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Fuelling Change: Digitalisation of the biofuel supply chain

Why the European biofuel industry should develop digital dynamic capabilities

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Key takeaways

- The Amsterdam-Rotterdam-Antwerp port-industrial region is Europe's main biofuel processing, trading and distribution hub.
- National and EU regulations are increasing the verification and reporting requirements for supply chain traceability, in turn driving up the cost and complexity of compliance for biofuel companies.
- Digitalisation is a promising way to mitigate or even gain a competitive advantage from these, but no clear pathway has been articulated at the industry level.
- To reduce cost and optimise supply chain traceability, firms need to develop dynamic capabilities and engage in coordination on a regional level.

Introduction

In October 2024, the EU launched the Union Database for Biofuels (UDB) for the biofuel supply chain.[1] The UDB is a centralised digital tool managed by the European Commission to consolidate, streamline and analyse data. In line with the EU's Renewable Energy Directives II/III (RED II/III), the UDB will be a unified source of all biofuel transactions within the EU. Essentially, the UDB serves as a digital ledger for recording the proof of sustainability (PoS) of biofuels for accountability purposes.[2]

The European biofuel industry will eventually be obligated to report to the UDB, increasing the pressure to fast-track the digitisation of paperwork, and meeting other compliance obligations under the EU Deforestation Regulation, Carbon Border Adjustment Mechanism, and potentially the Corporate Sustainability Due Diligence Directive. As the regulatory reporting burden is increasing, so are the risks of fraud and errors in a market characterised by opacity.[3] Digitalisation can reduce costs and risks, but there is no one-size-fits-all solution in a market that is adapting to new realities.

This ECTC briefing paper examines the role of digitalisation in advancing biofuel sustainability and traceability for meeting EU regulatory requirements. Industry players that embrace this digital transformation can leverage these tools for innovation and sustainability, thereby creating a competitive advantage. The paper discusses four strategic pathways that biofuel industry players can pursue when digitalising the post-trade execution process.

1 *Union Database (UDB),* ISCC System, https://www.iscc-system.org/certification/union-database-udb/.
2 *Union Database for Biofuels (UDB),* RSB, https://rsb.org/certification/udb-union-database-for-biofuels/.
3 *Inval bij bedrijf dat verdacht wordt van miljoenenzwendel met grondstoffen voor biodiesel*, Politie, 12 November 2024, https://tinyurl.com/42h4aw5n.

Biofuels in the ARA region

The Amsterdam-Rotterdam-Antwerp (ARA) port-industrial region is one of Europe's largest energy hubs, handling major biofuel processing and trading volumes. Rotterdam alone produced 2.7 million metric tonnes (MT),[4] and transshipped around 11 million MT of biofuel in 2023. The region has an extensive network of facilities and infrastructure dedicated to the production, storage, refining, blending, trading and transshipment of biofuels. The strategic position of its ports and strong hinterland connections offer exceptional access to global trade routes, thereby strengthening its global energy market position.

Table 1. Overview of the different biofuel feedstocks and biofuels.[5]

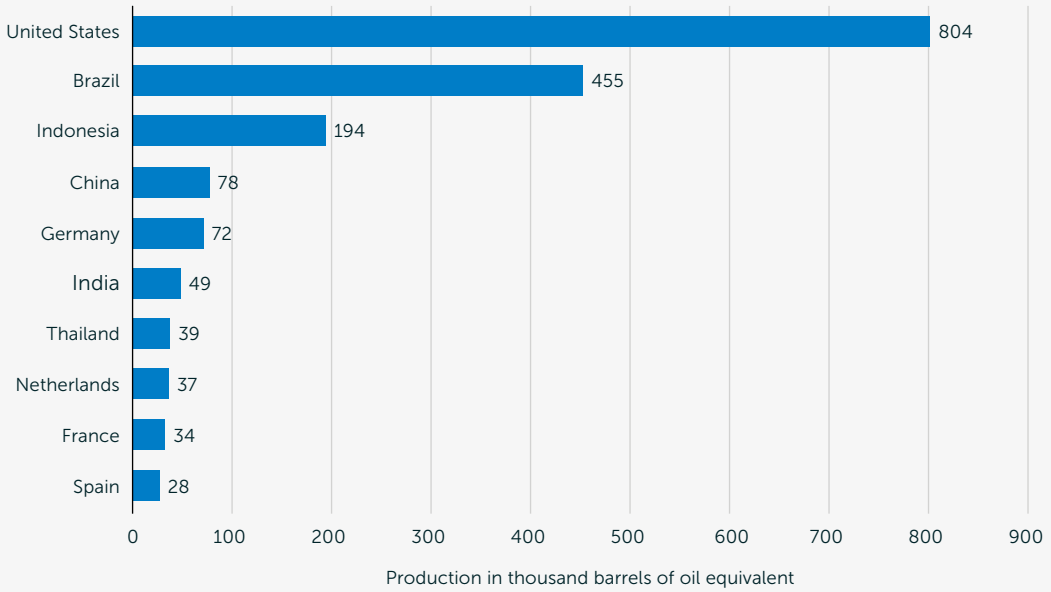
Origin	Generation	Feedstock	Biofuels
Biological origin	First generation – conventional biofuels	Food-related sources (e.g. corn, starch, wheat)	• Bioethanol • Biodiesel • Biogas • Fatty acid methyl ester (FAME)
	Second generation – advanced biofuels	Non-food related sources (e.g. waste, used cooking oil (UCO), agricultural or forest residues)	• Cellulosic ethanol • Used cooking oil methyl ester (UCOME) • Hydrotreated vegetable oil (HVO) • Hydroprocessed esters & fatty acids (HEFA)
	Third generation	Algae and microbes	• Algae biofuel
Non-biological origin	Renewable fuel of non-biological origin (RFNBO) also known as e-fuels	Produced from electricity	• Green hydrogen • Green ammonia • E-diesel • E-methanol

Biofuel production in the ARA region is focused on second generation waste-based biofuels to produce biodiesel, Sustainable Aviation Fuel (SAF), bioethanol and HVO/HEFA. The main sources of feedstock in the Netherlands are UCO, animal fats, sewage sludge and palm oil derivatives. The Netherlands is among the top eight EU producers of UCOME, which together account for 90% of total EU production in 2023. Since 2022, the Netherlands and Belgium partly shifted away from using UCO, palm oil and palm fatty acid distillate to using sewage sludge as feedstock.[6]

Major producers in the ARA region include Neste, Viterra, and the recently announced partnership between Gunvor Group and VARO Energy. Rotterdam has several large-scale tank storage companies dedicated to biofuels, such as Evos, VTTI, Chane and Vopak. In addition, energy companies such as Shell, BP and Total Energies are required to blend their fossil fuels in compliance with RED II. Argent Energy and the Trafigura-owned Greenergy in Amsterdam, Targray in Antwerp and Cargill's main production plant in Ghent are among the facilities that handle Europe's biofuel import and export, and are important locations for transshipment and blending of biofuels.

4 *European Union: Biofuels annual,* USDA Foreign Agricultural Service, 13 August 2024, https://tinyurl.com/bdfe2fez.
5 Kathleen Araújo et al., Global Biofuels at the Crossroads: An Overview of Technical, Policy, and Investment Complexities in the Sustainability of Biofuel Development. *Agriculture,* 7(4), 32, 2017, https://doi.org/10.3390/agriculture7040032.
6 *European Union: Biofuels annual,* USDA Foreign Agricultural Service.

Figure 1. Top 10 biofuel producers in 2023, in thousand barrels of oil equivalent.[7]



The Dutch government and industry are investing in innovative technologies and infrastructure, and developing partnerships like 'green corridors' to stimulate the production and maritime use of biofuels.[8] For example, ETA (part of VTTI) and Connex are developing a 400,000 MT facility in the port of Amsterdam to turn residual products into feedstock to produce biofuel.[9] Another recent collaboration is between VARO Energy and Orim Energy to provide biofuels for shipping customers in the ARA region.[10]

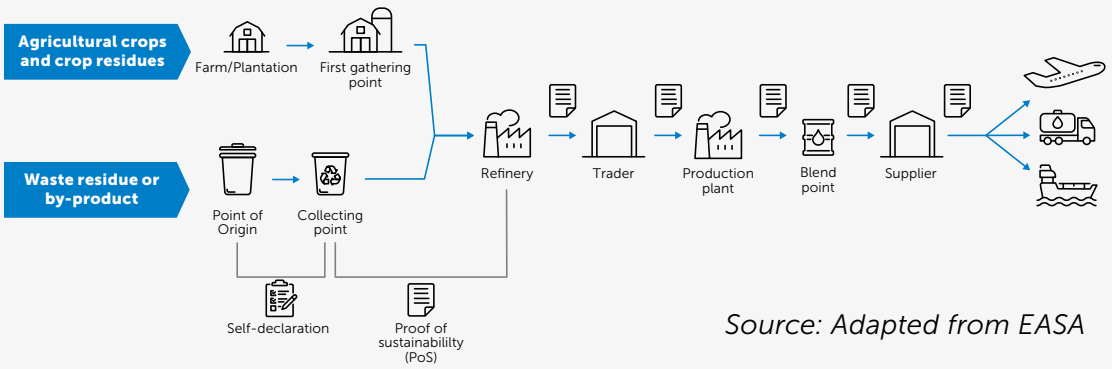
Other investments are being paused due to unfavourable market conditions and regulatory uncertainty. For example, Sweden's lowering of biofuel mandates for road transport in 2024 from 31% to 10% reduced ARA prices for HVO by 30% compared to last year.[11] Additionally, high production incentives in the US have surged supply and pushed down global prices, leaving European producers less competitive.[12] The EU's fragmented regulatory environment (e.g. different national mandates) has made long-term investment in biofuel assets riskier. As a result, several producers are re-evaluating or even pausing their investments. For instance, Shell paused the construction of its 820,000 MT Rotterdam-based biofuel plant due to weak demand.[13] UPM Biofuels, meanwhile, delayed its investment decision for the 500,000 MT SAF biorefinery in Rotterdam.[14]

7 *Leading biofuel producing countries worldwide in 2023*, Statista, 9 July 2024, https://tinyurl.com/enjpd7z9.
8 *Biofuels for the maritime industry in Rotterdam,* Rotterdam Maritime Capital of Europe, 24 May 2023, https://tinyurl.com/s7cr5ntz.
9 *Greenstock pretreatment facility,* VTTI, 21 October 2024, https://tinyurl.com/546xawnt.
10 Ajsa Habibic, *VARO partners with Orim Energy to provide biofuels in Amsterdam-Rotterdam-Antwerp region*. Offshore Energy, 21 February 2024, https://tinyurl.com/mt56fttb.
11 *Sweden to up biofuel mandates again after slashing them*, Argus Media, 28 August 2024, https://tinyurl.com/mr2jampj.
12 *U.S. renewable diesel production growth drastically impacts global feedstock trade*, USDA Foreign Agricultural Service, 11 July 2024, https://tinyurl.com/bdhken5t.
13 Carel Grol, *Biobrandstoffen: groot potentieel, beroerde markt*, FD, 8 July 2024, https://tinyurl.com/8v88jvww; *Shell to temporarily pause on-site construction of European biofuels facility*, Shell Global, 2 July 2024, https://tinyurl.com/4cnac4a7.
14 Fayaz Hussain, *Finland's UPM delays work on SAF/HVO site*, SAF Investor, 23 July 2024, https://tinyurl.com/bdey5jkb.

Sustainability compliance in the biofuel supply chain

The biofuel industry connects traditional energy markets with agricultural markets and increasingly with waste streams that serve as feedstock. This market is complex because market fundamentals and price discovery have not been fully articulated yet. Figure 2 illustrates a stylised version of the biofuel supply chain and the PoS chain of custody.

Figure 2. Traceability in the biofuel supply chain.[15]



Source: Adapted from EASA

PoS documentation follows the physical product along the supply chain. Before feedstock is transferred to a collection point, a PoS is created. With each product transfer, the PoS should be updated. This is a labour-intensive process that is mostly done manually using Excel templates, and at some points in the supply chain even remains paper-based. The first part of the supply chain is most susceptible to fraud because there is no standardised template for (digitally) recording the information, and authenticating it is difficult. For example, there have been cases where virgin vegetable oil was blended in and sold as UCO by Chinese suppliers due to UCO being traded at a higher price than biodiesel made from vegetable oil.[16] The EU has since imposed anti-dumping duties on Chinese biodiesel imports that will enter into effect in February 2025, which is a positive development for European biofuel companies.[17]

PoS certification through voluntary schemes

Under the EU's RED II directive, firms need to certify their PoS documentation under a voluntary scheme (VS). The European Commission currently recognises fifteen VS and has several applications under review.[18] The VS contracts independent certification bodies like Bureau Veritas, Peterson Control Union, SGS Tecnos, DEKRA Certification and ASG Cert to audit the documentation of the transacting parties. In case of a successful audit, a one-year certificate is awarded and the firm is listed in the VS registry.

15 Adapted from SAF *policy actions*, European Union Aviation Safety Agency, 2022, https://tinyurl.com/2bjs2wfc.

16 Sean Goulding Carroll, *EU industry demands answers as "fraudulent" Chinese biofuels continue to flow*, Euractiv, 7 July 2023, https://tinyurl.com/2xxt9ymy.

17 Kelly Norways and Harry Clyne, *EU imposes anti-dumping duties targeting cheap Chinese biodiesel imports*, S&P Global, 16 August 2024, https://tinyurl.com/3vx3v96h.

18 Recognised voluntary schemes as of November 2024 are 2BSvs, Better Biomass, Bonsucro EU, International Sustainability and Carbon Certification (ISCC EU), KZR INiG system, REDcert, Red Tractor Farm Assurance Combinable Crops & Sugar Beet Scheme, Roundtable on Sustainable Biomaterials (RSB), Round Table on Responsible Soy EU RED (RTRS EU RED), Scottish Quality Farm Assured Combinable Crops (SQC), Trade Assurance Scheme for Combinable Crops (TASCC), Universal Feed Assurance Scheme (UFAS), Sustainable Resources (SURE) voluntary scheme, Sustainable Biomass Program (SBP), Austrian Agricultural Certification Scheme (AACS). *Voluntary schemes*, European Commission, https://tinyurl.com/3vkju7tc.

Through certification market players gain market access, credibility and compliance. However, the certification process increases the administrative burden and can lead to operational hold ups due to incomplete PoS documentation transfers. The costs of certification are also significant. One VS, for example, charges a membership fee, a certification fee per item and a quantity dependent fee in €/MT. On top of this, the EU's UDB now adds another administrative hurdle.

A new digitised requirement: Union Database for Biofuels

The UDB is the EU's accounting system mandated by RED II. It serves as a ledger for all biofuel transactions that qualify towards the share of renewable energy in the EU's transport sector.[19] All firms will eventually be obligated to digitally report their sales transactions in(to) the European market. The EU's aim is for UDB to improve the traceability of biofuels in the maritime, road and inland shipping transport sectors, avoid double counting and mitigate the risks for irregularities and fraud. The PoS certificates can only be entered in the database once and their characteristics cannot be altered, which reduces the risk of double counting.[20]

Each actor in the supply chain reports their trade to the UDB, starting with the buyer of biofuel feedstock.[21] This first transfer is self-declared, which creates a vulnerability, as feedstock prior to initial certification can be susceptible to fraud.[22] Full traceability requires knowing the origin of the biofuel, its processing history and the distribution and location of the product after its delivery, from well to wheel.[23] If the EU's certification processes remain incomplete, so will the information in the database: garbage in is garbage out. The UDB prevents multiple uses of certificates but will not stop fraudulent behaviour in the issuing of certificates or poorly executed audits.[24] Irrespective of the limitations, firms and transacting parties are still expected to keep the UDB updated.

There are three options for digitally updating the UDB: via a built-in web interface for the reporting parties, using a licensed third-party Software-as-a-Service (SaaS) provider, who is connected to the UDB, or by connecting the reporting party's own IT-system to the UDB endpoint via a third-party service provider or to and endpoint owned by a voluntary scheme.

Key digitalisation challenges in biofuel sustainability compliance

The key sustainability compliance challenges in the biofuel supply chain are: verification and authentication of the feedstock's origin, traceability and transparency in the supply chain due to the reliance on manual processes and the number of parties handling PoS documentation, and complex and fast changing regulatory requirements.

19 *Union Database for Biofuels (UDB)*, RSB.
20 Galin Gentchev, *Union Database for Biofuels, Main concept & State of play*, European Commission, 6 October 2024, https://tinyurl.com/bdd5dy2h.
21 Galin Gentchev, *Union Database for Biofuels, Main concept & State of play; Ketenanalyse biodiesel*, Nederlandse Emissieautoriteit, 2023, 10 July 2023, https://tinyurl.com/2p8mu27k.
22 Jinke van Dam and Sergio Ugarte, *Accessibility and traceability in sustainable biofuel supply chains*, SQ Consult, 15 May 2020, https://tinyurl.com/5n85dymn.
23 Igor Konstantinov, 2 *levels of supply chain visibility: Traceability and transparency*, Circularise, 22 December 2021, https://tinyurl.com/3ta9nyey.
24 Sean Goulding Carroll, *Biofuel certification schemes slammed for failing to halt fraud*, Euractiv, 28 August 2023, https://tinyurl.com/4vcdjbch.

Digital transformations and dynamic capabilities: from SaaS to platforms

The biofuels industry has been slow in adopting digital solutions for supply chain traceability. However, with mounting regulatory pressure and rising consumer expectations it is no longer a question of if, but when and who will benefit most from this digital transformation. Adopting a digital tool is one thing, but exploiting platform technology to its full potential is a whole other. This shows the need for digital dynamic capabilities within the industry itself. Using rich academic and popular literature on the importance of the digital economy for business models of industry incumbents, this section addresses key definitions and conceptual frameworks that position the focal issue in more context.

There is an important distinction between *digitisation* and *digitalisation*, which are often used interchangeably. Digitisation is the process or task of converting analogous data into digital data. Digitalisation is the integration of digital technologies into business operations to optimise, increase user/customer value and to innovate, learn and gain a competitive advantage. Digitalisation is more substantial and directly connects to digital transformation, which is *"a change in how a firm employs digital technologies, to develop a new digital business model that helps to create and appropriate more value for the firm"*.[25]

The key questions from business leaders are what makes some firms or industries more prone to digital transformation and what does it take to be successful? The answer to those questions can be explained by the concept of *dynamic capabilities*. Every firm has capabilities, most of which are routine and allow for usual operation in a cost-competitive way. While crucial for the business to run, these capabilities are not sufficient in a dynamic business environment in which incumbent competitors or new entrants challenge the status quo. Dynamic capabilities are the abilities of a firm to sense, seize and transform internal and external resources and processes to achieve and sustain a competitive advantage in a rapidly changing business environment, potentially locking-in 'increasing returns'.[26]

While firms can sense the potential of digital technologies and solutions, they are often hampered in seizing their value due to various internal barriers. These include hierarchical management structures, cognitive biases among management, legacy systems, resistance to change by the workforce, and prioritisation of daily routines over the adoption of new digital tools.[27] Because of these, companies often fail to make a full digital transformation of the business model. Firms can improve their sensing or seizing capabilities in several ways. For sensing, firms can proactively scout for digital solutions or engage in specific scenario planning exercises that consider possible digital pathways the industry can take. For seizing, firms need to evaluate how to internalise digitalised functions, routines and tasks and extract value from them. This requires rapid prototyping of business solutions, setting up digital pilot projects, employing digital natives and support from management with clear mandates.

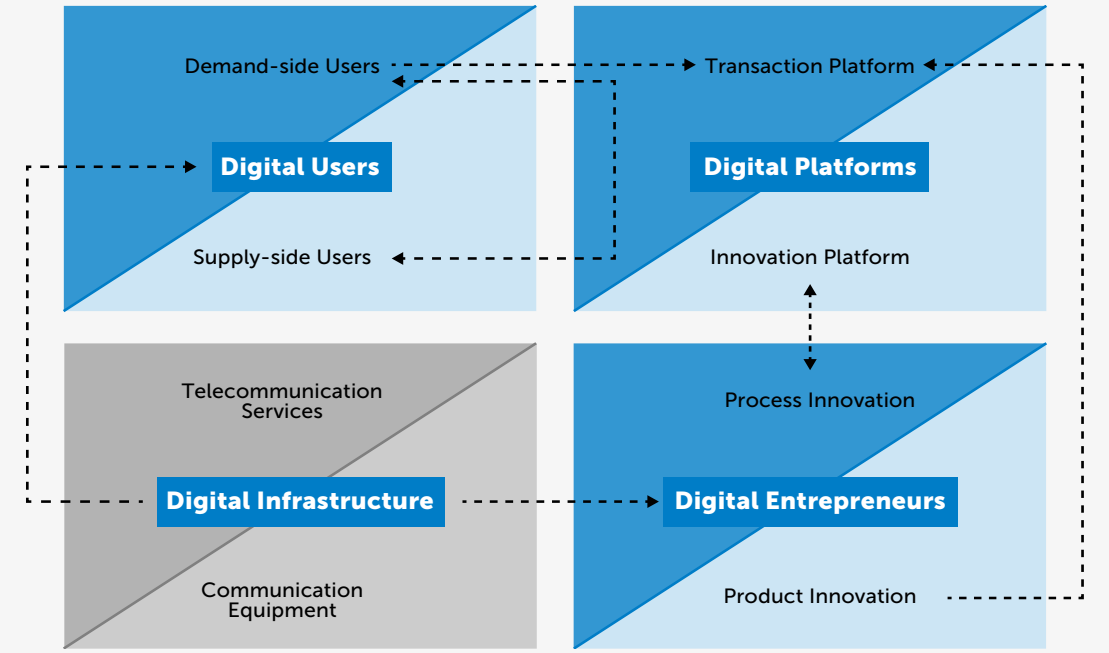
25 Peter C. Verhoef, et al., Digital Transformation: a multidisciplinary reflection and research agenda. *Journal of Business Research*, 122, 889-901, 2021.
26 David J. Teece, Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance, *Strategic Management Journal*, 28(13), 1319-1350, 2007; W. Brian Arthur, Increasing returns and the new world of business, *Harvard Business Review,* 100-109, 1996.
27 Karl S. R. Warner and Maximilian Wäger, Building dynamic capabilities for digital transformation: an ongoing process of strategic renewal, *Long Range Planning*, 52(3), 326-349, 2019.

Digitalisation and the platform economy

Digital technology and digitalisation reduce the costs *"of storage, computation, and transmission of data"*, and in doing so reduce search and transaction costs in a way that changes 'the nature of the firm'.[28] A digital platform is a business model that uses a software-based cloud infrastructure to facilitate interactions and transactions between people, organisations, and resources. The online infrastructure offers continuous accessibility and real-time interactions between users. Digital platforms are highly scalable, allowing more market transactions with a minimal cost increase. They automate business processes, which reduces manual labour, cuts costs and enhances resource management.[29] Digital platforms can be seen as an extension of the SaaS model that emerged in the 2000s by offering a *multi-sided* market exchange between users.

The digital platform economy has firms in four distinct and interconnected activities that together form the digital ecosystem, as shown in Figure 3.[30] The first activity provides the enabling infrastructure, the hardware, equipment and software that connects the ecosystem. The second set of firms are digital platform owners, with transaction- or innovation-based platforms. The third set of firms are the digital entrepreneurs that develop and improve cloud-based software applications and interfaces for the functionality of the platform. The last set of firms are the users of the platform, connecting supply-side users with the demand-side users. Overlap is possible with prospective demand-side users investing in digital entrepreneurship to develop digital platforms enabled by digital infrastructure providers.

Figure 3. A schematic overview of the digital platform economy.[31]



28 Zoltan J. Acs et al., The evolution of the global digital platform economy: 1971–2021, *Small Business Economics*, 57(4), 1629–1659, 2021, https://doi.org/10.1007/s11187-021-00561-x.
29 Kate Gibson, Digital Platforms: *What they are & how they create value*, Harvard Business School Online's Business Insights Blog, 8 May 2024, https://online.hbs.edu/blog/post/what-is-a-digital-platform.
30 Zoltan J. Acs et al., The evolution of the global digital platform economy: 1971–2021.
31 Zoltan J. Acs et al., The evolution of the global digital platform economy: 1971–2021.

Reasons for failures of digital platforms

When a digital platform competes in a traditional market, it usually emerges as the winner due its superior network effects. Yet, the failure rate for digital platforms is high, with an average lifespan of platforms being five years.[32] There are six major reasons why platforms have high failure rates, with a combination of factors usually responsible for the failure:

1. **Pricing:** Platform owner misprices the use of the platform, and users are not convinced with the value of adoption against its costs, such as the onboarding and learning costs of employees assigned to use the platform.
2. **Governance:** A lack of digital trust among involved parties results in limited adoption, exemplified by the case of TradeLens in Box 1, where an industry leader launched a platform without sufficient collaboration with industry peers.
3. **Network effects:** The platform does not reach a critical mass of participants. This could be due to lack of support from incumbents or part of the supply chain players missing. Successful platforms benefit from network effects of buyers attracting suppliers and the other way around, resulting in a winner-takes-all dynamic.[33]
4. **Market entry timing:** The market entry is too late or too early. In case of too early, the ecosystem is not yet in place, with many of the prospective users still identifying the solution to a problem internally and evaluating the potential alternatives. In case of too late, the competitors might have already locked-in the network effects.
5. **Value proposition:** The platform is technically feasible, but it does not solve a problem that is well articulated and considered a priority for its users, so the platform does not reach critical mass. Prospective users and incumbents might have other incentives to adopt an existing third-party digital solution.
6. **Competition:** Platforms face strong competition from other platforms or traditional businesses. In the latter case, startups may have technical solutions and the value proposition right, but incumbent businesses have their own initiatives that benefit from their position in the market.

Box 1: TradeLens – The failed Maersk and IBM digital logistics platform[34]

TradeLens was launched in 2018 by Maersk and IBM to consolidate global maritime logistics in a single system, aiming for full traceability and digitisation of cargo movement. It ceased operations four years later due to limited participation of two critical supply chain players: shippers and freight forwarders. Alongside a lack of clear incentives and financial sustainability issues, concerns with TradeLens's data governance model were a key obstacle for an industry concerned with information privacy. This underscores the role of digital trust and inclusive governance in ensuring that all essential participants are aligned.

32 David B. Yoffie et al., A Study of More Than 250 Platforms Reveals Why Most Fail, *Harvard Business Review*, 17 September 2021, https://hbr.org/2019/05/a-study-of-more-than-250-platforms-reveals-why-most-fail.
33 Zoltan J. Acs et al., The evolution of the global digital platform economy: 1971–2021.
34 Lora Cecere, *Tradelens Discontinues Operations. Why You Should Care*, Forbes, 5 December 2022, https://tinyurl.com/metnkym7.

Four digital pathways for the biofuel supply chain

The chain of custody digitalisation in the biofuels supply chain is still in its early stages, with four possible development pathways emerging. It is too early to determine which pathway will dominate, and it is likely that all four will coexist for some time in various forms. This evolution will be shaped by a combination of selection, network effects and pure chance.

Pathway 1: Interconnected SaaS. Separate SaaS providers continue to co-exist in different parts of the supply chain (upstream, midstream, downstream) and different geographies. They are interoperable in the digital chain of custody, but the network effects remain limited, with competition for users restricting coordination between the various SaaS. In some biofuel supply chains (e.g. SAF), large end-users (e.g. airlines) may move forward faster than in other biofuels and pick their winners, possibly setting up collaborative platforms themselves.

Pathway 2: Collaborative platform model. Leading midstream players (or large end users) collaborate to develop a platform. An example of this is TRACT, which was founded by Archer Daniels Midland Company (ADM), Louis Dreyfus Company (LDC), Cargill and Olam in 2023 for end-to-end supply chain traceability in the food and feed supply chain, with its own auditing and compliance requirements.[35] The founding companies are the main users, responsible for the critical mass and the network effects to make the platform successful, similar to the case of Covantis in Box 2. While some of those involved in TRACT and Covantis are involved in biofuels, and some of the reporting requirements overlap, there is no official plan to include biofuels in the current setup. In case biofuels are added, an unknown is the ability of leading energy and agricultural companies to collaborate in setting up a joint platform.

Pathway 3: Company-owned platforms. Some third-party SaaS co-exist with large company-owned inhouse platforms in a fragmented market. Large companies further digitise audit trails in their enterprise resource planning systems, locking-in their supplier and customer bases. The need for interoperability between the larger companies might result in a collaboration and joint venturing into collaborative platforms, similar to Pathway 2.

Pathway 4: Consolidation of third-party SaaS. Independent third-party SaaS vendors co-exist and manage to scale-up. After the initial scale-ups, these third-party vendors consolidate, either through mergers or via acquisitions.

Box 2: Covantis – A digital post-trade execution platform[36]

Launched in 2021 by agricultural traders ADM, Bunge, Cargill, COFCO International, LDC, Viterra and Marubeni, Covantis modernises post-trade execution by making commodity shipping processes faster, cheaper and easier. Initially focused on Brazilian soybean exports, it now supports grain and oilseed exports across the Americas. Covantis adopted an origin-market strategy, whereby they marketed and sold the platform in the country where products originated. This strategy leverages product attributes, quality, and authenticity to build digital trust and ensure standards.

35 *Announcing TRACT*, TRACT, 3 October 2023, https://www.tract.eco/news/announcing-tract.
36 *About*, Covantis, 2024, https://covantis.io/about/.

Strategic outlook for digitalisation in the biofuels market

The Netherlands and the ARA port-industrial region is Europe's key hub for the production and trade of biofuels. As the market for biofuels grows, it faces an evolving regulatory landscape, while the pricing of biofuels and some biofuel feedstocks is still opaque. The complexity of regulations on the national and EU levels creates both compliance challenges and opportunities for traders to play regulatory arbitrage. Compliance with the regulatory directives is an increasing cost due to the personnel needed for the tedious task of checking documentation. Although the EU postponed the obligatory reporting to the UDB, supply chain players are still required to report the PoS via the voluntary schemes and take responsibility in an auditable chain of custody under the RED II directive.

Considering the growth of the market (liquidity and number of transactions), the complexity of the reporting requirements and the costs of compliance (or that of non-compliance for that matter), digitisation of the chain of custody seems to be a logical way forward. Digital solutions and platforms for supply chain traceability and trade execution are not new. The success stories, however, are limited, which confirm the general observation that most digital platforms fail due to the lack of critical mass, wrong timing of entry, or inadequate governance arrangements. This is true for both small startups that depend on launching customers and incumbents' initiatives that fail due to lack of digital trust among transacting parties on the platform and the role of the incumbent as the owner of the platform.

Getting the governance right and securing upfront commitment through collaboration of industry users might be crucial for success, as the Covantis platform demonstrates. On the other hand, the biofuel ecosystem is fragmented when compared with the concentrated nature of the Brazilian soybean export market. In the biofuels market, both the traditional 'Big Energy' like Shell, Bp, Total and Repsol, and 'Big Ags' like Cargill, ADM and Viterra are active alongside a diverse group of niche and emerging producers, processors, traders, users and financial investors.

This briefing paper presents the four possible evolutionary pathways for the digitalisation of the biofuels chain of custody. The market is currently in its initiation phase, in which several digital startups like FuelFWD or Bioledger have emerged, while at the same time large industrials are looking into the problem themselves. These digital startups currently operate more according to the SaaS business model, rather than a pure platform. Their business model is to execute the documentary transfer of PoSs, and the recording of the documents into the UDB for customers. The customer does not incur large start-up costs, but with a subscription most costs are in the time used by the customer to onboard and learn to use the SaaS.[37]

In addition to the emergence of SaaS, there are four potential digitalisation pathways for the biofuel industry. **Pathway 1** is where sector, geography or supply chain specific SaaS coexist initially but later become interconnected. **Pathway 2** has more collaborative initiatives that lead to an industry-wide platform. **Pathway 3** has inhouse initiatives of industry incumbents initially coexisting with specialised SaaS providers, before pulling ahead due to lock-in of customers and suppliers. **Pathway 4** is where independent third-party SaaS consolidate into integrated, independent platforms.

37 Frank V. Cespedes and Jacco van der Kooij, The Rebirth of Software as a Service, *Harvard Business Review*, 18 April 2023, https://hbr.org/2023/04/the-rebirth-of-software-as-a-service/.

Overall, the biofuel ecosystem needs investment in developing digital dynamic capabilities that capture the value of digital transformations. The regulatory burden and the associated compliance costs are only likely to increase with further European regulation. The extent to which companies are capable of capturing value from digitalisation depends on the degree of desired interoperability, the legacy systems in place, the cognitive biases of management, degree of resistance by the workforce, and prioritisation and other forms of lock-in.

The ARA region plays a key role in Europe's production, trade and distribution of biofuels. Collaborative action at the regional level from industry, digital entrepreneurs and other stakeholders (e.g. port authorities, venture capitalists, end-users) in the biofuels supply chain is needed for accelerated digitalisation. Although geographical proximity is necessary to foster the development of a digital platform ecosystem, the defining factor is the shared understanding of the problem and the digital solution, including the way it is priced and governed.[38]

38 Peter Hall and Wouter Jacobs, Shifting proximities. the maritime ports sector in an era of global supply chains, *Regional Studies* 44(9), 1103-1115, https://doi.org/10.1080/00343400903365110.

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