Feedback on the student presentations

Overarching considerations

- **Life-cycle thinking is critical for effective chemical and material management:** Many of the challenges related to chemicals and materials originate as early as the molecular design phase. As a result, relying solely on end-of-pipe solutions is insufficient. Addressing these issues effectively requires upstream interventions (e.g., SSbD) and a comprehensive life-cycle approach. For instance, even if a material is technically recyclable, without the appropriate infrastructure in place, actual recycling may not occur. Life-cycle thinking, therefore, must also encompass considerations around system design, including infrastructure (e.g., availability of hydrogen for CO_2 use as a chemical feedstock) and end-use realities. Furthermore, life-cycle thinking should also take into account impurities, reaction by-products and transformation products.
- **Chemical simplification is essential to reduce system complexity and support sustainability:** Innovation alone cannot resolve the current challenges associated with chemicals and materials. Introducing new substances without careful consideration can add further complexity to already strained systems. For example, bio-based PEF is not compatible with PET in mechanical recycling processes. If both are used in beverage bottles without effective sorting methods, it could compromise existing PET recycling systems. To address this, it is crucial to pursue chemical simplification—focusing on essential needs and moving toward standardization—to achieve greater efficiency with less complexity (Fenner and Scheringer, 2022; Wang and Praetorius, 2023).

Specific considerations on carbon capture & utilization (CCU)

- **Retrofit for existing infrastructure and technologies:** As illustrated on slide #9, existing infrastructure will require retrofitting to accommodate the installation of carbon capture systems.
- **Downstream challenges of carbon utilization:** Using CO_2 as a chemical feedstock requires significant amounts of hydrogen, which is very energy-intensive to produce. A major challenge lies in the availability of green hydrogen—produced through water electrolysis using low- or zero-carbon electricity (see Huo et al., 2023).
- **Current deployment of CCU remains limited, requiring rapid scale-up:** As of the end of 2021, the global operational capacity for carbon capture was under 40 megatonnes (Mt) (see Huo et al., 2023), which is minimal compared to the 37.4 gigatonnes (Gt) of global fossil CO_2 emissions reported in 2024

(https://globalcarbonbudget.org). This highlights the urgent need for significantly faster deployment and scaling of CCU technologies.

Specific considerations on PMT/vPvM substances

- **Scope:** While plastic waste and the resulting environmental pollution are significant concerns, plastic waste itself does not fall under the category of PMT/vPvM substances. PMT (Persistent, Mobile, and Toxic) and vPvM (very Persistent and very Mobile) substances typically refer to small molecules that are highly persistent in the environment and can be readily transported through water systems (https://echa.europa.eu/new-hazard-classes-2023).
- **Identification:** The EU has established official criteria for identifying specific substances as PMT or vPvM. It is important to note that not all PFASs (per- and polyfluoroalkyl substances) meet these criteria. For example, many PFASs are high-molecular-weight polymers, which typically do not exhibit the mobility characteristics required for classification as PMT or vPvM substances.
- **Absorption of chemicals into plastics is generally not a major exposure concern:** Due to the strong absorption potential of plastics, the relatively low concentrations of chemicals in the environment, and limited desorption, the absorption of chemicals from environmental media into plastics is typically not a significant exposure pathway (Lohmann, 2017). Instead, a more relevant concern is the leaching of chemical additives from plastics, which occurs largely because these additives are present at concentrations way exceeding the plastics' absorption capacity.
- **Addressing the chemical aspect is essential to enable technological solutions to plastic pollution:** The presence of various chemicals in plastics poses significant challenges to developing and implementing technological solutions, such as biodegradable plastics and chemical recycling. Effectively managing these chemical-related issues is crucial to advancing sustainable and effective strategies for reducing plastic pollution (Wang and Praetorius, 2023).
- **Links to the topic of pharmaceuticals in the environment:** as many pharmaceuticals may be PMT/vPvM substances (due to their ionizable nature).

Specific considerations on bio-based chemicals

- **"Bio-based" does not always mean fully renewable—caution against greenwashing is needed:** A "bio-based" label does not necessarily indicate that a chemical is entirely derived from renewable biomass. For instance, bio-PET may contain only about 30% biomass-based raw materials, with the rest sourced from fossil fuels (see example). Therefore, it's important to critically assess such claims to avoid being misled by greenwashing.

- **Bio-based chemicals are not necessarily less toxic than their petroleum-derived equivalents:** the exact chemical structure matters.
- **Selecting agricultural and forest residues as bio-based feedstock:** Using residues from agriculture and forestry as feedstock for bio-based products is a strategy to minimize the demand for additional land, thereby reducing potential conflicts with food production and ecosystem conservation (Huo et al., 2024).
- **Stable supply remains a key current barrier:** For chemical plants, ensuring a consistent supply of raw materials—both in terms of quantity and quality—is essential for continuous processing and process optimization. Achieving this stability can be challenging when using bio-based raw materials. Gasification can help to achieve supply of raw materials with stable quality, but it is very energy intensive.

Specific considerations on EDCs

- **The full extent of EDCs in commerce is yet to be determined:** To date, only a limited number of chemicals have been tested for endocrine disruption potential. Around 1,000 have demonstrated some endocrine activity (not necessarily being endocrine disrupting), but further testing is necessary to identify the complete range of EDCs present in commercial use.
- **Not all EDCs bioaccumulate or persist in the environment:** Bioaccumulation is a distinct hazardous property that depends largely on a chemical's lipophilicity, and not all EDCs exhibit this trait. Likewise, not all EDCs are environmentally persistent, as persistence varies based on the chemical's structure and degradation potential.
- **Risk assessment is typically not suitable for EDCs:** Given the significant uncertainties surrounding endocrine-disrupting chemicals (EDCs)—such as non-monotonic dose-response behaviors and other key issues highlighted on slide #4—traditional risk assessment approaches may not be appropriate. In most, if not all, cases, a hazard-based assessment is more suitable for effectively addressing the potential impacts of EDCs.
- **TSCA in the US remains rather weak:** e.g., https://pubs.acs.org/doi/full/10.1021/acs.est.2c02079

Specific considerations on pharmaceuticals in the environment

- **Broader sources of pharmaceuticals in the environment:** Pharmaceuticals can enter the environment from multiple sources beyond household use, including wastewater discharges from pharmaceutical manufacturing facilities and runoff from agricultural activities where veterinary drugs are used, as seen in the Figure on slide #18 (UNEP).

- **Transformation products must be considered:** Many pharmaceutical pollutants in the environment are not the original active ingredients, but rather their transformation products or metabolites. These substances can also be biologically active and may pose environmental or health risks, making their inclusion in assessments essential.
- **Full life-cycle management of pharmaceuticals in the environment is essential:** As highlighted on slide #17, addressing pharmaceutical pollution requires solutions that span the entire life cycle—from production and prescription to disposal. For instance, Stockholm County has implemented prescribing guidelines to help doctors avoid recommending drugs known to have significant environmental impacts.
- **Environmental Risk Assessment (ERA) is not part of the approval decision for human pharmaceuticals in the EU:** While environmental risk assessment data are required during the approval process for human pharmaceuticals in the EU, these data are not currently integrated into the actual decision-making. As a result, environmental considerations do not influence whether a human pharmaceutical is approved.

Specific considerations on biodegradable plastics

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- **Addressing the chemical aspect is essential to enable technological solutions to plastic pollution:** The presence of various chemicals in plastics poses significant challenges to developing and implementing technological solutions, such as biodegradable plastics. Effectively managing these chemical-related issues is crucial to advancing sustainable and effective strategies for reducing plastic pollution (Wang and Praetorius, 2023).