Global Alliance POWERFUELS

Tracking models for liquid powerfuels

Overview, challenges, and opportunities for the market ramp-up of e-kerosene

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Content

Key takeaways

Different tracking models - as means to prove compliance with renewable energy and greenhouse gas reduction targets in EU regulation and in voluntary markets - enable different business cases.

Tracking models define rules on how to ensure traceability of traded goods and their sustainability characteristics. These can be employed in distinct supply and value chains, and to different energy carriers, thereby addressing different sets of actors and enable different business cases. This paper focusses on two tracking models: mass balance and Book and Claim.

Mass balance is the main tracking model used today to comply with EU regulation on liquid renewable fuels. It allows EU Member States to credit renewable energy volumes or greenhouse gas reductions against EU targets.

Book and Claim is currently used in voluntary markets and offers the possibility to de-couple the physical flow of a renewable energy carrier from the transfer and allocation of its sustainability attributes. In these markets, Book and Claim is employed as a tool to provide proof of corporate GHG reduction efforts.

The European Parliament proposed to allow for trading of e-kerosene through a Book and Claim-based mechanism within the ReFuelEU Aviation Regulation, which is currently under development.

The way in which liquid powerfuels are traded and tracked can have significant implications for their use and acceptance in the market. Currently, mass balance is the only tracking model allowed for all liquid powerfuels in the EU. However, the ReFuelEU Aviation regulation could allow a Book and Claim-based model for e-kerosene, as the European Parliament proposed to allow said model within ongoing interinstitutional negotiations. Such a model would result in the establishment of certificates for Sustainable Aviation Fuels (SAFs) or "SAF certificates". SAF certificates carry the environmental attributes of SAF. They would allow for SAF to be physically consumed in one location as aviation fuel, while its sustainability attributes such as emission reductions are claimed somewhere else (World Economic Forum, 2021). The amendments pertinent to a flexibility mechanism for SAF adopted by the European Parliament in its ReFuelEU Aviation Regulation proposal would make a Book and Claim-based tracking model for SAF admissible until January 2035.

E-kerosene traded through Book and Claim could have a competitive advantage compared to other fuels for which only a mass balance model in admissible.

The introduction of a Book and Claim-based tracking model under the ReFuelEU Aviation Regulation could result in a competitive advantage for the volumes of e-kerosene for which the model is employed.

Currently, in order for e-kerosene to count towards renewable energy targets within the existing EU regulatory framework, it must be tracked using a mass balance model. The Book and Claim model's greater flexibility in terms of how offtakers source e-kerosene has the potential to create a disadvantage for e-kerosene underlying the mass balance model, as the latter could be seen as a more restrictive option.

Book and Claim has the potential to facilitate business opportunities for e-kerosene that might not have been viable otherwise.

A Book and Claim-based tracking model could potentially enable business cases for the production of liquid powerfuels, including e-kerosene. In some instances, producers of liquid powerfuels may be unable to access or afford the physical transport of liquid powerfuels – as required by purely mass balance-based tracking models – to make them available to customers. Book and Claim removes the need to transport liquid powerfuels to costumers. This allows producers to access a set of costumers with a matching willingness to pay they would have otherwise not been able to access.

In order for SAF certificates to be trustworthy, robust and transparent auditing and certification practices need to ensure that the sustainability attributes of the traded fuels are only counted once.

In order for a Book and Claim-based tracking model to work reliably, SAF certificates must be trustworthy and traceable. This holds true, for example, In the case of procurement of SAF certificates that were registered (or "booked") by SAF producers from third countries. In such an instance, a robust certification system must ensure that sustainability attributes are not counted twice. To this regard, establishing rules for the trade of SAF certificates, including respective auditing and certification practices, can benefit from lessons learned from prior experiences and instruments.

A prominent example of a market for certified emission reduction credits from which shortcoming and lessons can be identified is the Clean Development Mechanism (CDM) set up under the Kyoto Protocol. The CDM lacked structures to reliably verify that carbon emission benefits were not exaggerated, mainly due to transparency issues and difficulties in proving that carbon credits were additional (Cames et al., 2016; Schneider, 2009; Spalding-Fecher et al., 2012) (European Court of Auditors, 2016).

Book and Claim-based systems are already being developed and used to meet corporate demand for (biogenic) SAF in voluntary markets.

Several examples of projects piloting Book and Claim-based systems for SAF already exist. The main stated goals of companies involved in SAF purchases via Book and Claim systems are two-fold: reducing scope 3 emissions and incentivising the ramp-up of SAF production by creating a market for its sustainability attributes. This logic is applicable to biological jet fuel and e-kerosene alike. Existing Book and Claim systems can be utilised for e-kerosene, too.

1 Introduction

91 % of global GDP is covered by net-zero emissions targets or pledges (NetZero Tracker, 2022). Green hydrogen has gained widespread attention as a key element for reaching net-zero emissions, as it can be utilized to decarbonize so called hard-to-abate sectors, i.e. sectors that cannot be electrified directly or are uneconomical to be decarbonized through other technological options. Hydrogen is one main building block of numerous synthetic molecules, or "hydrogen derivatives", such as renewable liquid hydrocarbons and e-ammonia, which serve as further technological decarbonisation options. Both renewable electricity-based hydrogen and its derivatives displayed in Figure 1 are referred to as "powerfuels".

In order for powerfuels to be counted towards voluntary or legally binding targets defined, e.g. at company, sector or county level, their sustainability properties such as greenhouse gas (GHG) emissions savings and the renewable origin of inputs used for their production, such as electricity, must be measured, certified, and tracked throughout their value chain via tracking models.

Tracking models define rules on how to ensure traceability of traded goods and their sustainability characteristics. This paper explores their role for liquid powerfuels within the regulatory framework of the European Union (EU) and in voluntary markets.

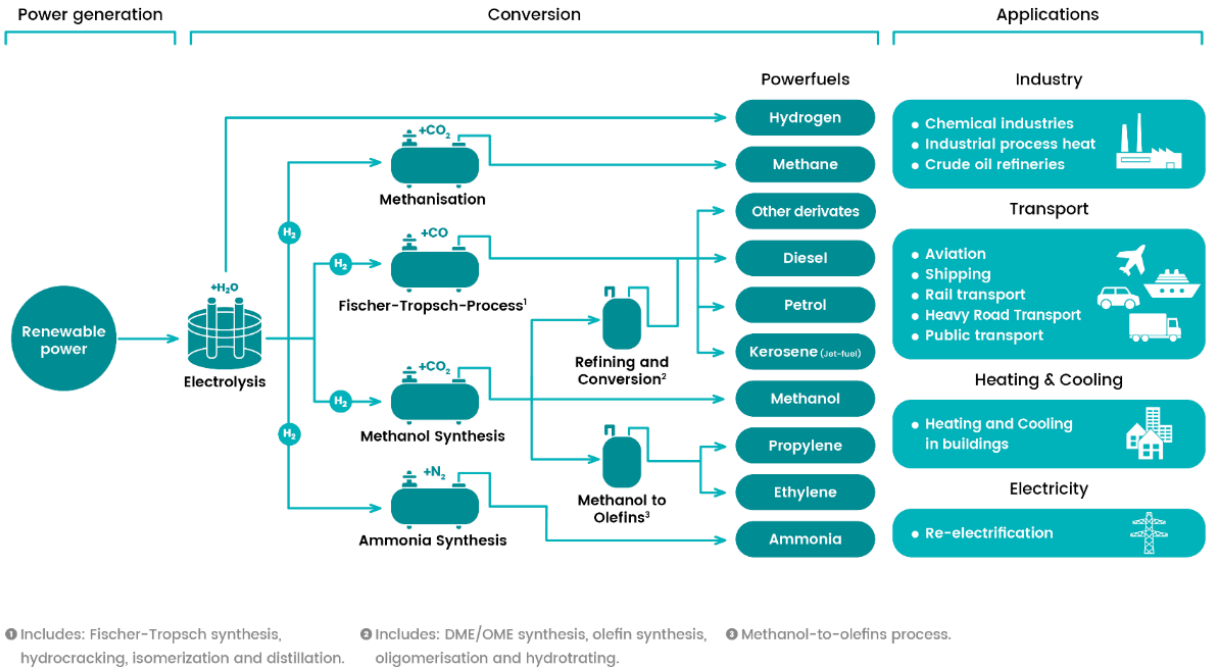

Figure 1: Graphical definition of powerfuels and their potential applications (own work)

2 General overview of tracking models

The four main tracking models in use today according to (Circular Economy 100 & Ellen MacArthur Foundation, 2019) are summarized below. They are employed for a variety of products, including renewable energy carriers such as biofuels and renewable electricity. This chapter describes their underlying principles, while their application to liquid powerfuels and the existing regulatory framework are discussed in the following chapters.

The presented tracking models are also called Chain of Custody models. "**Chain of Custody**" is a general term for making a connection between product properties and movements (e.g. carbon footprint, mass flows) along the product's supply chain. Within a Chain of Custody, and in the context of renewable energy, **Proof of Sustainability** certificates are used. In practice, a Chain of Custody is utilised to implement and verify control mechanisms for each economic operator in the chain. Each party in the supply chain must comply with this process; otherwise, the Chain of Custody is lost. Multiple Chain of Custody models are available for tracing material and product flows, and their properties along the product's supply chain (Plastics Europe, 2020).

Note on certificates traded in the four presented models

Different kinds of certificates or credits are traded through Book and Claim, depending on how a Book and Claim system is designed. For example, when Book and Claim is employed for electricity, gas, or heat as defined within the Renewable Energy Directive II (RED II, Directive 2009/28/EC), so-called **Guarantee of Origin (GO)** certificates or "Guarantees of Origin" (GOs) are used. When Book and Claim is employed for other purposes, **Proof of Sustainability (PoS)** certificates can be used. The three other models mentioned herein all provide PoS certificates.

GO and PoS certificates differ in their purpose. In their application to energy carriers, GO certificates are used to identify and disclose the origin or source of an energy unit to end consumers, while only PoS certificates can be used to count energy volumes towards renewable energy targets and prove compliance with sustainability criteria.

1. The identity preservation (IP) model

This model ensures that a specific product is uniquely traceable throughout the supply chain, from producer to consumer, by keeping it strictly separated from similar, but uncertified products, as well as other certified products from other sources (iseal alliance, 2016).

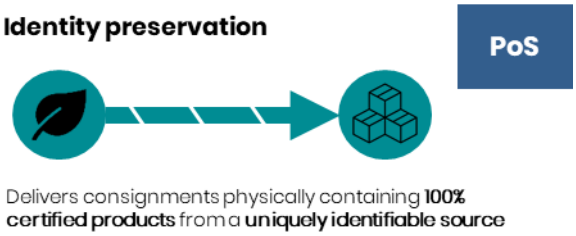

Figure 2: Schematic visualisation of the Identity Preservation model (own work)

2. The segregation (SG) model

SG keeps certified products separate from non-certified products throughout the supply chain, allowing for precise sustainability attribution at each stage from producer to consumer. Unlike in the IP model, certified products are allowed to be mixed. Therefore, only the certified sustainability of the product, but not the individual producer is traceable at each stage of the supply chain (iseal alliance, 2016).

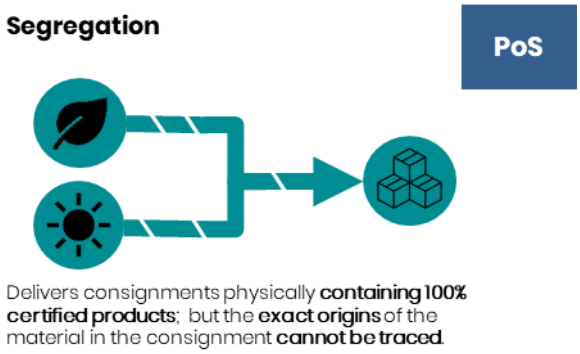

Figure 3: Schematic visualisation of the Segregation model (own work)

3. The mass balance (MB) model

Mass balance describes multiple approaches where certified and non-certified products may principally be mixed or blended, while their movements, handlers, and quantities are documented. Mass balance ensures physical blending and further enables the exchange of renewable fuel qualities. As a result, the supplier can make a precise claim about the volume or percentage of certified products in the sold final product (iseal alliance, 2016).

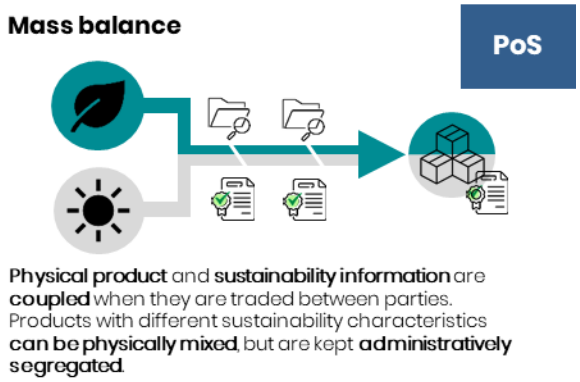

Figure 4: Schematic visualisation of the mass balance model (own work)

4. The Book and Claim (BC) model

In this model, sustainability certificates or credits are issued for a produced good at a given stage of its supply chain by an independent issuing body (iseal alliance, 2016; US EPA, 2022; Velazquez Abad & Dodds, 2020; World Economic Forum, 2021). Starting from said stage, the product and the certificate can be traded separately. If the product possesses sustainability attributes, these can be included in a certificate. This implies that one end user can claim the certificate of a product alongside its sustainability attributes, while another end user is in possession of the physical product. Strictly speaking, the Book and Claim model is not a Chain of Custody model, as the products are not physically traceable through the entire supply chain like in all Chain of Custody models. Yet, the quantity and properties of a certified product are virtually traceable (iseal alliance, 2016; Velazquez Abad & Dodds, 2020).

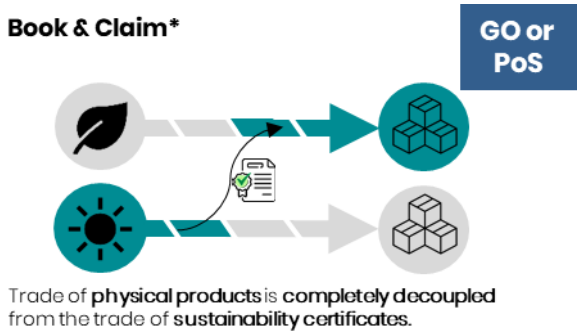

Figure 5: Schematic visualisation of the Book and Claim model (own work)

Per definition, Book and Claim is **not a CoC model, as there is no physical traceability through the supply chain. Yet it is often listed among CoC models, as it allows virtual traceability of product properties.*

3 EU regulation and Book and Claim for e-kerosene

As of today, mass balance is the only tracking model included in EU regulations to prove the compliance of liquid powerfuels with sustainability criteria defined in the EU regulatory framework. Yet, the EU ReFuelEU Aviation Regulation could introduce a Book and Claim-based tracking model for Sustainable Aviation Fuels, including e-kerosene.

RED II, Union Database, and ReFuelEU Aviation Regulation

RED II

The revised Renewable Energy Directive (RED II) is the predominant piece of EU legislation defining sustainability, production, and certification criteria for powerfuels – classified as "Renewable Fuels of non-biological Origin" (RFNBO) in the Directive (German Energy Agency [dena] & World Energy Council Germany, 2022). The RED II specifies that a mass balance system is the only accepted system for tracing the sustainability attributes of powerfuels. According to Art. 30 (1) RED II:

"Member States shall require economic operators to show that the sustainability and greenhouse gas emissions saving criteria [among others, of RFNBO] have been fulfilled. For those purposes, they shall require economic operators to use a mass balance system" (RED II, 2018)

Mass balance was already used to track the sustainable characteristics of renewable fuels used in the EU before the RED II entered into force in 2018. It was also the only mechanism allowed to prove compliance with the goals set by the first Renewable Energy Directive (RED), which had been in force since 2009 (RED, 2009). Consequently, the knowledge, experience, and actors required to set up a RED II-compliant mass balance system for powerfuels are largely already existent.

The RED II is currently undergoing a revision process to adjust for the increased ambitions for GHG emissions savings of the European Green Deal and Eu Climate Law. In March 2023, a provisional deal on the revision of the RED II was reached in the so-called trilogue negotiations between the EU institutions. A final text has not been agreed upon and is expected to be finalised in 2023. The proposal of the European Parliament contains a number of relevant adjustments for liquid powerfuels and tracking models. It confirms the extension of the mass balance system from biofuels to RFNBO both produced in or imported into the EU as mentioned in the European Commission's proposal. The transport sector is excluded from this extension, but it is regulated in additional frameworks, such as the ReFuelEU Aviation. The proposal also describes a Book and Claim mechanism for renewable hydrogen, yet a Book and Claim system for liquid powerfuels remains prohibited under the proposed amendments.

Union Database of the European Union

The Union Database of the European Union is a comprehensive digital repository that serves as a platform for reporting, monitoring, and certifying the sustainability of renewable energy sources within the European Union. As a key instrument for the implementation of the Renewable Energy Directive II, the database plays an important role in promoting the use of renewable energy and achieving the EU's renewable energy targets for 2030. The database is utilized by EU Member States to collect and report data on renewable energy production and consumption, while also facilitating the certification of renewable fuels in terms of their sustainability. In doing so, the database offers a transparent and dependable system for the monitoring and evaluation of the sustainability of renewable energy sources.

ReFuelEU Aviation

The ReFuelEU Aviation – equally part of the Fit-for-55-package – is a proposed European draft regulation which sets binding targets for the deployment of SAF within the EU between 2025 and 2050 (RefuelEU Aviation, 2021). SAF is a collective term for both biological jet fuel and power-to-liquid kerosene (or e-kerosene).

The draft regulation stipulates sustainability criteria and certification obligations aligned with RED II. The draft is currently undergoing formal trilogue negotiations between the European Parliament, the European Commission and the European Council. The trilogue is expected to be finalized in December 2022, leading to the adoption of a final text by the end of 2022 and its entry into force on January 1, 2023.

The proposal by the European Commission published in July 2021 requires all SAFs to be certified according to the aforementioned Article 30 of RED II[1] and therefore only allows for a mass balance system. In contrast, the ReFuelEU Aviation draft presented by the European Parliament on July 7, 2022 includes an amendment to implement a so-called "flexibility mechanism" for a transitional period of ten years, which would allow elements of a Book and Claim system – to be defined – alongside a mass balance system. The draft text states that:

"A **flexibility mechanism** should be set up with a **transitional period of 10 years** from the date of application of this Regulation to fuel suppliers and aircraft operators to allow them a reasonable amount of time to make the necessary technological and logistical investments. [During the transitional period] **elements of a Book and Claim system** may be used [to allow] aircraft operators to purchase sustainable aviation fuels through contractual arrangements with aviation fuel suppliers and to claim its use at Union airports." and further "allowing [...] aircraft operators to buy a **certificate linked to the amount of SAF acquired** [...]." (Amendment 38 to recital 31 of proposed ReFuel EU Aviation regulation; Amendment 51 to Art. 3 (1) of the proposed ReFuel EU Aviation regulation (Proposed Amendment ReFuelEU Aviation, 2022) boldface added).

Table 1: Allowed tracking models in the ReFuelEU Aviation draft proposed by the Euoprean Parliament.

From January 2025 to December 2034	B&C and mass balance
From January 2035	Mass balance only

The European Parliament's proposal further specifies that:

"[...] **fuel suppliers** [must] provide [...] information [...] [on] characteristics of the fuel supplied, [**transactions** made], its **sustainability characteristics** and the **origin of feedstock** used in the production of the fuel. That **information is reported in the Union Database**, established under Article 28 of [the RED II]" and that "The **Commission** will publish an **Implementing Regulation on sustainability certification** in line with Article 30(8) of [the RED II]." (European Parliament's adopted amendment 18 to add Recital 17a to proposed ReFuel EU Aviation regulation (Proposed Amendment ReFuelEU Aviation, 2022); RED Article on Union Database (Art. 28 in first RED II revision proposal from EC, Art. 31a in EP proposal (RED II Amendments, 2022) boldface added).

According to the draft proposal of the European Parliament, the design of the Book and Claim mechanism is to be defined via a Delegated Act, set to be published by January 1, 2025. The Delegated Act will include detailed rules regarding the registration, allocation, accounting and reporting of the supply and uptake of SAF (European Parliament's adopted amendment 98 to add Art. 13 (1a) to proposed ReFuel EU Aviation regulation (Proposed Amendment ReFuelEU Aviation, 2022)).

The European Parliament's draft of the ReFuelEU Aviation therefore implies the need for certificates indicating the quantity and sustainability attributes of SAF. As such certificates would be traded over a registry in the form of digital SAF quantities or certificates, they are here described as **"SAF certificates"**. For SAF certificates to be traded in compliance with EU regulations, they would need to be integrated into the Union Database.

The need for "SAF certificates"

The European Parliament's ReFuelEU Aviation proposal implies the need for "SAF certificates" and their integration into the Union Database.

[1] Art. 3 (1) of the proposed ReFuelEU Aviation regulation published by the European Commission

SAF certificates and SAF allowances are different items

SAF certificates as described in this paper are not to be confused with SAF emissions allowances (SAF allowances) as intended in the EU Emissions Trading System (EU ETS). SAF allowances are GHG emissions certificates exonerating airlines from the obligation of reducing a given amount of GHG emissions resulting from their fuel consumption. One allowance equals 1 ton of CO_2-equivalents. SAF allowances are to be introduced with the revised ETS directive to reportedly enter into force by May 2023. (Store, 2023)

Spotlight: A Book and Claim-based tracking model for SAF

SAFs are a suitable technological option to defossilise the aviation sector. Yet, production capacities are scarce and only available at few consumption sites.. This implies that mass-balancing based tracking models would require the simultaneous build-up of supply chains for SAF for each airport.

As visualized in Figure 6, SAF supply chains in which a Book and Claim-based tracking model is applied do require mass balance-based tracking for part of the supply chain. In this case, a SAF certificate is emitted at the blending point with conventional jet fuel. For the previous parts of the supply chain, mass balance is adopted to trace the fuel from its point of production until the point of storage. The SAF certificate is then transferred to an end consumer that claims the sustainability attributes and/or the corresponding fuel quantity. These can then be accredited toward fulfilling regulatory obligations such as a SAF blending mandate as in the ReFuelEU Aviation. The transaction is handled via a Book and Claim registry.

By removing the need to physically transport SAF to offtakers of SAF certificates, Book and Claim-based tracking models offer a solution to enable trade streams between SAF producers and offtakers which would have otherwise potentially not been possible under a purely mass balance-based system. However, Book and Claim in the context of SAF certificates is prone to the same challenges as Book and Claim in general. This section discusses three main risks to be avoided:

Double counting

The same volume of SAF could be counted towards regional or national targets (not ReFuelEU) as well as towards ReFuelEU targets simultaneously. This risk can be mitigated by extending mass balance-based tracking until the point of blending (Figure 6), in combination with strict and reliable auditing based on a clear definition of what is regarded as double counting.

Further learnings can be derived from mechanisms which have experienced double-counting issues. Prominent examples are the first renewable energy directive (RED) and the Clean Development Mechanism (CDM) set up under the Kyoto Protocol. The CDM lacked structures to reliably verify that carbon emission benefits were not exaggerated, mainly due to transparency issues and difficulties in proving that carbon credits were additional (Cames et al., 2016; Schneider, 2009; Spalding-Fecher et al., 2012). The RED provided several rules aimed at avoiding double counting. Yet, as described by the European Court of Auditors in a comprehensive 2016 report, it also produced several issues including the possibility for double counting (European Court of Auditors, 2016).

Inaccurate GHG emissions accounting

The Union Database requires the calculation of GHG emissions associated with liquid powerfuels based on the methodology for RFNBOs specified in the delegated act pursuant to Article 28 of the RED II. This methodology applies exclusively to energy carriers that are tracked through a mass balance model, and encompasses both transport and distribution emissions. However, for energy carriers tracked through a book and claim-based model, transport emissions generated beyond the point of emission of a SAF certificate are excluded from the scope of the methodology. One feasible solution to make the lifecycle emissions of an energy carrier comparable regardless of the employed tracking model would involve allocating the GHG emissions originating beyond the point of emission of a SAF certificate to the final en-

ergy carrier. However, this approach may be challenging to implement due to the need for physically tracking the energy carrier up to its final use.

Leaking of SAF to end uses outside the aviation sector

After the point of emission of a SAF certificate, the physical quantity of SAF is not further tracked as SAF, but as fossil jet fuel. Although unlikely due to its relatively high production costs (Micheli et al., 2022), said SAF quantity could be delivered to end-users other than airlines for uses such as heating, cooking or as a solvent. The result is a possible delay in infrastructure build-up and therefore local SAF uptake. One efficient countermeasure is here too, to extend mass balance-based tracking until the point of blending due to the associated additional certification measures in place.

Possible incompatibility of SAF certificates with the regulatory framework

The third central issue for a SAF certificate Book and Claim system is a regulatory challenge. Under the precondition that Book and Claim systems will be accepted as a tracking model in future EU regulations, SAF certificates must comply with the conditions stated in Art. 28 RED II, which defines the rules for the Union Database. Furthermore, feedstocks have to meet GHG and feedstock standards set by ReFuelEU Aviation and RED II(I). A possible approach to develop workable SAF certificates would be multi-stakeholder working groups aiming at designing a SAF certificate registry compliant with the mentioned regulations.

Book and Claim could alter the level playing field compared to mass balance

The Book and Claim model's greater flexibility in terms of how airlines source sustainable aviation fuels has the potential to create a disadvantage for SAF underlying the mass balance model, as the latter could be seen as a less efficient and more restrictive option. The introduction of the Book and Claim tracking model under the ReFuelEU Aviation initiative could therefore result in a competitive advantage for SAF underlying the Book and Claim tracking model in the aviation industry.

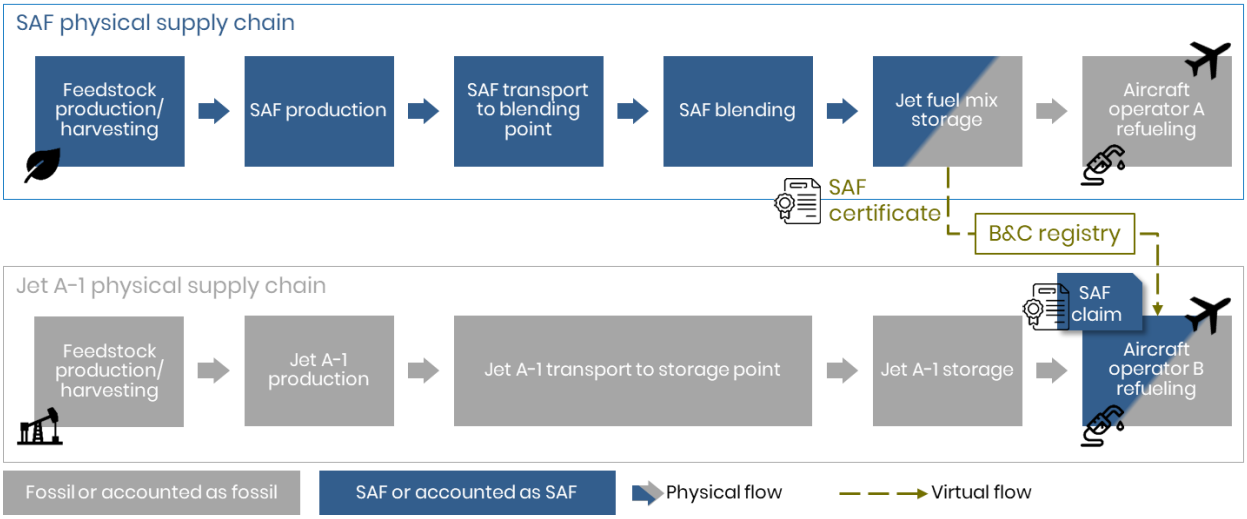

Figure 6: Example of a Book and Claim-based tracking model for SAF (own work)

4 Comparing mass balance and Book and Claim for liquid powerfuels

As described in detail in the previous chapter, mass balance and Book and Claim-based tracking models are the only ones employed or discussed as possibly applicable to liquid powerfuels within EU policy frameworks. This chapter therefore highlights and compares the opportunities and challenges associated with both of these tracking models.

Mass balance-based tracking models

Mass balance is a well-established system, as it has been the main tracking model for renewable energy carriers stipulated by EU regulation since the first Renewable Energy Directive (dena & World Energy Council Germany, 2022). The accumulated experience with mass balance therefore simplifies its application for liquid powerfuels. Furthermore, it is the only Chain of Custody model currently allowed under the recast of the EU Renewable Energy Directive (RED II, 2018). One main advantage of mass balance is the direct link between physical delivery of the energy carrier and the issuance of the associated PoS certificates. This implies that liquid powerfuels must be physically delivered to offtakers. Offtakers reside in geographical regions subjected to regulatory obligations (e.g. from the RED II) to source renewable energy carriers through mass balance systems. Therefore, physical supply chains need to be built between production sites and said regulated regions. This can in turn support the build-up of the infrastructure necessary within renewable energy systems. On the other hand, the requirement to build said supply chains can lead to investments in infrastructure that is not necessarily as cheap as possible and possibly lead to prohibitive costs for certain market actors.

Furthermore, the administrative costs of a mass balance model are significant, as each step of the supply chain must be monitored, and the energy carrier verified.

On the positive side, this process makes mass balance a robust and fraud-resistant tracking model. If the mass balance system is operated with one central registry, the risks of multiple sales and therefore multiple counting of the same energy unit are reduced (van de Staatj et al., 2012).

Book and Claim-based tracking models

A Book and Claim-based tracking model can help overcome logistical difficulties for powerfuels. Given that liquid powerfuels are currently produced in a small number of places and in limited quantities, long-distance transportation of liquid powerfuels would be required to reach potential offtakers, which are in contrast spread over larger geographies (Bölts, 2022; Ram M. et al., 2020). The need to physically transport powerfuels over long distances can lead to a reduction of GHG emissions savings, to higher costs for transportation, and ultimately to higher fuel prices.

Book and Claim offers multiple advantages resulting from removing the need to physical transport powerfuels to the costumers, i.e. the claimers of the virtual quantity of powerfuels. First, production capacities can be developed where they are cheapest. Second, end users can buy the certificates without physically consuming the liquid powerfuels. This allows for offtakers distant from the locations of production and with a willingness to pay matching the production price to enable a business case for producers that would have not otherwise been able to reach one. Third, by potentially reducing fuel prices, it can help develop market demand. This can potentially lead to an increased liquidity in powerfuels markets (Walker, 2021), thereby enabling a cost-efficient scale-up of production capacities paid for by offtakers with the highest willingness to pay.

However, given the novelty of such a construct, the scale of such effects is uncertain. Additionally, experience suggests that certificate trading can also lead to no installation of supplemental production capacities compared to a market without certificate trading mechanisms in place. This is the case in the renewable electricity market, where trading renewable energy certificates only marginally contributed to increasing renewable electricity production volumes according to (Jansen, 2017; Wimmers & Madlener, 2020).

A further argument against a Book and Claim model is that it does not incentivize the build-up of physical supply chains and the infrastructure required in fully renewable energy systems. A related criticism points to the lack of engagement of end-users with the physical supply chains, leading to no substantial behavioural changes on the consumer side (van de Staatj et al., 2012). A different concern refers to the potential problem of multiple claims of the same quantity of liquid powerfuels due to the separation of their certificate from the physical product. One further effect of Book and Claim can be described as follows: due to potentially lower cost compared to a mass balance model, it is possible that the equilibrium of the market for feedstocks used in the production of fuels that can be traded under either the Book and Claim or mass balance models, may be distorted in favour of the former approach. However, the authors of this paper have not identified comparative analyses on the topic. It is therefore impossible to provide a comparative quantitative evaluation of the mentioned issues.

Overall, a Book and Claim-based tracking model requires a robust and independent registration and monitoring entity, guaranteeing transparency and verification to build consumer trust. This in turn requires the harmonization of local and ideally international sustainability standards applying to liquid powerfuels. The harmonisation of said standards would allow the extension of the geographical scope of a respective Book and Claim model across its geographical scope, thereby connecting an even larger amount of potential producers and offtakers.

It is further pointed out that a Book and Claim-based tracking models must by definition make use of mass balance for part of the supply chain. This is described further in Section 3.

Table 2: Comparison of mass balance and Book and Claim-based tracking models for liquid powerfuels.

	Comparative opportunities	**Comparative challenges**
Book and Claim-based tracking model	Access to other markets for liquid powerfuels compared to a purely mass-balance based market	Does not incentivise or potentially hinders the creation of supply and transport infrastructure for each individual site of consumption
	Production sites uncoupled from offtakers of certificates allow for potentially optimal site selection	Potentially lower transparency, credibility, and consumer trust due to sole certificate trading
	More rapid commercial deployment of powerfuels due to cost effectiveness and reduced need for physical infrastructure	Can lead to multiple claims of GHG savings and renewable energy consumption
	Higher GHG emissions savings due to reduced transport requirements of the traded products	Novelty of tracking model applied to liquid powerfuels increases uncertainty about its large-scale deployment

	Fewer administrative costs and reduced burden for economic operators	Lack of engagement of end-users with the physical supply chains, leading to no substantial behavioural changes on the consumer side It is possible that the equilibrium of the market for feedstocks used in the production of fuels, which can be traded under either the Book and Claim or mass balance models, may be distorted in favour of the former approach
Mass balance-based tracking model	Incentivises the creation of supply chains for each consumption region Higher resistance to fraud or error due to physical monitoring of each stage of the supply chain Established and proven system for energy carriers, thus simplified application to liquid powerfuels Only Chain of Custody model currently allowed under the recast of the EU Renewable Energy Directive	Higher Administrative burden Potentially higher total cost due to higher transport and transport infrastructure costs Higher GHG emissions due to long distance transport of liquid powerfuels Potential delay in long-term market ramp-up due to less liquidity in powerfuels markets

5 Use cases of Book and Claim for SAF in voluntary markets

The ReFuelEU Aviation is the only EU policy framework in which the introduction of Book and Claim-based tracking models is being discussed.

Meanwhile, Book and Claim has been increasingly adopted in voluntary markets in recent years. This chapter showcases a selection of private sector use-cases for SAF Book and Claim mechanisms.. All use-cases deploy SAF of biogenic origin and no synthetic SAF.

The use-cases are reported to exemplify the interest of SAF offtakers as well as actors outside of the aviation industry to leverage Book and Claim for claiming the use or GHG emissions reductions of SAF. Besides eco-consciousness as societal trend (Growth from Knowledge, 2020), this interest find its origin in three main drivers:

1) Voluntary company-imposed internal GHG reduction or renewable energy targets;

2) Voluntary company-imposed GHG reduction or renewable energy targets for compliance with public frameworks such as the Global Compact or the Science-Based Targets Initiative;

3) Consumer demand for green premium.

Project start	2022
Quantity	33 million litres of SAF (over three years)
GHG reduction	96% reduction in lifecycle emissions vs. Jet A-1*
Carbon credits	80.000t CO_2 credits
Supplier	(unclear)
Physical offtaker	Air France KLM Martinair Cargo
Credits offtaker	Customers of DHL Global Forwarding
Auditor	KPMG for KLM, SGS for DHL
Registry	Internal
Aim	Offsetting scope 3 emissions of DHL Global Forwarding customers

*assuming a fossil emissions baseline of 3.16 t CO_2/t kerosene

Figure 7: Use-case 1 - DHL Global Forwarding, Air France KLM Martinair Cargo

One of the leading logistics companies globally, Deutsche Post DHL Group (DPDHL), announced a voluntary objective to reach climate neutrality by 2050. Two thirds of DPDHL's GHG emissions arise from the company's air transport operations. Recognizing the central importance of reducing the carbon footprint in this sector, DPDHL signed some of the largest purchasing agreements for SAF in the air transport history (Deutsche Post DHL Group, 2022b).

In 2022, DPDHL's air and maritime transport subsidiary DHL Global Forwarding therefore established a partnership with Air France KLM Martinair Cargo (AFKLMP) to purchase 33 million liters of SAF via a Book and Claim mechanism over the coming three years, accounting for estimated GHG emissions reductions of 80.000 tons of CO_2. This strategy not only contributes to DPDHL's climate goals, but also provides an attractive service to their clients by allowing for scope 3 emissions reductions (Deutsche Post DHL Group, 2022a).

The Book and Claim mechanism is audited by KPMG on the AFKLMP side and by SGS on the DPDHL side (Otley, 2021). The registry is operated internally so far, until reliable third party systems are in place.

Project start	2021
Quantity	21 t waste-based SAF
GHG reduction	80% reduction in lifecycle emissions vs. Jet A-1
Carbon credits	53t CO_2 credits*
Supplier	Air BP
Physical offtaker	United Airlines (in UK)
Credits offtaker	Microsoft
Auditor	RSB (Roundtable on Sustainable Biomaterials)
Registry	RSB B&C registry, developed by Sustainable Aviation Buyers Alliance (SABA) + RSB
Aim	Offsetting Microsoft's Scope 1-3 emissions

*assuming a fossil emissions baseline of 3.16 t CO_2/t kerosene

Figure 8: Use-case 2 - Microsoft, Air BP and United Airlines

The software company Microsoft has a dedicated climate strategy, aiming to become carbon negative as early as 2030 (Official Microsoft Blog, 2020). The central tool for reducing Microsoft's air travel related GHG emissions are Book and Claim agreements and SAF financing in cooperation with various partners. In 2021, Microsoft, United Airlines and Air BP announced a Book and Claim pilot, which is overseen by the Roundtable on Sustainable Biomaterials (RSB) (Deslandes, 2021). Air BP will provide United Airlines with 26.500 liters of waste-based SAF at multiple airports in the UK. The RSB Book and Claim system includes third party audits and ensures to guarantee full traceability for the SAF, avoiding double-counting of the GHG emissions reductions. (Roundtable on Sustainable Biomaterials [RSB], 2021)

Microsoft signed similar agreements with KLM (KLM Royal Dutch Airlines, 2019) and Alaska Airlines (Alaska Airlines News, 2022), with the declared goal of developing pilot Book and Claim systems, as well as providing demand signals to SAF producers. Via a Book and Claim system, airlines can claim scope 1 reductions, while contributing to Microsoft's scope 3 emissions reductions goals. What remains unclear about the Book and Claim mechanisms by Microsoft is how double-counting is avoided, since both United Airlines and Microsoft could claim the same CO_2-credits. The same question arises for the parallel claim of SAF certificates and CO_2 credits, which would effectively lead to additional double counting.

Project start	2022
Quantity	1 million gallons (~3.8 million litres) of SAF (1st year)
GHG reduction	80% reduction in lifecycle emissions vs. Jet A-1
Carbon credits	7700 t CO_2 credits*
Supplier	(unclear)
Physical offtaker	(unclear)
Credits offtaker	corporate clients
Auditor	(unclear, potentially RSB)
Registry	Avelia (blockchain based)
Aim	Validate voluntary ESG reporting of customers

*assuming a fossil emissions baseline of 3.16 t CO_2/t kerosene

Figure 9: Use-case 3 - Avelia

In June 2022, Shell, Accenture and American Express Global Business Travel (AMEX GBT) announced the launch of Avelia. Avelia is a block-chain based platform providing SAF Book and Claim opportunities to corporate customers and airlines. The platform serves as an addition to ongoing corporate SAF programs. The premise is to provide airlines with access to corporate clients aiming to reduce scope 3 emissions from air travel.

As mentioned above, corporate air travel is particularly suitable for initiating SAF rollout, as it provides airlines with 4.3 times more revenue per booking than leisure travel (Stalnaker et al., 2020). This leaves more margin to airlines to absorb the two to eight times higher price tag of SAF compared to convention jet fuel (Micheli et al., 2022). AMEX GBT provides an extensive network of 19.000 corporate customers in 140 countries, including 40 of the 100 companies with the highest travel expenses globally (Shell Energy, 2022).

Shell supplies the SAF, aiming to gather investments for a further SAF production ramp-up. The Energy Web Foundation (EWF) supported the development as a technical advisor. During the first year, Avelia has 1 million gallons (around 3.8 million liters) of SAF available on its network. The SAF and conventional jet fuel are blended in a 50/50 ratio, claiming to reduce lifecycle emissions by an average of up to 40 % (Avelia, 2022).

Project start	2022
Quantity	(unclear)
GHG reduction	(unclear)
Carbon credits	(unclear)
Supplier	Various
Physical offtaker	Various
Credits offtaker	AEG Fuels customers
Auditor	(unclear)
Registry	(unclear)
Aim	Offsetting or reducing AEG Fuels customers emissions

Figure 10: Use-case 4 - AEGFuels

AEG Fuels, a global supplier of aviation fuels with a network covering 197 countries, introduced a SAF platform with the aim of delivering a convenient solution for carbon-neutral flying (AEGFUELS, 2022a). The information on where the SAF is available and how much GHG emissions are avoided through the purchase of SAF is displayed in an associated app, as well as a web service. The customer has the choice of either physically obtaining SAF at one of the 20 airports of AEG Fuels' network where SAF is available, or only claim the SAF certificate via a Book and Claim service, thereby transferring the ESG benefits to the buyer of the SAF certificates (AEGFUELS, 2022b). The airports, where AEG Fuels have SAF available are located in England, the Netherlands, USA, Italy, Austria and Singapore (Corporate Jet Investor, 2022). This global availability is made possible due to AEG Fuels network of suppliers. For example in Vienna, Austria, AEG Fuels announced an agreement with the Austrian fuel company OMV, which includes the delivery of SAF via a pipeline directly to Vienna's main airport (Aviation International News, 2022).

Project start	2022
Quantity	1000 t of SAF
GHG reduction	80% reduction in lifecycle emissions vs. Jet A-1
Carbon credits	2500 t CO_2 credits*
Supplier	Neste
Physical offtaker	Changi Airport
Credits offtaker	Singapore Airlines Customers
Auditor	RSB
Registry	RSB b&c registry, developed with Sustainable Aviation Buyers Alliance (SABA)
Aim	Reduction of SIA customers emissions

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*assuming a fossil emissions baseline of 3.16 t CO_2/t kerosene

Figure 11: Use-case 5 - CAAS, SIA and Temasek

The Civil Aviation Authority of Singapore (CAAS), Singapore Airlines (SIA) and the global investment company Temasek started selling SAF certificates in July 2022. The SAF certificates are registered with RSB. The initial scope of this SAF certificates Book and Claim mechanism is limited to 1000 tons of neat SAF for now, which will be sold by SIA to corporate and individual customers as well as freight forwarders. Freight forwarders have the additional option of passing the credits on to their customers. From the fourth quarter of 2022, this system will be extended to all customers of SIA. The physical SAF is blended into the fueling system of Singapore Changi Airport (CAAS - CWP, 2022). Neste will provide the waste-based SAF, while ExoonMobil blends the SAF at its refinery and delivers it to the airport (Singapore Airlines et al., 2022). The claimed CO_2 emissions savings per ton of SAF are 2.5 tons (CAAS - CWP, 2022).

Lessons learned from existing Book and Claim systems

The examples laid out in this chapter show that Book and Claim systems are already being developed and used by private companies for trading SAF certificates. So far, the traded SAF is of biological origin, but the Book and Claim systems could accommodate e-kerosene as well.

The stated goal of several companies involved in the presented use-cases is, besides reducing scope 3 emissions, to incentivize the ramp-up of SAF production by providing demand. This logic is equally applicable to biological and e-kerosene.

However, renewable fuels sold within voluntary markets do not need to comply with the sustainability criteria set by national or international regulations unless this is specified in contractual agreements. This opens the door for fraud regarding the sustainability

characteristics and labeling towards end users (e.g. air travel passengers or recipients of goods transported by plane). On the other hand, some voluntary standards have equal or stricter sustainability requirements compared to the ones set in some EU regulations. The TÜV Süd CMS 70, for example, sets a higher GHG reduction target for green hydrogen than the RED II (dena & World Energy Council Germany, 2022).

Overall, voluntary markets can contribute to the uptake of sustainable fuels such as SAF, which does not necessarily imply an increase in the environmental sustainability of the applications where they are employed. In general, renewable fuels emerging from voluntary schemes can contribute to increasing environmental sustainability attributes of a sector, as long as they comply with rigorous sustainability certification schemes.

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About the Global Alliance Powerfuels

The Global Alliance Powerfuels was founded in 2018 and is backed by 15 member organisations and an international network of partner institutions. It is coordinated by the German Energy Agency (dena). All members and partners are united by the common goal of advancing the development of sustainable markets for powerfuels. Further details about the Alliance and its activities can be found at **www.powerfuels.org**.