NREL
Transforming ENERGY

Environmental and Social Justice Implications of a Circular Plastics Economy

Taylor Uekert, Hope Wikoff, Julien Walzberg, Meredith Doyle, and Birdie Carpenter

ACLCA 2023

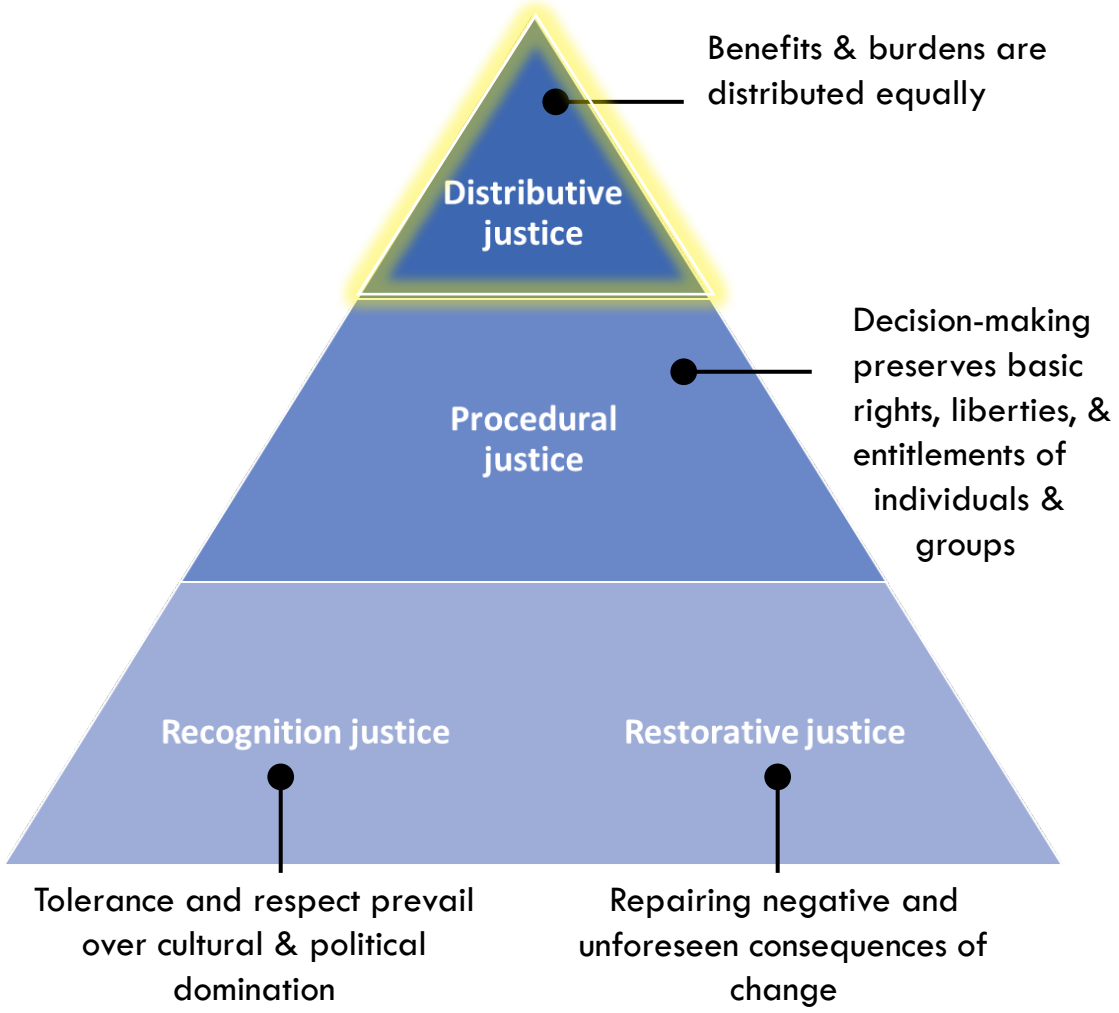
September 27th, 2023

Photo by Dennis Schroeder, NREL 46840

What are EJ and SJ?

- **Environmental Justice (EJ)** = fair treatment and meaningful involvement of all people in the development, implementation, and enforcement of environmental laws, regulations, and policies.
- **Social Justice (SJ)** = fair and equitable division of resources, opportunities, and privileges in society.

Environmental justice dimensions



https://www.epa.gov/environmentaljustice; J.T. Jost and A.C. Kay, Social justice: History, theory, and research, **2010**

Why EJ and SJ?

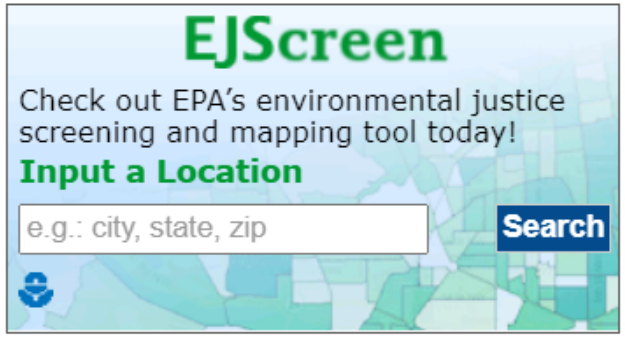
- EJ and SJ are a **basic human right** → allows everyone to have agency over decisions that impact their lives.
- Without EJ and SJ, technologies may:
  - Jeopardize people's lives and sustainability
  - Cause damage that must be mitigated or repaired
  - Face social acceptance issues

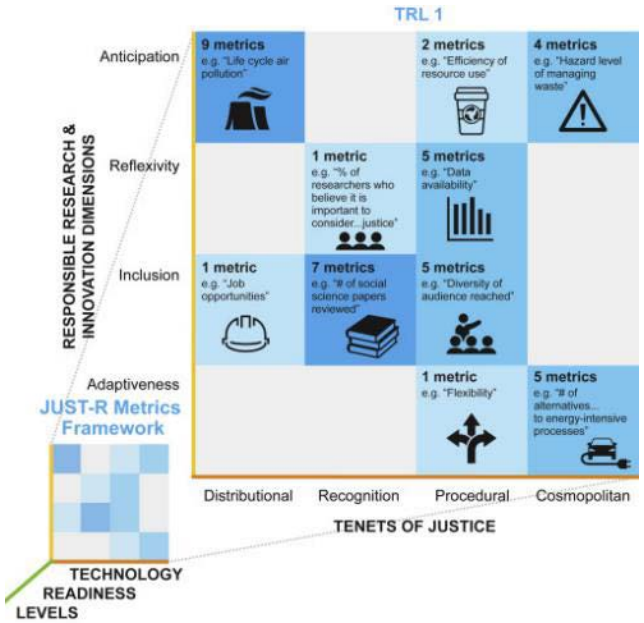
Protest against Louisiana's "Cancer Alley" where 150+ petrochemical facilities release toxic air emissions, disproportionally affecting minority and low-income communities.

https://www.rollingstone.com/politics/politics-features/louisiana-cancer-alley-getting-more-toxic-905534/

Existing indicators and frameworks

- Sustainability frameworks have (too) many social indicators:
  - Social Life Cycle Assessment (LCA) → 150+
  - Global Reporting Initiative (GRI) → 150+
  - Sustainable Development Goals (SDGs) → 200+
  - Many indicators are similar across frameworks.
- EJ tools require location → only suitable for deployed technologies:
  - DOE's EJ dashboard / EPA's EJScreen: 12 environmental indicators, 7 socioeconomic indicators
  - CalEnviroScreen 4.0: 13 environmental indicators, 8 socioeconomic indicators
- What about early-stage technologies?
  - JUST-R framework → focused on energy justice
- **Our objectives:**
  - Develop new analysis framework to include EJ and SJ for early to mid technology readiness level (TRL) innovations
  - Pilot the framework with a plastic recycling case study
  - Guide technological choices towards **more just and equitable outcomes**





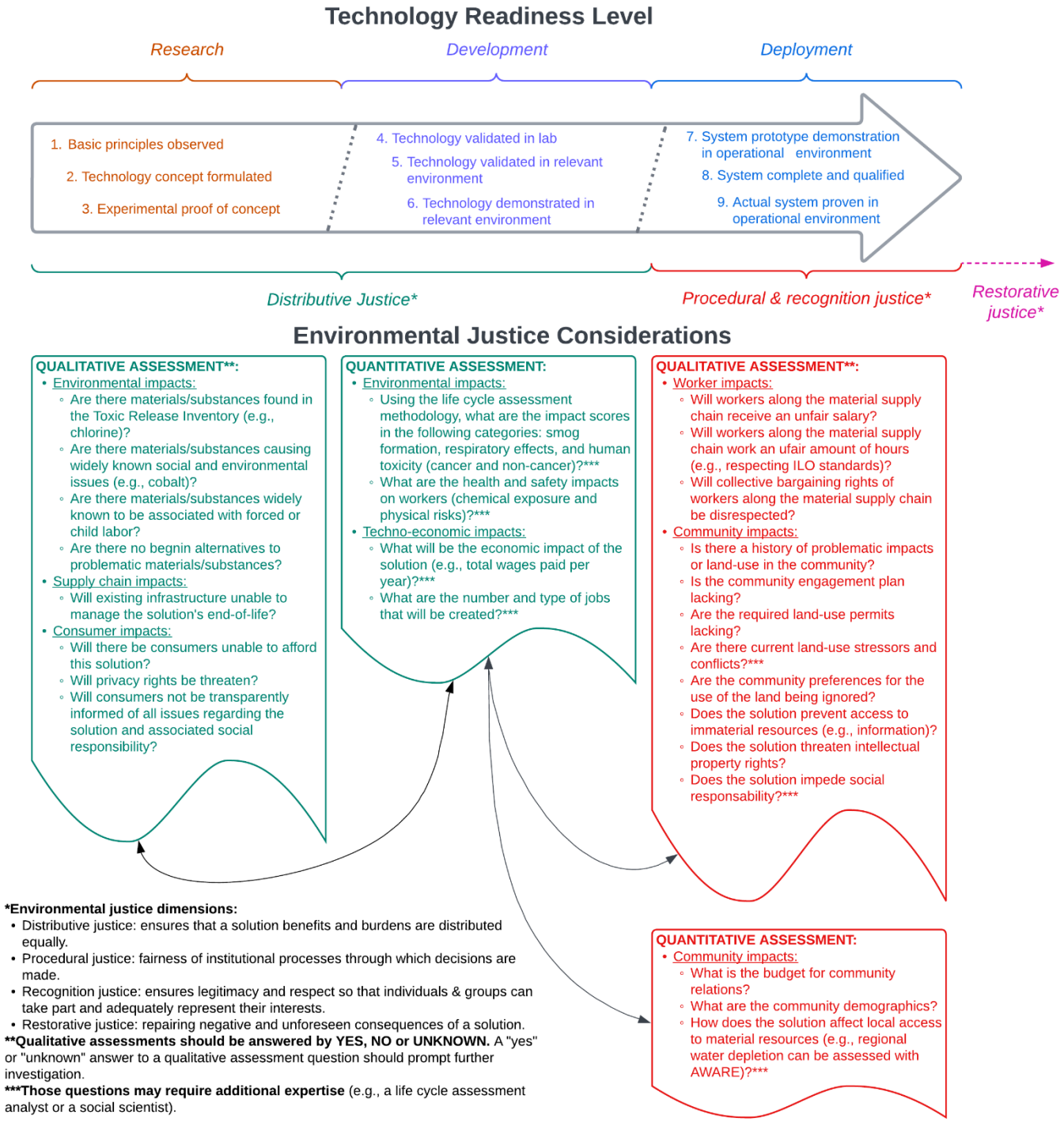
bottle
changing the way we recycle™
U.S. DEPARTMENT OF ENERGY

N. Dutta et al., *Joule*, **2023**, *7*, 431-437

Framework overview

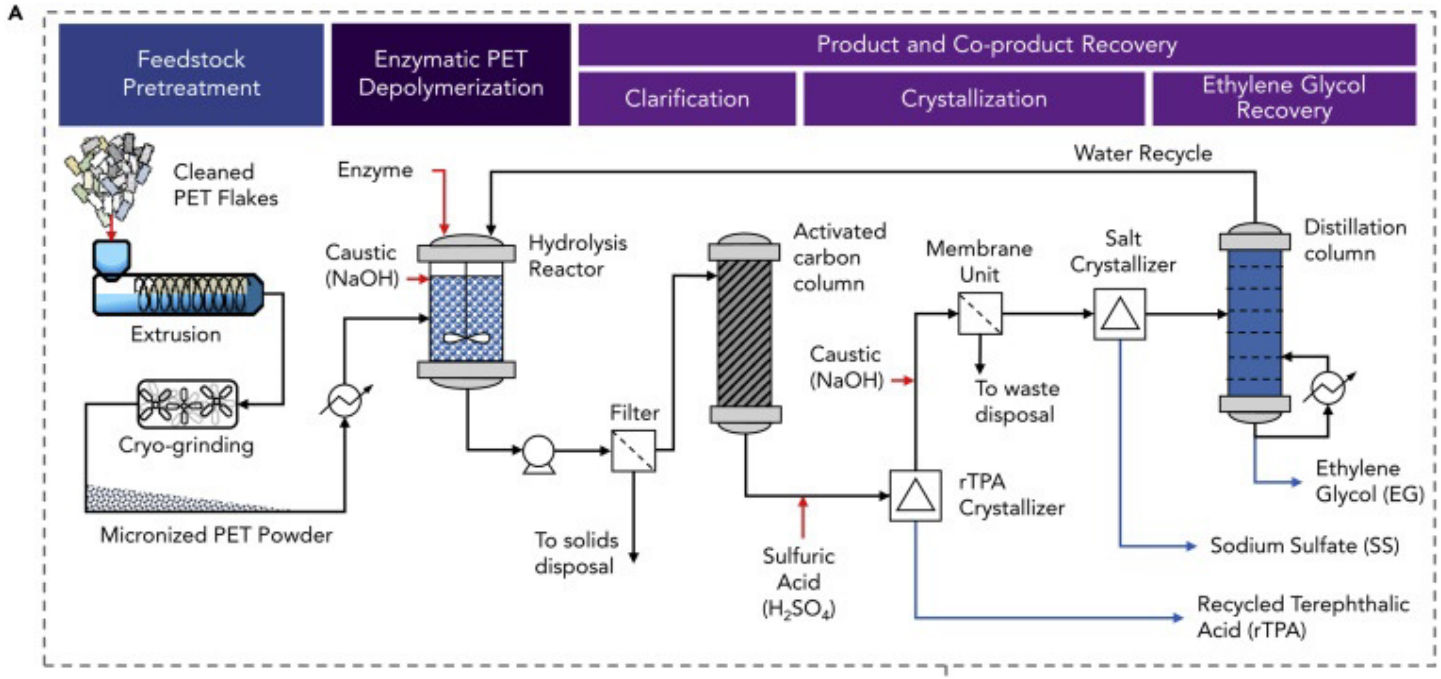
- The framework uses questions to establish the EJ/SJ profile of a technology.
- Low TRL (1-3):
  - Qualitative
  - "First pass" on the main materials within the product/technology
- Mid TRL (4-6):
  - "Second pass" assessment that includes all materials
  - TEA and LCA to inform relevant quantitative EJ/SJ indicators
- High TRL (7-9):
  - Localized impacts
  - Communities involved in the development process

Health and environment | **Affordability and consumer rights** | **Jobs and worker rights**



Example: Enzymatic recycling of PET into TPA

- Enzymatic recycling uses an enzyme, mild temperatures (60°C), and neutral pH (8) to break down polyethylene terephthalate (PET) bottles into the monomers terephthalic acid (TPA) and ethylene glycol.
- Classified as a mid-TRL (in scale-up) "chemical recycling" technology.
- Full technoeconomic analysis (TEA) and LCA available.



A. Singh et al., *Joule*, **2021**, *5*, 2479-2503.

Early-TRL methodology

Recommended for lab-scale researchers to facilitate social-conscious technology development, and for LCA practitioners to help put their work into an EJ/SJ context.

1. Draw a simple process flow diagram
2. Qualitatively answer questions with freely-available resources
3. Consider how to avoid or minimize potential problem(s)
4. Iterate

1. Does your process use materials or substances that are found in the Toxics Release Inventory (TRI)?

Procedure: Search (Ctrl + f) your chemicals in the EPA TRI database. In some cases, you may need to use a proxy for your material (e.g., lead rather than lead iodide).
https://www.epa.gov/system/files/documents/2022-03/ry-2021-tri-chemical-list-03-07-2022_0.pdf

If your answer is No, continue to Question 2.

If your answer is Yes, list the chemical(s):

Could the above chemical(s) be replaced with non-TRI alternative(s)?

If your answer is Yes, list the alternative(s), conduct the same TRI search procedure, and include the results here:

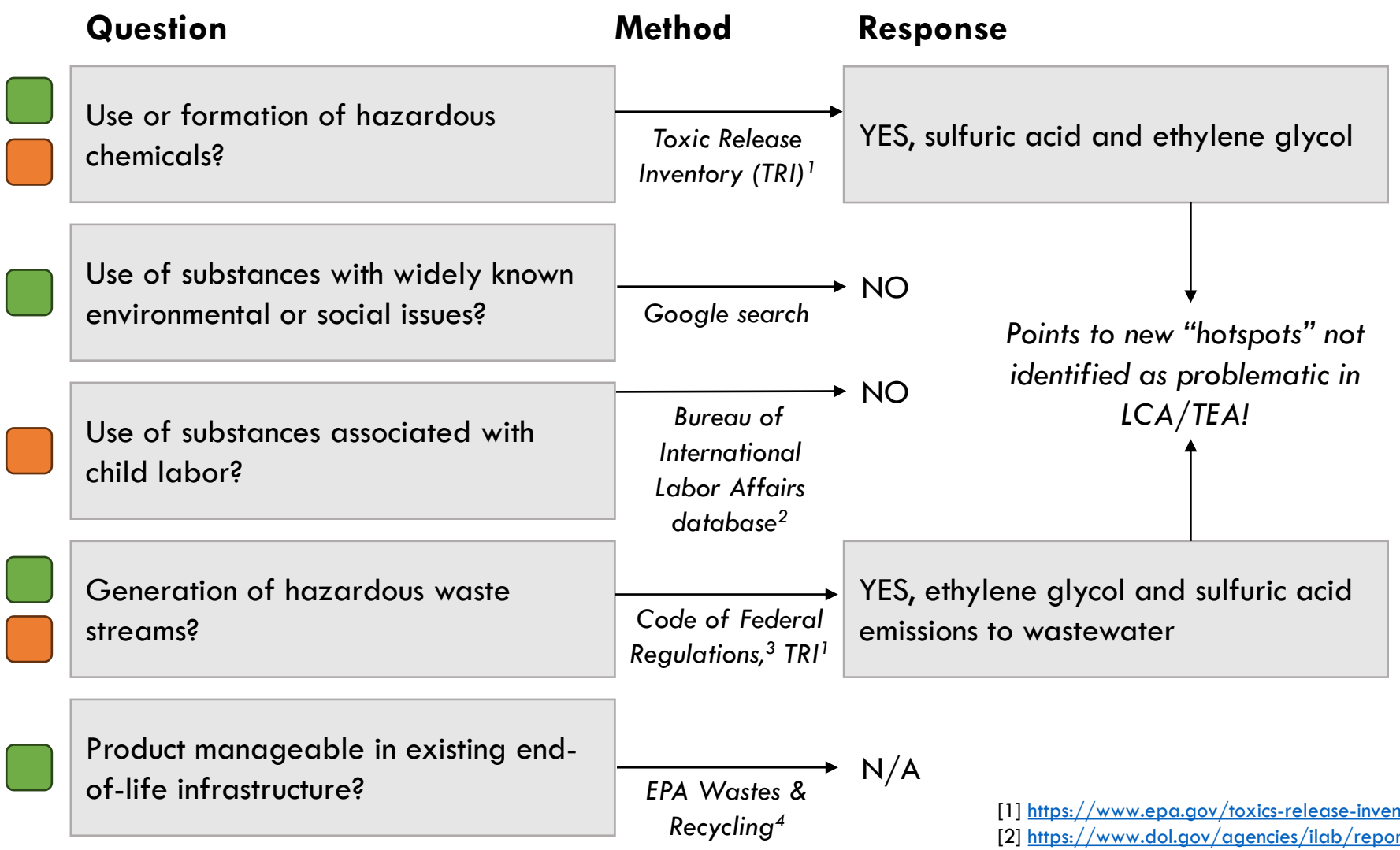
If your answer is No, why must the chemical(s) be involved?

What are some management strategies for preventing the release of the chemical(s)?

Reflection Space: How will you take the above results into consideration when designing your process?

Why are we asking this question? When your process is upscaled, the use of hazardous chemicals will directly affect the safety of workers at your facility. If these chemicals are not managed properly and escape the facility, they will impact the health of local communities and environments. It is also important to plan for proper safety and regulation as they will increase the cost of your process.

Early-TRL results & impact



Action

- Capture more ethylene glycol, which is a co-product
- Explore TPA separation strategies that don't require acidifying the solution

[1] https://www.epa.gov/toxics-release-inventory-tri-program/tri-listed-chemicals;
[2] https://www.dol.gov/agencies/ilab/reports/child-labor/list-of-goods-print;
[3] https://www.ecfr.gov/current/title-40/chapter-I/subchapter-I/part-261/subpart-D;
[4] https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling.

Mid-TRL methodology

Recommended for lab-scale researchers in collaboration with TEA/LCA practitioners to strengthen social-conscious technology development, and for TEA/LCA practitioners to help put their work into an EJ/SJ context.

1. Conduct a TEA/LCA
2. Revisit early-TRL questions and answer new mid-TRL questions quantitatively
3. Consider how to avoid or minimize potential problems
4. Iterate

Mid-TRL results & impact

Revisiting the early-TRL questions and answering quantitatively:

Question	Method	Response
What are the human health impacts?	*LCA*	See table below
Generation of hazardous waste streams?	*LCA, Code of Federal Regulations,[1] TRI[2]*	YES, per kg of TPA, the process emits: • 2.24E−6 kg ethylene glycol to air • 0.17 kg ethylene glycol to water (166 ppm < 1vol% limit) • 7.12E−23 kg sulfuric acid to water • 2.25 kg of solid waste

*DALsecs	Activated carbon	Sulfuric acid	Sodium hydroxide	Cooling water	Process water	Steam	Capital	Enzyme	PET flake	Electricity	Process emissions	Solid waste disposal	Wastewater
Carcinogenics	0.12	5.72	31.54	0.18	5.96	3.94	6.87	0.68	31.22	36.41	0.00	7.92	0.33
Non carcinogenics	0.17	23.91	50.04	0.09	5.14	3.85	14.41	3.41	82.40	29.17	0.22	29.35	1.36
Respiratory effects	0.33	7.63	57.16	0.06	5.23	6.29	2.79	1.60	42.65	83.48	0.00	0.98	0.10
Smog formation	0.00	0.01	0.03	0.00	0.01	0.01	0.00	0.00	0.03	0.01	0.00	0.00	0.00
	Supply Chain										*Facility*		

Action

- Consider methods to reduce sodium hydroxide and electricity use to lower impacts on communities near those plants
- Improve yields to lower waste production and implement suitable controls

[1] https://www.ecfr.gov/current/title-40/chapter-I/subchapter-I/part-261/subpart-D; [2] https://www.epa.gov/toxics-release-inventory-tri-program/tri-listed-chemicals.

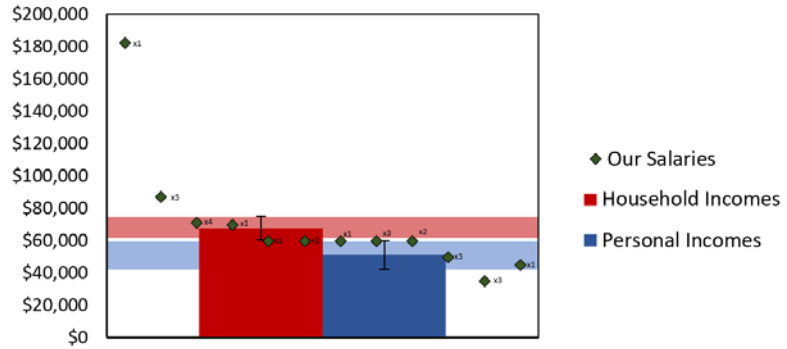
Mid-TRL results & impact

Quantitatively answering mid-TRL questions:

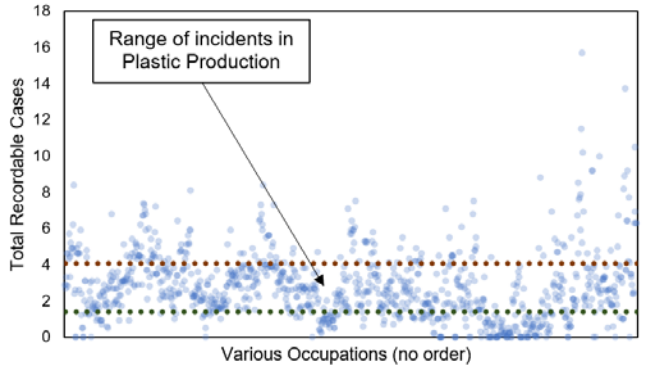
Question	Method	Response
Will consumers be able to afford the solution?	*TEA*	Recycled TPA is 2x more expensive than virgin TPA
What are the number, type, and salary of jobs that will be created?	*TEA, Bureau of Labor Statistics*[1]	25 jobs; salaries fall within or above U.S. personal and household income averages
What are the health and safety impacts for workers?	*Department of Labor*[2]	Accident rates in plastic production fall within average of all job types

Action

- Leverage TEA to identify opportunities to reduce costs so that recycled plastic can be accessible to more communities



Random Scatter of Incidence Rates from BLS, US Dep. of Labor



[1] https://www.bls.gov/iif/nonfatal-injuries-and-illnesses-tables/table-1-injury-and-illness-rates-by-industry-2021-national.htm;
[2] https://data.bls.gov/cgi-bin/srgate.

Try it yourself!

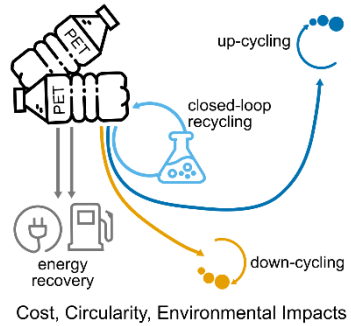
We have developed a guiding framework for evaluating EJ/SJ in early to mid-TRL technology development.

- Try out our worksheet for exploring EJ/SJ in early-TRL technologies
- Please provide comments and feedback on the questions or the process to help us refine it and make it more usable and useful! Contact us at taylor.uekert@nrel.gov

EJ/SJ Worksheet

https://docs.google.com/document/d/1dAmjPVXX2szeqX0utHzbOpE6o5YY8k8e/edit?usp=sharing&ouid=104157144537897841442&rtpof=true&sd=true

Check out more exciting work from our team!



Thursday 28 Sept, 8:30-10:00am

Tapajyoti Ghosh – Comparing parallel plastic-to-x pathways and their role in a circular economy for PET bottles

Thank you!

www.nrel.gov

NREL/PR-6A20-87332

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.