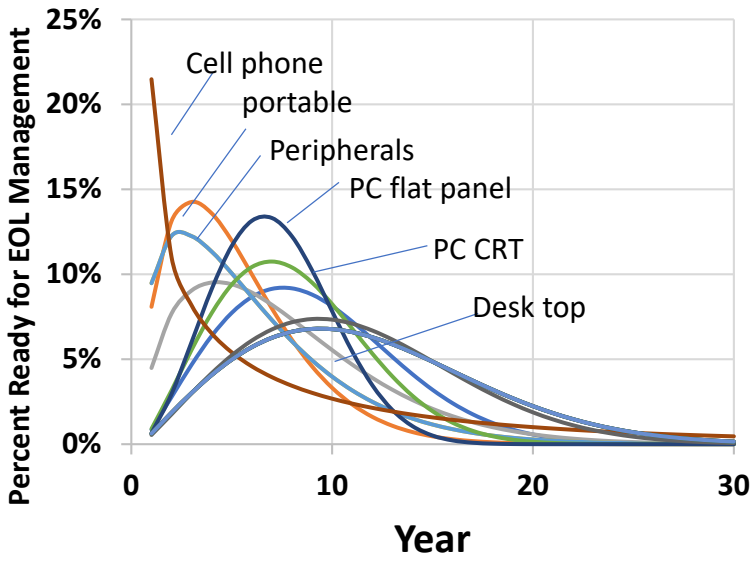
Weibull distributions to product lifetimes

$$\text{e-waste (t)} = \sum_{i=0}^{t \le T} Sales_t \cdot \left[\left(1 - e^{\left(\frac{T-t}{\beta}\right)^{\alpha}}\right) - \left(1 - e^{\left(\frac{(T-t)-1}{\beta}\right)^{\alpha}}\right)\right]$$

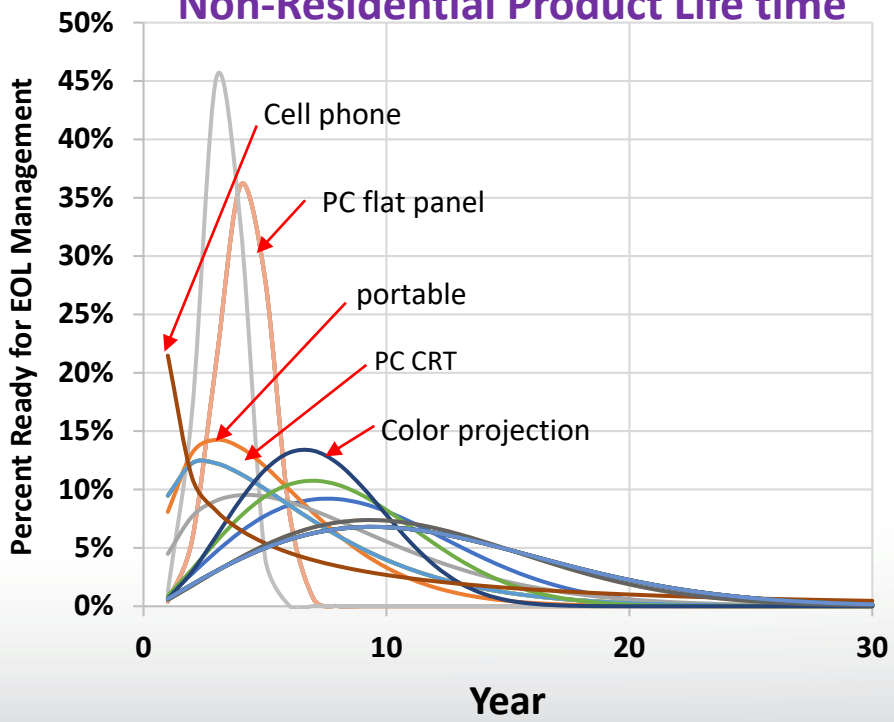
Where: t = Year when the product was sold
T = Year when e-waste was generated
$Sales_t$ = Industry sales for year t
β = Weibull distribution scaling factor
α = Weibull distribution shape factor

Lifetime depends on the type of product and economic sector

Residential Product Life time



Non-Residential Product Life time



Sources: Baldé et al., 2014; US EPA, 2011, and Authors calculations

Objectives of a Material Flow Analysis (MFA)

- Track the flow of electronic materials through to end use or disposal
- Implement a guidance tool which serves as a proxy for a regional environmental management and audit platform
- Identify data gaps, define the basis for evaluation
- Assess data requirements in a decision-oriented manner in concert with other complementary tools
- Examine short- and long-term flows and volumes as well as potential accumulated stockpiles
- MFA is an accounting and analysis tool that is based on a systems approach and mass balance. The system consists of a system boundary (e.g., state or region, processes, stocks, flows)

Material Flow Analysis – Assumptions

Product Sales: Historic sales data using historical 7-year growth trend (2000-2007 and 2007-2015) exception using 3-yr growth for flat panel TVs, State % of National GDP obtained from US Bureau of Economic Analysis (BEA) used to distribute national product sales

Market Share: Market shares for product purchases based on real data on market share (consider BEA's Total Requirement Tables)

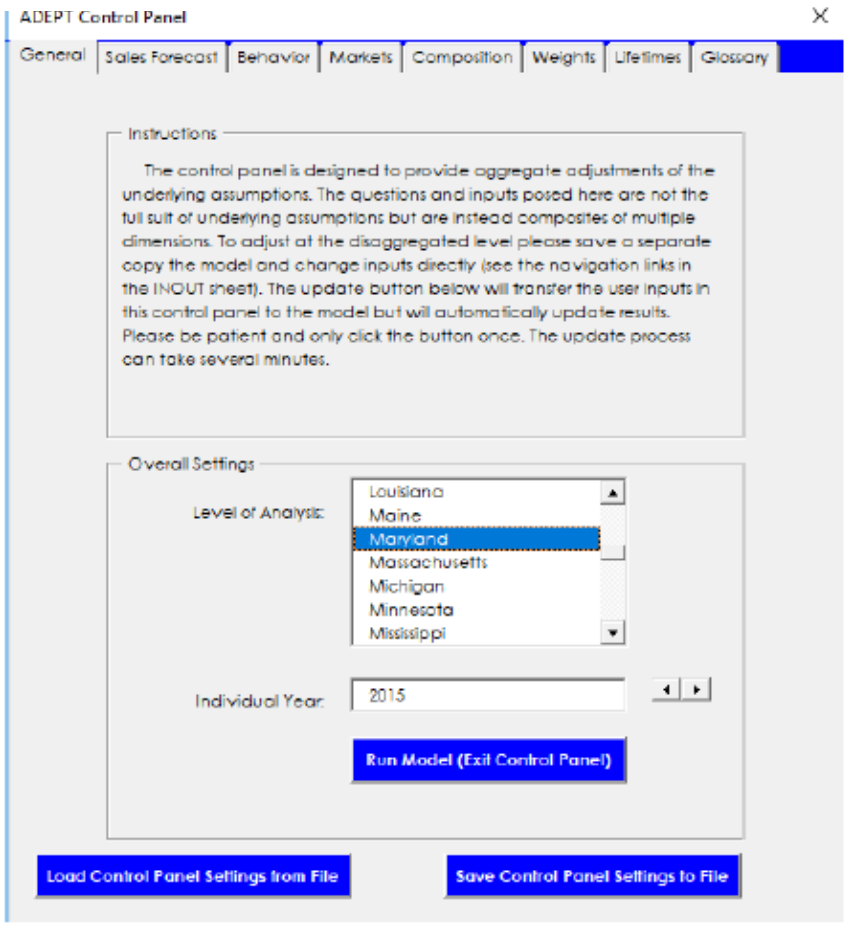
Lifetimes: Limited historical data available on the life span of electronic devices. Product lifetimes developed from UN data using Weibull distribution curves

Weights: Product weights assumed to be constant since 2007 EPA model estimates

Data Requirements to Model Flow of Products

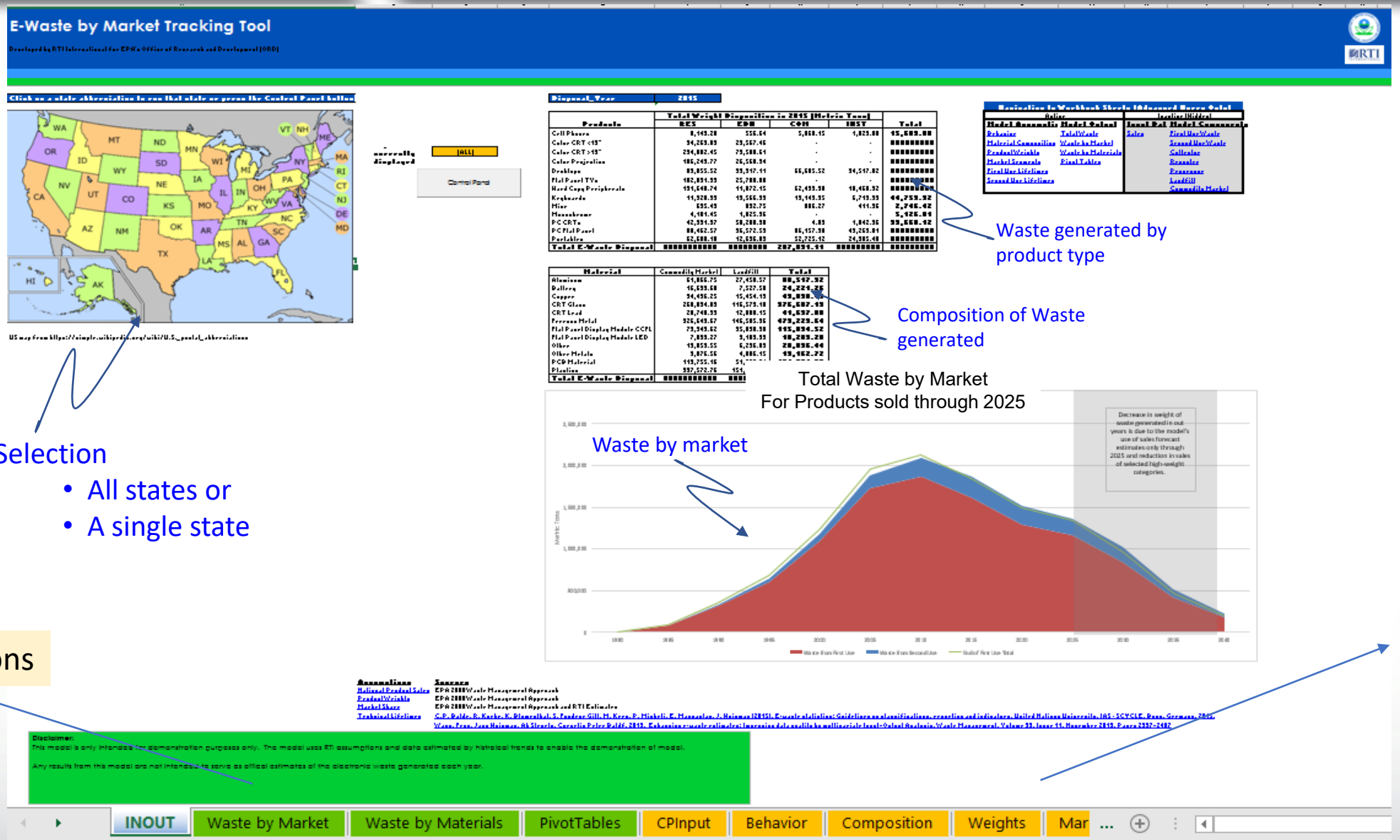
Quick Start

ADEPT Control Panel Interface *ce*



- Download as an Excel file and save it to a computer
- Open the file labeled **INOUT**
- Open the **General** tab on the Control Panel
- User can choose the analysis for a selected state or for the whole US
- User **selected year**

ADEPT for US – Interface Page



E-waste flow estimate example

Products	Total Weight Disposition in 2015 (Metric Tons)				Total
	RES	EDU	COM	INST	
Cell Phones	192.41	12.64	140.46	24.57	**370.08**
Color CRT <19"	2,128.51	532.13	-	-	**2,660.64**
Color CRT >19"	6,668.44	1,667.11	-	-	**8,335.56**
Color Projection	2,434.22	608.55	-	-	**3,042.77**
Desktops	1,928.01	2,306.24	1,597.07	825.35	**6,656.67**
Flat Panel TVs	2,449.52	612.38	-	-	**3,061.89**
Hard Copy Peripherals	3,104.05	260.53	1,496.66	250.63	**5,111.87**
Keyboards	267.42	320.30	311.28	158.65	**1,057.66**
Mice	16.41	19.66	19.08	9.73	**64.88**
Monochrome	88.41	22.10	-	-	**110.51**
PC CRTs	970.00	1,152.31	0.12	23.99	**2,146.41**
PC Flat Panel	1,899.94	2,280.66	2,063.39	1,035.49	**7,279.47**
Portables	1,502.27	302.82	1,262.56	597.86	**3,665.51**
Total E-Waste Disposal	**23,649.62**	**10,097.42**	**6,890.61**	**2,926.26**	**43,563.92**

Products

State: Washington
Year: 2015

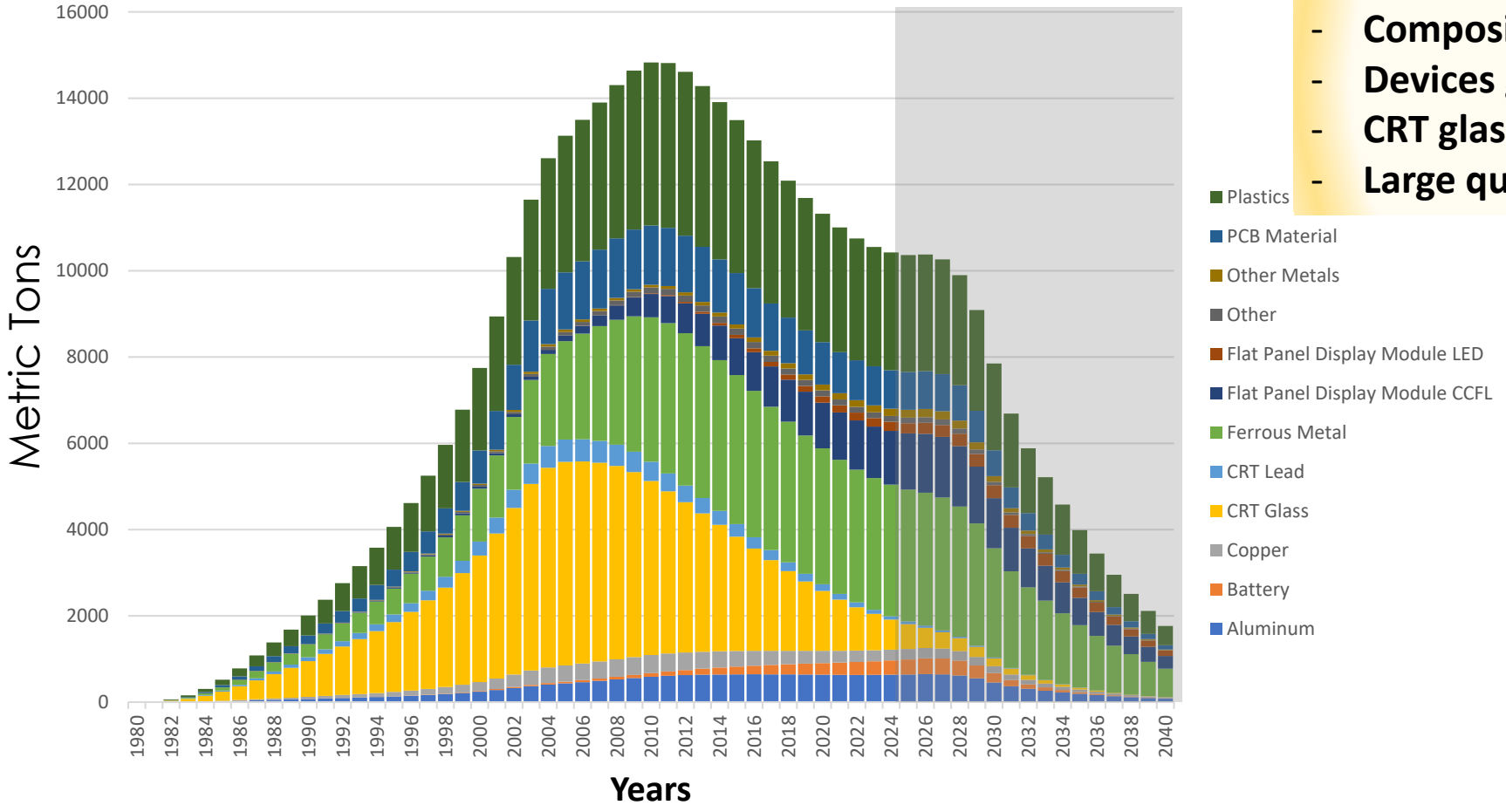
RES – Residential
EDU – Educational institution
COM – Commercial organization
INST – Institutions (e.g., hospitals)

Material	Commodity Market	Landfill	Total
Aluminum	1,433.47	644.40	**2,077.87**
Battery	399.60	180.19	**579.79**
Copper	805.13	361.33	**1,166.45**
CRT Glass	5,909.62	2,649.29	**8,558.91**
CRT Lead	653.33	292.89	**946.22**
Ferrous Metal	7,697.45	3,454.37	**11,151.81**
Flat Panel Display Module CCFL	1,903.77	854.71	**2,758.48**
Flat Panel Display Module LED	169.11	75.84	**244.95**
Other	328.04	147.62	**475.66**
Other Metals	215.93	97.21	**313.14**
PCB Material	2,648.43	1,189.03	**3,837.46**
Plastics	7,907.32	3,545.85	**11,453.17**
Total E-Waste Disposal	**30,071.19**	**13,492.73**	**43,563.92**

Materials

Material breakdown of E-waste: ADEPT

Material Breakdown for Landfill for Products Sold through 2025

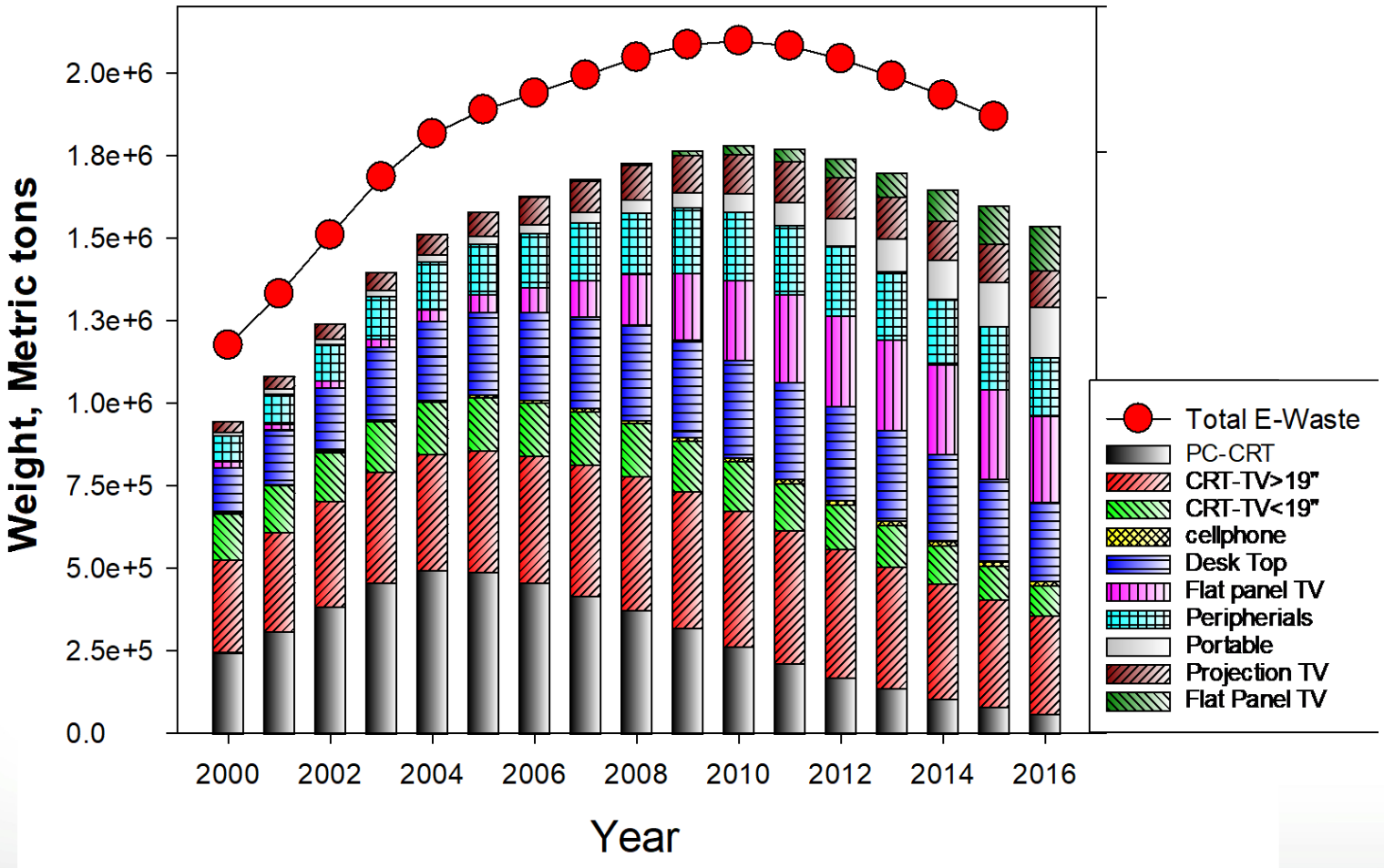


ADEPT – Multi-year output 1990 to 2040

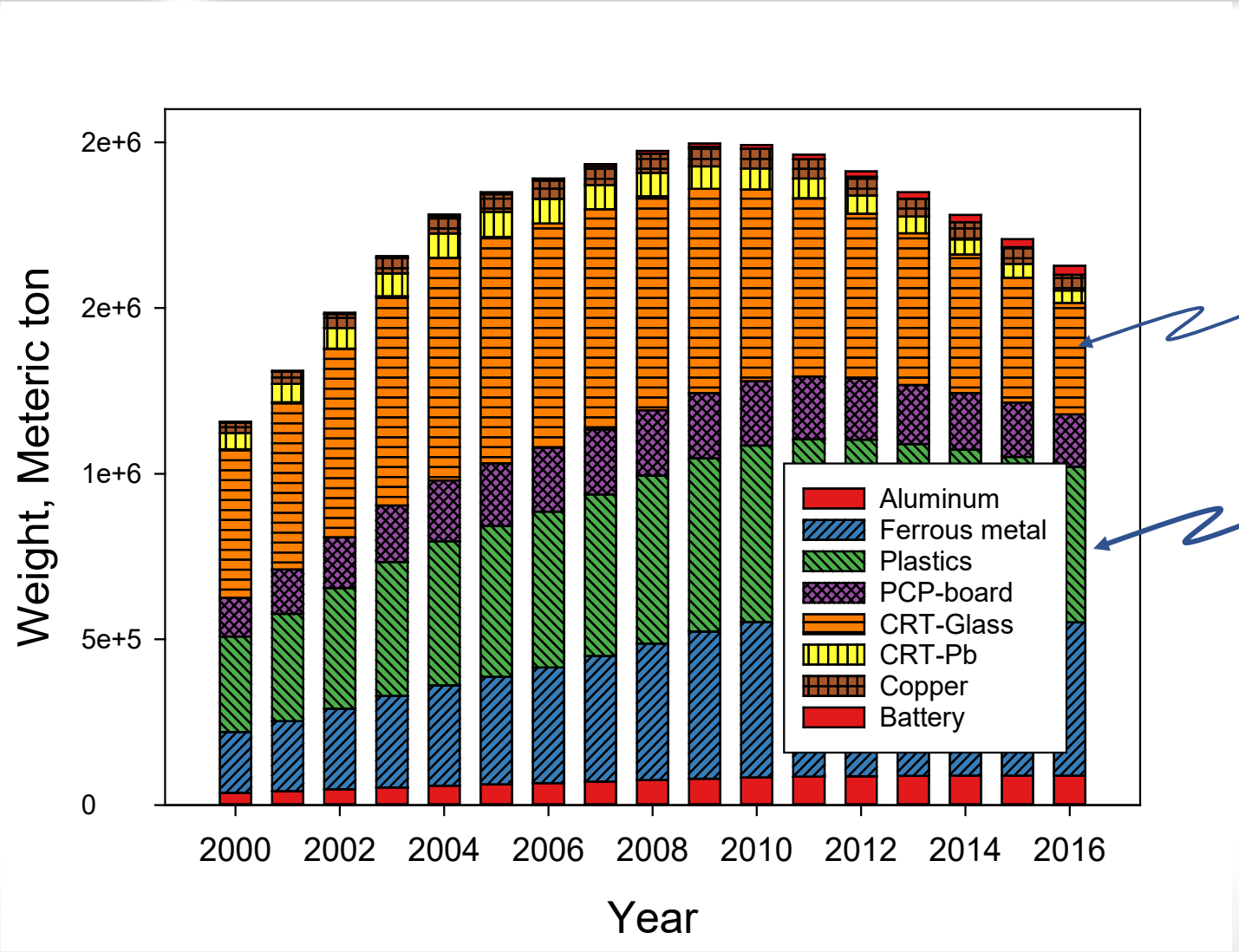
- **Exponential growth between 1990 to 2010**
- **Composition varying in the last 20 years**
- **Devices getting lighter**
- **CRT glass generation in decline**
- **Large quantities of CRT glass in storage**

Generation of E-Waste in the US

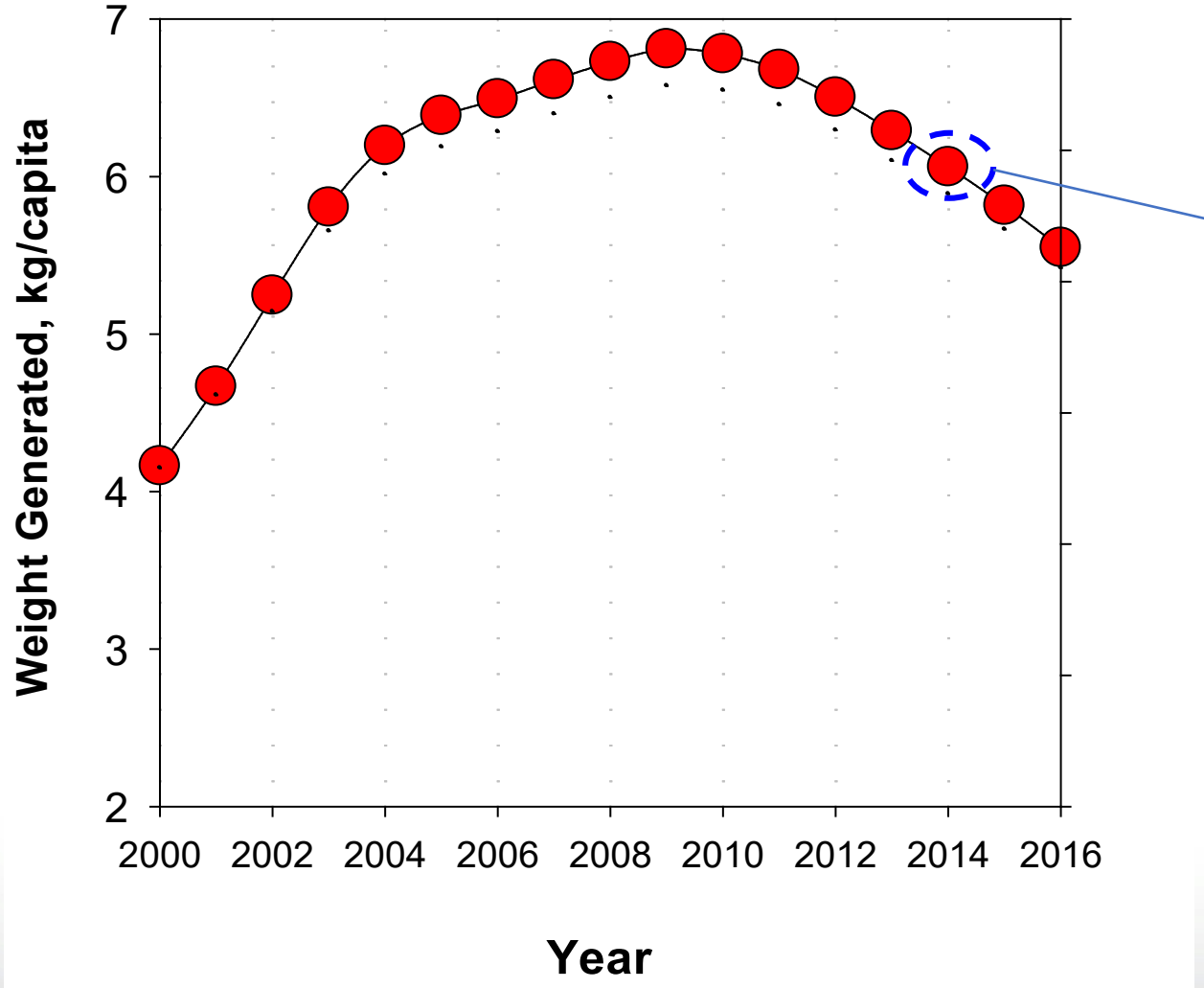
(in millions of tons)



Change in the material composition E-waste



Estimated E-Waste Generation per capita



Total Electrical and Electronics Equipment Waste

Country	Kg/capita
Global	6.1
Australia/New Zealand	17.3
Americas	16.6
Europe	11.6
Asia	4.6
Africa	1.9

Source: United Nation University (UNU) and Global E-waste Monitor, 2017

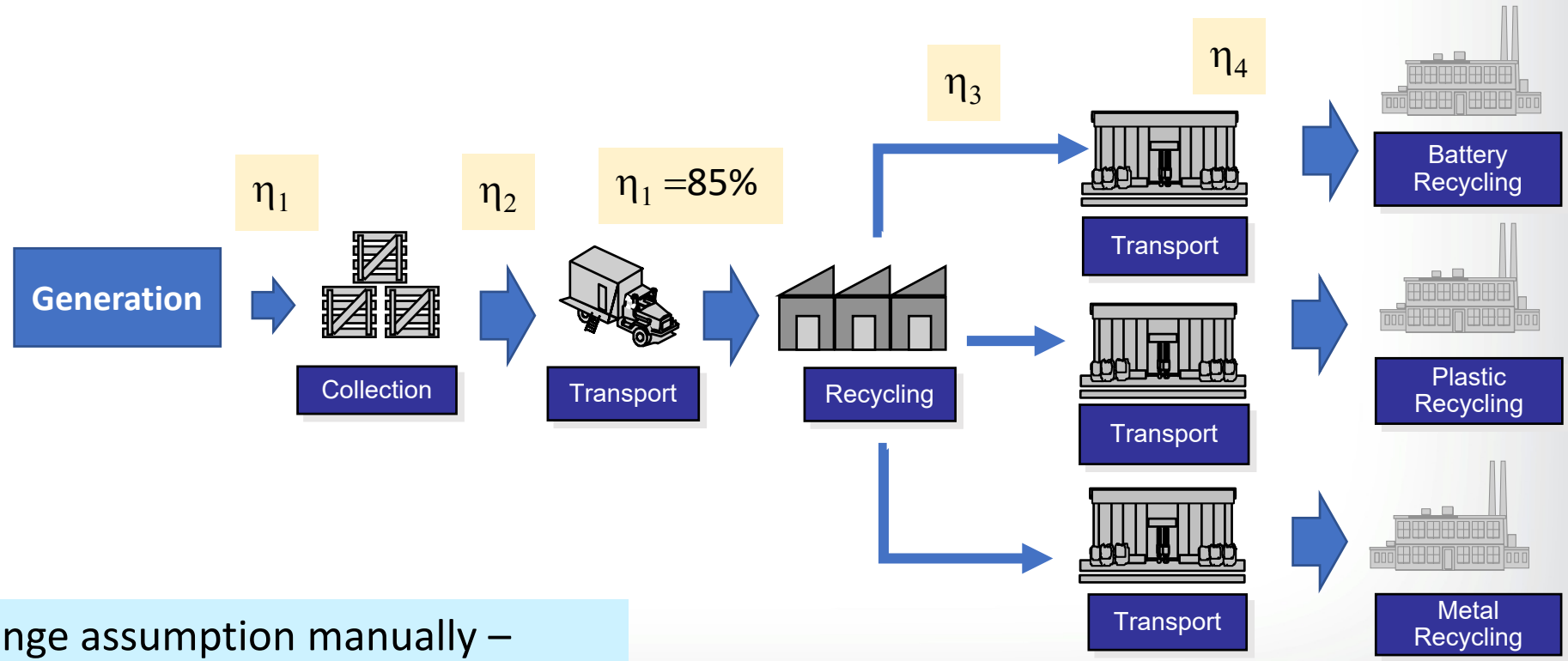
Advanced Setting of ADEPT

Control Panel Behavior Tab

- Behavior Table – assumptions
  Process Efficiency, % material that goes to landfill for each stage
- Device composition
- Device weights
- Market share
- Lifetime
- Second life

Example of Behavior shows assumptions made for each products

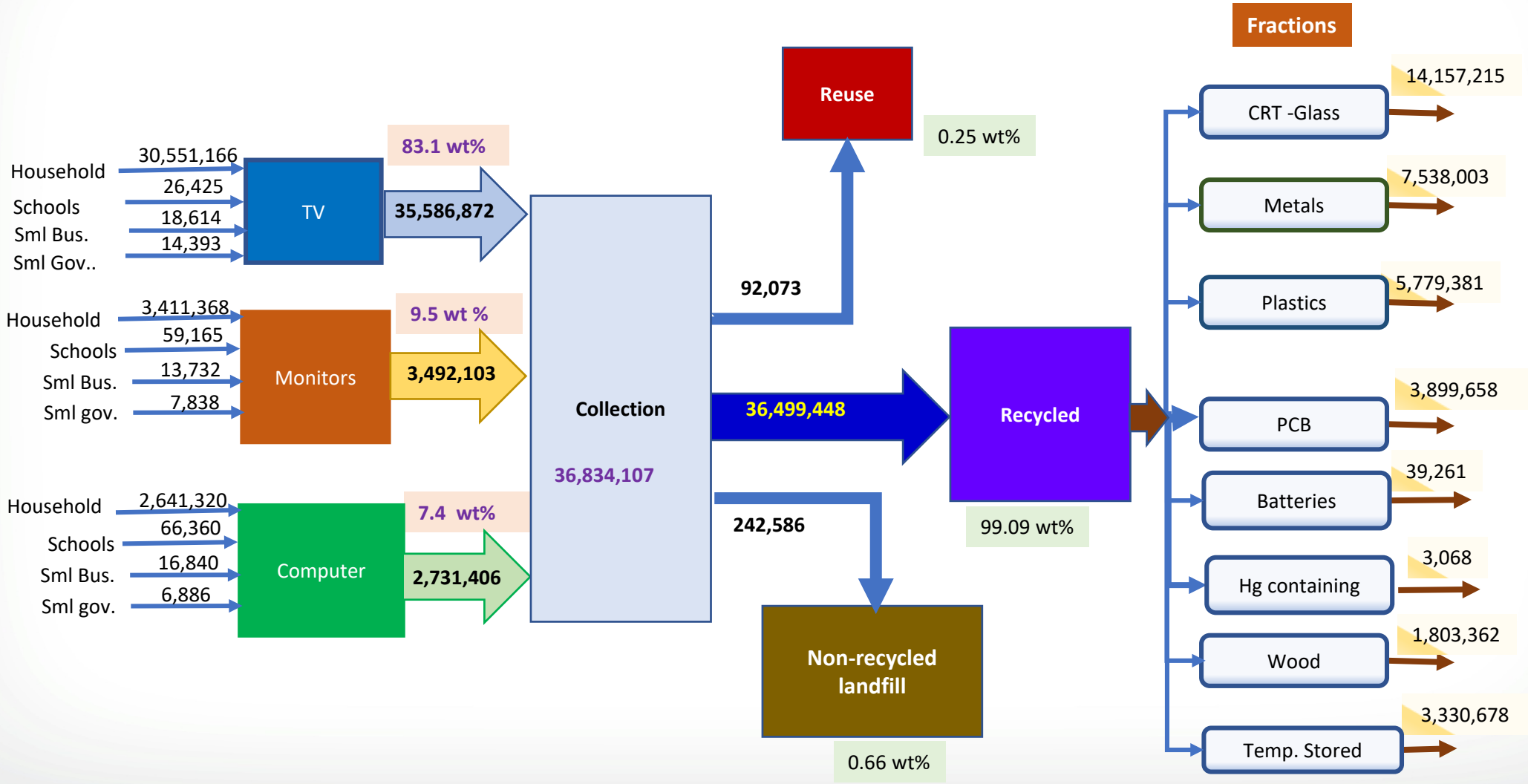
Waste Flows	Product	Recycled	2nd Use	Landfill
1st Use	Desktops	55%	20%	25%



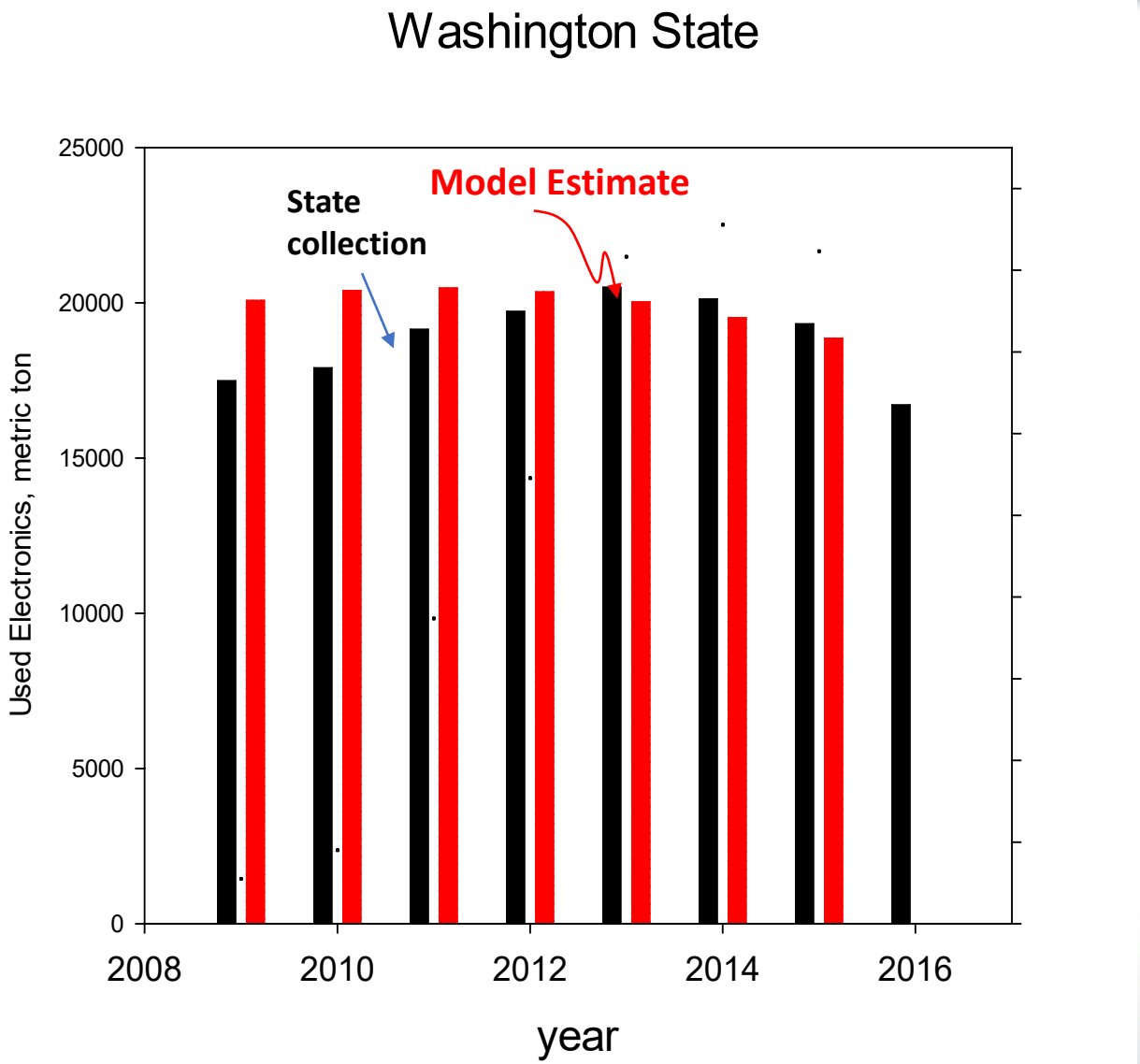
Advanced users can change assumption manually – e.g. scenario analysis

Model Validation

E-Cycle Washington State 2016 (State collected data, weight in lb)

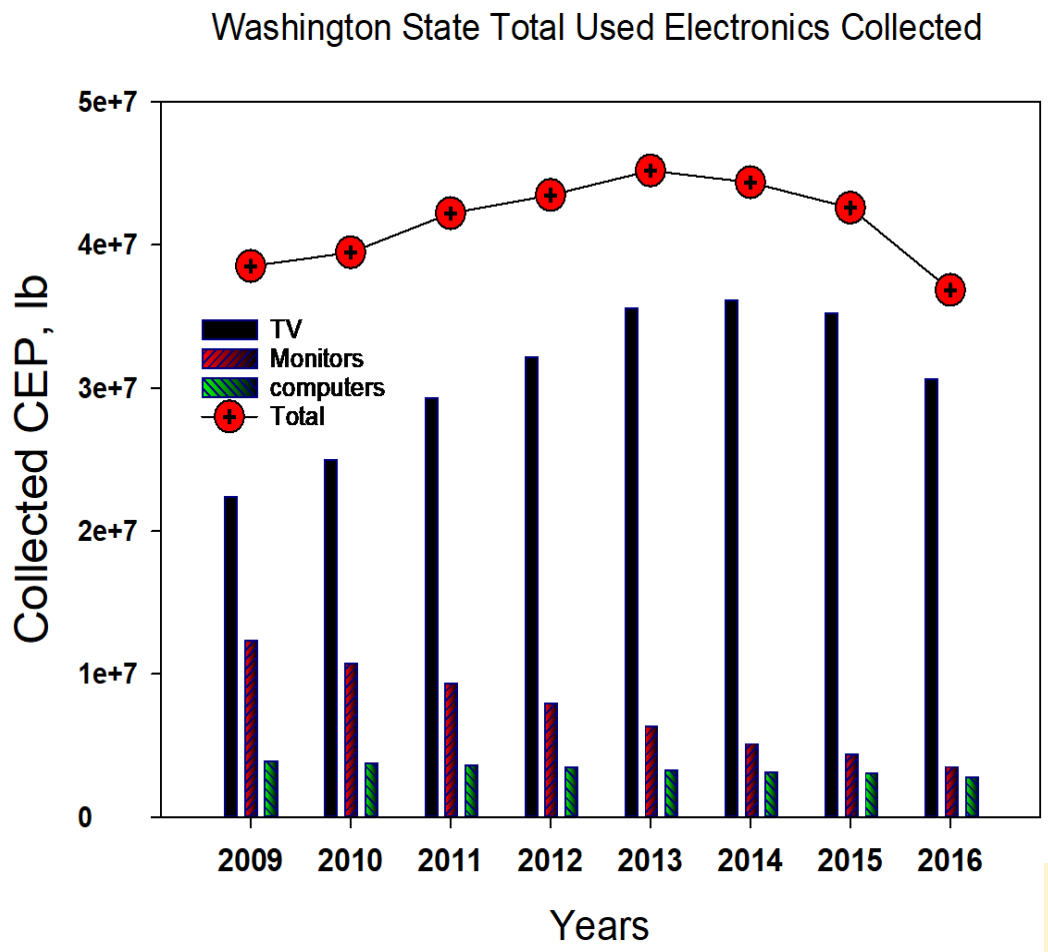


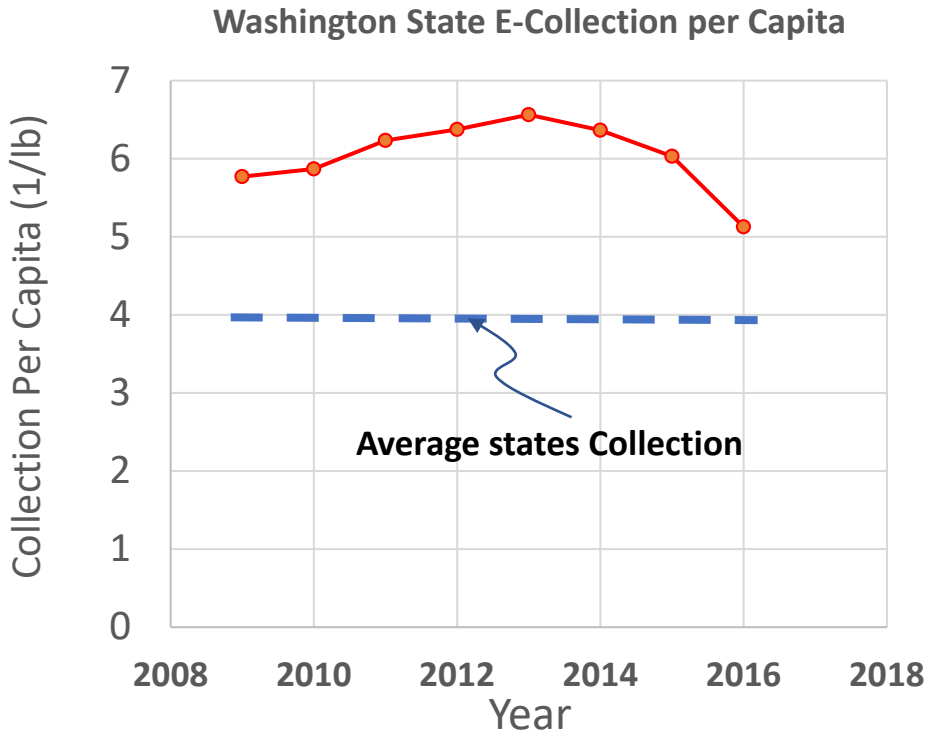
Comparing Washington State collection with model prediction for EoL



State collection	Model estimate
2009	80%
2014	100+%

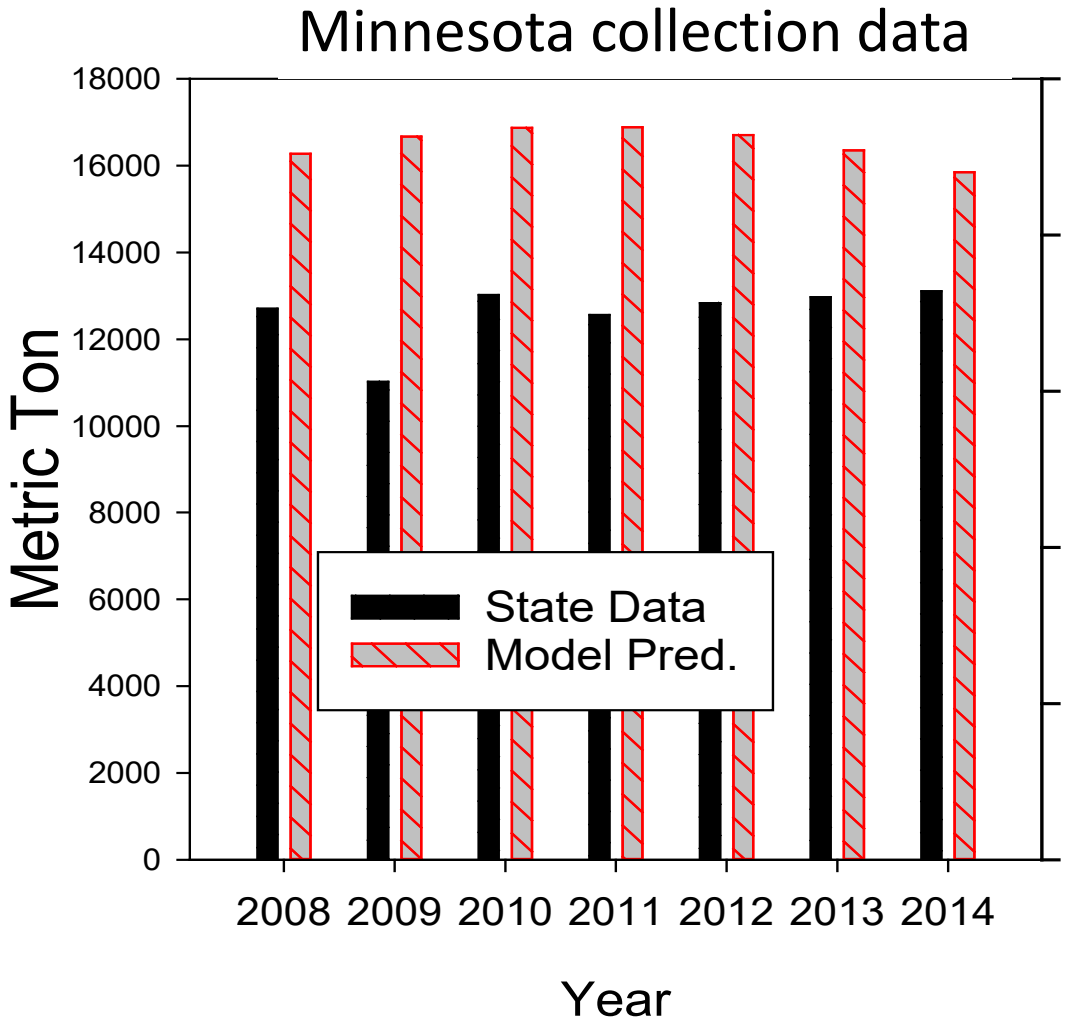
Washington State E-waste Collection





According to "Waste 360" in 2014, US generated 7.8 million tons, which is 48.6 lb/inhabitant

Comparing Minnesota E-waste Collection with ADEPT Estimates

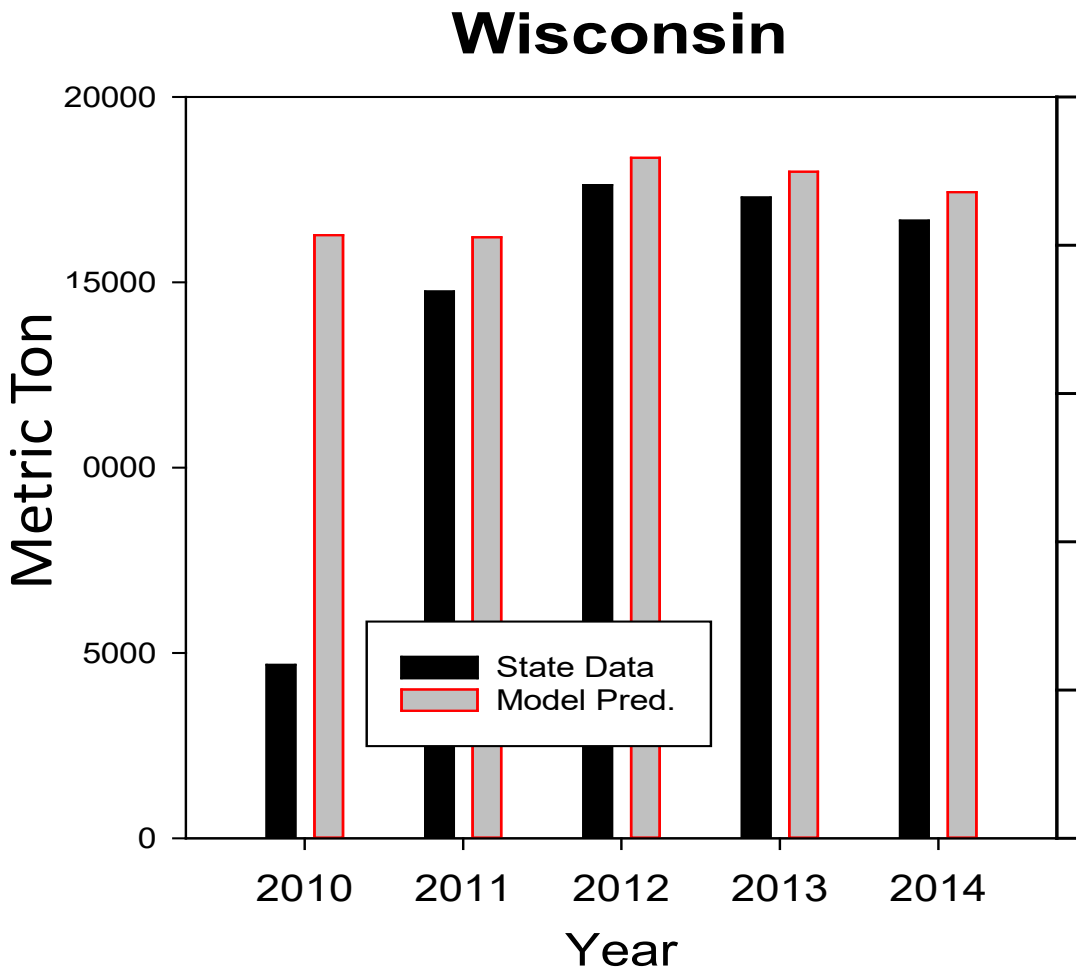


Passed in the 2007 Session/Amended 2016

- Manufacturer Responsibility based on sales weight
  - Market-based Extended Producer Responsibility (i.e., higher cost efficiencies and substantial landfill diversion)
  - Not based on return share or consumer fees on products as in other states
  - Manufacturers, collectors, recyclers and retailers
  - Selective collection and recycling, an increased burden on local governments

Minnesota Act has a broader scope and device screen size designation than other states

E-cycle Wisconsin Department of Natural Resources



Electronics Banned from Wisconsin Landfills and Incinerators

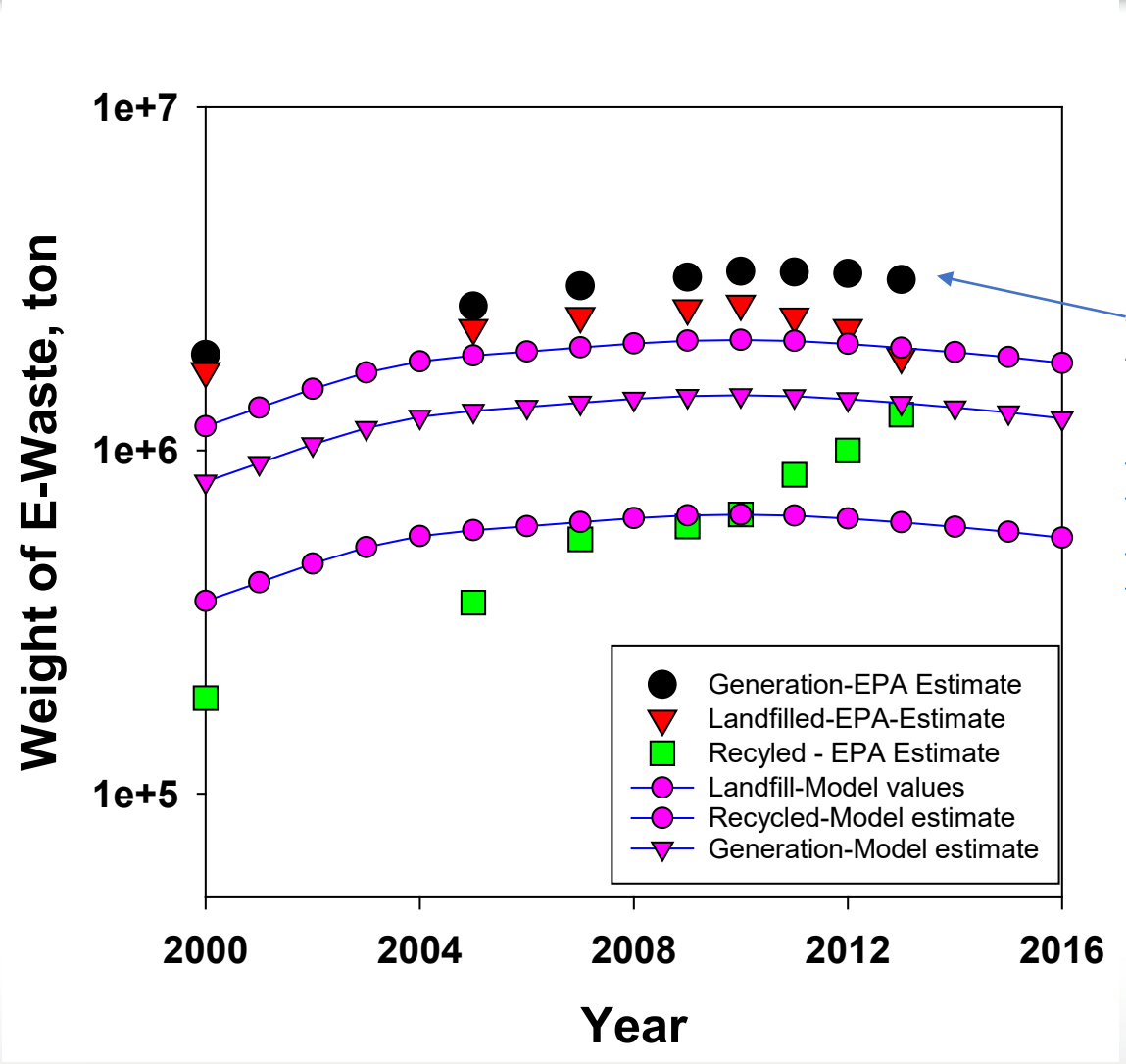
- **Televisions**
- **Computers** *(desktop, laptop, netbook and tablet computers)*
- **Desktop printers** *(including those that scan, fax and/or copy)*
- **Computer monitors**
- **Other computer accessories** *(including mice, keyboards and speakers)*
- **DVD players, VCRs and DVRs**
- **Fax machines**
- **Cell phones**

State Collection/ Model estimate	
2011	90%
2014	96%

The 2009 Wisconsin Act 50 banned most electronics from state landfills and incinerators. Electronics must be reused or recycled or managed as hazardous waste under federal and state hazardous waste laws.

E-Waste Generation and Landfill Disposal

Model Prediction vs US EPA Data



Source:
Advancing Sustainable Materials Management: Facts and Figures

https://www.epa.gov/smm/advancing-sustainable-materials-management-facts-and-figures

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Current Status and Data Gaps

- Flow model has been reviewed by several groups – states, EPA program and regional offices, recyclers, academics
- Provides good estimates of used electronics products and material composition for states that are not collecting data
- Indicates changes in product design favor reducing product weight as opposed to reducing toxicity or increasing recyclability
- May identify a discrepancy between model prediction and state data
  - Could be due to selectivity in collection and recycling for products with high materials values and low processing costs (e.g., TVs with CRTs cost high to recycle compared to computer or laptops)

Model Limitations and Data Gaps

- Limited regionally distinct data on sales, collection and disposition. Regional models could show the gap in collection, recycling and infrastructures between rural and urban area
- Lack of product sale projections
- Characterization of regional flows and final disposition
- Does not consider recycler market economics, e.g., impact of commodity market prices on recycling flow process

Access the Alternatives for Disposition of Electronics Planning Tool (ADEPT)

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Fraction of Used Electronics in the US