IAM analysis of biomass co-processing opportunities in the refinery sector

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Summary

Most of the deep decarbonization scenarios run in Integrated Assessment Models (IAMs) point to a major drop in petroleum refineries utilization due to the decreasing demand for oil products. However, these evaluations usually underrate refineries' technological complexities that open opportunities to the processing of renewable energy sources. These opportunities anticipate the energy transition and lower its costs, while avoiding the stranding of part of the refining sector assets. This work discusses this possibility and proposes its inclusion in IAM evaluations, even using a simplified procedure. Examples are provided from IAM analyses in global and national (Brazilian) models.

Abstract

Deep decarbonization pathways commonly show that the petroleum refining industry might face considerable challenges due to reduction in demand for conventional oil products, particularly gasoline. For instance, in the International Energy Agency's (IEA) *Net Zero by 2050* report (Bouckaert et al. 2021), electrification of road transport leads to a huge drop in demand for gasoline and diesel, causing a reduction of global refineries´ throughput of 85% between 2020 and 2050. This means that closures of refineries would be inevitable, or the stranding[1] of these assets. The same kind of result can be found in deep decarbonization scenarios run in different Integrated Assessment Models (IAMs). For instance, mitigation pathway scenarios explored in the Global Warming of 1.5°C Special Report from the Intergovernmental Panel on Climate Change (IPCC) indicate a steep decline of crude oil in the primary energy share, which implicitly implies closure of refineries (Rogelj et al. 2018).

This paper discusses the feasibility of low-carbon trajectories that consider not only the closure of refineries, but also the revamping and repurposing of some existing assets, since opportunities do exist for some assets even in deep decarbonization scenarios. These opportunities, which are not being accounted for by most IAM evaluations, include enhancing

[1] Stranded assets, according to IRENA (2017), can be defined as investments which, at some time before the end of their lifetime, no longer present an economic return. This happens as a consequence of external changes such as those resulting from the transition to a low-carbon economy.

the refinery-petrochemicals integration, synthesizing products from renewable hydrogen or processing bio-feedstocks (IHS Markit 2020). This study focuses on the possibilities brought by the processing of biomass in refineries and proposes its inclusion in IAM analyses.

Biomass processing in refineries might be achieved either by full conversion of conventional facilities into biorefineries or by co-processing of biomass-derived oils and fossil oils in existing sites. Figure 1 compares these two strategies and also the installation of new (greenfield) biorefineries.

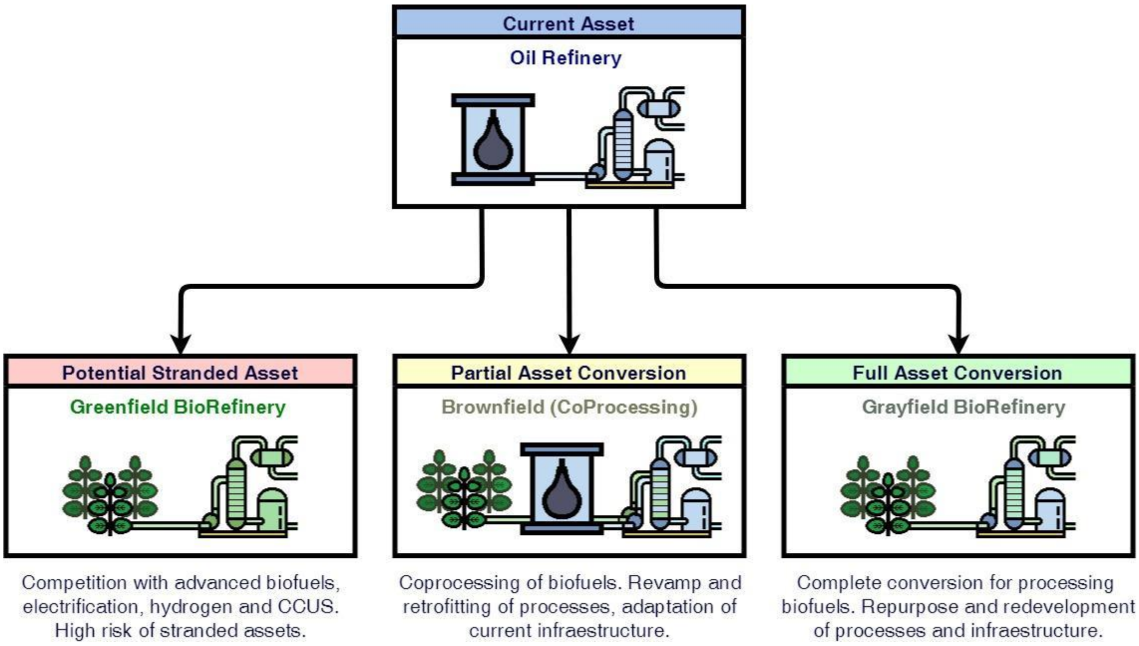

Figure 1. New biorefineries (greenfield), co-processing of biomass in oil refineries (brownfield) and full conversion of oil refineries (grayfield).

Biomass co-processing in oil refineries is a promising solution because it uses readily available process equipment, utilities, logistics and skilled labor. As a consequence, it requires low additional capital investment (Han et al. 2020; Al-Sabawi et al. 2012), and it could be readily applied in existing refineries. It does not involve the challenges of investing in a completely new biorefinery and training skilled personnel or in the full repurposing of existing sites. Thus, biomass co-processing has the potential to accelerate the transition towards sustainable fuels (Yáñez et al. 2021) while it allows the application of current refinery equipment. Besides, this strategy can be complemented by the increasing integration with petrochemicals, as some units processing biomass-derived oils can be diverted towards high-value-added chemicals (Al-Sabawi et al. 2012).

Two types of biomass-derived oils are most commonly proposed for use as feedstocks in co-processing: straight vegetable oils (SVOs) and pyrolysis oils (POs) (Al-Sabawi et al. 2012).

SVOs are extracted from oilseed crops such as soybean, rapeseed, sunflower, coconut, canola, cottonseed, jatropha and palm. POs are produced from lignocellulosic materials, which include agricultural and forestry residues. In both cases, direct use as fuels is challenging due to undesirable properties such as thermo-chemical instability and high viscosity (Dupain et al. 2007; Han et al. 2020). Thus, feeding these biomass-derived oils in conventional refineries is an alternative to convert them into fuels. Scientific literature usually suggests the co-processing of SVOs in Fluid Catalytic Cracking (FCC) (Dupain et al. 2007; Bielansky et al. 2010) and hydroprocessing operations (Lappas et al. 2009; Al-Sabawi et al. 2012). PO co-processing is commonly evaluated in FCC units (Pinho et al. 2015; Wang et al. 2018; Le-Phuc et al. 2020)

SVOs are produced in large volumes and are easy to integrate in refineries, while POs are not available in significant amounts and its integration in the refining process is more complex (Yáñez et al. 2021). Hence, the application of SVOs in refinery units is a more mature technology. Several facilities, mainly in Europe and in the US, already operate with biomass coprocessing. This includes companies such as Repsol, BP and Shell (IHS Markit 2020).

Therefore, this work aims to improve IAM representation of liquid fuel production (and even petrochemicals) by including the technical option of biomass co-processing in oil refineries, namely SVO and PO feeding in FCC and hydroprocessing units. This is achieved using auxiliary satellite models that simulate refinery schemes and biorefinery processes. The combination of refinery capacity, biomass source availability and conversion routes into the IAM indicates to what extent the co-processing is deployed in a given simulation. This is depicted in Figure 2:

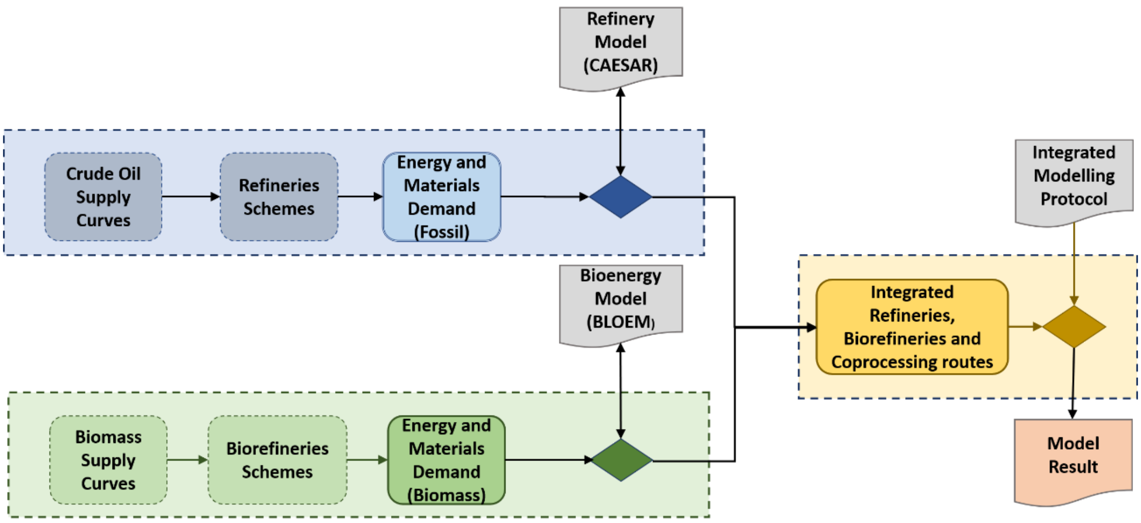

Figure 2. IAM scheme for considering biomass co-processing.

Preliminary results in the Brazilian IAM model BLUES (with a soft-link with satellite models: a biomass model - BLOEM - and a refinery model - CAESAR) suggest that co-processing of biomass in conventional refineries is an intermediate solution – between greenfield biorefineries and full conversion of existing facilities – which offer the advantages of lower investment costs while avoiding the stranding of at least part of the refining sector assets. According to (Caldecott et al. 2016), asset stranding is a high risk in the petroleum industry. The present work brings a contrasting point of view and shows that opportunities exist in the refining sector and, thus, literature might be over-estimating the magnitude of these risks.

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