Superstructure Design of Solvent-Assisted Plastics Recycling Processes

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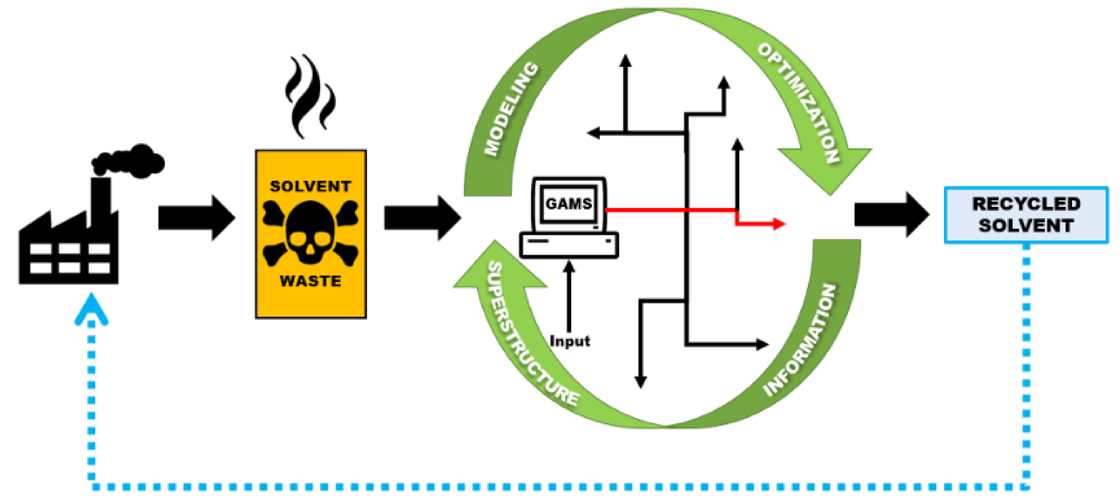
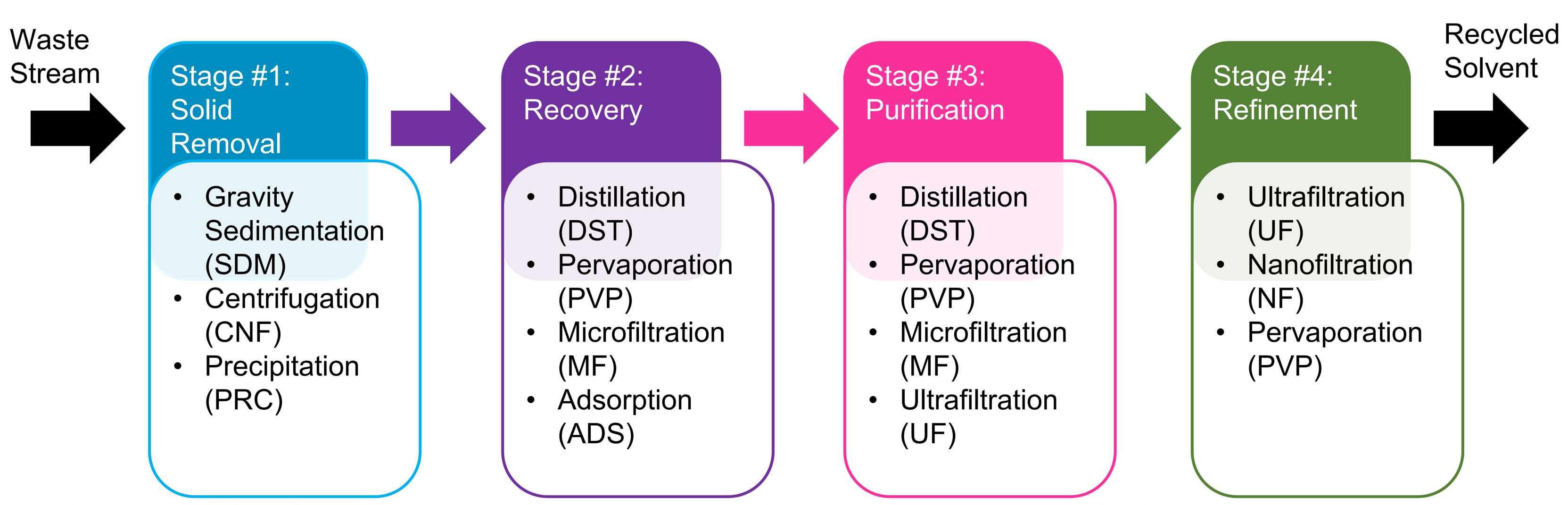
Background & Motivation

- The amount of solvent waste from processes in the global chemical industry is increasing annually
- Implementing solvent recovery methods aims to improve the greenness and sustainability of existing and future chemical processes
- An in-depth model can be used to allow operators and engineers to assess the feasibility of operating a solvent recovery process before implementation



Designing a Solvent Recovery Process



- Applicable for many solvents in industry because of the "superstructure" approach, which provides simultaneous comparison of all possible options to reach the desired result
- Additional stages of separation are implemented based on purity requirements

Technology Models

Model Statistics

Statistic	Value
Number of equations	657
Number of variables	435
Discrete Variables	19
Solution Time (s)	0.375

Model Equations (Ultrafiltration)

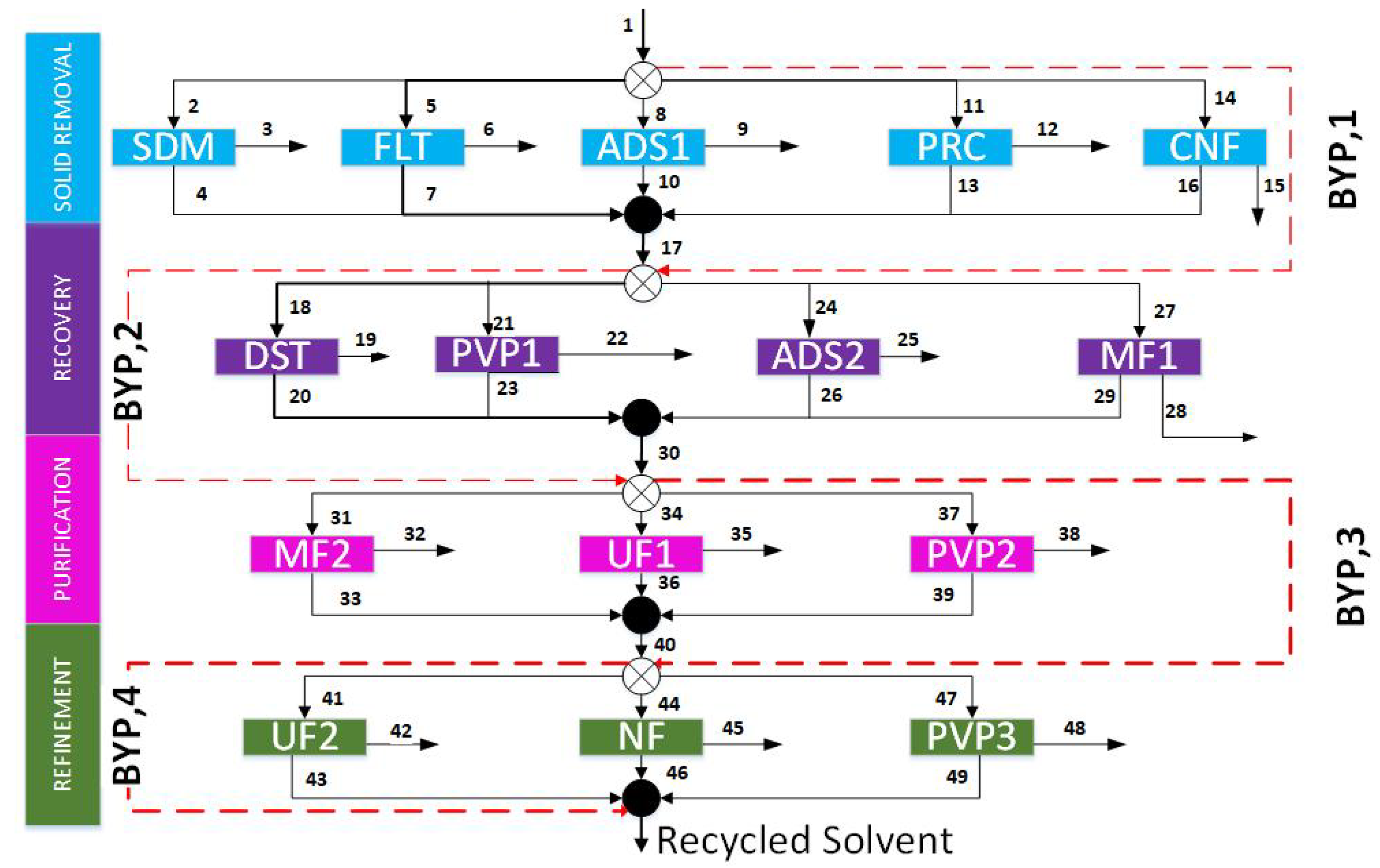
$$\xi_{k,UF} = \frac{M_{Jr_{UF},k}}{M_{Jin_{UF},k}}; \forall k \in K_j$$

$$CF_{UF} = \frac{\sum_{k\in K_j, Jfeed_{UF}} \left(\frac{M_{j,k}}{\rho_k}\right)}{\sum_{k\in K_j, Jretentate_{UF}} \left(\frac{M_{j,k}}{\rho_k}\right)}$$

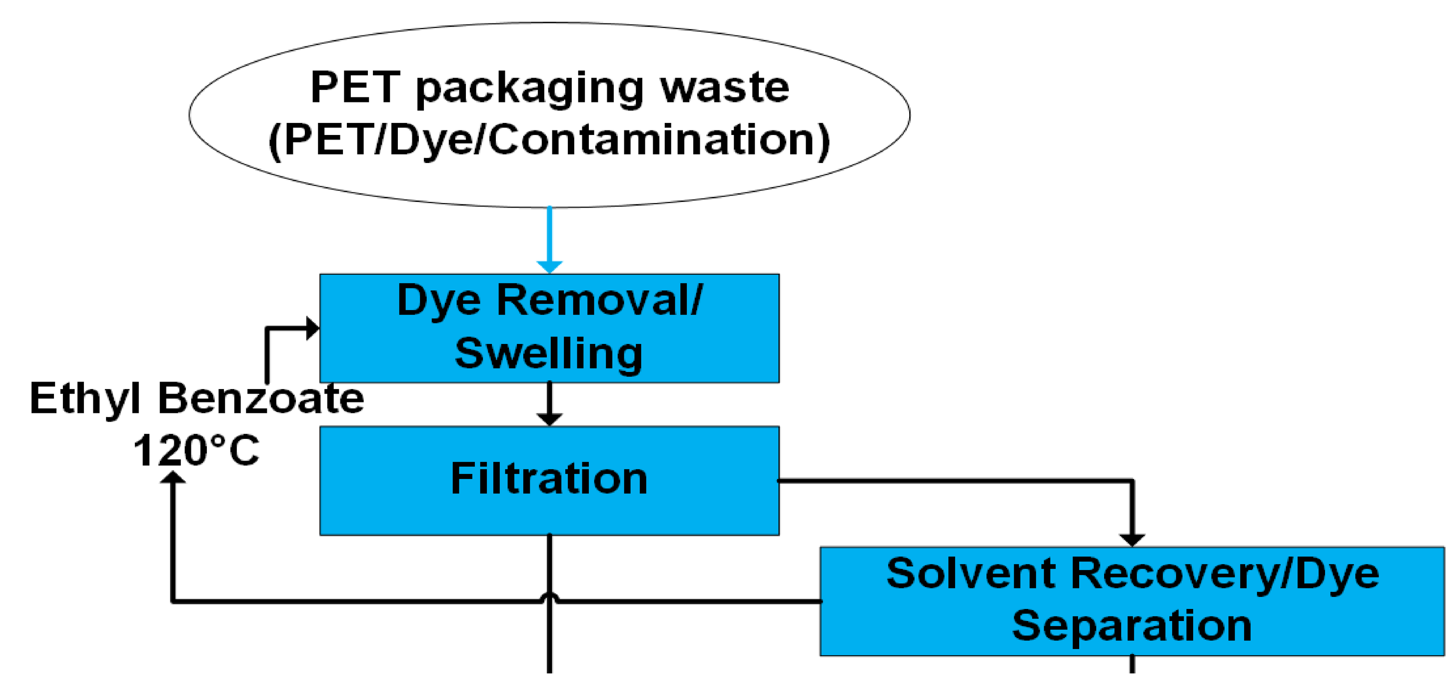
$$\zeta_{UF} Qc_{UF} = \sum_{\substack{k\in K_j \\ j\in J_{feed_{UF}}}} \left(\frac{M_{j,k}}{\rho_k}\right)\left(1 - \frac{1}{CF_{UF}}\right)$$

$$PW_{UF} = Wsp_{UF} Qc_{UF}$$

Superstructure Model



Polyethylene Terephthalate Case Study

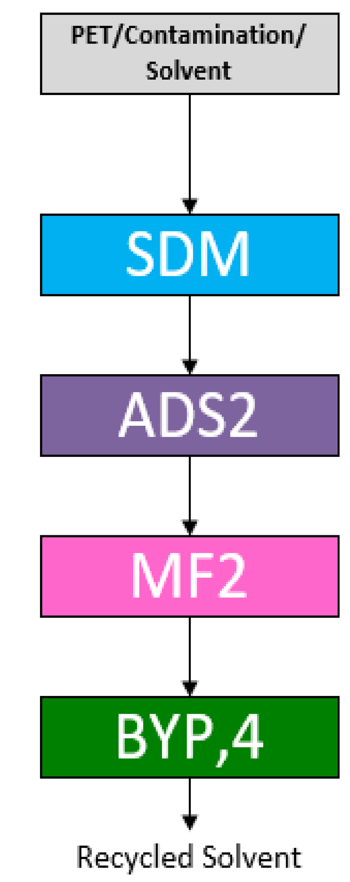


- Analyzing a case study involving the recycling of Polyethylene Terephthalate (PET) using solvent ethyl benzoate
- Producing results using this case study for input specifications provides proof of concept of the tool
- Shows the broad impact of the implementation of solvent recovery across multiple industries.

Chemical	Mass (kg/hr)	Inlet Mass Fraction	Output Requirements
PET	100	0.0421	Removal: >95%
Ethyl Benzoate	2278	0.9575	Purity: >99%
Additives	0.5	0.0002	Removal: >95%
Acetaldehyde	0.5	0.0002	Removal: >95%

- Inlet and outlet specifications are determined
- Purity or recovery is specified for desired solvents and removal is specified for undesired chemicals

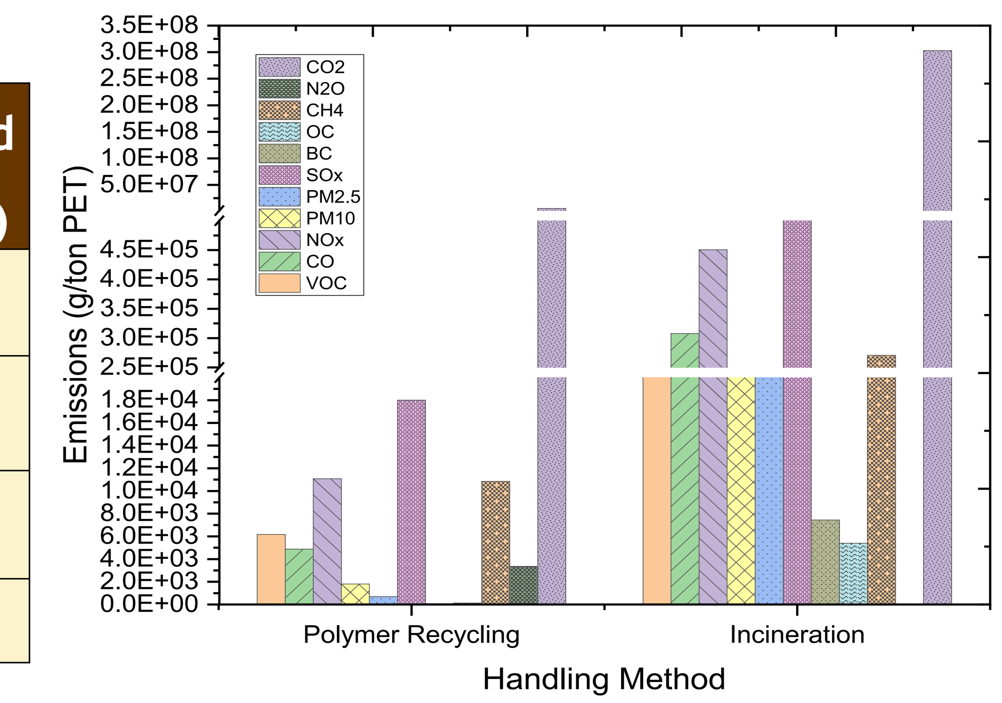
PET Case Study Results



Recovery Pathways	Annualized Cost ($ million/yr)	Prices ($/kg processed)
SDM-ADS2-MF2-BYP4	0.394	0.02
ADS1-ADS2-MF2-BYP4	0.431	0.03
Incineration	7.72	0.43

- 12.25 metric tons ethyl benzoate/yr (99% Purity).

Stage	Annualized Cost ($/yr)
SDM	932
ADS2	527
MF2	393,531
BYP, 4	0



- Cost per stage along with environmental impact of the most optimal pathway
- Incineration produces magnitudes more emissions and costs nearly 20 times more than solvent recovery

Summary and Future Work

- Superstructure model provides alternative methods to dealing with industrial solvent waste
- Perform addition case studies to further develop the superstructure model
- Continue to add more seperation technologies into the superstructure model

Acknowledgements

- Rowan University Chemical Engineering Department
- Sustainable Design and Systems Medicine Lab
- This work is supported by the U.S. Environmental Protection Agency's Pollution Prevention (P2) Grant Program (NP96259218)

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