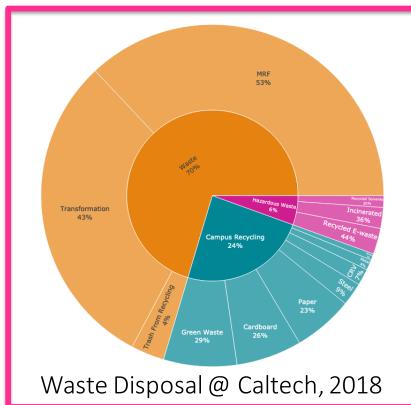
Achieving Net-Zero Lab Waste @ Caltech

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What is Waste Value (WV)?

Waste Value $(WV) = Waste\ Fraction \cdot [Disposal\ Cost + Environmental\ Cost - Recycle\ Cost]$

- Waste Value can be calculated for each type of waste (single-use plastics, cardboard, etc.), from each source (labs, facilities, etc.)
- "Waste Fraction" is the fraction of a waste source of a specific type
- "Disposal Cost" is the cost to properly dispose of that source or send to a landfill
- "Environmental Cost" is the cost of the damage of that source to the environment
- "Recycle Cost" is the cost to recycle or reuse that source—the cost of the sustainable alternative



Why is it important?

- Hazardous Waste accounts for only 6% of total waste generated (by weight), but more than 85% of yearly disposal costs
- The dangerous nature of chemical and contaminated waste makes it difficult and costly to throw away or recycle in compliance with state and federal regulations
- Labs are a significant source of waste:
- A 2015 study at University of Exeter found that their Bioscience Department produced as much as 280 tons of plastic waste per year¹ For every ton of plastic waste recycled, 5,774 kWh of energy is saved²
- Waste Value can be used to: identify sources of waste with greatest impact, direct decision of whether to recycle/reuse or mitigate generation of that source
 - A negative WV indicates recycle costs outweigh disposal costs (these sources should be mitigated)
 - A positive WV indicates disposal costs and cost to environment are high enough that recycling is financially viable

[1]"Labs should cut plastic waste too". Nature, 528, p. 479. [2]"Benefits and Savings of Recycling Plastic", Accessed online: https://homeguides.sfgate.com/benefits-savings-recycling-plastic-79284.htm

WV Case #1: Plastic Pipet Tips

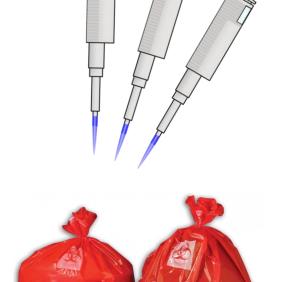
WV = -\$2,067.1 to \$6,207.48 per ton

Assumptions

- 100% polypropyle pipet tips
- Waste Fraction: pipet tips comprise 10-50% of total hazardous waste by weight
- Disposal Cost: average cost as \$ hazardous waste disposal for 2018 / tons of waste
- Environmental Cost: quantifies monetary impact of...
 - climate pollution, ozone depletion, ocean acidification, and eutrophication
 - excludes marine, human, & terrestrial toxicity
- Recycle Cost:
 - recycling/reuse method: Grenova TipNovus pipet tip cleaning machine

Sources of Uncertainty

- Waste Fraction: actual fraction unknown
- Environmental Cost: uncertainty in materials cost for PP manufacturing, significant uncertainty in assigning a \$ cost to ecosystem services
- Recycle Cost:
 - % savings achieved by pipet tip reuse (estimated 30-90%)
 - # machines needed (depends on waste fraction)
 - # employees needed (assumed 1 employee can operate 3 machines performing 4 wash cycles per machine per hour, working at 60-80% efficiency = 22,118 – 29491 tips cleaned/employee/day)





Grenova TipNovus

WV Case #2: Solvents

WV = +\$27.87 to + \$83.59 per ton

Assumptions

- Waste Fraction: (Tonnage of haz. waste incinerated in 2018 + tonnage of solvents recycled in 2018) / total hazardous waste in 2018
- Disposal Cost: average cost as \$ solvent disposal for 2018 / (Tonnage of haz. waste incinerated in 2018 + tonnage of solvents recycled in 2018)
- Environmental Cost: Product of:
 - Kg CO₂ / production of one ton of acetone
 - Conversion factor for Kg CO₂ to tons of CO₂
 - SC-CO₂ ("measure in \$ of long-term damage done b y a ton of CO₂ emissions in a given year," tabulated by EPA.gov). Numerical value used in upper estimate of WV calculation is for a 2.5% discount rate, while lower WV bound is for a 5% discount rate
- Recycle Cost: average recycling revenue for 2018 / (Tonnage of haz. waste incinerated in 2018 + tonnage of solvents recycled in 2018)

Sources of Uncertainty

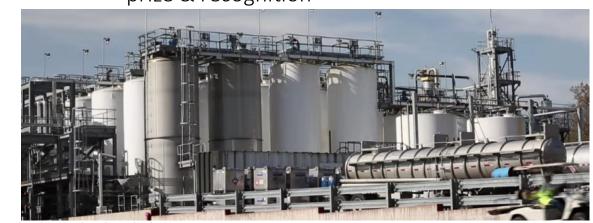
- Environmental Cost: Estimating CO₂ produced per ton of generic solvent with acetone as the generic solvent. Introduces error, as the other numerical values are tabulated for consolidation of all solvents.
- However, justified this assumption because acetone is one of the most common solvents used in labs, and likely constitutes over 40% of the solvent waste
- Did not factor in that Kg of CO₂ / ton solvent produced is different for pure solvent production vs. recycled solvent purification
- Disposal and Recycle Cost Uncertainties:
 - Value to normalize revenue with respect to
 - What percentage of the recycling revenue accounts for solvents
 - Uncertainty in cost differences for different methods of disposal and how this factors into average solvent disposal cost from 2018

[1] "Enhancing Solvents' Sustainability", Accessed online: https://www.chemistryworld.com/news/enhancing-solvents-sustainability/3010810.article [2] "The Social Cost of Carbon", Accessed online: 19 january 2017s napshot.epa.gov/climatechange/social-cost-carbon.html

WV: Next Steps

Obtain more specific, accurate data on lab waste

- Caltech two-month Lab Weigh-In
 - 1. First month:
 - Labs record all waste generated (# solvent bottles, gloves, tips, centrifuge tubes, etc.)
 - Rank labs by amt. of waste
 - Second month:
 - Labs employ sustainable options to reduce waste
 - Compete with other labs to reduce waste the most for a prize & recognition





#1 Waste

Reducing



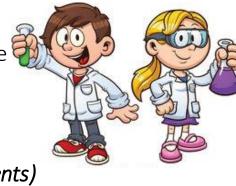
Pipet tips

- Streamline purchasing to brands made of same materials (100% polypropylene)
- Obtain accurate metrics of yearly pipette tip expenditures, uses/applications
- Analyze investment costs/benefits of
- using TipNovus machines (alternatives?) Solvents
 - Obtain values for specific solvents and do a complete breakdown of solvents WV's
 - Obtain recycling cost values vs. disposal cost values specifically from Veolia (Caltech's vendor)
 - Analyze ways to segregate waste more effectively in order to increase total solvent recycled

How can you contribute?

Be mindful of your lab waste

Only place *contaminated* waste in hazardous waste disposals (once placed in bin, it must be treated as hazardous)



Ready for X Pick-up

CALTECH Pasadena, CA

HAZARDOUS WASTE

Complete and Attach to Containe
When Waste Is First Generated

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Make it pH neutral (separate your solvents)

• Only pH neutral solvents can be recycled! Label your solvent waste

• The two top labels are most important!

Complete the Green Labs Scorecard

https://sustainability.caltech.edu/engage/green-labsnetwork

Sign your lab up for the Lab Weigh In

Contact Max Christman to learn about Green Labs!



Final Class Project ChE 190 | MS 150 | ESE 100

