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Abstract

EN

This study explores the potential of blockchain technology and digital solutions to support the implementation of European Union (EU) climate policies by the European Commission. The main objective is to identify EU climate policies that can benefit from distributed ledger technologies (DLT) and digital tools. The study comprises three tasks: Climate Policy Mapping and Scoping: This task involves collecting data to understand EU climate policies, analyzing existing use cases, and assessing how DLT can enhance these policies based on specific criteria. Case Studies on DLT Implementation: Task 2 thoroughly examines selected policy options, evaluating the prerequisites for integrating DLT and discussing potential outcomes. Recommendations on DLT and Digital Technologies: Task 3 presents the analysis results, outlines implementation strategies, and provides general recommendations for incorporating DLT into EU climate actions, and provides estimates of their range of time and costs required for their implementation. The study evaluates the advantages and disadvantages of deploying DLT in EU climate policies, covering aspects such as disintermediation, stakeholder adoption, record-keeping, technological readiness, and interoperability. It also explores the potential impact of DLT on specific climate policies, including Carbon Removal Certification, Ozone-Depleting Substances, and F-Gas.

FR

Cette étude explore le potentiel de la technologie blockchain et des solutions numériques pour soutenir la mise en œuvre des politiques climatiques de l'Union européenne par la Commission européenne. Le principal objectif visait à identifier des politiques climatiques européennes pertinentes et caractériser les effets de leur mise en œuvre des technologies de registres distribués (DLT) et des outils numériques. L'étude comprenait trois tâches. Premièrement, une cartographie des politiques climatiques et une délimitation du champ d'application : cette tâche a consisté à collecter des données pour comprendre les politiques climatiques de l'UE, à analyser les cas d'utilisation existants et à hiérarchiser l'utilisation de DLT pour ces politiques sur la base de plusieurs critères. Deuxièmement, des études de cas sur la mise en œuvre de la DLT ont permis d'examiner en profondeur 3 politiques, en évaluant les conditions préalables à l'intégration de la DLT et en analysant les effets potentiels. Enfin, une troisième tâche décrit les stratégies et ressources de mise en œuvre et fournit des recommandations générales pour l'intégration de la DLT dans les politiques climatiques européenne. L'étude évalue les avantages et les inconvénients du déploiement de la DLT dans les politiques climatiques de l'UE, couvrant des aspects tels que la désintermédiation, l'adoption par les parties prenantes, la tenue de registres, l'état de préparation technologique et

l'interopérabilité. Elle explore également l'impact potentiel de la DLT sur des politiques climatiques spécifiques, notamment la certification de l'absorption du carbone, les substances appauvrissant la couche d'ozone et les gaz à effet de serre fluorés.

Executive summary

English

This study explores the potential of blockchain technology and other digital technlogies in supporting climate policy implementations by the European Commission in the European Union (EU). The first objective of the study is to identify current and future EU climate policies that could potentially benefit from the use of distributed ledger technologies (DLT) and other digital technologies. To achieve this, the study examins different EU climate policies in light of the the potential of DLT use cases to address the needs or challenges to implement climate policies. The objectives were accomplished through meticulous analysis and close collaboration with European Commission (EC). It involved selecting a set of EU climate policies with direct mandate to Directorate-General Climate Action (DG-CLIMA), and developing three case studies that demonstrate the benefits of utilizing DLT for climate policies. The findings of the study were instrumental to formulate recommendations regarding potential strategies for implementing DLT for climate policies, including implementation schedule and development costs. The study is structured in three tasks: 1) Climate policy mapping and scoping; 2) Case studies on the potential implementation of DLT in selected climate policies; and 3) Recommendations on the use of DLT and other digital technologies for climate policies implementation strategies.

Task 1 involves a significant number of data collection activities aimed at: (i) developing an understanding and mapping climate policies and their key challenges, (ii) gaining insight through the analysis of existing use cases both within and outside the EU, the main features of DLT, and how DLT can be further leveraged/used in conjunction with other digital solutions (e.g., traceability systems, IoT, AI, etc.), (iii) analyzing how DLT can be used to support EU climate policy using specific criteria to determine the pros and cons of introducing DLT into identified EU climate policies. This approach allows identify climate policies where DLT would offer the best option towards their climate policies implementation. Focus grous and expert interviews were used during this task to gather feedback on the potential benefits and challenges of DLT for climate policies.

Task 2 conducts a comprehensive examination of the selected policy options, leveraging the data and analysis carried out in Task 1 to evaluate the essential prerequisites for incorporating DLT into their framework and to deliberate potential outcomes (both positive and negative) stemming from the utilization of DLT. The analysis merges: (i) expert opinions on feasible approaches to implementing DLT and the array of factors that should be considered, drawing from the data collected during Task 1, and (ii) conducting interviews with relevant stakeholders for the chosen climate policies and other DLT and digitalization experts.

Task 3 provides the results of the analysis and offers an overview of DLT implementation in climate policy. This is achieved through: (i) presenting implementation strategy for each of the policy options, providing practical guidance on overcoming DLT implementation challenges, the necessary support for sustaining DLT effectiveness (i.e., monitoring and evaluation), and (ii) offering general recommendations on the use of DLT in EU climate actions, discussing the benefits and risks associated with DLT. This tasks also offers a schedule for the implementation strategies and development and implementation costs of the three selected cases: Carbon Removal Certification, Ozone Depleting Substances, and F-Gas.

The **analysis of DLT potential in EU climate policies** involved assessing the advantages and disadvantages arising from examining the deployment of DLT in the public policies of EU member states. The following paragraphs present the topics considered regarding DLT systems in public policies.

Disintermediation refers to the replacement of centralized databases hosted by intermediaries like public agencies or financial institutions to facilitate transactions or store information, through the introduction of DLT. Access to the network can be secured using an authorized DLT system or open to the public, depending on the specific needs of the policy. This process enhances policy implementation and compliance with regulations through the immutable and tamper-proof preservation of data.

The **adoption** by stakeholders represents benefits as they are increasingly aware of DLT technologies and would be willing to embrace it provided it is governed by trusted institutions. One of the key advantages of adopting DLT for stakeholders is related to digital sovereignty. With the prior authorization of digital identities and the creation of digital wallets to manage documents and their approvals, individuals and businesses have greater flexibility in sharing specific identification details with designated entities. This means that stakeholders have autonomy in selecting the documents and information they prefer.

The analysis includes of the impact that authorized DLT systems can have on activities such as **reporting and compliance**, addressing issues related to the immutability of record-keeping and rule enforcement through smart contracts. In general, DLT systems can be employed to ensure compliance with predefined rules (i.e., licenses) through continuous data entry monitoring and identifying deviations from expected outcomes.

The **technological maturity** relates to whether DLT systems are technologically mature enough to be adopted by climate policies. DLT is a recent technology that the public sector has been hesitant to adopt, and most public sector DLT projects are not fully operational but in the pilot phase. One of the primary concerns is the ability to integrate DLT with existing systems or to transition to DLT-based systems.

Interoperability concerns the involvement of multiple countries or jurisdictions in DLT transactions or operations and is a major concern for deployment across the EU and internationally. DLT could facilitate the carbon markets, reporting on market restriction compliance, support the investigation of Economic Operators outside the EU jurisdictions, etc. International standards contribute to the adoption of DLTs, and may enable the EU to fulfill its international climate policy obligations, and under these conditions the deployment of DLT would add value to the EU's international commitments. Across jurisdiction and under well defined agreed standards, the international deployment of DLT can contribute to **international collaboration** among stakeholders.

Regarding the **Emission Trading Systems Monitoring Verification and Reporting**, the literature and discussion groups have referred to the possibilities of DLT providing positive benefits in terms of disintermediation, reporting, and compliance. This is due to the potential to generate immutable records on the origin, tracking, and ownership of carbon allowances, as well as supporting more cost-effective transactions compared to existing clearance timelines. Stakeholder participation would be encouraged as trust in the system would be strengthened, and opportunities for fraudulent activities reduced. International cooperation could be enhanced through the integration of carbon markets.

Land Use, Land-Use Change and Forestry (LULUCF). The primary benefit of disintermediation would be to provide a EU-wide system that harmonizes the implementation of the LULUCF by encouraging more consistent application of methods and the use of satellite data. It could also facilitate proof of compliance and digital sovereignty by sharing evidence that specific methodological standards have been met (rather than making analyses transparent).

Stakeholder adoption would be encouraged as DLT would strengthen the proof of ecological principles required today for sustainable land management - smart contracts would support cross-border enforcement.

DLT could have positive implications for stakeholder engagement, reporting, and compliance in the cotext of the **Carbon border Adjustment Mechanisms**. DLT can contribute to improving product traceability and supply chain transparency immutably for all relevant stakeholders. Carbon accounting and certification systems require significant safeguards and data resources to ensure the integrity of the entire system. DLT systems appear as a solution to automate transactions with carbon certificates while securing data recording and the integrity of the entire system.

The EU climate policies mentioned above were ultimately not part of the in-depth evaluation. Among the analyzed policies, three were selected for case studies: **Carbon Removal Certificates, Ozone-Depleting Substances, and Fluorinated Gases**. These three policies are currently under negotiation or review, and the proposed changes introduce elements that could be beneficial if certain features are managed by DLT and other digital technologies.

The **carbon removal certification** faces serious risks, including: double-counting carbon removal units, carbon removal projects, carbon removal certificates, and double-selling. DLT solutions can reduce these risks while enabling multiple voluntary carbon registries to coexist interoperably. The indepth analysis presents two scenarios. Scenario 1 represents a system in which all carbon systems manage independent DLT databases that communicate directly without a single underlying registry. Scenario 2 represents a single pan-European transactional registry that underpins and links independently managed rules and databases (subject to a minimum level of alignment with the proposed regulation) of different carbon systems. Both scenarios are based on the EBSI. A comparison of scenarios 1 and 2 indicates that a single EU-level DLT registry based on the EBSI is easier to implement.
More generally, the conditions for a successful implementation of a blockchain system are as follows: **Raising awareness** among potential users about the benefits of the system and competent agents in all roles. For example, users should know where to onboard, where to certify registry compliance, how to request DIDs, etc. **Consistent alignment** of off-registry governance and certification processes with technical systems and interoperability requirements. Additionally, certificate and NFT **specifications should remain stable** to avoid multiple iterations of processes and applications, which would result in increased sunk costs for certification systems and public interest organizations.
At the EBSI level, expanding and adopting the EBSI ecosystem into other use cases, such as government-backed digital identities, will help establish standards that can increase adoption and cooperation. Additionally, these additional use cases can be integrated into the CRC process rather than creating standalone, single-use case structures and systems that risk duplication. Several EU governments are already exploring digital identity options (Belgium, the Netherlands, the EC itself), and it is essential that these options include EBSI technical standards and protocols if they are to contribute to EBSI function interoperability.
While DLT offers several advantages for reducing administrative burdens related to reporting and auditing in the voluntary carbon market activities, the issue of international interoperability can pose a risk to certification systems operating within and outside the EU. For blockchain infrastructures operating on fundamentally different protocols, blockchain bridges are currently unable to solve this problem. In this case, a political cooperation is proposed to determine minimum international interoperability standards.

The licensing system for **ozone-depleting substances**, based on recent impact assessments, has the potential to address various challenges related to improving license traceability, monitoring report extensions, increasing the number of stakeholders, proper legislation enforcement, and fraud detection. DLT solutions could help tackle these challenges and contribute to transparency and efficiency in reporting, monitoring, and compliance. In the case of **licensing**, it has been demonstrated how DLT is applied in similar cases by the private sector and how it could be adapted to the ozone-depleting substance (ODS) licensing system. DLT applications could enhance control and notification processes and provide real-time data on the status and location of goods. It has also been shown that a DLT system can enhance data security by limiting access, significantly reducing the possibility of altering historical chain information, and providing an immutable records all data and any changes made.

The use of **verifiable digital identities** or license keys, especially for legal entities, to stamp data transactions on the DLT system improves auditability and reduces the possibility for ODS supply chain actors to create and use fake identities within the system. This reduces the risk of over-licensing and increases the likelihood of accurate reporting in the ODS system.

While DLT can bring several enhancements to current and future processes, it remains important to leverage existing systems such as EBSI and examine how changes to the ODS licensing system will affect its integration into the EU single window. Integrating these systems will require consideration of the relative strengths and weaknesses of each component and should be evaluated based on existing investments and the system's readiness for change. In this regard, similar results can be achieved using non-DLT systems, but with potentially higher administrative burdens.
The proposed amendment to the regulation on **fluorinated greenhouse gases (F-gas)** includes a series of provisions to address challenges related to the quota system, such as those linked to illegal activities (fraud). Some provisions have been proposed to assess whether tracing methods for fluorinated greenhouse gases placed on the market could help control illegal trade; the proposed provisions may require increased engagement from stakeholders in multiple jurisdictions, whose potentially non-interoperable systems could make information exchange difficult or inaccurate. It hasben distribed in the study how the combination of DLT and already existing traceability systems can be integrated and allow to monitor not only quota transfers of the F-Gas portal, but also to validate the quotas with the actual physical movement of gases along the supply chain until the final user it is industrial, or the final seller if it is a retailer.

French
Cette étude explore **le potentiel de la technologie blockchain et d'autres technologies numériques pour soutenir la mise en œuvre de la politique climatique par la Commission européenne dans l'Union européenne (UE)**. L'objectif principal de l'étude est d'identifier les politiques climatiques actuelles et futures de l'UE qui pourraient potentiellement bénéficier de l'utilisation des technologies de registres distribués (DLT) et d'autres technologies numériques et de caractériser les effets de leur mise en œuvre des technologies DLT et des outils numériques. Pour ce faire, l'étude a examiné différentes politiques climatiques de l'UE à la lumière du potentiel des cas d'utilisation des DLT pour répondre à leurs besoins ou leurs défis de mise en œuvre. Après avoir étudié les politiques climatiques de l'UE, notamment celles portées par la Direction générale de l'action pour le climat (DG CLIMA), trois études de cas ont été développées pour analyser les potentiels effets de l'utilisation de la DLT pour leur mise en œuvre. Les résultats de l'étude ont permis de formuler des recommandations concernant les stratégies possibles de mise en œuvre de la DLT pour les politiques climatiques, y compris le calendrier de mise en œuvre et les coûts de développement. L'étude a été structurée en trois tâches : 1) cartographie et séléction des politiques climatiques à analyser en détail ; 2) réalisation d'études de cas sur la mise en œuvre potentielle de la DLT pour les trois politiques climatiques sélectionnées ; et 3) recommandations sur l'utilisation de la DLT et d'autres technologies numériques pour la mise en œuvre des politiques climatiques.

La tâche 1 a impliqué des activités de collecte de données visant à : (i) développer une compréhension et une cartographie des politiques climatiques et de leurs principaux défis, (ii) obtenir un aperçu, à travers l'analyse de cas d'utilisation existants à l'intérieur et à l'extérieur de l'UE, des principales caractéristiques de la DLT, et comment la DLT peut être davantage exploitée/utilisée en conjonction avec d'autres solutions numériques (par exemple, les systèmes de traçabilité, l'IoT, l'IA, etc.), (iii) analyser comment la DLT peut être utilisée pour soutenir la politique climatique de l'UE en utilisant des critères spécifiques pour déterminer les avantages et les inconvénients de l'introduction de la DLT. Cette approche a permis d'identifier les politiques climatiques pour lesquelles la DLT présentait le meilleur potentiel. Cette tâche s'est basée à la fois sur de l'analyse documentaire, des groupes de discussion et des entretiens avec des experts.

La tâche 2 a examiné en profondeur une sélection de trois politiques climatiques (Certification d'absorption du carbone, substances appauvrissant la couche d'ozone et gaz fluorés), pour évaluer les conditions préalables nécessaires à l'incorporation de la DLT pour leur mise en œuvre et pour analyser les effets potentiels (à la fois positifs et négatifs). L'analyse s'appuie notamment sur : (i) les opinions d'experts sur les approches réalisables pour mettre en œuvre la DLT et l'ensemble des facteurs qui devraient être pris en compte, en s'appuyant sur les données recueillies au cours de la tâche 1, et (ii) la conduite d'entretiens avec les parties prenantes concernées par les politiques climatiques choisies et d'autres experts de la DLT et de la numérisation.

La tâche 3 présente les résultats de l'analyse et offre une vue d'ensemble de la mise en œuvre de la DLT dans la politique climatique. Ceci est réalisé à travers : (i) la présentation de la stratégie de mise en œuvre pour chacune des trois politiques, fournissant des conseils pratiques pour surmonter les défis de mise en œuvre de la DLT, le soutien nécessaire pour soutenir l'efficacité de la DLT (c'est-à-dire, le suivi et l'évaluation), et (ii) des recommandations générales sur l'utilisation de la DLT dans les actions climatiques de l'UE, discutant des avantages et des risques associés à la DLT. Cette tâche propose également un calendrier pour les stratégies de mise en œuvre et les coûts de développement et de mise en œuvre des trois cas sélectionnés.

L'analyse a notamment consisté à évaluer les effets découlant d'un potentiel déploiement de la DLT dans les politiques publiques des États membres de l'UE. Les paragraphes suivants présentent les sujets examinés concernant les systèmes DLT dans les politiques publiques.

- La **désintermédiation** fait référence au remplacement des bases de données centralisées hébergées par des intermédiaires, tels que les organismes publics ou les institutions financières, pour faciliter les transactions ou stocker des informations, grâce à l'introduction de la DLT. L'accès au réseau peut être sécurisé à l'aide d'un système DLT autorisé ou ouvert au public, en fonction des besoins spécifiques de la politique. Ce processus améliore la mise en œuvre des politiques et la conformité aux réglementations grâce à la conservation immuable et infalsifiable des données.
- **L'adoption par les parties prenantes** représente des avantages car elles sont de plus en plus conscientes des technologies DLT et seraient prêtes à les adopter à condition qu'elles soient régies par des institutions de confiance. L'un des principaux avantages de l'adoption de la DLT pour les parties prenantes est lié à la souveraineté numérique. Avec l'autorisation préalable des identités numériques et la création de portefeuilles numériques pour gérer les documents et leurs approbations, les individus et les entreprises disposent d'une plus grande flexibilité pour partager des détails d'identification spécifiques avec des entités désignées. Cela signifie que les parties prenantes sont autonomes dans le choix des documents et des informations qu'elles préfèrent.
- En ce qui concerne la **déclaration et la conformité**, les systèmes DLT autorisés peuvent traités de sujets liés à l'immuabilité de la tenue des registres et à l'application des règles par le biais de contrats intelligents. En général, les systèmes DLT peuvent être utilisés pour assurer

la conformité avec des règles prédéfinies (c'est-à-dire des licences) grâce à un contrôle continu de la saisie des données et à l'identification des écarts par rapport aux résultats attendus.

- **La maturité technologique** adresse l'enjeu de savoir si les systèmes DLT sont suffisamment avancés pour être adoptés par les politiques climatiques. La DLT est une technologie récente sur laquelle le secteur public se pose des questions, et la plupart des projets DLT du secteur public ne sont pas pleinement opérationnels mais en phase pilote. L'une des principales préoccupations est la capacité d'intégrer la DLT dans les systèmes existants ou de passer à des systèmes basés sur la DLT.
- **L'interopérabilité** concerne l'implication de différentes parties prenantes (pays, juridictions) dans les transactions ou opérations DLT, et constitue une préoccupation majeure pour le déploiement dans l'UE et au niveau international. La DLT pourrait faciliter la mise en réseau des marchés du carbone, l'établissement de rapports sur le respect des restrictions du marché, les enquêtes sur les opérateurs économiques en dehors des juridictions de l'UE, etc. Les normes internationales contribuent à l'adoption des DLT et la technologie pourrait permettre à l'UE de remplir ses obligations internationales en matière de politique climatique ; dans ces conditions, le déploiement des DLT apporterait une valeur ajoutée aux engagements internationaux de l'UE. Le déploiement international des DLT peut contribuer à la collaboration internationale entre les parties prenantes, par-delà les juridictions et dans le cadre de normes bien définies.

Au regard de ces critères, plusieurs politiques climatiques de l'UE ont été analysées pour leur potentiel de déploiement de la DLT, dont les trois ci-dessous :

- En ce qui le **système d'échange de quotas d'émission**, et notamment la surveillance, la déclaration et la vérification, les analyses montrent que la DLT pourrait apporter des avantages en termes de désintermédiation, de déclaration et de conformité. Cela est dû à la possibilité de générer des enregistrements immuables sur l'origine, le suivi et la propriété des quotas de carbone, ainsi que de soutenir des transactions plus rentables par rapport aux délais actuels. La participation des parties prenantes serait encouragée, du fait d'une confiance renforcée dans le système serait renforcée et d'une réduction des possibilités d'activités frauduleuses. Enfin, la coopération internationale pourrait être renforcée par l'intégration des marchés du carbone.
- Pour **l'Utilisation des Terres, Changement d'Affectation des Terres et Foresterie** (UTCAF, ou LULUCF *pour Land Use, Land Use Change and Forestry*), le principal avantage identifié de la désintermédiation serait de fournir un système à l'échelle de l'UE qui harmonise la mise en œuvre de l'UTCATF en encourageant une application plus cohérente des méthodes et l'utilisation de données satellitaires. Elle pourrait également faciliter la preuve de la conformité et la souveraineté numérique en partageant la preuve que des normes méthodologiques spécifiques ont été respectées. L'adoption par les parties prenantes serait encouragée car la DLT renforcerait la preuve des principes écologiques requis aujourd'hui pour la gestion durable des terres - les contrats intelligents soutiendraient l'application transfrontalière.
- La DLT pourrait avoir des retombées positives sur l'engagement des parties prenantes, l'établissement de rapports et la conformité dans le contexte du **Mécanisme d'Ajustement Carbone aux Frontières** (MACF). La DLT pourrait contribuer à améliorer la traçabilité des produits et la transparence de la chaîne d'approvisionnement de manière immuable, et ce pour toutes les parties prenantes concernées. Les systèmes de comptabilisation et de certification du carbone nécessitent d'importantes mesures de protection et des ressources de données pour garantir l'intégrité de l'ensemble du système. Les systèmes DLT

apparaissent comme une solution pour automatiser les transactions avec les certificats de carbone tout en sécurisant l'enregistrement des données et l'intégrité de l'ensemble du système.

Malgré le potentiel intérêt d'utilisation de la DLT, les politiques climatiques de l'UE mentionnées ci-dessus n'ont finalement pas été sélectionné pour une analyse approfondie. Parmi les politiques analysées, trois ont été sélectionnées pour des études de cas : les certificats d'absorption du carbone, les substances appauvrissant la couche d'ozone et les gaz fluorés. En effet, ces trois politiques font actuellement l'objet de négociations ou d'un examen, et les changements proposés introduisent des éléments qui pourraient être bénéfiques si certaines caractéristiques sont gérées par la DLT et d'autres technologies numériques.

La **certification de l'absorption du carbone** est confrontée à de sérieux risques, notamment le double comptage (unités, projets, certificats) et mutliple commercialisation. Les solutions DLT peuvent réduire ces risques tout en permettant à de multiples registres volontaires de carbone de coexister de manière interopérable. L'analyse approfondie présente deux scénarios. Le scénario 1 représente un système dans lequel tous les systèmes carbone gèrent des bases de données DLT indépendantes qui communiquent directement sans registre sous-jacent unique. Le scénario 2 représente un registre transactionnel paneuropéen unique qui sous-tend et relie des règles et des bases de données gérées de manière indépendante (sous réserve d'un niveau minimum d'alignement avec le règlement proposé) de différents systèmes carbone. Les deux scénarios sont basés sur l' Infrastructure européenne de services de blockchain (EBSI, *European Blockchain Services Infrastructure*). Une comparaison des scénarios 1 et 2 indique qu'un registre DLT unique au niveau de l'UE basé sur l'EBSI est plus facile à mettre en œuvre.
Plus généralement, les conditions d'une mise en œuvre réussie d'un système de blockchain sont les suivantes :

- **Sensibilisation des parties prenantes** (utilisateurs potentiels, agents à tous les niveaux) aux avantages du système. Par exemple, les utilisateurs devraient savoir où certifier la conformité du registre, comment demander des DID, etc.
- **Alignement des processus de gouvernance** et de certification hors registre sur les systèmes techniques et les exigences d'interopérabilité.
- En outre, les spécifications des certificats et des NFT doivent rester **stables** afin d'éviter les itérations multiples des processus et des applications, qui entraîneraient une augmentation des coûts irrécupérables pour les systèmes de certification et les organismes d'intérêt public.

L'extension et l'adoption de l'écosystème EBSI dans d'autres cas d'utilisation, tels que les **identités numériques** soutenues par les gouvernements, permettraient d'établir des normes susceptibles d'accroître l'adoption et la coopération. En outre, ces cas d'utilisation supplémentaires peuvent être intégrés dans le processus CRC plutôt que de créer des structures et des systèmes autonomes à usage unique risquant de faire double emploi. Plusieurs gouvernements de l'UE explorent déjà des options en matière d'identité numérique (Belgique, Pays-Bas, Commission Européenne également), et il est essentiel que ces options incluent les normes techniques et les protocoles EBSI afin de contribuer à l'interopérabilité des fonctions EBSI.
Alors que la DLT offre plusieurs avantages pour réduire les charges administratives liées à la déclaration et à la certification pour les activités de marché carbone, la question de l'**interopérabilité internationale** peut présenter un risque pour les systèmes de certification opérant à l'intérieur et à l'extérieur de l'UE. Les infrastructures de blockchain peuvent fonctionner sur des protocoles fondamentalement différents, et les ponts entre systèmes blockchain sont actuellement incapables de résoudre ce problème. Il est donc nécessaire de s'accorder internationalement sur les normes minimales d'interopérabilité.

Sur la base d'évaluations d'impact récentes, le système d'octroi de licences pour les **substances qui appauvrissent la couche d'ozone (SAO)** doit adresser plusieurs défis liés à l'amélioration de la traçabilité des licences, au suivi des extensions de rapports, à l'augmentation du nombre de parties prenantes, à l'application de la législation et à la détection des fraudes. Les solutions DLT pourraient aider à relever ces défis et contribuer à la transparence et à l'efficacité du rapportage annuel, du suivi et de la vérification. Dans le cas de l'octroi de licences, il a été montré comment la DLT est appliquée dans des cas similaires par le secteur privé et comment elle pourrait être adaptée au système SAO. Les applications DLT pourraient améliorer les processus de contrôle et de notification et fournir des données en temps réel sur le statut et la localisation des marchandises. Il a également été montré qu'un système DLT peut renforcer la sécurité des données en limitant l'accès, en réduisant considérablement la possibilité de modifier les informations de la chaîne historique et en fournissant un enregistrement immuable de toutes les données et de toutes les modifications apportées.

L'utilisation d'**identités numériques vérifiables** ou de clés de licence, en particulier pour les personnes morales, afin d'estampiller les transactions de données sur le système DLT, améliore l'auditabilité et réduit la possibilité pour les acteurs de la chaîne d'approvisionnement en SAO de créer et d'utiliser de fausses identités au sein du système. Cela réduit le risque d'octroi excessif de licences et augmente la probabilité d'une déclaration exacte dans le système ODS.

Si la DLT peut apporter plusieurs améliorations aux processus actuels et futurs, il reste important de tirer parti des systèmes existants tels que l'EBSI et d'examiner comment les changements apportés au système d'octroi de licences ODS affecteront son intégration dans le guichet unique de l'UE. L'intégration de ces systèmes nécessitera la prise en compte des forces et faiblesses relatives de chaque composante et devrait être évaluée sur la base des investissements existants et de l'état de préparation du système au changement. À cet égard, des résultats similaires peuvent être obtenus en utilisant des systèmes non DLT, mais avec des efforts administratifs potentiellement plus élevés.

La proposition de modification du règlement relatif aux **gaz à effet de serre fluorés (gaz F)** comprend une série de dispositions visant à résoudre les problèmes liés au système de quotas, tels que ceux liés aux activités illégales (fraude). Certaines dispositions ont été proposées pour évaluer si les méthodes de traçage des gaz à effet de serre fluorés mis sur le marché pourraient contribuer à contrôler le commerce illégal ; les dispositions proposées pourraient nécessiter un engagement accru des parties prenantes dans plusieurs juridictions, dont les systèmes potentiellement non interopérables pourraient rendre l'échange d'informations difficile ou inexact. L'étude explique comment la combinaison de la DLT et des systèmes de traçabilité existants peut être intégrée et permettre de contrôler non seulement les transferts de quotas du portail F-Gas, mais aussi de valider les quotas avec le mouvement physique réel des gaz le long de la chaîne d'approvisionnement jusqu'à l'utilisateur final, s'il s'agit d'un industriel, ou le vendeur final, s'il s'agit d'un détaillant.

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2 Introduction

2.1 Consortium

The consortium led by Technopolis Group and supported by COWI conducted this Study on the potential of blockchain technology and other digital tools in facilitating EU Climate Policy implementation Under Framework contract CLIMA.A4/FRA/2019/0011. The study was conducted on behalf of European Commission's Directorate General for Climate Action.

The purpose of this study is to present the horizontal possibilities of introducing blockchain technology into EU policies, actions, initiatives. As a tool to support public policies and initiatives, the strength of blockchain lies in its capacity to ensure data traceability, security, verification, storage, etc. Blockchain creates a digital "fingerprint" of data which it then stores (rather than storing the data itself). Any alteration to the original data is almost immediately identifiable because it no longer matches the digital fingerprint present on the blockchain. Thus, blockchain has the potential to enable digital public services that would rely on ensuring accurate, consistent and uncorrupted information.

Through this study, the consortium aims to contribute towards the EU discussion regarding Blockchain deployment in EU policies, with this work particularly focusing on the potential benefits to EU climate policies. This report first describes relevant EU climate policies and the general state of play of distributed ledger technologies. Climate policy challenges are discussed and match with potential distributed ledger technologies solutions. Case studies are later presented to illustrate the general theoretical benefits of implementing DLT solutions.

Preliminary implementation strategies scenarios are later described to guide policy makers in potentially future implementations in each climate area.

Recommendations derived from the activities of this study include potential synergistic advantages of jointly implementing climate policies, as well as of exploring possible implementation of demos/pilots or living labs, for a more realistic and less theoretical cost/benefit assessment of the use of DLTs use in addressing climate policies challenges.

2.2 Study objectives

The aim of the study is to analyse the potential of blockchain technology and other digital tools in facilitating EU climate policy, is underpinned by three overarching objectives.

The first objective of the study was to identify existing and future EU climate policies that potentially could be considered for a future use of DLT technology. This is achieved through mapping EU climate policies and DLT use cases to form a comprehensive overview of where DLT has the potential to benefit each climate policy. The second objective of the study was achieved through careful analysis and in close coordination with the EC officials, which consisted in selecting a set of EU climate policies to develop three case studies to illustrate the advantages of using DLT for climate policies. The third objective of the study was to collected insights and deliver recommendations on the potential implementation strategies for implementing DLTs for climate policies.

2.3 Methodology

The objectives are achieved through the completion of three tasks, each corresponding to the appropriate objective and divided into individual activities that support the task's completion.

- Task 1 sees the widest range of data gathering activities aimed at: (i) developing an understanding and mapping the climate policies, and their main challenges, (ii) developing an understanding through analysis of existing use cases within and outside of EU of what are the main characteristics of DLT, how DLT can be further enabled/used in combination with other digital solutions (i.e., IoT, AI, product passport) and, (iii) analysis of how DLT can be used to support EU climate policy using criteria to determine the pros and cons of introducing DLT into the EU climate policies identified. The approach will produce an outline of climate policies where DLT would offer the best option in strengthening its implementation. Focus group discussions are used during the task to collect expert input regarding the potential benefits of DLT for climate policies.
- Task 2 is a comprehensive review of selected policy options that builds on the data and analysis already conducted during Task 1 to assess the necessary conditions required to implement DLT in their framework as well as discussing the potential outcomes (both positive and negative) that could emerge from DLT use. The analysis will combine: (i) expert insights into plausible developments on how DLT should be implemented and the range of considerations that should be accounted for, basing these deliberations on the data collected during Task 1 as well as, (ii) conducting interviews with relevant stakeholders for the selected climate policies and other experts in DLT and digitisation.
- Task 3 provides the analysis results and overviews the implementation of DLT in climate policy. This will be achieved through: (i) a presentation of the draft implementation strategies for each of the policy options, with practical advice on how to overcome challenges with DLT implementation, support required to maintain effectiveness of DLT (i.e., monitoring and evaluation) and, (ii) general recommendations on the use of DLT in EU climate actions, discussing the benefits and risks associated with DLT.

2.4 Results

The analysis of DLT potential in EU climate policies included assessing the pros and cons derived through the review of DLT deployment in public policies across EU Member States. The following presents subjects that are examined regarding DLT systems in public policies.

- **Disintermediation** refers to the replacement of centralised databases hosted by intermediaries such as public bodies or financial institutions to facilitate transactions or store information, through the introduction of DLT. Network access can be made secure using a permissioned DLT system or made open to the public depending on the specific needs of the policy. This process enhances policy implementation, regulatory compliance through its immutable and tamper-proof record keeping.
- **Stakeholder uptake** represents benefits for stakeholders if they would be willing to adopt DLT. A key pro around DLT adoption for stakeholders concerns the advantages around digital sovereignty. With prior authorisation of digital identities, and creation of digital wallets to manage documents and the approvals thereof, persons and companies are offered greater choice around sharing specific ID details with designated entities. This means that stakeholders have autonomy over which documents are shared.
- **Reporting and compliance** considers the impact that permissioned DLT systems may have on activities like reporting and compliance, and cover issues around immutability of record

keeping and enforcing of rules through Smart Contracts. Generally, DLT systems can be used to ensure compliance with preset rules (i.e., licenses) through constant monitoring of data input and identification of deviations from expected results.

- **Technological maturity** regards the questions whether DLT systems are sufficiently technologically mature for adoption by the climate policies. DLT is a recent technology which the public sector has been hesitant to adopt and most public sector DLT projects are not fully operational, are in piloting phases. A key concern is the feasibility of combining DLT with existing systems or ensuring transition towards DLT-based systems.
- **Cross jurisdiction** concerns the involvement of multiple countries or legal jurisdictions in DLT system transaction or operation and is a key concern for EU-wide deployment. DLT could facilitate the networking of carbon markets, reporting of compliance with market restrictions, etc.
- **International implications** considers whether the adoption of Blockchain allows the EU to fulfil its international obligations vis-a-vis climate policy and whether DLT deployment would provide added value in EU's international commitments.
- **Strengthened political cooperation on EU Climate Policy.** This recognises that the deployment of DLT should be used as a means for further strengthening international cooperation around climate policy.

Under those considerations several EU Climate policies were considered for their potential in DLT deployment.

- **EU ETS**. Literature and focus groups referred to the possibilities of DLT to provide positive benefits around disintermediation, reporting and compliance given the possibilities to generate immutable records on the origin, tracking and ownership of carbon allowances, and support more cost-efficient transactions when compared to existing timeframes for clearance activities. Stakeholder uptake would be encouraged since trust in the system would be enhanced, and the possibilities for fraudulent activities reduced. However, the benefits of disintermediation were questioned, and it was felt that there would be a negative reaction from stakeholders in reforming a system that was established and well-functioning. It was also suggested that the current intermediary financial exchanges are efficient, and there were doubts concerning potential transaction costs reduction.

- **EU ETS MRV**. There is the possibility to link IoT and the monitoring of emissions to DLT with a view to creating an immutable emissions reporting system. This would improve trust in the compliance system and ease enforcement activities, for example, using software that could detect differences between allowances held and actual emissions. Moreover, it could be possible to develop a DLT system that could produce records on the status of the reporting activities, such as on the validation, submission and editing of the reports. Some stakeholders may consider their emissions data as a privacy issue, since the timing and intensity of their energy usage could be considered as a trade secret and thus would be against transparency in this area.

- **EU LULUCF**. The main advantage of disintermediation would be to provide an EU-wide system that to harmonise the implementation of the LULUCF by encouraging a more consistent application of methods and use of satellite data. It could also facilitate proof of compliance and digital sovereignty through sharing of proofs that specific methodological standards have been met (rather than making analyses transparent). Stakeholder uptake would be encouraged since the DLT would reinforce proof of green principles demanded nowadays for sustainable land management – smart contracts would support cross-border enforcement. There could be challenges around interoperability and the complexities of connecting on-chain and off-chain community activities and subsequently assuring any interoperability needed between and across different blockchain systems has not been implemented and evaluated in large scale operational systems.

- **Sustainable Product Initiative**. With regards to the SPI framework, DLT could provide positive benefits related to disintermediation, stakeholder uptake and reporting and compliance. Indeed, the introduction of digital product passports (DPPs) would require setting-up a decentralised system for data sharing which could be supported by DLT. DLT can contribute to enhance product traceability and value chain transparency in an immutable way for all involved stakeholders. Solutions exist to ensure data protection. At the international level, the implementation DLT-based DPPs could provide an incentive towards better product sustainability and circularity. It is possible to set up new global value chains upon a DLT due to the strong drive to address green transition challenges or to verify net-zero or nature-positive claims of economic activities (i.e., supporting companies and supply chains, born green) during EU Green Deal times. The implementation of DPPs using DLT could raise concerns regarding data privacy and industrial competitiveness but also data quality, thus impacting stakeholder uptake.
- **CBAM**. DLT could provide positive benefits related to stakeholder uptake and reporting and compliance. DLT can contribute to enhance product traceability and value chain transparency in an immutable way for all involved stakeholders. Carbon accounting and certification systems need significant safeguards and data resources to ensure the integrity of the whole system. DLT systems are emerging as a solution to automate transactions with carbon certificates, while securing the record of the data and integrity of the whole system. However, DLT could raise concerns regarding data privacy and industrial competitiveness but also data quality, thus impacting stakeholder uptake.

These previously described policies represent EU climate policies that ultimately were not selected for further assessment. Of the analysed policies, three were selected for case study analysis: Carbon removal certificates; Ozone Depleting Substances; and F-gas. The three policies are currently being negotiated or under review, and their proposed amendments introduce elements with potential benefits should certain features be managed by DLT and other digital technologies.

- The **carbon removal** certification faces risk of double counting carbon removal units : double registering of project and double selling. DLT is relevant to the proposed Regulation due to its potential to mitigate the main risks around double counting while at the same time offering transparency, automation and interoperability. Moreover, the key benefits that DLT can offer the voluntary carbon removal markets are, firstly, the reduction of errors or fraud related to double counting, double claiming and wrongful issuance. Secondly, the reduction of administrative burdens related to auditing projects and credits, and the corresponding enforcement of regulations. The key concern related to DLT is that of interoperability, particularly outside of the EU, so that carbon offset schemes operating in multiple jurisdictions may be unable to participate. A DLT system for the proposed EU Regulation for Carbon Removal Certification should be limited to a single decentralised register with access to nodes provided to key actors such as certification bodies therefore reducing the level of technical complexities and risks associated with linking multiple DLT systems.

- The **Ozone Depleting Substances** licencing system upon recent impact assessments has the possibility to address various challenges linked to improving the traceability of licences, monitoring and reporting requirements, the increase in the number of players, the correct application of legislation and the detection of fraud. There is potential for DLT solutions to address such challenges to contribute to more transparent and efficient reporting, monitoring, and compliance.
- The proposed amendment to the **F-gas regulation** includes a set of provisions to overcome challenges regarding the quota system, for example, related to illegal activities. Some of the proposed provisions are to analyse whether methods for tracing fluorinated greenhouse gases placed on the market could help control illegal trade. It would be desirable to understand whether DLT could be used as a tracing method as well as to answer the question whether DLT could secure the existing F-gas portal. There is potential for DLT in combination of other digital technologies for traceability management to address the above challenges.
- Concenring ODS and the F-gas regulation, the lack of knowledge and skills, together with the uncertainty around compliance with evolving regulations on DLT, could hamper the successful roll-out of the technology. When it comes to reporting and compliance, an important con is the need for interoperability between different stakeholder's systems. Concerning cross-jurisdiction, the main obstacle is the different requirement and enforcement frameworks at national level that might be difficult to accommodate when it comes to standardising the procedures.

There is potential for these policies to leverage existing EBSI infrastructure towards greater cost-efficiency in the development and deployment of DLT systems. It is estimated that collaboration with EBSI towards development, from the initial workshops, data gathering, application development and piloting, could take around 4.5 months before full-scale deployment of these systems could be initiated. The relatively fast timing enables the Commission to incorporate DLT development into planned revisions, changes, etc. to the climate policies.

3 State of play of EU climate policies and Distributed Ledger Technologies

3.1 Overview of EU climate policies

The project undertook a scoping and filtering exercise of EU climate laws and policies, notably those managed by DG CLIMA. The list of selected policies and legislation includes the following elements, presented briefly below:

- EU Climate Law Regulation (EU) 2021/1119
- EU Climate Strategies and Targets
- EU Emissions Trading System (ETS) Directive 2003-87-EC
- ETS Implementing Regulation No 601/2012 (Monitoring, Reporting and Verification).
- EU Strategy on Adaptation to Climate Change COM/2021/82 final
- Effort Sharing Regulation (EU) 2018/842
- Land use, land use change and forestry (LULUCF) Regulation 2018/841
- EU 'Ozone Regulation' – Regulation (EC) 1005/2009
- Regulation (EU) No 517/2014 (the 'F-gas Regulation')
- Funding for Climate Action (Innovation Fund and Modernisation Fund)
- International Action on Climate Change (Climate Finance and Voluntary Carbon Markets)
- EU Sustainable Product Initiative
- The Regulation 2019/631 on CO_2 emission performance standards for new passengers cars and for new light commercial vehicles
- EU Carbon Removal Certification
- The Carbon Border Adjustment Mechanism (CBAM).

EU Climate Law Regulation (EU) 2021/1119

Adopted by the European Parliament and the Council in April 2021, The EU Climate Law, sets the EU's objective of reaching climate neutrality by 2050 and establishes the framework for achieving this goal. The law establishes a governance structure to ensure that the EU and its member states are held accountable for their climate action. It requires Member States to prepare national climate and energy plans to set out how they will contribute to the EU's objectives. The law includes measures to keep track of progress through the EU governance process system. Member States must submit their energy and climate policies and their national energy and climate plans on an ongoing basis whereafter they will be assessed by the Commission. If a member state is not meeting its targets, the Commission can initiate enforcement measures, including financial penalties or legal action.

EU Climate Strategies and Targets

EU has set ambitious climate strategies and targets to address the urgent challenge of climate change. The primary objectives of these strategies and targets are: Mitigating greenhouse gas emissions, increasing the share of renewable energy and supporting climate action in developing countries. Key climate and energy targets are set in the following frameworks:

- 2020 Climate and Energy package

- 2030 Climate and Energy framework
- 2050 long-term strategy

The legislation requires member states to report their GHG emissions and other relevant data annually, which are then compiled and assessed by the European Commission. Member States must submit their energy and climate policies and their national energy and climate plans on an ongoing basis whereafter they will be assessed by the Commission (coordinated by the European Environment Agency). If a member state is not meeting its targets, the Commission can initiate enforcement measures, including financial penalties or legal action.

EU Emissions Trading System (ETS) Directive 2003-87-EC and Monitoring, Reporting and Verification (MRV)

The EU Emissions Trading Scheme (EU ETS) was established in 2005 to implement the Kyoto international climate change agreement. The EU ETS provides a 'cap and trade system' to reduce GHG emissions annually. Each year, a limited amount of EU Allowances (EUAs) is made available for trading in the market and this is reduced yearly in order for the EU to meet its target of a 55% reduction in GHG emissions by 2030 relative to 1990, and net zero by 2050. The EU ETS enables for operators to trade carbon allowances with each other. Currently in its fourth phase, the EU ETS Directive limits emissions from various sectors, including electricity and heat generation and energy-intensive industry sectors (e.g., oil refineries, steel works, production of iron, metals, glass, paper, or bulk organic chemicals). The scope was extended to maritime transport and international aviation, creation of a new scheme covering road transport and buildings.

Following a compliance procedure of MRV, operators must submit data, to a centralised Commission database (i.e. the Union Registry), to demonstrate the annual volume of emissions vis-à-vis the number of allowances retained. Every year, operators must submit an emissions report. The data for a given year must be verified by an accredited verifier by 31 March of the following year.

EU Strategy on Adaptation to Climate Change

This strategy aims to help Member States to build resilience to the impacts of climate change, such as increased frequency and intensity of extreme weather events, rising sea levels, and changes in temperature and precipitation patterns. The Strategy provides provisions for development of better adaptation data, development of national adaptation strategies, fostering resilience through dedicated initiatives, integration with fiscal frameworks, promotion of nature-based solutions, monitoring.

Effort Sharing Regulation

The Effort Sharing Regulation (ESR) sets binding annual GHG targets for Member States for the period 2021-2030 for sectors that fall outside of the EU ETS. It requires that emissions are reduced by 40% by 2030 compared to 2005 levels. The ESR accompanies the EU ETS by covering sectors not in the scope of the EU ETS (although the proposed extension of the EU ETS will cover transport and buildings).

Land Use, Land Use Change, and Forestry (LULUCF) regulation

The LULUCF (Land Use, Land Use Change and Forestry) sector is used to account and report the CO2 flows between different terrestrial reservoirs (biomass, soils, etc.) and the atmosphere that take place on the managed surfaces of a territory. It can thus constitute a net source or a net sink of CO2. The Regulation covers emissions and removals of GHG on several land accounting categories such as afforested land, deforested land, managed cropland, managed grassland, managed forest land and managed wetlands. The regulation requires Member States to provide accounts and perform accounting activities concerning emissions and removals of GHG from the designated land categories – this includes a record of all data used. Member States need to submit two compliance reports between 2021 and 2030 to the Commission showing the balance of total emissions and total removals.

EU Ozone Regulation – Regulation

Introduced in 2009, the objective of the EU Ozone Regulation (Regulation (EC) No 1005/2009) is to protect the Earth's ozone layer by limiting and controlling the production, use, import, export, and placing on the market of substances that deplete it. The regulation aims to ensure that ozone-depleting substances (ODS) are phased out and replaced with more environmentally friendly alternatives. The EU Ozone Regulation covers a wide range of ODS, including, among others, chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), halons, carbon tetrachloride, and methyl chloroform. The EU aims to prevent the equivalent of 32,000 tonnes of ozone depleting potential (ODP) emissions by 2050 through the implementation of new measures aimed at products in which ODS were previously used legally. The regulation requires that companies engaged in the production, import, export and/or use (for feedstock, process agents, laboratory and analytical purposes and, for halons, also critical uses) of ODS or ODS containing products must maintain records of their transactions and report this information to the Commission on an annual basis via the ODS Licensing System and, for what concerns the reports, the European Environment Agency's (EEA's) Business Data Repository (BDR).

The ODS licences for bulk substances and most products and equipment must include information on the quantities, type and intended use of the ODS, as well as the parties involved in the transaction, as such licences are issued per shipment. The ODS licences for products and equipment containing or relying on halons for critical use in the aviation sector contain information on the products and the halons with no indication of the quantity and the third party involved in the import/export, since they can be used multiple times. To support these activities, the regulation requires the use of a centralised database called the ODS licensing system, which allows for the tracking and verification of ODS and importquotas, of the import/export licences and the production authorisations.

F-gas Regulation

F-gas Regulation (EU) No 517/2014 aims to reduce the EU's F-gas emissions by two-thirds by 2030 compared with 2014 levels. The regulation sets out rules on containment, use, recovery and destruction, the placing on the market and the use of F-gases and it establishes quantitative limits for their placing on the market. It also establishes reporting requirement for producers, importers and exporters of f-gases, companies destroying f-gases or using them as feedstock, for companies that place f-gases in products or equipment.

The regulation sets out rules on the production, use and trade of F-gases, in particular:

a) a phase-down of the amount of f-gases that can be placed on the EU market,

b) bans on the use of certain f-gases in specific applications,

c) requirements for leak checking, maintenance and servicing of equipment that contains f-gases,

d) certification requirements for personnel who handle f-gases,

e) reporting requirement for producers, importers and exporters of f-gases.

Register in the F-gas Portal & HFC licensing system is mandatory for companies to receive and transfer quotas and authorisations. All companies that report on the annual F-gas-related activities must register in the F-gas Portal & HFC Licensing System, managed by the Commission, to enable access to the reporting forms. This license is a necessary step, but not sufficient condition for being allowed to import into and export from the EU. Other conditions also apply, notably when imported goods are being placed on the EU market. These conditions include labelling requirements (Art. 12 of the F-gas Regulation) and requirements related to the HFC quota system (Art. 14 and 15 of the F-gas Regulation).

Funding for Climate Action (Innovation Fund and Modernisation Fund)

Raised from Horizon 2020, the Innovation Fund seeks to help create favourable financial conditions for investment projects for the next generation of technologies, to stimulate growth and competitiveness by offering European companies a unique opportunity to become world technology leaders and to support innovative low-carbon technologies to develop and penetrate the market in all EU Member States. The EU ETS is providing the revenues for the Innovation Fund from the auctioning of 450 million allowances from 2020 to 2030. Calls for projects target several areas of the Climate sector:

- Renewable energies
- Carbon capture, use and storage (CCUS)
- Energy-intensive industries, including substitutes
- Energy storage.

The Modernisation Fund is a dedicated funding programme to support 10 lower-income EU Member States in their transition to climate neutrality by helping to modernise their energy systems and improve energy efficiency. The Modernisation Fund is supported by revenues from the auctioning of about 2% of the total allowances for 2021-30 under the current EU ETS as well as additional allowances transferred to the Modernisation Fund by some of the recipient Member States.

Scope: The Modernisation Fund support investments that help to modernise energy systems and improve energy efficiency. It includes:

- Generation and use of electricity from renewable sources
- Improvement of energy efficiency
- Energy Storage
- Modernisation of energy networks
- Support to a just transition in carbon-dependent regions in the beneficiary Member States.

International Action on Climate Change (Climate Finance and Voluntary Carbon Markets)

The Paris Agreement reaffirms that developed countries should take the lead in providing financial assistance to countries that are less endowed and more vulnerable, while for the first time also encouraging voluntary contributions by other Parties

Climate finance refers to local, national or transnational financing—drawn from public, private and alternative sources of financing—that seeks to support mitigation and adaptation actions that will address climate change.

Carbon markets exist in two forms. In compliance markets, regulated entities obtain and surrender emission permits (allowances) or offsets to comply with an imposed regulation or a regulatory act. In contrast, the voluntary carbon market (VCM) is a market where carbon offsets are not purchased to be used in an active regulated market but rather 'with the intent to re-sell or retire to meet carbon neutral or other environmental claims. VCMs operate outside governmental regulatory schemes, which naturally raises concerns about the validity and the quality of carbon credits sold. For such a credit to be credible a lot of information needs to be put on that certificate and that information needs to be transparent to all market participants, especially buyers. Currently, offsets are legitimised by accredited independent third-party bodies. When verified, credits are issued, entered into a registry and made available for trade. The registry records and labels the credit, tracks the owners, and makes information about credits on offer publicly available through a ledger.

Regulation 2019/631 emissions performance standards for vehicles

The current legislation on CO2 emission performance standards for new cars and light commercial vehicles. Regulation (EU) 2019/631, sets targets for the EU fleet-wide average CO2 emissions. Average CO2 emissions from new passenger cars and vans registered in the EU will have to be 37.5 % lower in 2030, compared to the limits in 2021 (95g CO2/km). For new vans, the reduction target is 31 % by 2030 (compared to 147 g CO2/km in 2021). A dedicated incentive mechanism aims to accelerate the market uptake of zero- and low-emission vehicles. By 2035 of new passenger cars and vans CO2 emissions would have to be reduced by 100 %, i.e. all new vehicles would have zero emissions. The incentive for zero and low-emission vehicles would stop to apply from 2030. From 2030, only manufacturers responsible for less than 1 000 new vehicle registrations would be able to apply for a derogation from the specific emissions target. The derogation for manufacturers responsible for between 1 000 and 10 000 cars or between 1 000 and 22 000 vans will end in 2029.

Manufacturers are required to submit compliance plans outlining how they will meet the emission targets, which must be approved by national authorities in each Member States.

EU Carbon Removal Certification

On 30 November 2022, the European Commission adopted a proposal for a Union certification framework for carbon removals. Carbon removal means extracting greenhouse gases from the atmosphere and storing them on land, underground, or in the oceans. This storage must be permanent, which duration depends on a given activity, to ensure that the removed gases do not seep back into the atmosphere. Removing several hundred million tonnes of CO2 out of the atmosphere will become increasingly necessary every year. Carbon can be removed and stored in three broad ways: permanent storage, Carbon farming and Carbon storage in long-lasting products.

The draft Regulation includes both quality criteria for identifying carbon removals and rules for third party verification and certification. An operator must apply to a certification scheme approved by the Commission. An independent certification body carries out periodic audits of the carbon removal activity to verify the compliance with the quality criteria and, if positive, it issues a certificate of compliance. To track certified carbon removals, the Regulation requires certification schemes recognised by the Commission to set up and maintain inter operable certification registries.

The Carbon Border Adjustment Mechanism (CBAM).

The CBAM puts an emissions tariff on imports of goods with a high risk of carbon leakage from countries which are not members of the EU Emissions Trading System (ETS). CBAM will begin to operate on provisional basis from October 2023

The CBAM system will work as follows: EU importers will buy carbon certificates corresponding to the price of carbon that would have been paid if the goods had been produced under EU carbon pricing rules. Conversely, once a non-EU producer can demonstrate that it has already paid a price for the carbon used in the production of the imported goods in a third country, the corresponding price can be fully deducted for the EU importer. The CBAM will help reduce the risk of carbon leakage by encouraging third country producers to green their production processes.

The CBAM applies to selected materials produced in non-EU countries. CBAM will initially cover a number of specific products in some of the most carbon-intensive sectors: iron and steel, cement, fertilisers, aluminium, electricity and hydrogen, as well as some precursors and a limited number of downstream products. Indirect emissions would also be included in the regulation in a well-circumscribed manner.

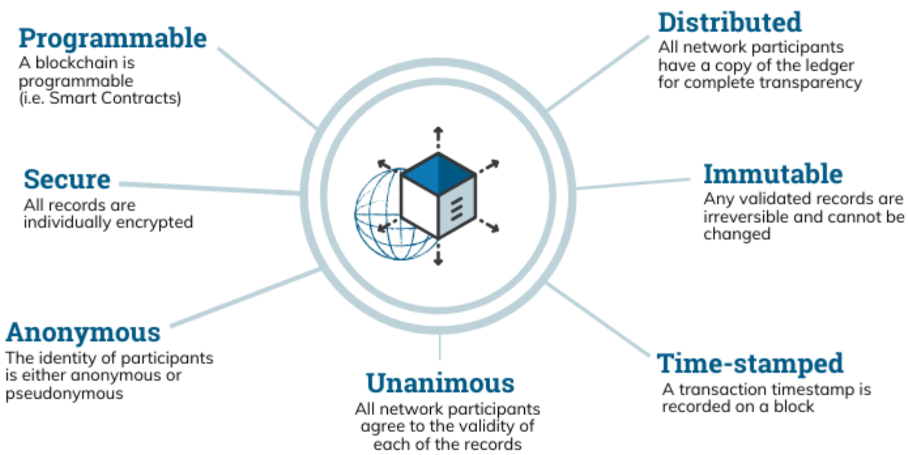
3.2 Overview of DLT

Distributed Ledger Technology (DLT) refers to the technological infrastructure and protocols that allow records to be accessed, validated and updated simultaneously and immutably over a distributed network of multiple entities (or nodes) in a secure manner. DLT covers a broad category of technologies that allow multiple participants to maintain and replicate a common digital ledger in a decentralized manner, i.e., removing the need for a central authority to append and replicate the ledger directly.

DLT allows transaction-related data to be stored securely and accurately, using cryptographic hashes. Once data is stored, it becomes an immutable database that is governed by network rules.

DLT is a system that records transaction data in immutable way that makes it difficult, if not impossible, to change, hack, or cheat. There are several DLT methods for creating a common digital ledger – this can include blockchains, directed acyclic graphs (DAGs), hashgraphs and tangles etc. Since blockchains are the most common, this approach is explained further.

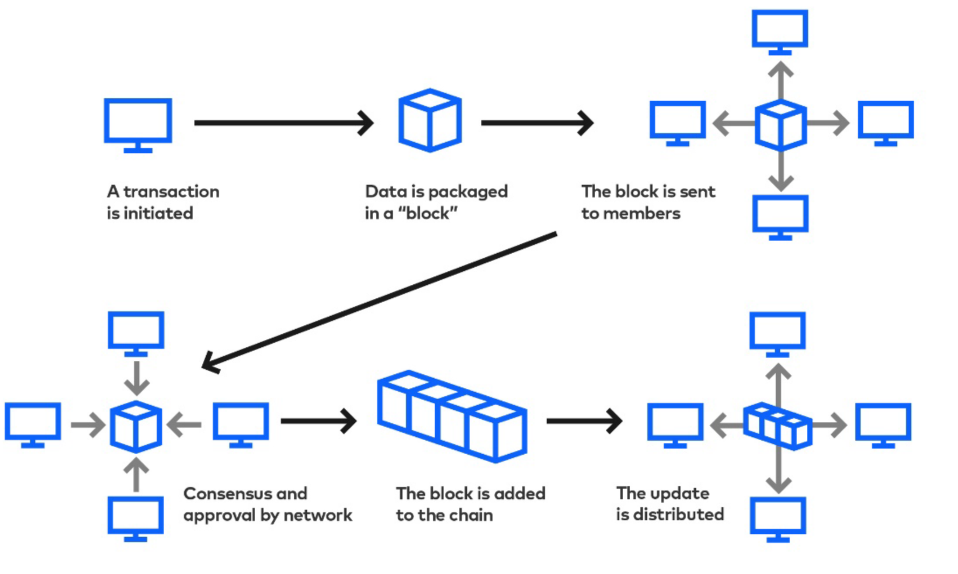
Figure 1 Properties of DLT



Source: Euromoney Learning (2020). What is blockchain?

A blockchain is essentially a digital ledger of transactions that is replicated and distributed across the entire network of computer systems called nodes. The blockchain is cryptographically secured against retrospective manipulation and uses a consensus mechanism to maintain the consistency of the database whenever new transactions need to be validated. Data storage on the blockchain is secured by cryptographic hashes in which the hashed data returns a fingerprint that verifies the authenticity of the data.

Figure 2 How DLTs function



Source: Slalom (2023). How blockchain will disrupt your industry

Tampering with the original data causes the hash of the modified data to no longer match the original digital fingerprint. Hash values representing transactions on blockchain are aggregated and stored in blocks. The combined hash of these transactions is also stored, and each subsequent block stores the combined hash of the previous block. This creates a cryptographically secure and linked chain of blocks containing the information - the blockchain. Any attempt to change the information requires a new storage of not only the block corresponding to the transaction, but also all subsequent blocks.

Blockchain represents a major innovation that is used in the alternative investment sector. Indeed, blockchain technology has been developed to support transactions carried out via crypto-currencies/crypto-assets (of which Bitcoin is the best-known example) and which have as their main characteristic that they do not depend on a centralizing body (such as a central bank) and that they function cross-border on an international level. Payments and validating international transactions are the most common blockchain application areas so far, reflecting the historical development of this technology in relation to cryptocurrencies and the financial sector more broadly. IT security, copyright, intellectual property (IP) protection, digital identities, as well as voting are other areas, all of which build their use cases predominantly on the security aspect of blockchain.

However, since its introduction, different use cases are being developed across many industries. For example, a German power company RWE is testing blockchain technology to manage billing for autonomous electric vehicle charging stations, while a large French supermarket company Auchan plans to use DLTs to increase transparency and drive value at every step of the supply chain.

But the potential of DLT and blockchain applications is far greater and this extends to climate policies. It can significantly improve accountability and traceability, for instance of greenhouse gas emissions. It helps companies provide more accurate, reliable, standardized and easily accessible carbon emissions data. With the global increase of carbon prices and taxes, monitoring and tracking carbon production and emissions with end-to-end traceability solutions should be a competitive edge to organizations to drive the UN's Sustainable Development Goals. Traceability is increasingly becoming a priority, to support organisations to meet their sustainability objectives, aligning with their business goals and building a responsive and resilient system. Traceability solutions will be able to build efficient value chains with minimal disruptions and certify sustainable products and processes.

EU has taken some measures to harness DLTs and Blockchain for climate action including:

- Promoting their development and adoption to encourage actors to reduce their carbon footprint, reduce societal impact and environmental of their actions. For instance, the Building a low-carbon, climate resilient future: climate action in support of the Paris Agreement (H2020-LC-CLA-2018-2019-2020) funded an ongoing project setting up Smart Cities Climate contracts (SCCo) delivered by co-designing new business models supported by blockchain technologies[1].
- Developing technical assistance and investment programmes for DLT-based digital innovations that contribute to climate change mitigation and adaptation. For instance, tThe EIC-FTI 2018-2020 topic funded a project on Flexible Communities business models empowered by Blockchain and AI, contributing to control energy demand[2], and which has been integrated into various companies services[3].
- Stimulating solutions that facilitate the interconnection of suppliers and consumers, with the aim of involving all potential societal actors.
- Supporting the use of DLTs to finance climate action, including through the emergence of green bonds, fintech solutions and alternative financing mechanisms. For instance, in January 2023 it was reported by the European Investment Bank its issuance of digital bonds worth 50 million pounds[4].
- Supporting European governments to collaborate on the development and adoption of DLTs that support climate action and greenhouse gas emission reductions. For instance, through the LIFE programme, the EC is currently supporting the Murcia Region in Spain to validation an advanced CO2 life cycle model and non-speculative Emissions Trading System in a digital platform (blockchain) for an efficient sustainable forest management[5].
- Developing partnerships (ongoing) with strategic partners, including UN agencies and international financial institutions, such as the World Bank, the European Investment Bank[6].
- Support start-ups and small and medium-sized companies to improve their access to clean technology finance and greater integration into various markets (i.e., opening-up the energy market to small and medium sized green energy producers to sell directly to the consumer).

[1] https://cordis.europa.eu/project/id/101003799

[2] https://cordis.europa.eu/project/id/870146

[3] https://www.flexunity.eu/consortium

[4] https://www.eib.org/en/press/all/2023-030-eib-issues-its-first-ever-digital-bond-in-british-pounds

[5] https://webgate.ec.europa.eu/life/publicWebsite/project/details/101074388

[6] https://digital-strategy.ec.europa.eu/en/policies/blockchain-climate-action

- Supporting the development of new prosumer-based business models in energy communities with the potential of extension of the business model beyond. Such is the case of the multiple ongoing initiatives on power system allocation with metering and billing integration reported by the JRC of the EC[7].

However, an initial hurdle of DLTs was the public perception of uncertainty of the technology, which was grounded in the discourse of the crypto markets' volatility, and the initial hesitancy of governments to regulate DLTs and related solutions.

Another issue was the energy consumption required by the earlier blockchains, such as Bitcoin. However, DLT systems using other consensus mechanisms have illustrated that the energy consumption can be lowered significantly, as the Ethereum has illustrated. It moved away from Proof of Work consensus (still used by Bitcoin) to Proof of Stake, thereby reducing the energy consumption by 99%.

Key features and differences between types of DLT systems

This section provides technical details to clarify some of the key features and differences between different types of DLT systems with respect to network access, tokenization, consensus mechanisms.

A key distinction in blockchain networks concerns the method of **network access** and **data management**.

Under a **permissionless** DLT, anyone may assess the network without requiring permission from a central authority or administrator. Evidently, this means that the DLT is made public and there are no barriers for anyone to join. Normally, anyone can become a node in the network and contribute to the consensus mechanism to maintain the integrity of the ledger.

In contrast, **permissioned** DLTs are restricted, meaning that access is limited to a specific group of participants that hold verified credentials and require permission to join from a more or less centralized governing body or administrator. Only registered nodes can become part of the network.

Thus, in a permissioned network, the transactions made are validated by a governance body that is centralised to a certain extent. An example of a permissioned system is Hyperledger Fabric that is designed to automate business transactions using Smart Contracts between parties in a controlled and closed DLT system.

However, it is also possible to have **hybrid systems** with **public** processes in **permissioned** networks. This would generally provide two features, access right management (by permissioned systems), and access to publicly available services (accessible for everyone).

A possible application of blockchain is to use it to support exchange of assets such as property, stocks or commodities – this process is known as **tokenization** and involves converting an asset or piece of information into a digital token that can be transferred and tracked on a blockchain network. In this context, a token represents a unit of value, ownership, or a specific right or entitlement.

[7] https://ses.jrc.ec.europa.eu/power-system-blockchain-solutions

Tokenization has various applications, including the digitization of physical assets such as property, art, or other types of ownership. It also includes the digitization of financial instruments such as stocks, bonds, and other securities. Additionally, tokenization is used in payment systems, loyalty programs, and other applications that require tracking of ownership or entitlement.

In the context of carbon emissions management, tokenization is seemingly relevant where trading is needed between a significant number of buyers and sellers. Typically, tokens are used to represent carbon credits or allowances and are traded to support off-setting of emissions, investment in climate friendly technologies, and compliance with environmental regulations.

Each carbon credit is represented by a unique token on the blockchain, which contains information about its origin, ownership, and other relevant data. The tokens are then traded and exchanged directly on the blockchain, without the need for intermediaries, reducing transaction costs and increasing exchange efficiency. Where transactions are made, the blockchain ledger is immutably updated, thus supporting transparent tracking of tokens.

A blockchain **consensus mechanism** is a set of rules and procedures that enable different nodes in a blockchain network to agree on the state of the network and is often used to validate transactions, i.e., trading of tokens. In a blockchain network, a consensus mechanism is needed to ensure that all nodes in the network have the same replica of the ledger and that the transactions added to the ledger are legitimate.

A fundamental difference between different DLT systems is the type of consensus mechanism used. While several methods have been deployed, the most common types are explored in this section, namely Proof of Work, Proof of Stake and Proof of Authority.

The consensus mechanism **Proof of Work** (PoW) is used to validate transactions and add new blocks to the blockchain (this is known as 'mining'). In this case, nodes in the network compete to solve complex cryptographic problems known as 'hash puzzles', the first node to solve the puzzle is rewarded (typically with cryptocurrency) and the new block is added to the chain. The accurate completion of the puzzle provides evidence that the work has been done to publish the block. Once a node completes the work, they send it to the other nodes on the network to seek verification that the work has been done. If so, the nodes add the block to the ledger and distribute the block throughout the network.8 This work ensures that the transactions made are verifiable.

Proof of stake (PoS) is another consensus mechanism. In contrast to proof of work (PoW), which relies on miners solving complex computational puzzles, PoS relies on validators who are chosen to create new blocks based on the amount of tokens they hold and are willing to "stake" as collateral.

Normally, validators are chosen at random to create new blocks, and the probability of being chosen depends on the amount of cryptocurrency they have staked. This means that the more cryptocurrency a validator holds and stakes, the higher their chances of being selected to create a new block. Validators are incentivized to validate transactions correctly, as their staked cryptocurrency acts as collateral and can be lost if they fail to do so.

[8] Draft NISTIR 8202, Blockchain Technology Overview

In a PoS system, new blocks are validated and added to the chain through a process called forging or minting, rather than mining. Validators are responsible for validating transactions and creating new blocks, and they receive transaction fees and newly created tokens as rewards.

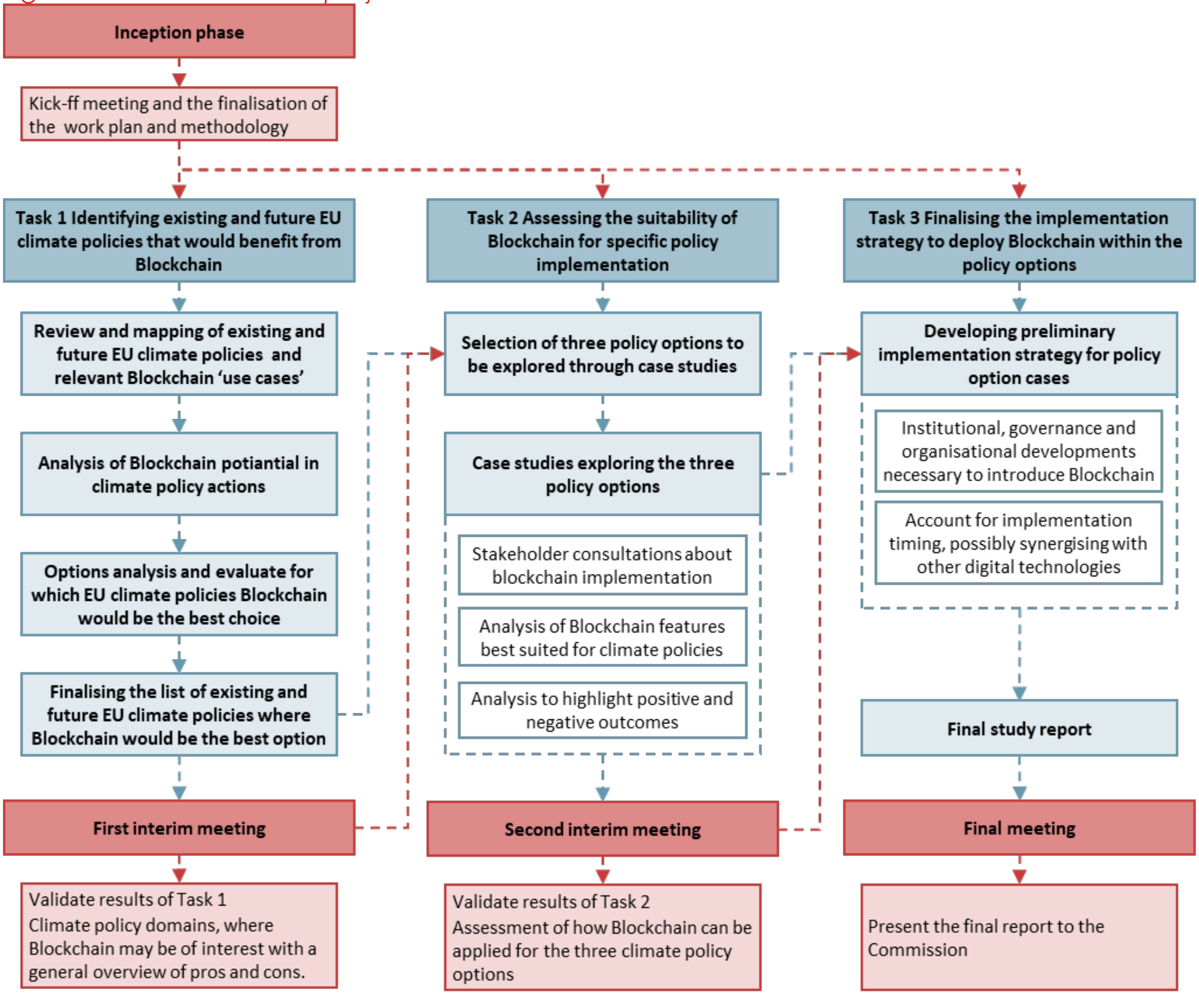
In a permissioned DLT networks, the consensus mechanism that often applies is the **Proof of Authority** (PoA). Under this approach, the ability to validate and publish new blocks to the blockchain is extended to authorised nodes, referred to as validators. An important feature of this is that all validators are pre-approved by a governing authority based on their known identify and reputation, and interests in maintaining their good reputation by ensuring accurate validations. The validators have the responsibility of verifying transactions and maintaining the blockchain ledger. This can be done automatically using software as opposed to tasking validators with manual interventions. Similarly, the users that perform the transactions must also be pre-approved, and identifiable to the verifiers based on their authorised credentials.

4 Methodology

4.1 Overall approach

To achieve the objectives the project is divided across three tasks. The tasks are sequential with each task building on the accumulated data from prior work. To further support the efficiency of the work, each task is broken into activities to either collect or analyse qualitative and quantitative data on climate policies and the possibilities offered by DLT. Below is a brief overview of the tasks with more detailed methodologies.

Figure 3 Overview of the project structure



Source: Technopolis Group

Methodology for Task 1

The overall rationale for Task 1 was to identify existing and future EU climate policies that would benefit from DLT – resulting in a shortlist of three pieces of legislation selected as most relevant for illustrative technical application of DLT under Task 2. A series of legislation and policies were proposed by DG CLIMA for initial review. This provided a basis for EU the climate policy to be investigated focusing on policies and legislation 'owned' by DG CLIMA.

The identified policies were analysed considering the relevance of the legislation for DLT adoption. The criterion of relevance was informed by prior research funded by H2020 that indicated how DLT can benefit public sector activities. Thus, following the existing logic of selecting public policies for DLT applications, the project considered if the EU climate policies were associated with requirements demanding large scale record generation and involving a multiplicity of actors (e.g., authorities, regulators, third parties, business sectors, consumers etc.). Moreover, climate legislation was considered especially relevant in areas where requirements demand large scale fulfilment of compliance activities, transactions between parties, submission of verifiable personal details, indication of completed verification activities etc. To support the analysis separate reviews of the legislation were performed, briefly summarising the key features of the policies, and outlining the central policy mechanisms, and finally making judgements on their relevance for inclusion for further analysis.

From this review, nine policies were selected as relevant for further investigation to identify the potential for application of DLT. This process involved wider literature review, analysis of the policies, project team observations and feedback from two expert focus groups that lasted 1.5 hours each and took place on the 3rd and 6th of March attended by a total 10 experts. Additionally, two expert interviews were conducted for those interested in but not able to attend the focus groups. The focus group discussed each of the filtered EU climate policies one-by-one, their main challenges and the pros and cons of adoption DLT solutions to enhance implementation. The focus groups involved experts from:

- European Environment Agency
- United Nations Environment Programme
- Agreena – Carbon Farming
- KLIMATE – Carbon Removal
- NEXI – European PayTech
- Surge - Sustainability performances through Blockchain technology
- SINE Foundation – DLT/Cryptography
- Open Earth Foundation – Research body bridging Tech and Climate
- Intercontinental Exchange (ICE)
- Western Norway Research Institute
- Modul University Vienna
- Potsdam Institute for Climate Impact Research

The literature review and focus group input informed the pros and cons of DLT adoption in EU climate policies. The analysis was presented in the first interim report and the feedback from DG CLIMA supported the selection of policies for case studies under Task 2.

Methodology for Task 2

The results of Task 1 were used to select three EU climate policies for Task 2, considering items such as the relevance, feasibility, and the current timing in introducing DLT applications that may be aided by proposed reforms or launching of new regulations.

- The carbon removal certification faces risks of double counting carbon removal projects, and double selling of individual carbon removal credits. There is potential for DLT solutions to reduce such risks while allowing multiple voluntary carbon registries to coexist in an interoperable fashion.
- The Ozone Depleting Substances licencing system upon recent impact assessments has the possibility to address various challenges linked to improving the traceability of licences,

monitoring and reporting requirements, the increase in the number of players, the correct application of legislation and the detection of fraud. There is potential for DLT solutions to address such challenges to contribute to more transparent and efficient reporting, monitoring, and compliance.

- The proposed amendment to the F-gas regulation include a series of provisions to overcome challenges regarding the quota system, for example, related to illegal activities. There are provisions linked to a further assessment of traceability methods of f-gas placed on the market. There is potential for DLT in combination of other digital technologies for traceability management to address the above challenges.

The case studies involved desk research of EU policies and Blockchain reports, a series of workshops with the European Blockchain Services Infrastructure (EBSI), and interviews with certification schemes, carbon removal auditors and other experts including:

- Minespider – a Blockchain supply chain sustainability software provider.
- Agreena and Puro Earth – carbon removal certification bodies.
- Verra and Gold Standard –carbon removal certification schemes.
- World Bank – Climate Action Data Initiative.
- CLIMA officers, TAXUD, & EBSI officers from DG DIGIT for the ODS and F-gas cases.

Methodology for Task 3

Task 3 responds to the specific objective to deliver to the Commission a recommendation report on the deployment of Blockchain in climate policy, both specific to the identified policy options and recomendations on the potential wider deployment of Blockchain in EU climate actions.

Task 3 contextualises the case study analysis by considering the actions within the European Commission's administrative capacity to support blockchain implementation and then re-evaluate how this affects stakeholders, supporting actions and impacts.

Task 3 also sees the delivery of the final report that collects the results of all three tasks and present recommendations to the Commission on the implementation of blockchain in climate policy.

The implementation strategies entailed close coordination and agreements with policy officers from DG CLIMA responsible for CRC, ODS, and F-Gas, and EBSI officers.

5 Findings

5.1 The potential of Distributed Ledger Technologies to address EU Climate Policies challenges

Selection process of key climate policies

After presenting the CLIMA policies, an in-depth analysis was carried out in Task 1 of the project to determine which policies would benefit most from DLT. In a nutshell, DLT can best support climate policy implementation where there is a need to produce secure records at scale, and where there is potential to facilitate or strengthen regualtory compliance, monitoring and enforcement.

The policies were reviewed according to the following criteria:

- Multiplicity of actors subject to record generation (modest +, high ++, very high+++)
- Completion of administrative formalities (Yes/No)
- Submission of validated credentials (Yes/No)
- Indication of verification of compliance (Yes/No)
- Transactions between parties (Yes/No)
- Indication of verifiable data or claims (Yes/No)

The greater the number of players, transactions between parties, information to be recorded, administrative costs and a complex compliance process, the greater the potential of DLT. Regarding to the results presented in the first interim report, the following CLIMA policies were selected for investigation vis-a-visDLT since they scored highly on the criteria above:

- EU Emissions Trading System (ETS)
- Monitoring, Reporting and Verification (ETS MRV)
- Effort sharing Regulation (ESR)
- LULUCF Regulation
- Protecting the ozone layer
- F-gases
- International Action on climate change
- Carbon removal certification
- CBAM

Further insights into the rationale for selecting policies are indicated as follows:

EU-ETS

Many sectors and actors are in the scope of the ETS and are involved in large scale data recording and exchange. For example, a key feature of the ETS is the transaction of emission allowances between operators via financial intermediaries, and the free allocation and auctioning of emissions allowances instigated by Member States for assignment to operators.

The exchange of emission allowances involves the exchange of key records connected to a given allowance, including the account holder information, type of GHG covered, year of issuance, a unique identifier used to identify and track the ownership of the specific allowance, and the compliance period the allowance remains valid etc.

The Union Registry, a Commission Database, records the issuance, transfer, and cancellation of carbon allowances, while the EU ETS Transaction Log automatically checks, records and authorises all transactions between accounts that are hosted in the Union Registry.

Further compliance activities are undertaken to record emissions. This operates under a third party MRV system, with emissions plans and annual emission reports stored in the Union Registry. The MRV system needs to take stock of whether the annual emissions are aligned with the number of allowances held by the operator. If emissions are lower than the number of allowances held, operators can transfer these to other parties.

LULUCF

Member States are tasked to provide accounts and perform accounting activities concerning emissions and removals of GHG from designated land categories covering the national territory. Although only a small number of actors are mandated to perform designated GHG accounting duties, there is potential for exploration for adoption of DLT considering the large-scale record and accounting management on the status of land parcels and the use of removals to offset emissions.

ESR

The main rationale for considering the ESR for DLT adoption is that the ESR 'intersects' with the EU ETS and LULUCF in that allowances and removals are used to manage and balance emissions, and therefore the same rationale applies as mentioned above already.

F-gas

The area of F-gases (Regulation 517/2014) could be considered for further investigation when it comes to adopting DLT. A revision of the regulation, currently negotiated by the co-legislators aims to deliver higher ambition, improve enforcement, and achieve more comprehensive monitoring of F-gases placed on the EU market. The revision is intended to set a tighter quota system for hydrofluorocarbons (HFC) gases.

A key element of the regulation is the quota system put in place to implement the gradual reduction of the quantities of HFCs placed on the EU market. A central registry as required by the current F-Gas Regulation for the allocation and transfer of quotas and authorisations for placing HFCs on the EU market has been set up and is technically operated by the European Commission. Member States, including their customs authorities can check the data registered about a company including their quota availability and/or number of authorisations to use quota for customs clearance. Considering the wide range of actors, the enforcement and monitoring of the regulation can be quite challenging and time-consuming.

Protecting the ozone layer: Ozone-depleting substances (ODS)

The key elements of the regulation for the assessment relate mostly in the management of tlicenses for the export and import of ODS, including the record of transactions, verification, and compliance process to increase the efficiency of the system. Similar to the F-gases regulation, the European Commission established a licensing system for the import and export of ODS and the EEA set up a reporting system to track data on the production, consumption and trade of ODS. The EU Ozone Regulation sets out requirements for compliance activities, such as the certification and training of personnel involved in handling ODS, the completion of administrative formalities, and the submission of verifiable personal details.

Regulation on Carbon Removal Certification (CRC)

There are a high number of actors in scope such as all operators carrying out a carbon removal activity, certification schemes, certification bodies, the European Commission, and national accreditation bodies.

Operators of carbon removal activities will have to apply to an EU approved, public, or private, certification scheme and will be regularly verified and certified by independent certification bodies. One of the main difficulties is to track and trace the issuing of certificates of compliance and of the certified removal units. The main problem with this difficulty is the risk of double counting removals. DLT could help to reduce the risk of double counting. This problem is expanded upon in the next sub-sections.

The certified carbon removal units can be used in several contexts: they can be exchanged on voluntary carbon market (VCMs), they can be used for contribution claims by coorporates, they can be used for State Aid and, in the future, under possible EU compliance markets for permanent removals or land-based removals. For such a credit to be credible, a lot of information needs to be integrated to the certificate, in a transparent way for to all market participants, especially buyers.

Under the current voluntary carbon markets, offsets are verified by accredited independent third-party bodies, while carbon credit registries managed by certification schemes or programmes record the carbon offset's retail chain to track the existence of the credits. When verified, credits are issued, entered a registry and made available for trade.

CBAM

They are a very high number of actors (all foreign companies…). Importers will have to register with national authorities before importing the goods and declare annually the number of goods imported and their integrated emissions. The declaration must include data on the number of goods, the total integrated emissions and the total quantity of CBAM certificates. Digital traceability solutions make the emissions accounting process for the CBAM easier. The use of blockchain has potential to better track information on embedded emissions for goods, which will better determine which external products should be taxed.

Other legislations were considered as having less relevance for investigation for DLT adoption, primarily since the underlying policy mechanisms partially or mostly did not align well with the functionalities of DLT. This is especially true with respect to the absence of functions supporting large scale record or data generation especially on a designated target population group or business sector etc. This includes a lack of large-scale data generation around business compliance activities involving a multiplicity of actors such as authorities, regulators, third parties, business sectors and consumers.

This is the case **for Funding for Climate Action policy** (that rather the Innovation Fund and the Modernization fund) where there is a relatively low number of actors and no transactions. Similar observations were made of the EU **Climate Strategies and Targets and the Strategy on the EU Strategy on Adaptation** to Climate Change where only a small number of actors that engage in infrequent sharing of in-depth reports. When it comes to the Regulation 1029/631 **CO2 emission performance standards for new passenger cars** on CO2 emission performance standards, the preliminary analysis highlighted the limited relevance due to no transactional activities foreseen by the regulation.

Focus group results: EU climate policies, challenges and DLT solutions

After an initial review of the cases, focus groups were used to gather feedback from DLT and climate policy experts with a view to learning of the main challenges facing the climate policies, and the core characteristic solutions that DLT offers that may address those challenges.

The main challenges discussed and identified included the following:

- Lack of trust
- Security
- Indication of verification
- Need for transactional history.
- Fraud
- Tax evasion
- Regulatory uncertainty
- Poor enforcement
- Monitoring challenges
- Reporting delays

EU-ETS

Challenges have been documented concerning the secure holding of credits, insufficient security around verified identification for new account openings, lack of sufficient Member State enforcement and checks on existing accounts, need for clearer histories on the origin of allowances and tracking of transactions, and more generally issues with the level of trust in the carbon markets. However, some of these challenges have been addressed through the introduction and development of the Union Registry.

However, DLT systems may strengthen traceability and security aspects concerning the transparency of credit allowances through immutable indication of their origin and transaction history, the indication of the verification of organisations and emissions reports, reducing transaction costs via Smart Contracts considering the current involvement of financial intermediaries, Member States and verifiers, and more ambitiously the monitoring of emissions using IoT that could provide real time data for reporting and compliance purposes.

LULUCF

The main challenge identified by the project team's academic DLT expert was the uneven approach to implementation in terms of usage of methods and (satellite) data. DLT could be used therefore to strengthen a harmonised approach by allowing countries to show that certain standards have been met. This would be done by using proofs of compliance issued via Smart Contracts after Member States have completed their caculations. This would permit digital sovereignty since it would simply provide evidence that standards have been met rather that provide insights into the analyses, and therefore support potential extension of the approach to other countries.

Proposed Carbon Removals Certification Regulation

Within the framework of the proposed Carbon Removals Certification Regulation [COM(2022) 672 final], the possible benefit of DLT is to provide additional securacy, transparency and traceability of carbon removal units managed by certification schemes (for more details on possible implementation issues see the section 8.2 Task 2 appendixes 'CASE STUDY 1. Carbon removals certifications'and for estimated costs of a preliminary implementation strategy see section 'Preliminary implementation strategy scenario for Carbon Removal Certification' [please note that there is no numbering of these sections]).

A key benefit of DLT system would be to provide tracking and a visible window on the issuing and ownership of carbon certificates. In doing so, the most important risk addressed is the avoidance of fraudulent activity concerning **double-counting**. This type of fraud entails selling the same certificate twice and using the same certificate for more than one off-set.

Risks concerning double counting scenarios can be reduced by using a common DLT fabric that is accessible to independent certification scheme registries. DLT technology incorporated in the DLT fabric can securely store all information on issuance, ownership and retirement of certificates. This information is immutable. A transaction recorded on DLT does not allow for another record of the same transaction. By providing a single window and permanent record on all tansactions, opportunities are provided for tracking and audting (in real-time) of global certificate transactions.

CBAM

Due to the complex nature of modern supply chains, CBAM might bring challenges associated with the inaccessibility of information, confidentiality concerns, errors, and lack of scalability. The use of DLT has great potential to better track information on embedded emissions for goods, which will better determine which external products should be taxed. For complex goods, which require other complex goods as inputs, it could be very challenging to track back the embodied GHG emissions.

There might be a role for digital technologies to play in facilitating the implementation of such schemes.

F-gas and ODS

The key challenges highlighted during the focus group and through desk research mostly relate to transactional costs, monitoring, verification and enforcement challenges. DLT could be used to automate certain reporting and keep records of activities, by ensuring accurate and up-to-date information. DLT could be used to automate certain compliance activities, such as tracking licenses, and maintenance history and to verify certifications and licenses to make sure that only certified personnel and equipment are used.

When it comes to verification and enforcement challenges, it has been mentioned that it can be difficult to verify certification and license due to a range of issues, as the increasing number of actors subject to compliance obligations and differences in national enforcement frameworks. Moreover, the limited visibility into the F-gas supply chain can make it difficult to prevent and identity non-compliance, fraudulent activities and illegal trade. This is another potential benefit of applying DLT then it could reduce fraud and provide the automation of certain compliance and monitoring activities.

Concerning the Ozone Regulation, similar challenges were identified. The European Commission set up one licensing system for the entire EU, through which undertakings can apply for import/export licences. Customs offices have access to this system to clear import/export licences. The European Union and Member States - as parties to the Montreal Protocol - must report to the Ozone Secretariat of the United Nations Environment Programme on the production, import and export of ozone-depleting substances. This information is collected from undertakings that report to through the EEA's BDR, then the EEA aggregates data at EU and MS level and provides these data to the UNEP Online Reporting System through machine-to-machine communication. DLT could support in the providing a secure and decentralised platform for sharing information and facilitating the implementation of the regulation.

Case studies on potential use of Distributed Ledger Technologies for EU climate policy challenges

Introduction

As mentioned in previous sections, a key objective of this study is to identify three policy options where DLT and other digital technologies can contribute to EU climate policies.

This section presents the three case studies on different policy options selected for further analysis, namely Carbon removal certificates; Ozone Depleting Substances; and F-gas.

The **rationale** for the selection of these policy options can be summarised as follow. The three policies are currently being negotiated or under review, and their proposed amendments introduce elements with potential benefits should certain features be managed by DLT and other digital technologies. In case of the **carbon removal certification (CRC)** DLT would allow multiple voluntary carbon registries to coexist in an interoperable fashion, thus addressing the risk of double counting carbon removal units. The **Ozone Depleting Substances licencing system (ODS)** case according to recent impact assessment[9] has the possibility to address various challenges linked to improving the traceability of licences, monitoring the extension of reporting, the increase in the number of players, the correct application of legislation and the detection of fraud. There is potential for DLT solutions to address such challenges to contribute to more transparent and efficient reporting, monitoring, and compliance. Similarly, to the ODS case, the **F-gas regulation** provisions an electronic registry for quotas for placing HFCs on the market. The amendment to the F-gas regulation introduces new provisions, among which are measures to consider if tracing methodologies for gases placed on the market could be used among measures to monitor illegal trade. DLTs in combination of other digital technologies for traceability management may contribute to integrate the quotas and authorisations with the actual monitoring of the F-gas flows along their supply chains, contributing to prevent illegal trade. The following section summarise task 2 findings related to the three case studies discusses earlier.

[9] European Commission (2022). SWD (2022)99 final, Commission Staff working document, impact assessment report for regulation on substances that deplete the ozone layer and repealing Regulation (EC)No. 1005/2009. Available at: https://climate.ec.europa.eu/system/files/2022-04/ods_impact_assessment_en.pdf

Scenario for DLT implementation on Carbon removal certification

For the development of potential scenarios of DLT use for carbon removal certification, several options were considered and then filtered out. In particular, an early decision was made by the project consortium to focus on the use of EBSI as the underlying blockchain framework due to its existing infrastructure in the EU and alignment with EU data regulation, its utilities-oriented design (as opposed to market-oriented), and its accountability features (notably, Decentralised Identifiers for legal entities).

Furthermore, the project consortium also determined that a single, underlying DLT fabric should form the basis of any scenario in order to link any new or existing registries managed by carbon schemes into a single source. With respect to feasibility, this has the benefit of allowing carbon schemes to continue managing their data through whatever system they find most appropriate and cost effective. It does so through the creation of an API (Application Programming Interface or application) which links the carbon scheme's data to the EBSI blockchain (see the figure below for the transactional database). Use of a single source also has the operational benefit of the reduction of administrative burden for auditors (fewer sources from which data must be requested, and also more uniform data which leads to less time spent cleaning the data) and potentially for project operators (potential reduction of pre-certification guarantees and assurances of not double-registering their projects).

An analogy of this single, connecting fabric setup is that of the Internet. While there may be different access providers (such as your home broadband subscription), different means of access (mobile network, wifi etc.) and different websites, they're all part of the same internet ecosystem. By conforming to the rules of this ecosystem, different devices and websites can communicate while being operationally independent. Similarly, the existance of different carbon removal registries, can be operated upon a single blockchain infrastructure.

Scenario 1: Non-transactional database

Scenario 1 (Scenario 0.5 in the case study appendices) represents a non-transaction version of the pan-European DLT system. It is largely based on the Climate Action Data (CAD) Trust's decentralised metadata platform (see Box below) which links, aggregates and harmonises all major carbon registry data to enhance transparent accounting in line with Article 6 of the Paris Agreement[10]. In addition to the CAD Trust model, Scenario 1 incorporates as a feature the use of DIDs (decentralised identifiers) for added accountability, which is not an inherent characteristic of DLT. DIDs are enabled by the database's construction on EBSI blockchain infrastructure.

A key difference between this database and the one proposed in Scenario 2 is the exclusion of NFT issuance and exchange. Instead, carbon schemes link their certificate data to the DLT system, which acts as a single public window to all certificate data subject to the proposed Regulation. This public window can be coupled with applications that enable its use as a Certificate Search Engine. The key benefits and drawbacks of the non-transactional database are listed below:

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[10] CAD Trust Brief Deck, Yuvaraj DINESH Babu / Climate Action Data Trust

Benefits:

- To secure the system, the only actors required to have EBSI-compatible digital wallets are carbon removal certification schemes (for DIDs and for data entry) and certification bodies (for DIDs).
- Only carbon removal certification schemes are expected to interact with the registry in terms of data creation and updates. This reduces the number of interfaces and actors to be accounted for in system design, thus reducing implementation complexity.
- With a view to reducing fraud, the lower levels of automation limit the end-to-end capabilities of the registry in comparison with Scenario 2, eg. the case of automatic prevention of double claiming. However, careful design of the Certificate Search Engine will yield a system that facilitates traceability and audit activities by providing a single, immutable source of data. While faults such as double claiming would not be actively blocked, any instances of double claiming would be easier to trace in a well-designed Certificate Search Engine.
- As is the case for Scenario 2, double counting is addressed through the inclusion of geospatial data in carbon removal certificates. While geospatial data is already a requirement in Annex 2 of the draft EU carbon removal certification regulation, DLT adds value by providing access to a database that is always accessible (no single source of failure as for centrally operated systems) and is inherently highly structured which lends to auditability.

Drawbacks:

- In comparison to Scenario 2, this Scenario relies heavily on the data management practices of participating carbon schemes since certificate exchanges and retirements aren't automatically monitored through the NFT capability.
- Unlike a transactional database, transactions are not facilitated in a peer 2 peer environment. Therefore, the sales process is external to the system and involves financial intermediaries, therefore it is likely to be slower and more expensive.
- While the system offers a simpler design for development and implementation, sufficient resources and stakeholder collaboration are needed to get the project off the ground. The implementation details are provided in section 6.1.2.

Summary of Climate Action Data (CAD) Trust
P

The CAD Trust is a common metadata database to which carbon schemes operating around the world can voluntarily submit their certification data. The database can link, aggregate and harmonise certification data from major carbon registries to enhance transparency under Article 6 of the Paris Agreement (however, the CAD system does not yet provide a clear link to measuring meeting of Nationally Determined Contributions).

The main intention behind this common database is to improve environmental integrity, transparency, verifiability, inclusivity, and cost-effectiveness. In particular, there is a need to reduce the risk of double counting and increase the level of trust in carbon data and carbon markets to encourage investment – this is especially the case when considering international governance of carbon removal - this is why DLT has been selected.

Data can be manually entered by participants or automated / linked to their own registries; these registries need not be DLT-based. However, the database itself makes use of a blockchain metadata layer to store submitted certification data. This database does not currently have a transactional layer, so it cannot monitor origins and exchanges apart from updates to data submitted by the schemes. However, the CAD trust operates as a window to the carbon markets to enhance integrity.

The content submitted is largely harmonised and to a high standard. Having a common taxonomy is critical for the possibility of aggregating data. The CAD Trust system uses the Chia Network, a public blockchain. It is open source, so there are no fees associated with the use of the database itself (i.e. No fees to the CAD Trust), though there are transaction fees associated with the Chia Network.

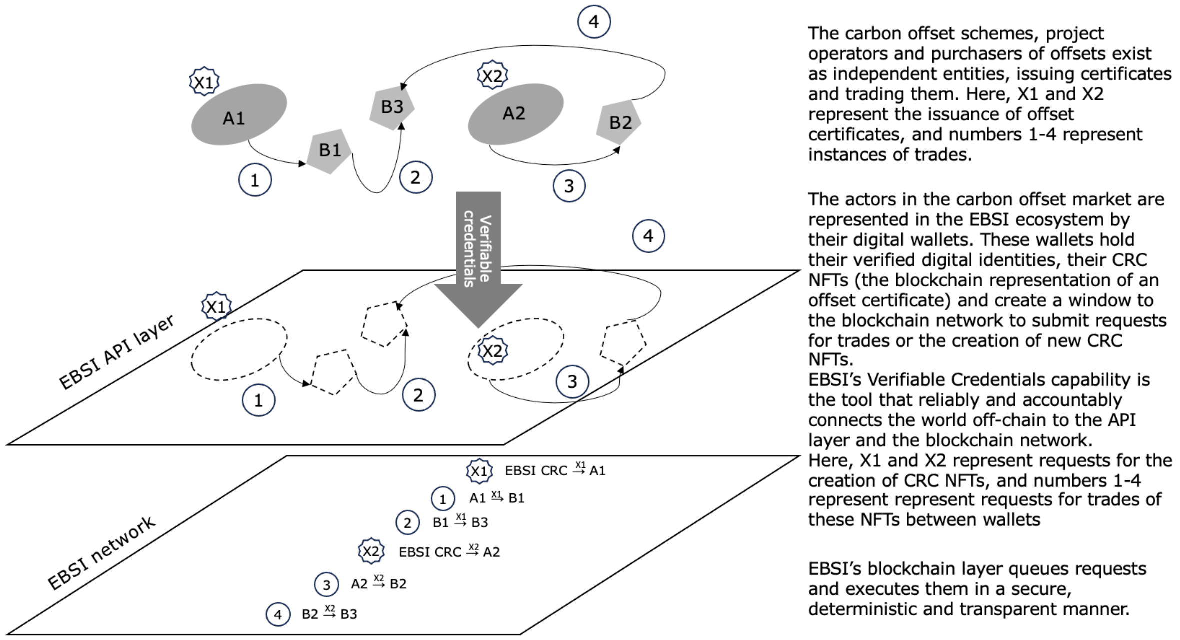
Each registry / certification standard has access to the CAD application. The use of DLT provides digital sovereignty and security of the data that is shared with CAD, while providing transparency. Data is transferred in real time with files uploaded from the registries. A common data taxonomy is used – this ensures information can be structured and harmonised.

The CAD provides transparency from issuance to retirement – this is important to preventing double counting.

Scenario 2: Transactional database

Scenario 2 describes a situation in which certification schemes are linked to a single, pan-European DLT system, as well as the high-level governance and components required for effective operation at the EU level. While at the blockchain level there exists a single, consolidated database (the DLT system), certification schemes still operate independently, issue their own certificates and maintain their respective certificate databases. These carbon removal databases do not need to be based on DLT. However, each certificate is simultaneously issued as a CRC NFT on EBSI, and it is these NFTs which will be traded across a common blockchain environment.

Figure 4 Scenario 2. Layers of the carbon offset market with respect to the EBSI



A full description of the Scenario can be found in the appendices to this report. However, the key features, benefits and drawbacks of this transactional database are:

Benefits:

- Each unit is issued on the ledger as an NFT. This NFT points to the certificate data held on the respective databases of participating carbon removal registries.
- Each actor in this ecosystem who participates in the issuance or exchange of certified carbon removal units requires an EBSI compatible digital wallet and a DID.
- The combination of smart contracts with NFTs allows for automated retirement of carbon removal units (CRUs), real time identification unit owners, active prevention of double claiming as well as automation of other checks and balances, such as the prevention of exchanges with restricted parties. However, implementation of such a highly automated system is expected to be complex given the number of processes affected and stakeholder systems that must be linked.
- Similar to Scenario 1, double counting is already addressed through the inclusion of geospatial data in CRUs, but is enhanced by their accessibility within a single source of data (the DLT system).

Drawbacks:

- A key restriction to this Scenario is that in order to facilitate NFT exchange, all connected applications and data fields must be standardised. Any carbon schemes or traders who already subscribe to the protocols of blockchains other than EBSI (for example, if they are subject to a similar Regulation outside of the EU which builds on different blockchain protocols) are likely to be excluded from trading and issuing certificates across all jurisdictions, and no interoperability standards are agreed upon.
- The number of interfaces and actors that need to be accommodated in the system design may increase implementation costs, timeframes and complexity.

Conclusions

Both Scenario 1 and Scenario 2 can address the key issues in the carbon removals certification industry, to varying extents.. Further pros and cons vis-à-vis Scenarios 1 and 2 are indicated as follows:

Table 1 Scenario 1 pros and cons with respect to Scenario 2.

Pros	**Cons**
Only two actor types must set up and manage an EBSI compatible wallet (for DIDs / data entry)	No end-to-end automation due to absence of transactional / token (NFT) capability.
Can operate and yield notable benefits without end-to-end automation. • Operational reliability (no single source of failure in comparison with centralised digital solutions) • Highly auditable ledger of data (inherently structured nature of DLT) • Database integrity and resistance to tampering (immutable nature of DLT)	*Implementation detail*: For a transactional / token-based system to operate effectively and deliver all the intended benefits of DLT, all actors in the CRU market must transition their operations to this system at once. Otherwise there will exist in parallel multiple different trading systems which must all be consolidated manually for audits to take place. Implementation of system-wide digital transformation in a small business can take 18 months for a minimum viable product[11]. Multi-country, multi-stakeholder transformation should expect far greater complexity and implementation times.
No changes to current trading methods needed.	
Limited number of actors required to interact with the DLT applications.	
Significantly reduced design complexity.	
Greater interoperability with non-EU carbon removal certification schemes.	Less automation means more reliance on the data management practises of the carbon removal certification schemes.

Further detail regarding the scenarios and the recommended implementation strategies can be found in section 4.3.2.

Scenario DLT and digital technologies implementation on Ozone Depleting Substances

For stakeholders engaged in ODS trade there are two main digital components they have to interact with. The ODS licensing system was established by the European Commission which manages the import and export of ODS. The EEA manages the ODS reporting system through the BDR which tracks data on the production, consumption and trade of ODS. The information

[11] How long does it take to digitally transform your small business? Available at: https://economictimes.indiatimes.com/small-biz/sme-sector/how-long-does-it-take-to-digitally-transform-your-small-business/articleshow/99025434.cms?from=mdr

collected through the BDR is aggregated for the individual Member States and the EU and is provided to the UNEP Online Reporting System through machine-to-machine communication.

In 2022, the EU Commission proposed to amend the Ozone Regulation to increase the efficiency of existing measures to achieve additional emission reductions and ensure a more comprehensive monitoring of ODS. Monitoring and enforcement challenges have been connected to the reporting requirements placed on the multitude of actors that need to report their ODS-related information. Indeed, verifying compliance with the EU Ozone Regulation can be a complex and time-consuming process, particularly when dealing with cross-border transactions.

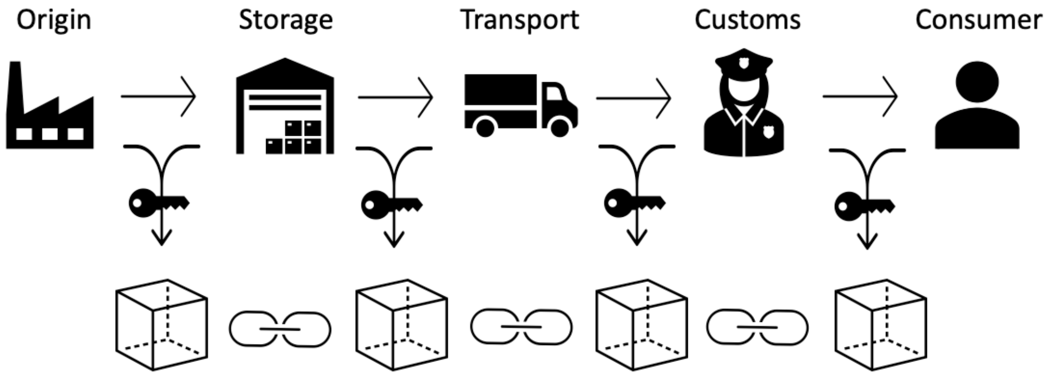
Additionally, enforcement can be challenging due to the differences in national regulations and enforcement procedures, as well as by the involvement of third-party countries in the trade of these substances. In terms of fraud, it can also be difficult to detect and prevent illegal activities, such as the illegal production and trade of ozone-depleting substances (ODS). Stakeholders, in particular the chemical industry, have expressed great concern about growing importance of illegal trade, placing illegally ODS on the EU market. DLT could support solving these challenges by providing a secure platform for sharing information and facilitating the implementation of the regulation.

The following presents a discussion on possible use cases for DLT that will be further elaborated upon during Task 3, including discussing the specifics of their implementation within the ODS framework.

Use case 1: Monitoring and Reporting

The objective of DLT based monitoring is to provide authorities, stakeholders, and the general public with a greater understanding and overview of ODS-related trade and use. By leveraging the transparency and immutability of DLT, it becomes possible to optimise audit processes and accountability within the industry, thereby reducing incentive for misclassification. The following demonstrates how a DLT-system could be used to enable an audit trail that captures the entire lifecycle of the substances along with all associated actors and their designations. Note that this is a hypothetical example which assumes the capacity to implement a DLT-based monitoring system across the entire supply-chain.

Figure 5 Simplified schematic of how ODSs could move through a DLT-based supply chain monitoring system.



A blockchain based supply chain monitoring system can be used to provide real-time updates regarding the status and location of ODSs. For example, each time an ODS is manufactured or changes hands, these actions can be logged by the relevant actors onto a single network. The logging of information can be automated through IoT or other digital applications to further reduce administrative intervention. Authorisation to submit updates to the system can be regulated directly, or by the integration of complementary systems such as those which grant licenses and registrations.

Source: Technopolis Group

All data transactions on a DLT system are stamped with the unique "address" of the digital wallet that originated the request meaning that all data input on the DLT system can be traced to a specific digital wallet as the data origin – this association and all the data uploaded onto the DLT system is immutable.. The association of these licenses and registrations with a unique digital wallet ensures that ODS transactions from the supply chain system can be traced directly to an accountable party. The record of these transactions would also be safe from tampering and manipulation. By making such a supply chain system visible to stakeholders, including regulatory bodies, their verification activities can be simplified. The inspection process could be incorporated into the DLT based system and enhanced by smart contracts that could trigger alerts and run origins checks whenever real-world inspection data does not match on-chain classification data. Each transaction related to the movement or handling of ODS can be recorded on a dedicated supply chain DLT system which is linked to complementary databases (such as those which hold and issue licenses and registrations) via smart contract. This integrated system could create an audit trail that captures the entire lifecycle of the substances along with all associated actors and their designations. Data can include imports, exports, production, destruction, process agent use, feedstock use, stocks, and for both controlled substances and, when relevant, fordata on new ODS.

This can be viewed as a best case scenario where sufficient resources are available to develop a comprehensive DLT-based monitoring system which integrates the different stakeholders involved in the ODS life-cycle. Such a monitoring system could leverage ODS labelling where the scanning of the label would automatically input data onto the DLT system and enabling the monitoring of the ODS lifecycle. However, it is also possible to leverage DLT by applying it to existing digital infrastructures. While resulting in a less comprehensive monitoring system, it would enhance the monitoring of data being submitted to the BDR. This later scenario will be explored further in the implementation strategy (see chapter 6.1.3 Preliminary implementation strategy for Ozone Depleting Substances).

The introduction of DLT for the ozone regulation could set a positive example for other countries on effective climate policies when it comes to strengthening political cooperation. Moreover, it could find strong support among the business community looking for solutions to level the playing field against illegal trade of ODS.

Due to the close linkages between the ODS and F-gases regulations, some economies of scope could be identified to use the same technology for similar aspects (monitoring, reporting and compliance requirement). Furthermore, the ODS licensing system could leverage EBSI as the framework to adopt DLT to manage ODS licensing. EBSI is a multi-chain DLT system that is being supported by the European Commission and European Member States directly, bringing with it the added assurance that the DLT system is designed under the considerations of operating within the EU context.

Use case 2: Security

Increasingly stringent requirements on data protection and security are expected to drive administrative costs at the European level (Commission and EEA). Data protection consists of different aspects for which a DLT system can offer varying degrees of utility. The primary aspect of data protection involves the preservation of information against damage, loss or corruption. DLT application in this area depends on whether this sensitive information is stored on-chain or whether instead the data transactions 'point' to data stored externally. The former case is highly secure, as all nodes in the network would have a copy of the data which could be recovered should any of the other nodes suffer damage. However, this method of storage would also require larger data transaction sizes and therefore impose higher storage and computational requirements on every node in the network. The latter case is less data-heavy for the network itself and requires only a single database to which the network 'points', but this database is at risk of being a single point of failure should it be damaged or compromised. In such an instance the data would not necessarily be recoverable, but the DLT system would still detect any changes in information stored externally as the hashes generated for each block incorporate the metadata from externally stored files. Therefore, even when data is stored externally, DLT is ideal for detecting whether data has been tampered with.

Another aspect of data protection relates to data sovereignty. Public DLT systems promote data sovereignty as their networks are maintained and updated in a decentralised manner. Consequently, their data does not belong to a centralised organisation. However, as data transactions can be requested anonymously, public DLT systems also lack accountability. Consortium or private DLT systems can solve this issue by limiting participation in the network to trusted parties but may do so at the expense of data sovereignty in the same way that centralised digital systems do. Some DLT systems are addressing this, for example, EBSI has GDPR and other European privacy and sovereignty regulations built into it, and node operators must be compliant. Therefore, given a well-designed system, DLT can be used to simultaneously promote accountability and data sovereignty.

Consortium DLT systems are also applicable for cybersecurity, as the right to modify or view data can be restricted to trusted parties. And as a further assurance, a hash value representing the state of the DLT system at a particular point in time can be periodically saved on an external, public DLT system. While this process does not actually report or save the database itself, it creates a record of the state of the DLT system that cannot be altered by the actors in the consortium.

Conclusions

A well-designed DLT system can address several of the current issues faced by ozone regulation processes in the EU. The application of DLT to the ODS could improve monitoring and reporting processes and provide real-time data on the status and location of goods. The complexity of the monitoring system can leverage DLT according to the capacity to adopt the technology – from a comprehensive system that covers the entire life-cycle to monitoring specific data inputs made on the existing infrastructure (i.e. the BDR). It has also been shown how a DLT system can enhance data security by limiting access, by drastically reducing the ability to change historical on-chain information and by providing an immutable log of data and any changes to data.

The use of verifiable digital identities or license keys, particularly for legal entities, to stamp data transactions on the DLT system improves auditability. This in turn reduces the possibility of fraudulent license terms and increases the likelihood of accurate reporting across the ODS system.

Though DLT can offer several improvements to current and future processes, it remains important to leverage existing systems like EBSI and consider how changes to the ODS licensing system will affect its integration with the EU Single Window. The integration of these systems will require consideration of each component's relative strengths and weaknesses and must weigh these against investments already made and the system's readiness for change. In this regard, it is possible to achieve similar outputs using non-DLT systems, though with potentially higher administrative input.

Next steps in relation to this case study on ODS, is laying down the potential preliminary implementation strategy focused on the role of European Commission's administrative capacity to enable blockchain implementation and how this affects the requirements for blockchain and the impacts that can be achieved.

Scenario for DLT and other digital technologies implementation on F-gas

As it was described in section 2.1, activities that fall under Regulation (EU) No 517/2014 the 'F-gas Regulation') require companies to register in the F-gas Portal & HFC licensing system. With the obligatory introduction of the single window environment for customs, the portal will validate custom's request for whether a company has or not a valid licence and if the company has or not enough quota or authorisations for import/export. This will be done on the basis of companies' customs declarations. All companies that report on the annual F-gas-related activities must register in the F-gas Portal & HFC Licensing System to enable access to the reporting forms. The F-gas Portal & HFC Licensing System is managed by the European Commission (DG CLIMA) and is accessible on a need-to-know basis to EU and national authorities, the companies themselves, and, when necessary, third parties like contractors of the Commission (subject to confidentiality agreements).

Annual reporting on their activities with F-gases by undertakings is performed through a tool managed by the European Environment Agency (EEA) called Eionet Business Data Repository and linked to the F-gas Portal & HFC Licensing System. Some of the new proposed provisions (see e.g. as elaborated upon in section 'Introduction', p.24) introduce the possibility of tracing methodologies being uses.

Thus, there is rationale for the use of DLT solutions in combination with other digital technologies such as traceability systems (e.g., QR codes, RFID, etc.), to facilitate compliance to the new proposed provisions of the regulation.

Firstly, the shifting from free to priced quotas may create disincentives to potentially fraudulent economic operators to register in the system, however it shall not be the only mechanisms to prevent illegal trade, as it is has not been the case for most products and services traded illicitly.

And secondly, provision 24 of the proposed regulation includes the possibility of delegating act where tracing methods may be required to reduce the potential risks of illegal trade linked to movements of gases from temporary storage to customs warehousing, free zones, or in transit, and in general to gases present in the market.

Interoperable and cross-architectures DLT may allow seamless real-time traceability and information about fluorinated greenhouse gases' placed on the market, incl. to verify that gases are correctly accounted for within the quota system. Thus, this case study contributes to the evaluation of solutions to render the licensing tool more secure and explore possibilities to trace F-gases throughout the economy, along the whole supply chain from import/production to end-user/ export to ensure that the history of the gas can be traced. This includes the interaction between multiple institutional actors, such as the European Blockchain Services Infrastructure, the TAXUD's CERTEX/Single Window[12].

Business logic

A high level flow can be described as follows. **Step 1**: identifiers are issued in the Registry corresponding to the amount of quota allocated to that company, e.g. company A. **Step 2**: company A produces or imports HFCs. If a container is placed on the market, a tracing label is assigned to the cylinder, indicating its content such as type of F-gas and quantity, the date of filling of the cylinder, the location, etc. When a purchasing company B (buyer/importer/retailer) or authority scans the label, he/she gets a notification regarding the status of the cylinder with with regards to the quota system, whether it is accounted, last holder of the quota of the cylinder (etc. its seller), location, fill date, quantity, etc. **Step 3**: company B can split the content of its purchased F-gas into various cylinders to resell on various markets. In this case company B shall place a tracing label to each new/additional cylinder, indicating its content such as type of F-gas and quantity, the date of filling of the cylinder, the location, etc. Company B shall update the F-Gas Portal entries to reflect each one of the cylinders (current and additional) with their respective quantities/quotas. **Step 4**: If company C purchases F-gas cylinders from various economic operators, when the company scans the label, he/she gets a notification regarding the status of the cylinder with with regards to the quota system, whether it is accounted, its last quota holder, location, fill date, quantity, etc.

For all these transactions, the initial identifiers are modified so that they are immutable and can the verified. The container and the tracing information (identifier plus the additional information) are tracked until the final customer. This business logic accounts for the fact that downstream along the value chain, **economic operators do not necessarily have full supply chain visibility** of the original producer, importer, etc. This supply chain management strategy allows for protection of its actor's economic interest. On the other hand, when they scan the traceability lables, **Authorities and the EC have full supply chain visibility** (see figure 19).

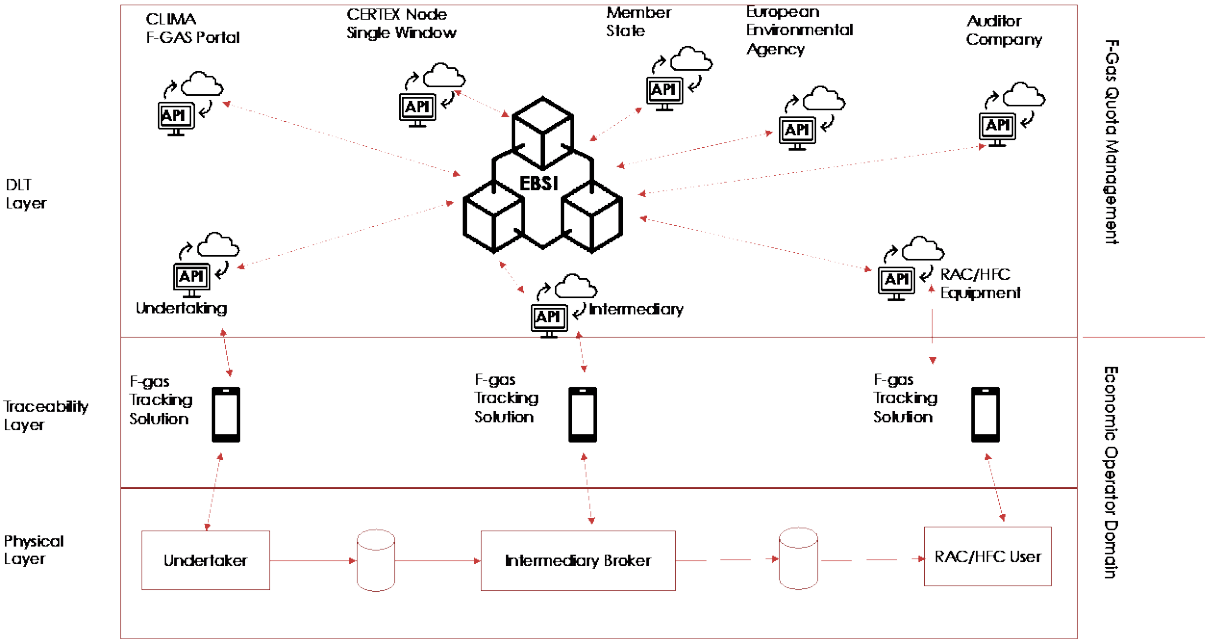
Integration of DLT and Traceability systems to the F-gas portal HFC licensing system

The challenges, rationale and business logic described above are addressed with a proposed architecture integrating the DLT capabilities of the EBSI system and traceability system. The proposed architecture of DLT and traceability, represents the capabilities of the system, which

[12] The European Commission and Member States are already on a voluntary basis working to connect the F-gas Portal & HFC Licensing System to the so-called EU Single Window Environment for Customs. The 'Single Window' will enable electronic exchange of data and documents between customs domains and the F-gas Portal & HFC Licensing System via a central EU Customs Single Window Certificates Exchange System when goods are checked for customs clearance. The use of the Single Window Environment will become mandatory. At least one MS is already piloting with exchanging data related to F-Gas formalities.

requires further assessment and revision in the context of the current evolving legal frameworks. It entails three layers: DLT, Traceability, and Physical.

Figure 6 Scenario F-Gas, Traceability System and DLT High Level Integration Architecture



Source: Technopolis Group

DLT layer

In this case, the distributed ledger is provided by one of the chains in EBSI. Upon an event performed by Stakeholders, an API/Webapp managing requests and generation of hash and storage of it in EBSI. The data is not transferred to the EBSI, as it remains in custody of the stakeholder. Stakeholder roles include:

› F-gas portal role: Manages and registers transactions related to the quota management life cycle. It validates that the amount of trade registered by the traceability systems do not exceed quotas or authorisations[13]. It updates the amount of available quotas of the EOs. In the current (and future legal set-up), the EC has the responsibility for verifying registration requests in the registry and is the one allocating quotas on the basis of historic amounts or on the basis of annual needs declared.

› Economic Operators' (i.e., Bulk HFC producer/importer; Importer of refrigeration, AC and heatpump equipment containing HFCs) roles: Manages and registers transactions related to quota and quota authorisations and used quota and quota authorisations. Manage further compliance documentation such as records keeping. Manages the traceability system and DLT hash generation to store in the EBSI DLT layer. In the current (and future legal set-up) economic operators' role is to initiate transactions in the registry (see decription earlier in the document) which may or not be accepted by beneficiaries and

[13] This system resembles the European Union Intellectual Property Office's anti-counterfeiting blockchain architecture (https://euipo.europa.eu/ohimportal/en/web/observatory/blockathon). The added value of the F-gas-traceability-EBSI use case is the capacity to verify and control traceability data and trace flows based on the quotas and authorizations held by economic operators.

economic operator's currently (and in the future) also do not manage compliance documentation such as records keeping.

› CERTEX/SW role: Manages customs declarations from EOs. Customs authorities request validation credentials of EOs to the F-gas portal, and validity of quotas and authorisations. In exeptional cases, customs officers may bypass the F-gas authorisation, activating a smart contract for automated update of the quota authorisation balance.

Traceability layer

Figure 5 shows the components of F-gas tracking solutions and the interaction with the EU F-Gas Management System (API/Webapp). Without considering the data connectivity forms, the tracking solution is composed of a reader and an F-Gas Management Tool. When a cylinder reaches a specific step in the supply chain, the economic operator reads the information from the cylinder. The reader sends the data to the F-Gas Management Tool. The F-Gas Management tool generates a hash to be stored in EBSI and sends it to the F-GAS Portal. The F-GAS Portal verifies that the data is authentic through the matching of the hash received with the hash in EBSI. The Commission officers coordinating the F-gas portal information in their supervisory role can access the data of the event with the hash transmitted by the EO and verified by EBSI, directly in the F-Gas portal. The data contains information regarding the expected or unexpected conditions on the cylinder. If there is nothing to reported or alerted, the data is approved and passed to the economic operator's F-Gas Management Tool, and records are updated on the F-gas portal and the EO's F-gas management tool. The flow is showed in figure 6 below.

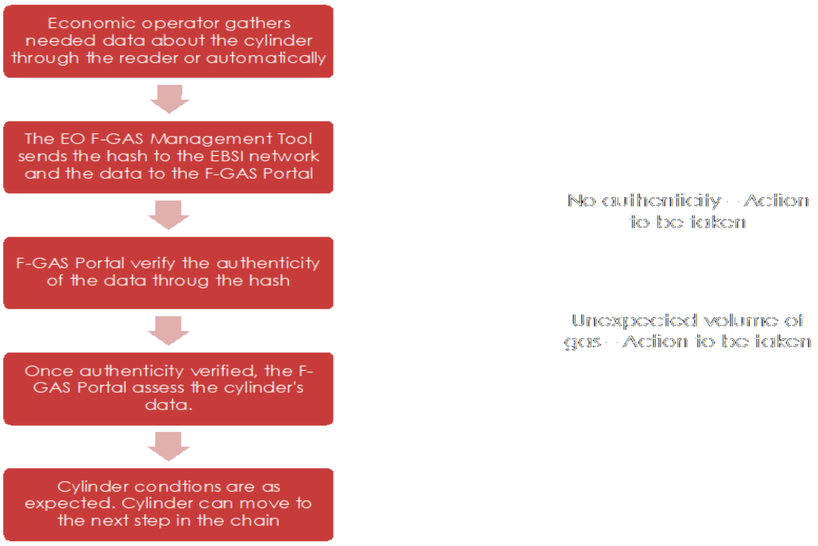
Physical layer

The physical layer represents the traditional supply chain flow, where the F-gas bulk producer ships bulk that places HFC in the market ships to a wholesaler, and in turn to a user of HFC applications such as RAC equipment. Full description initial design of the f-gas case study can be found in in appendices for Task 2.

Conclusion

A DLT architecture with the combination of other digital technologies (i.e., traceability systems) allows to address the potential inclusion of provision 24 of the proposed F-gas regulation. Whilst the DLT is a new architecture being assessed, the use of traceability systems is not actually new in the industry. It is in fact a standard used to protect assets along supply chains. Thus, its adoption may be feasible from the point of view of the acceptability of the industry.

Figure 7 Simplified Traceability layer workflow without cyliders being split into smaller quantities along the supply chain



Source: Technopolis Group

Remarks

The case studies presented scenarios where specific climate policy implementation objectives are addressed with DLT and other digital tools. Particularly, the EBSI is an enabling infrastructure capable of handling multiple use cases, including manging double counting and selling of carbon removal units; monitoring and reporting with secure access to data in the context of the ozone depleting substances licencing system; and the interaction of traceability systems with the f-gas portal to match and verify credentials of EOs, validity of quotas and authorisations, and monitor the physical flow of f-gases along the supply chain, accounting for the expected balances of quotas by EOs.

The next section presents preliminary implementation strategies for the use of DLT and other digital technologies. They describe the planning and costs related to developing pilots of these use strategies. As it was found and discussed with EBSI, DG DIGIT, DG CONECT, and DG CLIMA, the concept of implementation strategies were feasible for the three cases. Although the ODS and the F-gas present similar challenges, they are proposed to be developed independently; and they are in different web portals, one if the F-Gas portal, and the other is the OSD licencing system.

6 Preliminary implementation strategies

Introduction

This section describes two preliminary implementation strategies. This description is an approximation, and accounting for a full real implementation timeframe and costs required to set up a pilot stage of the system. Thus, the preliminary implementation strategies described below include testing, piloting, and preliminary user experience, which could provide further information for the next steps towards an effective roll-out. These preliminary implementation strategies consider two implementation strategies.

One Implementation strategy looks at the development of a pilot of the carbon removal certification management with EBSI over a 6-9 month period to . The other implementation strategy looks at implementation of a pilot system of the f-gas portal, and DLT with traceability systems on EBSI, over a ca. 4,5-7 months period. There is no assumption of deadline for the ODS implementation.

All the estimates related to these three implementation strategies are indicative, and relate to the development and implementation of pilot systems (in a test environment). The estimates of required timing, manpower and budgetary costs to effectively implement such a system, after the development of such pilot systems, are not covered in this report.

Preliminary implementation strategy scenario for Carbon Removal Certification

Problems addressed and processes replaced by use of DLT

Double counting and double claiming

To inform the development of the case study (see Task 2), several interviews were conducted with leading organisations and experts in the fields of carbon removal and DLT (see further details in section 8.2.1). The actual scale of double counting and claiming was considered to be non-existent or small although it poses an existential threat if discovered that would severely damage the reputation and value of the market. Certification schemes such as the Gold Standard have therefore developed internal quality assurance procedures on how to manage the risk of double counting when assuring projects and issuing certificates.[14] Moreover, by association, the EU and participating certification schemes, face a significant issue if double counting is discovered under the proposed regulatory framework and therefore should take action upfront to mitigate such risks, thereby ensuring that investment in carbon removals remains a secure proposition while also helping to meet climate targets.

As mentioned, a key concern is that operators may fraudulently request their removal activities to be certified under different certification schemes, thus leading to the same removal activity being falsely registered twice. However, for registration schemes that voluntarily operate under the EU Regulation, this risk would be reduced since the proposed DLT system would account for all registered projects e.g., by using unique identifiers and other information such as geographical data, although would require accurate submission of data upon certificate issuance

[14] Our new double-counting guidelines | The Gold Standard

Similarly, there is a risk that the same certificate, or a token based on a single certificate, is incorrectly sold or claimed twice, for example, as part of offsetting schemes. However, DLT can ensure that issuing and ownership of certificates are traceable and securely identifiable vis-à-vis their owners, therefore, limiting the problem of fraudulent selling.

Although DLT cannot solve all issues, especially fraudulent entry of registration data, such systems should be carefully considered. Since the proposed EU regulation establishes a certification framework that allows accredited and independent third parties to operate under, it makes sense for regulators and other interested parties to have insights into their activities. Moreover, it is also essential that the wider carbon offsetting market has confidence in the system so to encourage sustained investment.

Thus, DLT can help position the Regulation for stronger implementation. By linking registration databases, a platform can be provided from which market surveillance, and if necessary, enforcement actions can take place. Moreover, DLT can offer traceability of certificates issued and their retirement, which is an attractive feature considering the scale of investment that is needed to meet climate targets.

Changes expected from use of DLT

DLT based system has the potential to do address these problems given its unique characterists especially that of immutability and decentralised transparency while offering no single point of failure. Moreover, the European Blockchain Services Infrastructure (EBSI) is primed to offer, using its existing DLT system, services to ensure a verified digital identify and document traceability that adhere to European public sector standards, and access to digital wallets.

Referring to the scenarios presented in Task 2, a single, pan-European blockchain-based connecting fabric was found to offer the greatest benefits with respect to ease of implementation, governance, and auditability. Two versions of this single registry were presented: a highly automated, transactional DLT database, and a less automated, non-transactional database. The key features and differences are highlighted in the figures below. For the implementation of the Regulation, a non-transactional database has been selected for further elaboration in Task 3. This decision has been based on the comparatively higher technical interoperability (particularly for actors with operations beyond the geographical scope of the Regulation) and lower implementation cost and complexity. The key benefit arising from this option is its ability to unify multiple different data sources in a single database as well as the ability to do so in a transparent, traceable manner which is inherent to blockchain technology; other digital technologies cannot easily produce similar results without designing such a system from scratch. Another key benefit of even this simplified implementation over other digital solutions is its decentralisation; by storing the database across multiple, trusted nodes, no single system fault or governance issue (political or otherwise) can corrupt the content or render it inaccessible. This option does, however, sacrifice some degree of operational efficiency in comparison to transactional database options, which in turn may lead to fewer benefits with respect to system-wide auditability and the associated verification costs.

Operationally speaking, a non-transactional database should not significantly alter existing processes and governance of **carbon schemes** that participate in the proposed Regulation, except for:

- Acquisition of a digital wallet that is compatible with EBSI's DIDs. These wallets are market-based.

- Application for a DID (described below). To reduce administrative burdens to the system, this application can be rolled into the same process by which carbon schemes are formally recognised by the European Commission under the proposed Regulation.
- Submission of certification data through a purpose-built application that logs data onto the ledger. This application may be linked to the carbon scheme's existing digital systems for automated data submission, or carbon schemes may manually enter data into the application.
- Any other changes to operations are the result of adherence to the proposed Regulation itself, and not implementation of a single registry.

For **certification bodies**, no changes to processes or governance are expected except for:

- Acquisition of a digital wallet that is compatible with EBSI's DIDs. These wallets are market-based.
- Application for a DID (described below). To reduce administrative burdens to the system, certification bodies may receive their DIDs through same process by which they are accredited for carbon removals certification.

For **project operators**, no significant changes to processes or governance are expected.

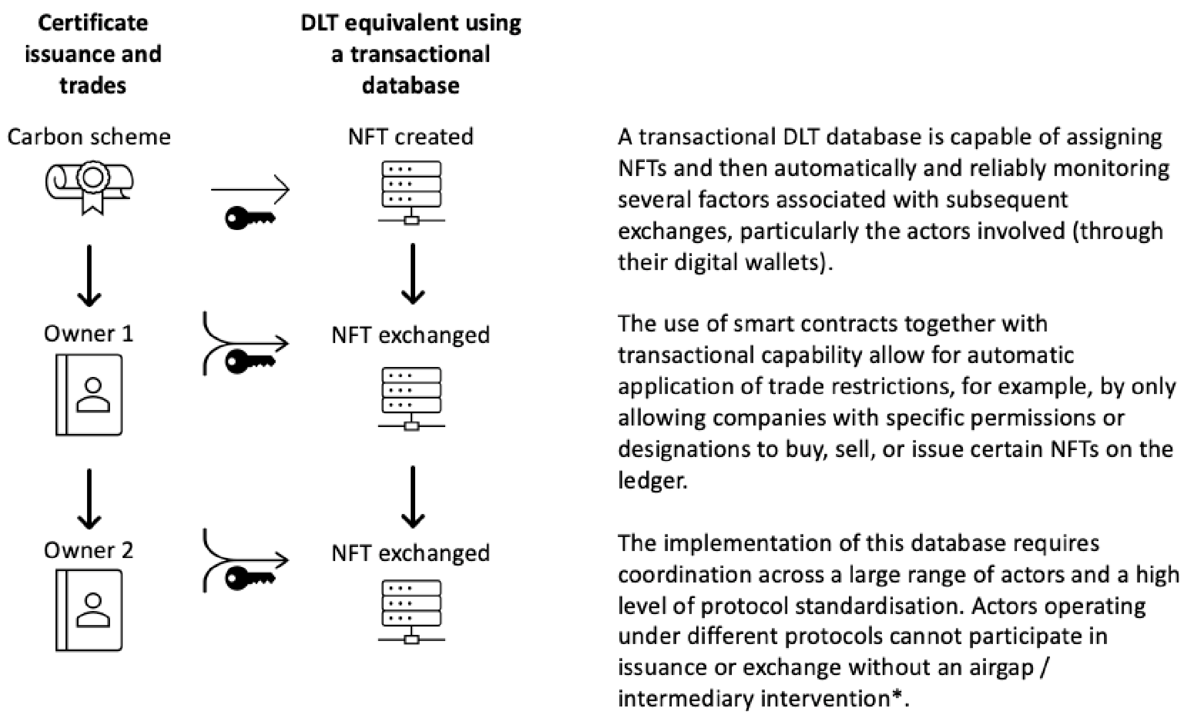
For the **European Commission and other authorities**, some changes to processes should be expected:

- Accreditation of DIDs will be an additional process that can be done in parallel with the processes for accreditation and recognition proposed in the Regulation, and by the same actors. In this way, no changes to governance are expected at this level.
- Oversight of the DLT system and its associated input and output APIs. Given the limited interdependencies of the non-transactional database, the need for technical expertise can be limited to the EBSI team. However, regarding governance there should be support in place for:
  - DID applications (information on the process, key contacts, applications that need to be downloaded, technical support).
  - The application used for certificate submission (information on the process, technical support).

The application(s) used to view, search and filter registry data (information on the process, technical support).

t

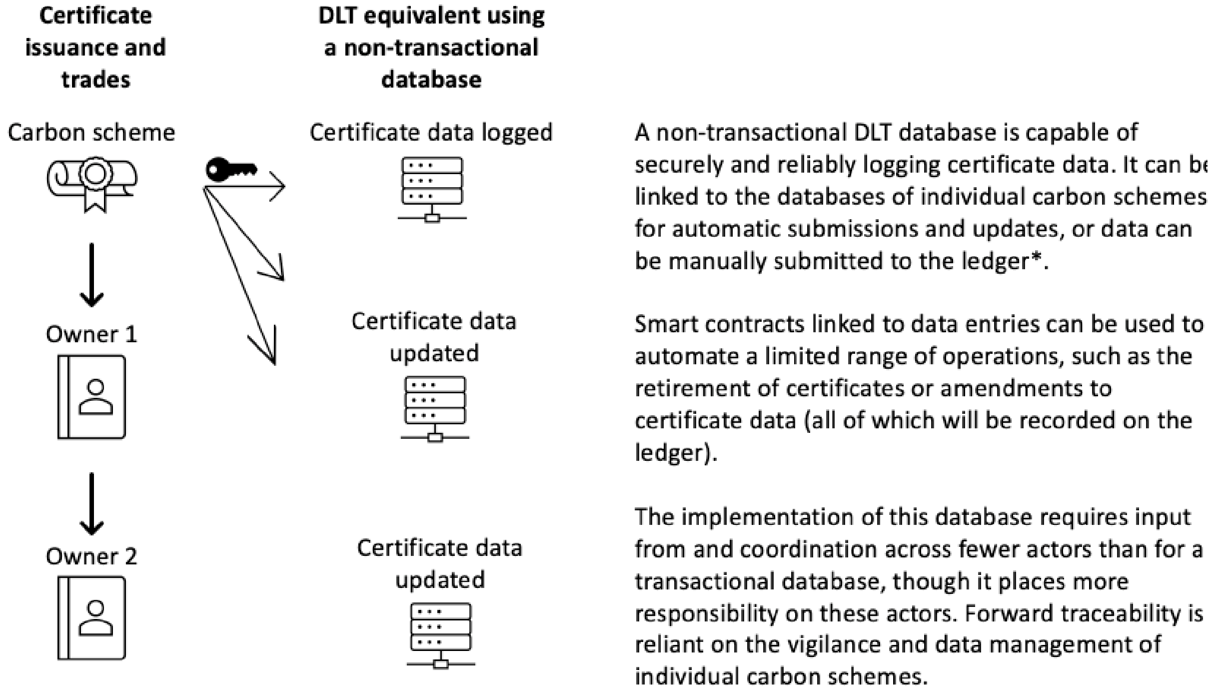
Figure 8 Transactional database overview



Source: Technopolis Group

*Airgaps / intermediary intervention are required to isolate and extract the target transaction under a certain protocol (for example, a blockchain protocol that is based on blocks of X number of transactions, with a Y-sized data limit per transaction), convert it into the destination protocol (often a manual process) and enter it onto the desination blockchain as a new transaction. The manual intervention is required represents a break in the digital trust chain, making it necessary to recruit only trusted intermediaries to carry out such work.

Figure 9 Non-transactional database overview



Source: Technopolis Group

*Whether done manually or via automation, carbon schemes will make use of an application developed specifically for the purpose of entering carbon removals data onto the target registry (described in the implementation strategy below).

Below is a diagram that summarises the changes to activities expected from the implementation of a non-transactional DLT database for CRUs.

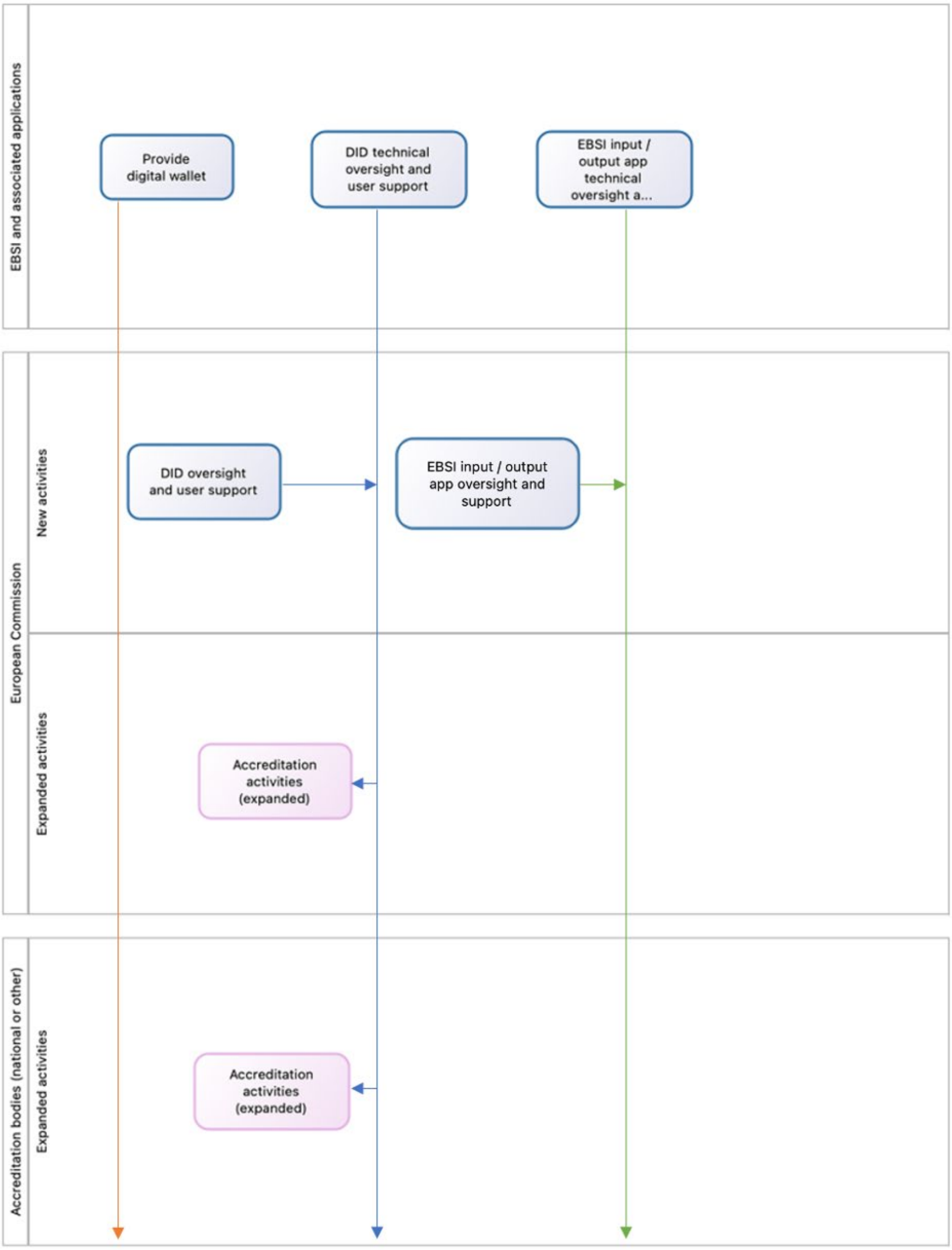


Figure 10 Summary of high level activities that are new, remain unchanged or expand due to implementation of the non-transactional DLT database. Continued on next page.

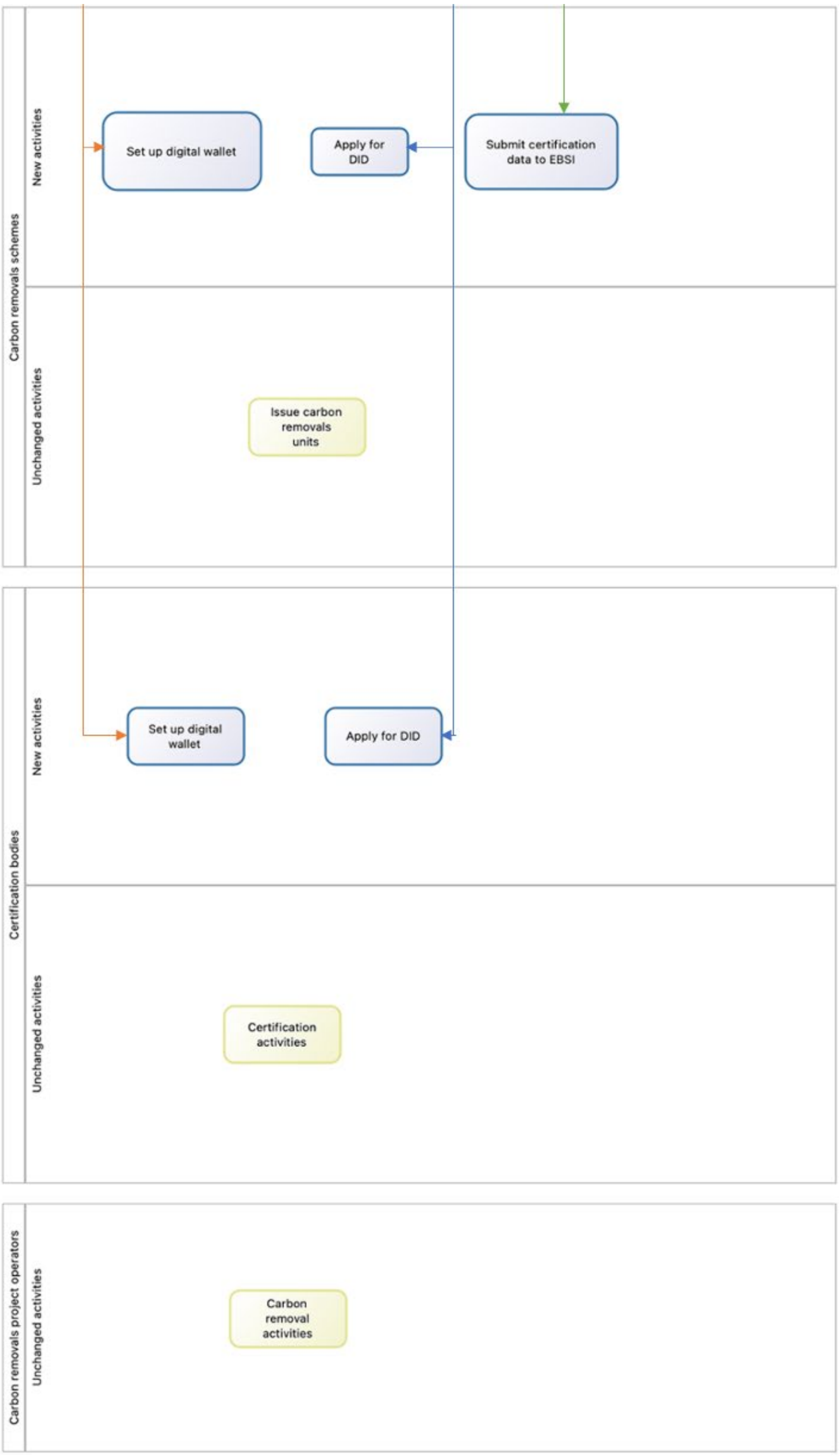


Figure 11 Continued... Summary of high level activities that are new, remain unchanged or expand due to implementation of the non-transactional DLT database.

Trust in the system

DLT in combination with one of EBSI's key features, Decentralised Identifiers (DIDs, specifically those intended for legal entities), can provide automated assurances of certification integrity, primarily by improving accountability within the system. Considering the application of DIDs at different levels of the certification pipeline:

- **Certification bodies** responsible for certifying project operations and issuing reports shall obtain DIDs accredited by the same **national accreditation body** responsible for their competence accreditation, as specified by Regulation (EC) No 765/2008 of the European Parliament and of the Council. By adding the certification bodies' DIDs to certification data logged on the single registry, these actors can be easily identified and held accountable, which in turn incentivises fair and accurate reporting on their part.
- **Certification schemes**' DIDs shall be accredited by the same division of the **European Commission** that will be responsible for recognition of the scheme's alignment with the proposed Regulation. Only those schemes with the necessary DID credentials will be allowed to log certification data to the single registry. By limiting rights to write onto the registry, the integrity of certification data is maintained.
- **Project operators** will not require DIDs, as their data will form part of the relevant certificates and reports which will be visible on the single registry.

Double counting

For the issue of double counting, use of a single, highly transparent database allows for greater traceability and auditability. Where there are multiple registries (DLT or other), the potential for gaps or duplication is large in comparison to a single source of truth.

The combination of the transparency and immutability of the single DLT registry with an API for viewing, filtering and searching for data according to the fields captured in certificates (as well as any other parameters that auditors of carbon removals may deem useful) will result in a highly efficient search engine that makes the identification of fraud easy, and therefore reduces its scope. For example, the inclusion of standardized geospatial data for projects can enable searches for overlapping land parcels and potential double registration. Even for those carbon storage or removal projects not linked to land-use, geospatial data is of use; assuming that geospatial data is verified by certification bodies, and that there are clear rules regarding the definition of borders eg. the entire legal parcel of land on which storage or removals have taken place and not a portion thereof, even where removal activities are limited to a portion. This prevents the perverse incentive to register non-overlapping parts of the same legal parcel of land, thus duplicating the project. The advantage of DLT in this case comes from the single source of truth from which audit data (including timestamps and data origins) can be extracted. While other digital technologies could produce similar results, the inherent ability of blockchain to store non-conflicting versions of the database make implementation for this purpose more efficient in the case of DLT.

Double claiming

The issue of double claiming is not directly addressed by a non-transactional database as it would be for a transactional blockchain that records the exchange of tokens. However, the blockchain ledger will not allow accidental duplication, so that the database can be used as the single source of truth in cases where double claiming are brought forward. Furthermore, the search engine function described above will enable quick identification of CRU ownership histories to aid in instances of double counting.

The effectiveness of the DLT fabric in this regard is dependent on the data management and monitoring activities of carbon schemes, because the schemes are the key source of data for the ledger. If carbon removal certification schemes do not update their databases with changes of CRU ownership or certificate data, the unified ledger will similarly not reflect the necessary changes.

Implementation strategy

To ensure successful delivery of a single, DLT fabric for carbon removal data, the following plan is recommended:

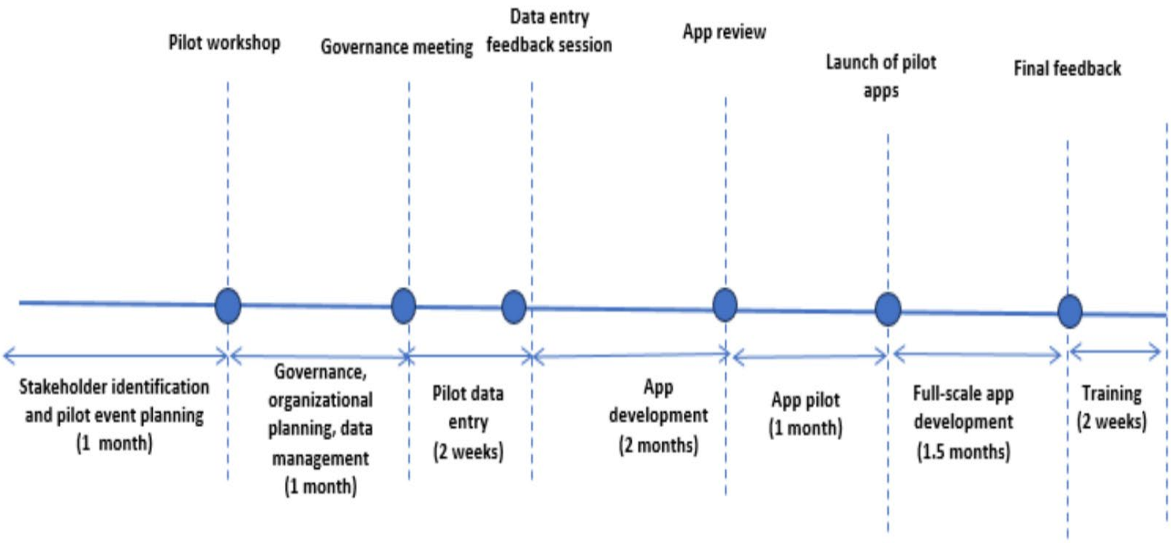
1. **Stakeholder identification and pilot event planning**. Willing participants from key carbon schemes and certification bodies must be identified for a pilot workshop and data entry exercise. Trainers from the EBSI team should be identified. Training requirements should be compiled, and the appropriate material developed. Failure to identify a relevant group of stakeholders may result in specification blindspots, so that the applications designed on the basis of stakeholder consultation is not truly fit for purpose. This can be mitigated by consulting with stakeholders as they are identified in order to confirm relevance of the stakeholder list.
2. **Pilot workshop**. The aim of this workshop will be twofold; firstly, it will seek to train the representatives from carbon schemes and certification bodies identified in step 1 in the use of and application for DIDs, and basic data entry and data look-up on EBSI. Secondly, the workshop will undertake user journey mapping exercise to develop the high level requirements for a dedicated carbon certificate data entry application (Input Application) as well as a dedicated carbon certificate data look-up application (Certificate Search Engine). Failure to train representatives in the use of DIDs and EBSI will prevent them from engaging with the pilot phase, which in turn may prevent the development of applications that are fit for purpose. This can be mitigated through careful preparation of training and proper allocation of time for queries and practise runs. As for above, failure to properly map user journeys will lead to an application design that is not fit for purpose. This should be mitigated through strong stakeholder engagement during the workshop. Ultimately, this would result in a one day cost for participants.
3. **Governance, organisational planning and data management.** To put the project in a solid framework several planning steps need to be undertaken. This includes ensuring that the governance framework for the DLT development and the project are established so that the roadmap for design and execution is documented. Organisaitional planning needs to be appriorуately framed to ensure that project team are dedicated with sufficient resources including replacements and to allow for sufficient spot checks, reviews and piloting. Data management involves establishing processes for collecting, storing, securing, and utilizing data throughout the project lifecycle, ensuring data integrity and accessibility. Failure to ensure appropriate planning can lead to poorly developed deliverables, misused resources and missed deadlines. Appointing experience project managers and technicians would ensure effective implementation.
4. **Pilot data entry**. The carbon scheme participants from the pilot workshop will be asked to enter CRU data into the registry over a fixed period, during which they will compile detailed feedback on potential useful features for the Input Application. Failure to record CRU data will limit developers' and users' understanding of process bottlenecks, thus limiting the potential for optimal application design. This may be mitigated by providing user participants with sufficient support from the development team during this phase. One would expect a cost of up to half a day for participants..

5. **Data entry feedback session**. The participants from the pilot workshop will provide their detailed feedback to the EBSI development team, from which the EBSI team shall compile the Input Application Requirements and Certificate Search Engine Requirements. Failure to capture feedback may result in sub-optimal application design. This should be mitigated through careful planning of the feedback session to allow for all views to be heard and recorded. This would involve half a day for participants.
6. **Certificate Search Engine stakeholder identification**. Given that a wider range of users is expected for the Certificate Search Engine than for the Input Application, additional stakeholders should be identified and invited to test the application during the pilot phase. Failure to identify all relevant stakeholders may lead to specification blindspots, which in turn would result in an application that is not sufficiently auditable and does not yield the expected benefits. This can be mitigated by consulting with a wide range of experts, including current / potential CRU owners and traders, auditors and environmental NGOs. Again, up to half a day is envisaged for participants.
7. **App development**. The EBSI development team shall develop a beta Input Application and Certificate Search Engine. Failure to develop the target applications leads directly to project failure. To mitigate this, the capacity and capability of the development team should be verified prior to commencing the project.
8. **App pilots**. The same group of participants from the data-entry pilots will participate in a trial of the beta Input Application. The EBSI development team will gather feedback continuously throughout the trial and make changes as necessary. The wider group of stakeholders identified in step 5 will trial the beta Certificate Search Engine, for which the EBSI team will gather similar feedback and action changes as necessary. Failure to collect and apply feedback will result in the development of a final application that is not fit for purpose. This should be mitigated by planning the pilot launch such that there is sufficient support for pilot testers from the development team, and that the development team has sufficient capacity to manage tester support as well as development functions. Participants would need to allocate up to half a day to this.
9. **Final feedback and app finalisation**. At the end of the trial period, testers will be invited to submit final feedback, after which the EBSI development team will develop the full-scale applications.
10. **Dissmeninaiton and Training** Finally, dissemenination and training are need to ensure that the main actors including authorities and certification schemes are aware of the availability of the system and are updated on their responsibilities and approach to access the system. This should be assisted by online training and Q and A, and distribution of troubleshooting guidance. Failure to provide this service would likely result in a limited uptake and increased time burden to learn of the steps. Appointing an experienced trainer and materials developer would ensure the clarity of the service. Clearly, there would be time implications for stakeholder learning on how to engage with the system but this should be quite limited e.g. 1 to 3 days including acquisition of a digital wallet.

Implementation timelines

The following timeline is proposed for the developmen of the ready-to-launch single DLT fabric for carbon removals registries and its associated APIs.

Figure 12 Single registry and API development timeline



Source: Technopolis Group

The expected development period is therefore 7.5 months, including event planning, small-scale trials and finalisation of the Input Application and Certificate Search Engine for full-scale roll-out. Note, however, that these timelines do not include the wider roll-out of the registry and its APIs, as these must be aligned with the timelines for the implementation of the proposed Regulation itself.

Resource requirements [15]

Description

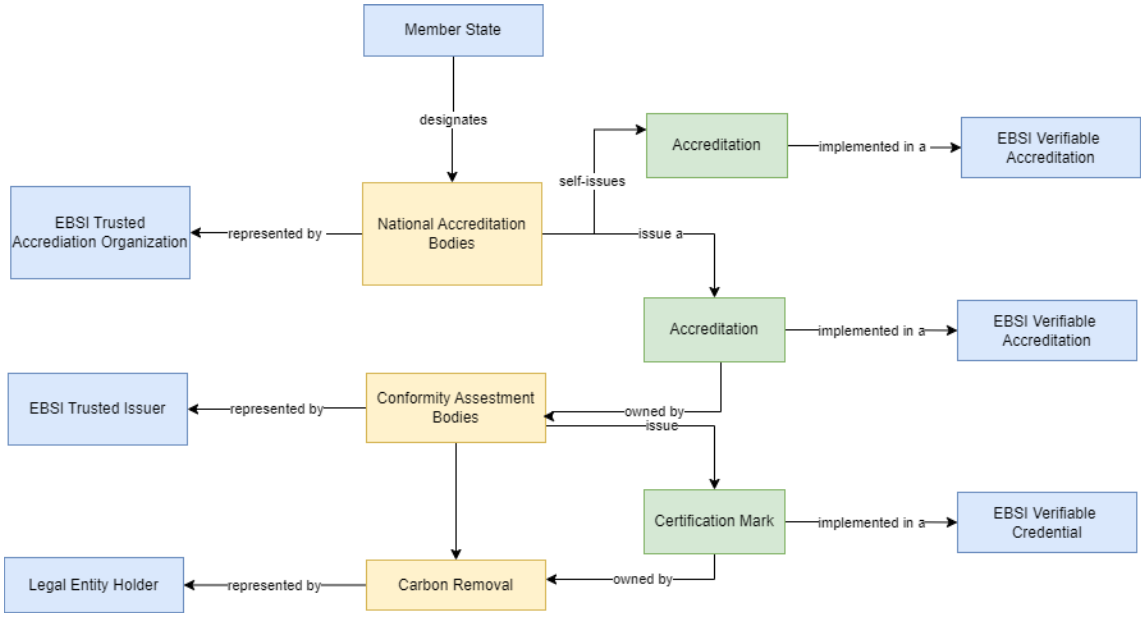
- EBSI will be used to implement the trust chain to verify carbon removal certification attestations (represented by verifiable credentials).
- The expected trust chain will follow a common pattern in the European regulation: National Accreditation Bodies (NABs) and Conformity Assessment Bodies (CABs).
- NABs will issue accreditations to CABs, and CABs to organizations involved in carbon removal.
- The lifecycle of these accreditations should be managed (valid, suspended, revoked).
- It will be explored how to distribute these attestations (on-chain, off-chain).

Taking all these into account, the following diagram describes the trust model and relationships between the actors.
Figure 13: Trust model outline of stakeholder relationships

It is possible to identify components from the previous diagram with EBSI actors.

[15] Based on EBSI provided data and information.

Figure 13 Single registry and API development timeline



Estimation of resources / time need to deploy EBSI compliant applications

The following estimation refers to a self-built solution that considers the estimation describes in the previous section. It would take a workload of between 220 to 380 days over a 7.5 month period. The team could consist of 6 periods, with a project manager, an architect and three developers, and a dissemination and training specialist. Roughly, this would equate to a work rate of 28% to 49%, therefore, providing some flexibility with team resources.
Zooming-in on the DLT / API development activities, a mid-way estimation at 185 days across a break down of activities would be in the region of the followjg estimate:

- **Architecture efforts: Total of 55 days.**
  - High level architecture: 10d
  - In-depth documentation for 4+1 architecture: 30d
  - Guiding the development teams on the topics: 15d

- **Organisation Wallet for NABs, CABs & Carbon Removal (Accredit and Authorize): Total of 80 days.**
  - Cloud based Key Service Management: 10d integration.
  - Authorisation Server implementation: Total of 50 days.
    - Persistent State Machine: 10d
    - Pre-registration capabilities: 5d
    - Metadata configuration: 2d
    - Authorisation Request and Response: 5d
    - ID Token Request and Response: 10d
    - VP Token Request and Response: 10d
    - Token Request and Response: 5d
    - Access Token implementation: 3d
  - Credential Issuer implementation: Total of 20 days.
    - Metadata configurations: 3d
    - In-time issuance: 5d

- Deferred issuance: 10d
- Authorisation server trust integration: 2d

- **Verifiable Credential data models and schemas: 10d**
- **Environments pipelines and configuration: 20d**
- **Conformance Testing efforts: 20d**

The estimation is done considering the re-utilization of shared libraries and tools to reduce the estimated development time.
The cost estimates of the efforts are displayed in the table below, which includes a high level estimate of post implementation operational costs associated to EC and EBSI developers.

Table 2 Preliminary carbon removal certification use case implementation strategy cost estimates[16]

Activities	**Effort estimate (person-day)**		**Daily rate range €**		**Total cost estimate €**	
	Low range	Upper range	Low range	High range	Low estimate	High estimate
Project management	30	30	900	1500	27000	45000
Stakeholder identificaiton and workshop	5	10	900	1500	4500	15000
Governance, Organisation and Data Management	10	20	900	1500	9000	30000
DLT/API development and integration within EBSI (Architecture, Wallet, Verifiable Crednetials, Environmental pipelines, conformance testing, Piloting and Full scale development)	130	260	900	1500	118800	388500
Dissenination and training	15	30	900	1500	13500	45000
Assessment, reporting and migration of solutions from developer to owners	30	30	900	1500	27000	45000
Total	*220*	*380*			***199.800***	***568.500***
Estimated Operational costs						
	Full Time Equivalent		(Year, €)		Total yearly cost, €	
	Low range FTEs	Upper range FTEs	Low range	High range	Low estimate	High estimate
EBSI Developer	*0.5*	*1*	*64332*	*119292*	*32166*	*119292*
CLIMA Developer	*0.5*	*1*	*64332*	*119292*	*32166*	*119292*
EBSI infrastructure fees	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
Total	*1*	*2*			***64.332***	***238.584***

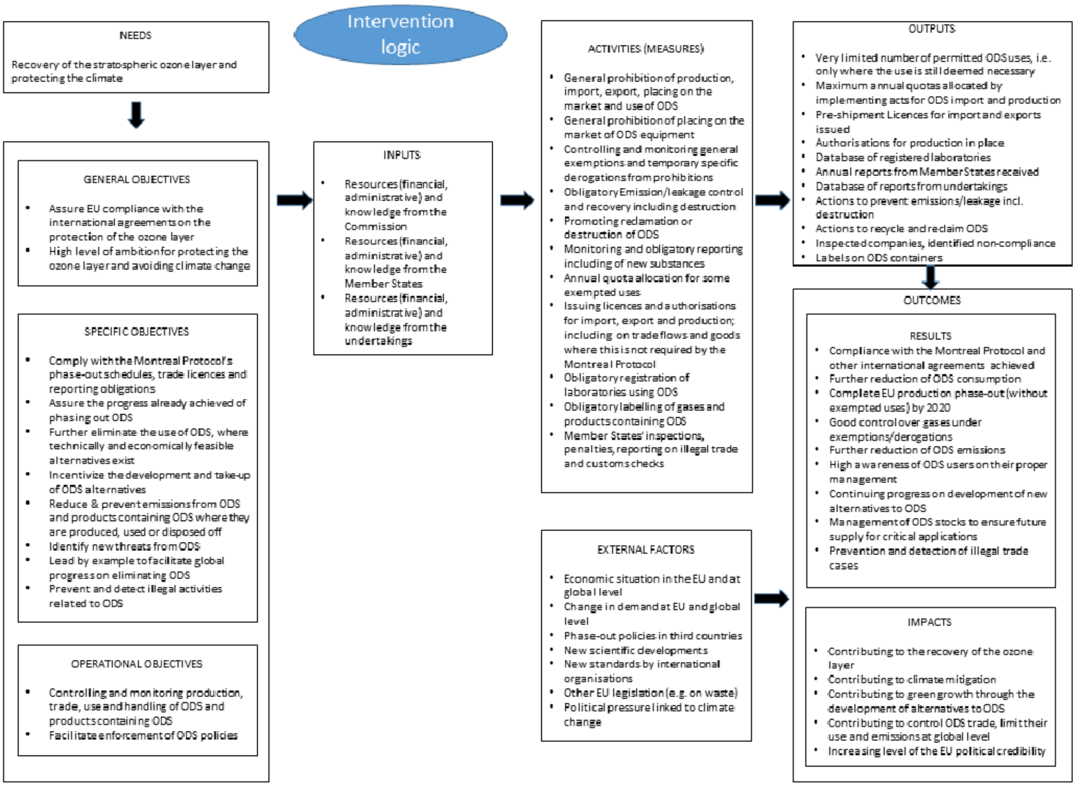
Source: Technopolis Group

[16] Due to the basic knowledge on functional requirements and the lack of knowledge on non-functional requirements, this estimation should be considered as a first iteration, which must be re-evaluated after the development of a pilot with EBSI services.

Problems addressed and processes replaced by use of DLT

The objective of Task 3 is to identify how the DLT monitoring use case could fit within the ODS regulation. The following figure taken from the 2020 "EVALUATION of Regulation (EC) No 1005/2009 of the European Parliament and of the Council of 16 September 2009 on substances that deplete the ozone layer" presents the logic framework for the ODS regulation in the EU and forms the background of Task 3.

Figure 14 ODS regulation intervention logic



Source: European Commission (2020). EVALUATION of Regulation (EC) No 1005/2009 of the European Parliament and of the Council of 16 September 2009 on substances that deplete the ozone layer

The following examine the identification of DLT-based monitoring possibilities within the ODS logic framework. Within the ODS intervention logic, the deployment of DLT-based monitoring could support "Monitoring and obligatory reporting including new substances". The ODS reporting system encompasses several stakeholder groups that would be affected by changes to the current system. These include:

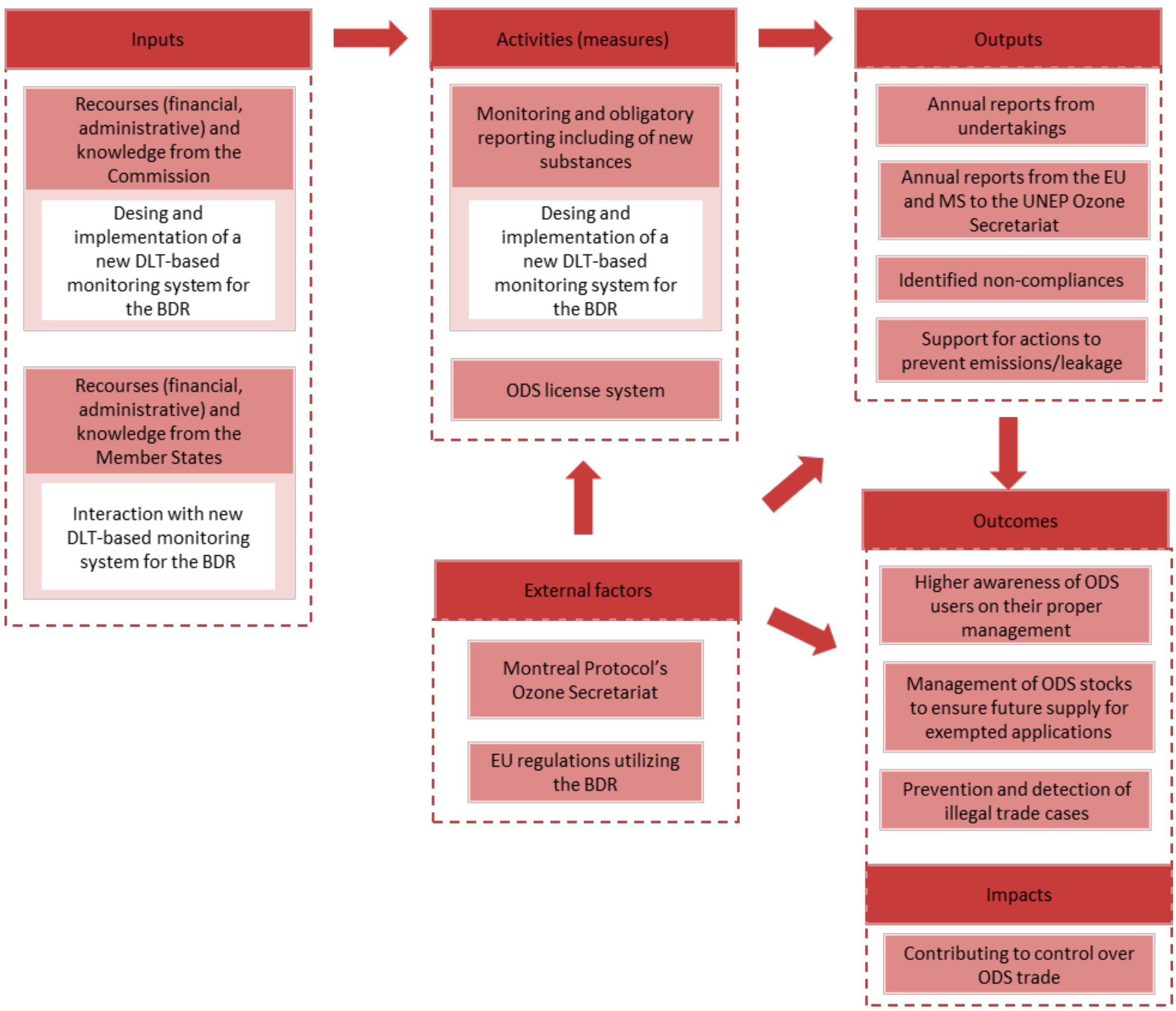
- European Environment Agency (EEA) – manages the annual reporting by companies trading in ODS through the Business Data Repository (BDR). The BDR is accessible to designated EEA staff members or to designated external experts or contractors working on behalf of the EEA.
- BDR users, that is, ODS licence holders and ODS users – those stakeholders who have reporting obligations regarding ODS. These include, amon others, feedstock users, process

agent users, producers and destruction facilities,companies that engage in ODS trade and have to report data to the EEA.

- Montreal Protocol's Ozone Secretariat – receives the collected ODS reports from the EEA.
- EU undertakings with reporting obligations - confirm the national ODS production and destruction data to the Montreal Protocol's Ozone Secretariat. Such national data are fed into the UNEP online reporting system by the EEA from BDR through machine-to-machine communication. Designated EU Member State authority staff can access the BDR to check the reports submitted by companies in their MS (access restricted, the staff only see data relevant for their specific country).
- Additionally, the BDR is also used for reporting by the F-gas Regulation, the Regulation setting emission performance standards for new cars and vans, and the HDV monitoring and reporting Regulation.

Of these stakeholder groups, it is the EEA and the EU undertakings with reporting obligations who would be affected the most directly as they have the highest level of engagement with the BDR system. It would also be necessary to account for how changes to the BDR could affect the other three regulations that use the BDR as their reporting tool.

Figure 15 Changes to the ODS regulation intervention logic with DLT-based monitoring system



Source: Technopolis Group

The above figure indicates an overview of the part of the logic framework that would be affected, with a focus on how changes to the BDR and the introduction of DLT system would necessitate new or revised inputs, affect outputs linked to ensuring compliance with ODS license requirements and support achieving outcomes and impacts linked with controlling ODS trade. The figure is a zoomed-in look and within the overall ODS intervention logic, the changes achieved through DLT systems would facilitate efficiency and be a contributing factor to the success of ODS implementation but not a driving factor.

In the following chapter, we look at the steps of introducing DLT into the monitoring and reporting for ODS and discuss how these changes affect the ODS logic framework parts highlighted in Figure 15.

Changes expected from use of DLT

The EU-wide ODS Licensing System, which includes the quota and licensing processes, and the managing of exemptions and derogations are implemented at EU level by the Commission. The EEA manages the annual reporting by companies. For Member States authorities the main implementation tasks relate to market surveillance, inspections and custom controls; issuance of penalties in cases of non-compliance; promoting recovery, reclamation and destruction; reporting on halons and illegal trade; establishing qualifications for technicians; as well as granting production authorisations through the EU ODS licensing system (the latter for a few Member States only where production for laboratory and analytical uses takes place).

The implementation of DLT-based monitoring would require the addition of several digital infrastructures to the BDR – verifiable digital credentials (associated with an BDR user), digital wallet (to store BDR user information) and a DLT-based audit trail mechanism which would support the data verification done by the BDR. To illustrate the application/integration to the BDR the chapter uses (and notes) real examples of DLT systems being employed in the EU.

The reporting of ODS data by BDR users is handled by the BDR portal where BDR users have their individual accounts and submit required information by opening a "New Envelope" which is the form that is subsequently filled out before submitting the data to the EEA.[17] The introduction of DLT system would keep most of these elements in place – each BDR user would have an individual identity on the BDR; however, the submission of data would be irrevocable once done. Changes could take place but these would be recorded on the system and the EEA would be informed that data associated with a specific BDR user has been updated. DLT offers increased efficiency in the monitoring of the submitted data and ensuring the reported ODS use, trade, destruction is in compliance with the specific points found with each ODS license.

The first change the BDR would require is the introduction of Verifiable Credentials for the BDR users. As noted by EBSI, there are different methods of issuing verifiable credentials.

- A centralised model represented by the EU gateway. It showcases how: "the Commission can manage a centralised service responsible for managing and distributing the certificates of issuers of electronic documents."
- Federated Trust Model which is represented by the eIDAS Regulation (or its successor EU Single Digital Identity). It is an example of working towards cross-border electronic ID

[17] EEA (2014). User Manual for Uploading Data on the Business Data Repository of the European Environment Agency. Available at: https://circabc.europa.eu/sd/a/97d8bca6-158a-4ddc-aaae-4bd6c5f574fa/BDR%20User%20Manual.pdf

verification for EU citizens[18] that is being supported by the Commission and demonstrates the possibility of a centralised approach to verifiable credentials.

- Finally, a distributed trust model which is represented by EBSI. EBSI's approach "leverages blockchain and W3C's Decentralised Identifier standard to create a fully distributed trust model where each sector or Member State defines and manages the issuer accreditations of electronic documents."[19]

Of the three models, the distributed trust model leverages the strengths of DLT and can be combined with centralised or federated trust models, such as with the Eionet account required for the BDR users to access the BDR.[20] In other words, it is possible to combine a DLT-based approach to Verifiable Credentials with the existing Eionet infrastructure of the EEA.

After enabling BDR user identification through verifiable credentials the next requirement is a digital wallet associated with the BDR user. A digital wallet is an essential requirement for the functionality and interaction with a DLT system as it manages the data input by users. All holders of verifiable credentials are issued with their unique keys enabling access to the system (while the system holds corresponding keys used to verify the user and data input). Thus, data transactions on a DLT system are stamped with the unique "address" of the digital wallet associated with a specific BDR user.

As BDR users submit reporting data to the BDR, they would utilise their digital wallets to input, log or otherwise note the ODS transactions taking place. The user experience and requirements would be similar to the current processes and the DLT-based monitoring system would be "attached" to the existing BRD portal. Simultaneously, the association of these inputs with a unique digital wallet ensures that ODS transactions can be traced directly to an accountable party.

The third part of a DLT-based monitoring system is a Verifiable Audit Trail linked with the data verification system. Verifiable audit trail is a DLT-based monitoring system which automatically tracks the data being submitted to the wallet and subsequently to the BDR (where the data verification takes place) and compares it to any preset requirements that are associated with the individual BDR user and their verifiable credentials and digital wallet (for example, if the user is a ODS license holder, the system compares the data input with the licensing agreements and parameters) . A verifiable audit trail enables near instantaneous detection of any discrepancies between the licensing agreement and the data being submitted (including cumulative ODS trading information). The verifiable audit trail itself does not stop the transactions taking place, but it notifies the relevant authorities (EEA, the European Commission) of the issues between the licensing agreement and the data being submitted by the BDR user. Once these issues are detected, the EEA is notified and can take appropriate action in contacting the BDR user to identify the source of the issue, etc.[21] Importantly, the verifiable audit trail protects from both external and internal threats to data input, data accuracy, etc. as it tracks and traces the individual data inputs to the source.[22]

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[18] European Commission (2023). eIDAS Regulation. Available at: https://digital-strategy.ec.europa.eu/en/policies/eidas-regulation

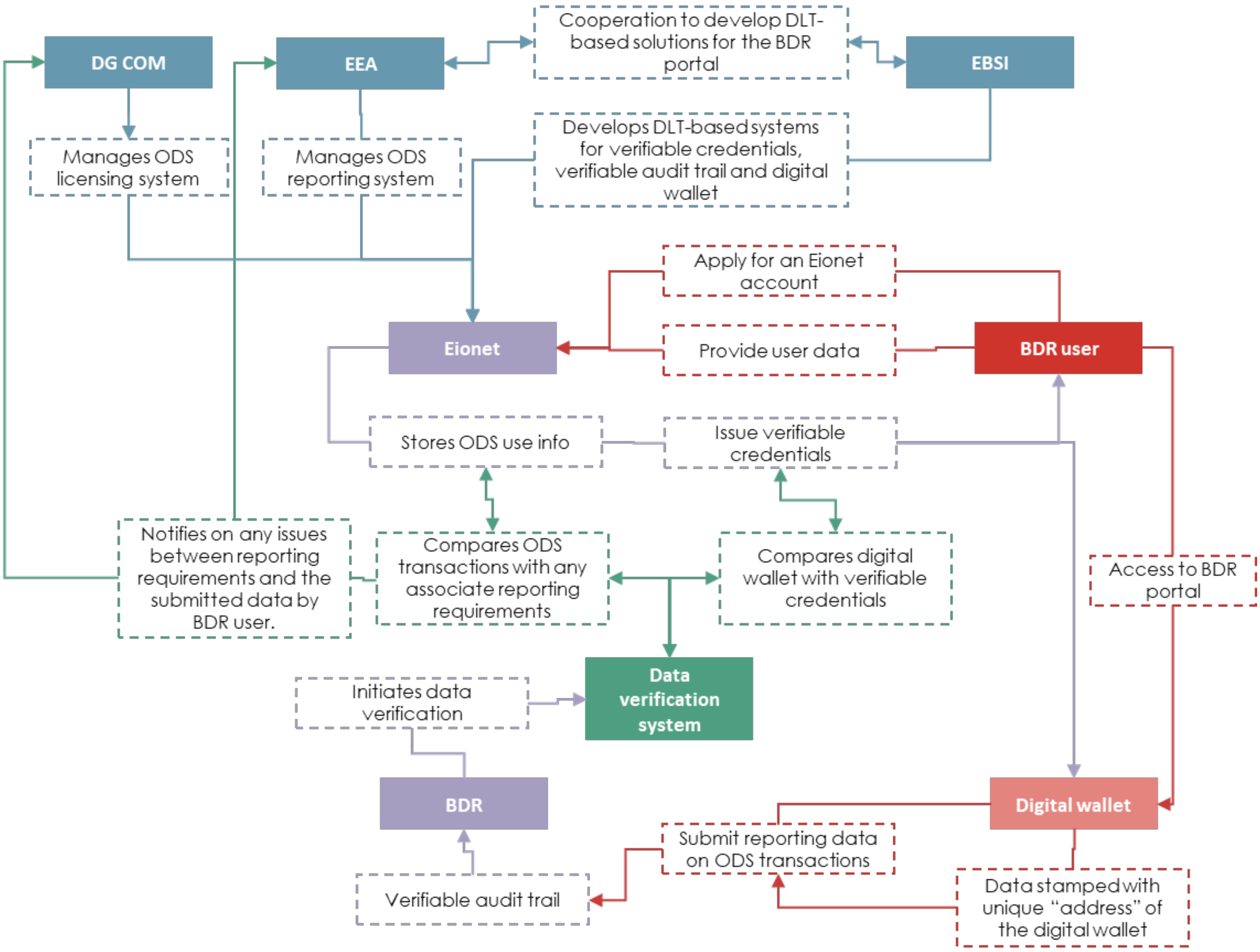
[19] EBSI (2022). Verifiable Credentials Explained. Available at: https://ec.europa.eu/digital-building-blocks/wikis/download/attachments/600343491/Chapter%201%20-%20EBSI%20VC%20.pdf?api=v2

[20] EBSI (2022). Verifiable Credentials Explained. Available at: https://ec.europa.eu/digital-building-blocks/wikis/download/attachments/600343491/Chapter%201%20-%20EBSI%20VC%20.pdf?api=v2

[21] Guardtime (2023). TrueTrail Truth, not trust. Available at: https://guardtime.com/truetrail

[22] Guardtime (2022). Cryptographic deterrence against insider threat. Available at: https://guardtime.com/truetrail/cryptographic-deterrence-against-insider-threat

Figure 16 Outline for flow of business logic for a DLT-based monitoring for ODS



Source: Technopolis Group

A verifiable audit trail is used by the Estonian blockchain system. The Estonian Ministry of Interior (SMIT) has introduced a verifiable audit trail to ensure compliance with regulatory requirements by parties submitting data to the Estonian e-Government system. The verifiable audit trail offers: "proof of the time and integrity of the events, as well as proving that events are in the correct order, and none have been deleted".[23]

The introduction of DLT to the overall reporting of ODS through the BDR would not introduce many changes to those providing or requesting data from the BDR (representatives of EU Member State authorities, the ODS lifecycle stakeholders, contractors working on behalf of the European Commission and EEA). It is for EEA and the other EU regulations that utilise the BDR for reporting that the most significant changes would take place. As noted, use of DLT purely for monitoring purposes does not pose as many technical challenges for implementation as, for example, the introduction of a new DLT-based licensing system. The use of verifiable credentials

[23] Guardtime (2020). Estonian Ministry of Interior (SMIT) partners with Guardtime on independent audit for distributed systems. Available at: https://guardtime.com/blog/estonian-ministry-of-interior-smit-partners-with-guardtime-on-independent-audit-for-distributed-systems

can be added into the existing infrastructure as a supplement, the most significant requirements being the verifiable audit trail which would need either the development or the application of an off-the-shelf digital product as an addition to the BDR which would monitor the data transactions from BDR users. Another pathway is seeking collaboration with EBSI in introducing the existing EBSI applications (digital credentials, digital wallet) as well as examining the potential of leveraging the EBSI infrastructure towards monitoring data and audit trail verification.

Implementation strategy

For the implementation of DLT-based monitoring to the Eionet and BDR a possible course of action is to leverage the available EBSI infrastructure. For one, EBSI is looking to expand its deployment use cases into cross-border application as well as new sectors. Furthermore, it is apparent that there are plans to use the EBSI infrastructure for the tracking and tracing of documents.[24]

Furthermore, there are no license, usage or service fees for the Commission or any third party looking to integrate EBSI. For EEA, the costs would be linked to the development, application hosting, resource and computing costs.[25]

To support the development of a DLT-based monitoring system for ODS, the following presents an outline of steps to be taken.

- **Stakeholder identification and pilot event planning**. Key participants from EEA working with ODS data administration and trainers from the EBSI team should be identified. Training requirements should be compiled, and the appropriate material developed to ensure knowledge transfer to the EEA staff.
- **Pilot workshop**. The aim of this workshop will be twofold; firstly, it will seek to train the EEA staff in the use of and application for EBSI infrastructure (verifiable certificates, digital wallets, etc.) required to implement DLT-based monitoring. The workshop also identifies the requirements for incorporate EBSI infrastructure with EEA's systems, with the aim towards as little disruption as possible. Thus, the workshop should include knowledge exchange between EEA and EBSI teams to develop the high level requirements for a DLT-based monitoring solution for EEA that would monitor the ODS data entries over the BDR.
- **Pilot data entry**. The EEA team will compile the ODS data entry requirements from BDR users for a comprehensive list of reporting data that would be monitored over the DLT Monitoring Application as well as the technical specification of the Eionet and BDR which would be involved in the issuing of verifiable certificates, participate in data verification and host the DLT Monitoring Application.
- **Data entry feedback session**. The EEA staff will provide their detailed feedback to the EBSI development team, from which the EBSI team shall compile the Monitoring Application Requirements, considering its introduction into the EEA systems.
- **App development**. The EBSI development team shall develop a beta Monitoring Application.

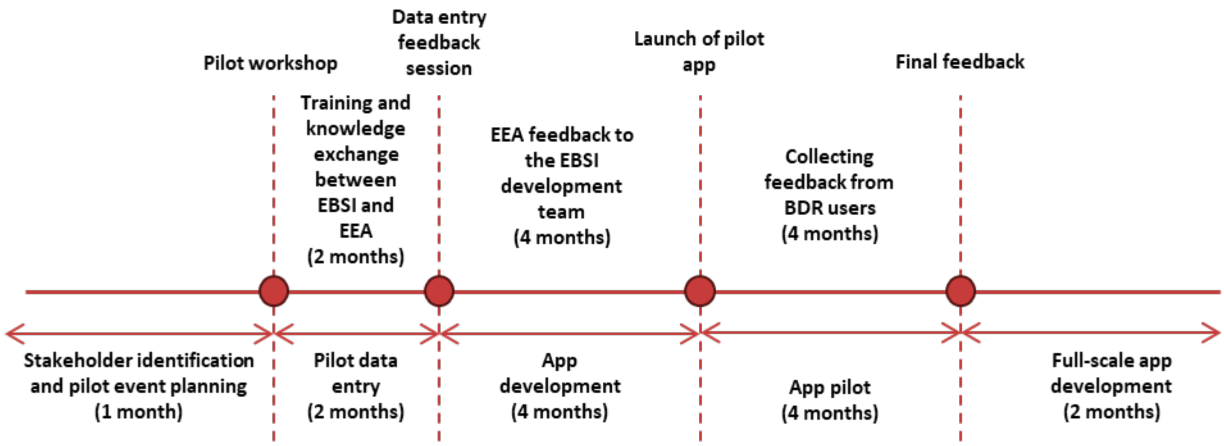
[24] EBSI (2023). Business: What can you do with EBSI? Available at: https://ec.europa.eu/digital-building-blocks/wikis/display/EBSI/What+is+ebsi

[25] EBSI (2020). European Blockchain Services Infrastructure. Available at: https://theblockchaintest.com/uploads/resources/EU%20Parliament%20-%20European%20Blockchain%20Services%20Infrastructure%20-%202020.pdf

- **Pilot**. The pilot Monitoring Application will go through a piloting phase, involving BDR users reporting their ODS trade data over the BDR. The EBSI development team will gather feedback continuously throughout the piloting phase and make changes as necessary.
- **Final feedback and app finalisation**. At the end of piloting phase, testers will be invited to submit final feedback, after which the EBSI development team will develop the full-scale application.

The following timeline is proposed for the development of the DLT-based Monitoring Application to be used for ODS reporting.

Figure 17 DLT-based Monitoring Application for ODS development timeline



Source: Technopolis Group

The expected development period is 4.5 months, including event planning, small-scale trials and finalisation of the Monitoring Application, ensuring it is properly integrated into the Eionet and BDR for full-scale roll-out. Noe that the timeline estimates the development and piloting of the DLT-based application and not the full-scale deployment. Considerations should be made for the on-boarding of BDR users, based on the amount of changes the DLT system will introduce to the reporting procedures currently being employed. Whilst the implementation strategy can be reduced by allocating more DLT developers, for instance by passing from 1 to 4 may reduce the pure DLT and APIs development time from 4 months to 1, it is important to consider coordination time and between stakeholders, which lead to set a feasible implementation time on 4.5 months. The cost estimates of the efforts are displayed in the table below, which includes a high level estimate of post implementation operational costs associated to EC and EBSI developers.

Table 3 Preliminary Ozone Depleting Substances use case implementation strategy cost estimates[26]

Effort concept	Effort estimate (person-day)		Cost estimate (daily rate €)		Total cost estimate €	
	Low range	Upper range	Low range	High range	Low estimate	High estimate
Project management	30	30	900	1500	27000	45000
DLT/API integration with EBSI	40	80	900	1500	36000	120000
Governance, Organisation and Data Management	5	10	900	1500	4500	15000
Dissenination and training	15	30	900	1500	13500	45000
Assessment, reporting and migration of solutions from developer to owners	30	30	900	1500	27000	45000
Total	120	180			**108.000**	**270.000**
	Operationall costs					
Effort concept	Low range FTEs	Upper range FTEs	Low range (AD5)*	High range (AD9)*	Low estimate	High estimate
EBSI Developer	0.5	1	64332	119292	32166	119292
CLIMA Developer	0.5	1	64332	119292	32166	119292
EBSI infrastructure fees	N/A					
Total	1	**2**			**64.332**	**238.584**

*Based on 2022 remuneration of officials and servants of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52022XC1214(02)

Source: Technopolis Group

Preliminary implementation strategy for Fluorinated Gases

Processes to be replaced by integrating EBSI-F-gas portal-Traceability systems

Traceability system capabilities integrated to the f-gas portal and integrated with EBSI, would not replace functionalities, but add to the business logic the verification of the quotas with the real physical flow of f-gases.

The upgraded business logic as described in the case study and in this implementation strategy, implies the **F-gas portal IT system to adopt an API/webapp** through which the traceability including volumes of f-gases moved throughout supply chains is registered by Economic Operators (undertaking, intermediaries, RAC/HFC equipment manufacturers/importers/users) and links the legal volumes with the EOs total legal quotas.

The traceability data generated EOs needs beforehand to be transferred to an API/webapp, which will generate a hash. The hash and the traceability data are both reported to the F-gas portal, for accounting purposes (i.e. accounting for availability of quotas), and for verification purposes with a hash of immutable proof of the content of the data related to the event such as location, date, f-gas amounts and type, shipper, consignee, transporter, etc. For the EO there is no imposition of the traceability technology, but there is an imposition on the traceability data needed for reporting, which it is best collected in fact with traceability systems but can also be done manually by the EO and uploaded into their traceability data system, which can be accessed with the label scanning of the cylinder.

[26] Due to the basic knowledge on functional requirements and the lack of knowledge on non-functional requirements, this estimation should be considered as a first iteration, which must be re-evaluated after the development of a pilot with EBSI services.

Customs officials shall consult the F-Gas portal before clearance of F-Gas. However, in specific circumstances customs officials can bypass the F-gas portal and clear from customs those imports/exports coming from valid quota holder, even without knowledge on whether the total amount of quotas have already been imported/exported. The implementation strategy allows the F-gas to risk assess in near-real time and manage a declaration from a quota holder that already "used" its yearly quota "allowance", enabling customs with more data/information elements for their risk assessments.

EOs are required to report on a yearly basis their quantities of production/import/export/destruction/feedstock use/placing in equipment of F-gas to the Commission, via the European Environmental Agency (EEA) BDR tool. The proposed system allows EOs to generate automated/periodic reports to be submitted in due time with the API/webapp with the traceability data generated by the system. Whilst the traceability system could allow to report some of the amounts placed on the market for the first time, it does not appear to include the capability to submitting all the required data to be reported as laid down in the Commission Implementing Regulation (EU) No 1191/2014. Customs, Member States, EEA, F-gas officers can verify validity of some of the data thought the hash stored in EBSI.

Figure 18 Traceability system transactions architecture with the F-gas and EBSI

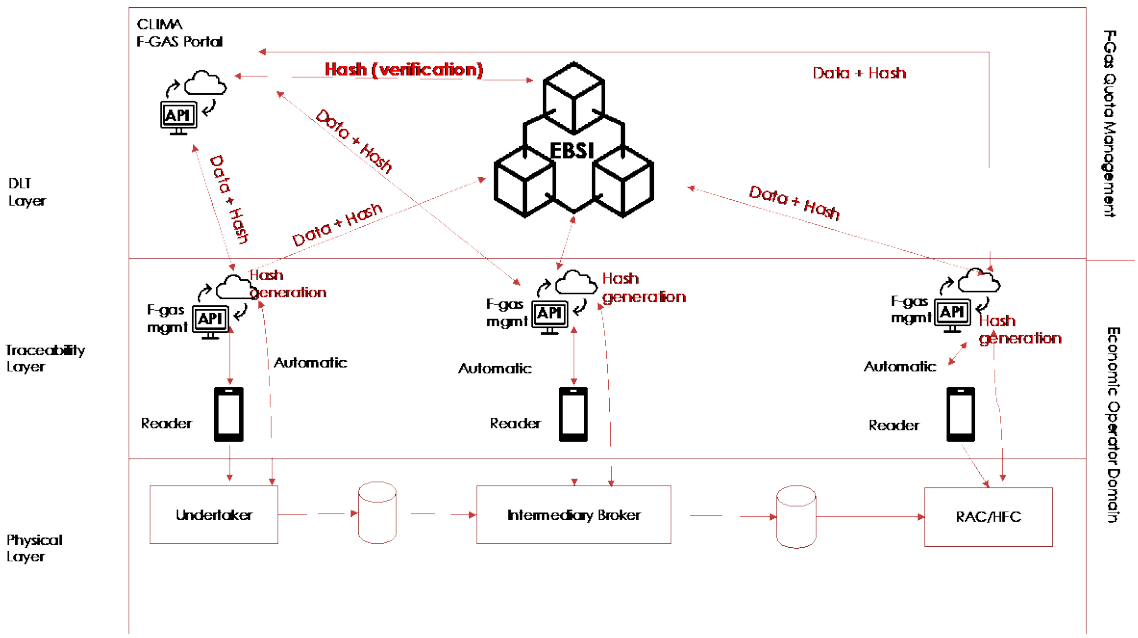
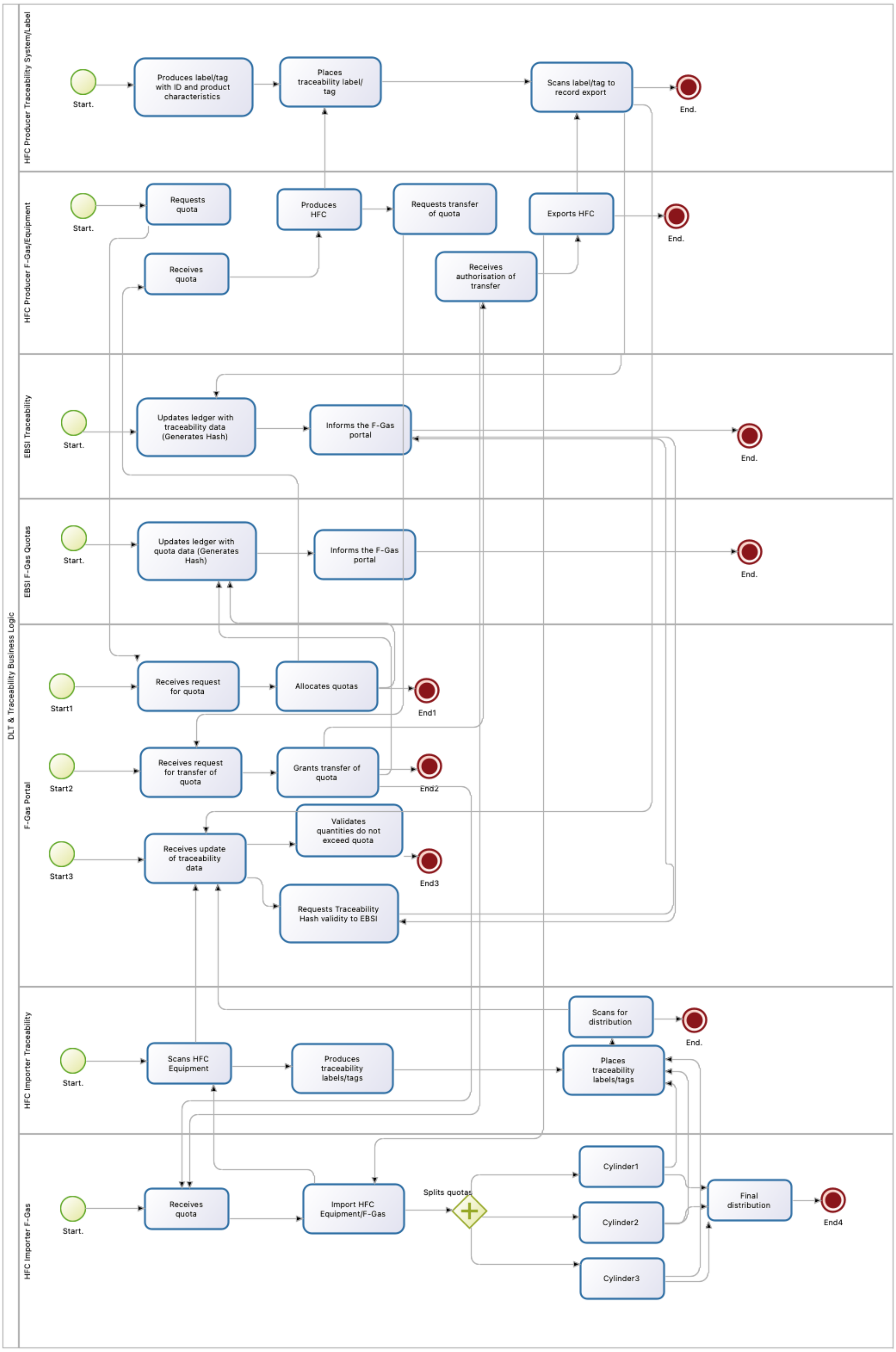


Figure 19 Business logic of the F-gas DLT and traceability functionalities[27]



Source: Technopolis Group

Implementation strategy

Description[28]
DG DIGIT recommended to store the events off-chain and register hashes on-chain. This can be done by building deterministic and sharded hash-trees (merkle tree) or hash-tables and register on-chain only the roots to attest the cluster of events. Sharded hash-trees could be treated as ordered log, where previous root is a child hash of the next cluster. The type of the tree-hash, and the required validation capability depends on the domain. The estimated effort to choose and build tree-hashes, or hash-table is 15 days for AWS S3 based replicated hash-table, and depending on how it is exposed might incur 15 days more (if not using AWS S3 to publish).

EBSI Traceability capabilities
The following table summarises the capabilities provided by the EBSI Timestamping API and a reference implementation client webapp.

Table 4 EBSI Timestamping API and implementation client webapp capabilities

	Webapp	Timestamping API
Compute Hash	YES	NO
Anchor Hash	YES	YES
Retrieve Hash	YES	YES
Manage metadata	YES	YES

Description of the Timestamp API:
EBSI Timestamp API is a straightforward tool designed to facilitate seamless integration of traceability functionalities into your existing systems. Key features of our API include:

- Data ingestion: Our API enables easy integration of data from various sources, allowing you to collect and store relevant traceability information efficiently. 5 days (as Org Wallet feature)
- Data querying: With our API, you can perform queries to retrieve specific traceability data, enabling you to consult and verify timestamped records. 5 days (as Org Wallet feature) complete documentation -> https://api-pilot.ebsi.eu/docs/apis/timestamp/latest#/

Description of Provided Tools:
In addition to EBSI Timestamp API, EBSI offers a range of tools to support your traceability initiatives:

- Traceability webapp (reference implementation): EBSI provides a user-friendly interface for managing and monitoring your traceability processes, however this version would require an update to support the new authentication scheme (effort estimated to 20 days).

As, for the time being details about the collection of events, off-chain storage for events or about how to interact with other components from the f-gas supply chain is missing, it is

27

28 Based on EBSI provided data and information.

difficult to provide additional estimation and therefore it is advisable to exploring this track in a dedicated pilot programme/living lab.

To support the development of an EBSI-F-gas-Traceability system, the following presents an outline of steps to be taken.

Figure 20 Phases of the F-gas-EBSI-Traceability system development and implementation roadmap

Source: Technopolis Group

Business Case Development. The business case for traceability systems integration with EBSI and the F-gas portal is handled by a cross-organisational team for quality assurance and collaboration across organisations.

Solution design. The solution design happens externally, and involves the planning of the development steps, who to involve, and the eventual need of partnerships for covering relevant EOs' F-gas supply chains.

Proof of concept. The solution design phase gives options on how to interface the multiple traceability systems with the API/webapp. Those options become proofs of concept. There will then be the assessment of those proofs of concept to validate the multi-traceability system capability of the API/webapp.

Pilot phase testing. Once the concept is proven, it's time make sure the traceability systems generate the right data, the API/webapp generates the hashes, and executes the transactions with the f-gas portal and EBSI. It is time to verify that all the APIs/webapps to generate, transfer, and store hashes function effectively and absence of scalability problems. Whilst no major business logics and stakeholder relationships changes are expected, this is the moment such assumptions/statements are verified and corrected if necessary.

Full deployment. The solution is then deployed on all the organisation and on all its devices.

Maintenance and upgrade. The organisation implementing the solution should have a monitoring framework to assess the performance and the life of the solution. That monitoring can lead to adjustments and solutions upgrades. Sometimes, the need of solution upgrades is so substantial that there is the need to start from phase 1. For that reason, professionals also talk about DLT and traceability systems development lifecycle.

The implementation strategy requires the involvement of **multiple key stakeholders**, among which are: Economic Operators (F-gas/ODS Undertakings); EBSI/DIGIT; External experts (Traceability Systems/DLT); CLIMA; Project management/coordinators/technological adoption cost benefit assessment experts.

In this f-gas use case, a reasonable feasible implementation time is like the ODS, 4.5 months. The following table presents the estimated efforts and implementation costs estimates, and a high level estimate of post implementation operational costs.

Table 5 Preliminary F-gas-EBSI-Traceability System use case implementation strategy cost estimates

Development and pilot costs (estimates)														
Organisation	**Person days requirements**						Effort range in days			Cost estimate (daily rate €)		Total cost estimate €	
	Business case	Solution design	Training	Proof of concept	Pilot	Pilot CBA, Impact Assessment	Total effort in days	Low range	High range	Low range	High range	Low estimate	High estimate
Economic Operators (F-gas/ODS Undertakings)	15	15	5	30	30	15	110	77	154	In-kind	In-kind	In-kind	In-kind
EBSI	5	60	5	5	5	5	85	59.5	119	300	800	17850	95200
External experts (Traceability Systems/DLT)	15	15	5	15	15	15	80	56	112	900	1500	50400	168000
DG CLIMA	5	15	5	15	5	5	50	35	70	300	800	10500	56000
Project management/ coordination/ assessment/ Dissemination	10	5	5	5	10	10	45	31.5	63	900	1500	28350	94500
Cost	50	110	25	70	65	50	370	259	518			**107.100**	**413.700**
Operationall costs							Low range FTEs		Upper range FTEs	Low range (AD5)*	High range (AD9)*	Low estimate	High estimate
EBSI Developer							0.5		1	64332	119292	32166	119292
CLIMA Developer							0.5		1	64332	119292	32166	119292
EBSI infrastructure fees							N/A		N/A	N/A	N/A	N/A	N/A
Total							**1**		**2**			**64.332**	**238.584**

*Based on 2022 remuneration of officials and servants of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52022XC1214(02)

Source: Technopolis group

7 Recommendations to the Commission on the deployment of blockchain on climate policy

- It would be advisable to initiate any implementation strategy through a pilot to have a full understanding of the potentialities of the proposed solutions in control environments before full deployment. This would give sufficient time for assessment of the solutions within the foreseeable regulatory train of the proposed regulations and amendments of the current regulations.
- Leverage the existing EBSI infrastructure and opportunities to be involved in the piloting and development of new application pathways. EBSI offers an opportunity to leverage EU-level development for DLT systems, with the EBSI team looking for new pilot projects for cross-border application of DLT and in new sectors. Furthermore, EBSI offers a library of DLT applications and there are no license, usage or service fees for the Commission to integrate EBSI applications.
- Opportunities for DLT deployment exist even on a small-scale and with reduced disruption. DLT systems can be applied to existing digital infrastructures. Opportunities to enhance monitoring of data input (as in the case of ODS for example) could be achieved through the introduction of DLT systems to either centralised model or federated trust model for verifiable credentials (both of these are in use by EU with EU gateway representing a centralised and the eIDAS Regulation representing a federated trust model). These possibilities are enhanced by opportunities to cooperate with EBSI and leverage either already existing DLT applications and the opportunities to develop new applications with EBSI involvement.
- Include analysis for potential DLT deployment in future revisions to Eu climate policies. The conducted analysis of DLT deployment in public policies across the EU Member States demonstrate the range of sectors where DLT opportunities are being explored either through piloting projects or full implementation. The capacity to enhance effectiveness and efficiency of monitoring, verification processes, create alternative market/payment mechanisms, support monitoring of value chains present opportunities for future developments. If new revisions are considered with the exploration of DLT deployment in mind, it would enhance the uptake of this technology and would allow EU to lead by example in DLT deployment for public policy making.
- Implementation strategies of the use cases can benefit from synergies between them. The efforts allocation for the experts in-house and external, can be organised in stages. The priority could be for instance the full deployment of the Carbon Removal Certification pilot. Implementation efforts of the f-gas and ODS cases in parallel, would stress the experts integrating the various development between the EBSI, CRC management system, f-gas, ODS, and so on, creating stress and increasing the risk of system and personnel overload. A tiered approach would benefit from the learning and learning process, identification of bugs and glitches in the system to be addressed in controlled environments.

8 Appendixes

8.1 Task 1

Scoping analysis of the policies

This section provides details on the scoping analysis in terms of the relevance of Blockchain. The analysis considers whether the policies have key features that make them relevant for further exploration for Blockchain adoption considering the:

- Number of actors in scope that are subject to EU climate policy requirements and are involved in record generation or similar (such as a business sector, population segment etc.);
- Compliance activities that may use centralised databases (at local, national or EU levels) to submit information for validation or similar that potentially could be made more efficient using Blockchain;
- Transactional activities that may use of centralised databases (at local, national or EU levels) to facilitate exchange of credits or similar that potentially could be made more efficient using Blockchain.

Table 6 The policies included in the scoping analyses were as follows

No	Legislation / Policies
1	EU Climate Law Regulation (EU) 2021/1119
2	EU Climate Strategies and Targets
3	EU Emissions Trading System (ETS) Directive 2003-87-EC
4	ETS Implementing Regulation No 601/2012 (Monitoring, Reporting and Verification).
5	EU Strategy on Adaptation to Climate Change COM/2021/82 final
6	Effort Sharing Regulation (EU) 2018/842
7	Land use, land use change and forestry (LULUCF) Regulation 2018/841
8	EU ‘Ozone Regulation’ – Regulation (EC) 1005/2009
9	Regulation (EU) No 517/2014 (the ‘F-gas Regulation’)
10	Funding for Climate Action (Innovation Fund and Modernisation Fund)
11	International Action on Climate Change (Climate Finance and Voluntary Carbon Markets)
12	EU Sustainable Product Initiative
13	The Regulation 2019/631 on CO2 emission performance standards for new passengers cars and for new light commercial vehicles
14	Proposed EU Carbon Removal Certification
15	The Carbon Border Adjustment Mechanism (CBAM)

The separate scoping analyses are indicated below.

Table 7 Scoping analysis: EU Climate Law (EU) 2021/1119

Criteria	Scoping analysis: EU Climate Law (EU) 2021/1119
Summary	*Objective*: The EU Climate Law, which was adopted by the European Parliament and the Council in April 2021, sets the EU's objective of reaching climate neutrality by 2050 and establishes the framework for achieving this goal. The law establishes a governance structure to ensure that the EU and its member states are held accountable for their climate action. It also requires Member States to prepare national climate and energy plans to set out how they will contribute to the EU's objectives. The law establishes an independent European Climate Change Council, which will provide scientific advice and assess progress towards the EU's climate objectives. In practice the law includes measures to keep track of progress through the EU governance process system.[29] *Scope*: The EU Institutions and the Member States are bound to take the necessary measures at EU and national level to meet the target set out by the law.
Relevance	*Actors in scope*: The EU Climate Law involves multiple actors at different levels of governance, including the European Union institutions, member states, and the civil society.[30] *Compliance activities*: The Climate Law includes measures to keep track of progress and adjust our actions accordingly. The EU tracks the Member States progress through regular monitoring and reporting through a process called Regulation on the Governance of the Energy Union. It requires Member States to report their GHG emissions and other relevant data annually, which are then compiled and assessed by the European Commission. Member States must submit their energy and climate policies and their national energy and climate plans on an ongoing basis whereafter they will be assessed by the Commission. The Union has a centralized inventory system for monitoring and reporting emissions that ensures the timeliness, transparency, accuracy, consistency, comparability and completeness of national inventories with regard to the Union greenhouse gas inventory. To ensure the quality and accuracy of the reported data, the legislation requires member states to submit their data to an independent review by accredited experts. The European Environment Agency (EEA) coordinates and manages the review process, which involves a thorough assessment of the data and methodology used by Member States. The European Commission assesses the reported data and the independent review reports to determine whether Member States are meeting their emissions targets under the EU climate law. If a member state is not meeting its targets, the Commission can initiate enforcement measures, including financial penalties or legal action.[31] *Centralised database*: The Commission has established an online platform (e-platform) to facilitate communication between the Commission and Member States, to promote cooperation among Member States and to facilitate public access to information.

[29] EUR-Lex - 32018R1999 - EN - EUR-Lex (europa.eu)

[30] EUR-Lex - 32021R1119 - EN - EUR-Lex (europa.eu)

[31] Governance of the Energy Union and Climate Action Regulation

	Relevance: Given that it is only public entities that provides information on the e-platform, and that there is no industry compliance, large scale generation of personal records, validation or other types of transactional activities, investment in DLT seems not to be justified.

Table 8 Scoping analysis: EU Climate Strategies and Targets

Criteria	Scoping analysis: EU Climate Strategies and Targets
Summary	*Objective*: The EU has set itself targets to progressively reduce its greenhouse gas emissions up to 2050. The EU has set ambitious climate strategies and targets in order to address the urgent challenge of climate change. The primary objectives of these strategies and targets are: Mitigating greenhouse gas emissions, increasing the share of renewable energy and supporting climate action in developing countries. Key climate and energy targets are set in the following frameworks: 2020 Climate and Energy package 2030 Climate and Energy framework 2050 long-term strategy *Scope*: The EU Institutions and the Member States are bound to take the necessary measures at EU and national level to meet the target set. There is a reporting mechanism in place, to follow the progress of each Member State. *Proposed reform*: The EU will continually update the Climate and Energy targets, to comply with the EU Climate Law, and the objective of being climate-neutral in 2050.
Relevance	*Actors in scope:* The Member States are subject to compliance obligations. A designated competent authority for each Member State must deliver the integrated national energy and climate progress reports. *Compliance activities:* The EU tracks the Member States progress through regular monitoring and reporting through a process called Regulation on the Governance of the Energy Union. The legislation requires member states to report their GHG emissions and other relevant data annually, which are then compiled and assessed by the European Commission. Member States must submit their energy and climate policies and their national energy and climate plans on an ongoing basis whereafter they will be assessed by the Commission. The Union has a centralized inventory system for monitoring and reporting emissions that ensures the timeliness, transparency, accuracy, consistency, comparability and completeness of national inventories with regard to the Union greenhouse gas inventory. To ensure the quality and accuracy of the reported data, the legislation also requires member states to submit their data to an independent review by accredited experts. The European Environment Agency (EEA) coordinates and manages the review process, which involves a thorough assessment of the data and methodology used by member states. The European Commission assesses the reported data and the independent review reports to determine whether member states are meeting their emissions targets under the EU climate law. If a member state is not meeting its targets, the Commission can initiate enforcement measures, including financial penalties or legal action.

	Centralised database: The Member States are obliged to submit their national energy and climate strategies using an e-platform maintained by Commission. The e-platform has been developed to facilitate communication, promote cooperation and public access to information. The e-platform should also facilitate timely submission of reports as well as improved transparency on national reporting. The e-platform is developed to complement, and build on existing reporting processes, databases and e-tools, such as those of the European Environment Agency, Eurostat, the Joint Research Centre and the experience gained from the Union's Eco-Management and Audit Scheme[32]. *Relevance*: Given that it is only public entities that provides information on the e-platform, and that there is no industry compliance, large scale generation of personal records or details, validation or other types of transactional activities, investment in DLT seems not to be justified.

Table 9 Scoping analysis: EU Emission Trading System 2003-87-EC and MRV

Criteria	Scoping analysis: EU Emission Trading System and MRV
Summary	*Objective*: The EU Emissions Trading Scheme (EU ETS) was established in 2005 to implement the Kyoto international climate change agreement. The EU ETS provides a 'cap and trade system' to reduce GHG emissions annually.[1] [2] This is done through the allocation and trading of emissions allowances between installations and other operators. *Scope*: Currently in its fourth phase, the EU ETS Directive limits emissions from various sectors, including electricity and heat generation and energy-intensive industry sectors (e.g., oil refineries, steel works, production of iron, metals, glass, paper, or bulk organic chemicals). *Proposed reform*: The Commission has proposed changes to the existing ETS that would result in significant reductions in emissions compared with 2005, by both strengthening the current provisions (e.g., phasing out of free allowances for aviation and sectors covered by the carbon border adjustment mechanism, review of the market stability reserve) and extending the scope of the scheme (e.g., maritime transport and international aviation, creation of a new scheme covering road transport and buildings).[4]
Relevance	*Actors in scope*: A large part of industry is subject to compliance obligations under the EU ETS including operators involved in electricity and heat generation, energy intensive sectors and commercial aviation. There is a proposed extension to maritime, road transport, and buildings. *Compliance activities and centralised database*: Following a compliance procedure of Monitoring, Reporting and Verification, operators must submit data, to a centralised Commission database (i.e. the Union Registry), to demonstrate the annual volume of emissions vis-à-vis the number of allowances retained. This further requires the use of third parties in providing approvals of the information submitted and oversight by Member State authorities. *Transactional activities and centralised database*: The EU ETS provides opportunities for operators to trade carbon allowances with each other. These

[32] EUR-Lex - 32018R1999 - EN - EUR-Lex (europa.eu)

	can be exchanged with the support of financial intermediaries and their centralised databases. Moreover, allowances offered by Member States can be purchased via auctions managed by intermediaries such as the European Energy Platform. *Relevance*: The large and likely increasing number of market actors subject to EU ETS strengthens the rationale for investment in a Blockchain system that could potentially provide benefits around the compliance and transactional activities that are currently supported by centralised database systems.

Table 10 EU Strategy on adaptation to Climate Change

Criteria	Scoping analysis: Adaptation to climate change (EU Strategy on Adaptation to Climate Change)
Summary	*Objective*: The EU Strategy on Adaptation to Climate Change aims to help the EU and its Member States to build resilience to the impacts of climate change, such as increased frequency and intensity of extreme weather events, rising sea levels, and changes in temperature and precipitation patterns. The Strategy provides provisions for development of better adaptation data, development of national adaptation strategies, fostering resilience through dedicated initiatives, integration with fiscal frameworks, promotion of nature-based solutions, monitoring and evaluation etc. *Scope*: The scope of the policy concerns establishing national responsibilities around adaptation to climate change around policy formulation, implementation, monitoring and reporting.
Relevance	*Actors in scope*: The main actors in scope concern the national authorities tasked to engage and respond to the Strategy. *Compliance activities and centralised database*: The implementing regulation on the Governance of the Energy Union and Climate Action establish the reporting requirements for Member States. This reporting also supports the National Energy and Climate Plans, for instance in the protection of the security of the EU's energy supply against climate impacts. There is also reporting on adaptation to be conducted under the MRR on national adaptation actions in line with the UNFCC that complement the reporting requirements under the Strategy. *Relevance*: The relevance is low since the obligations set for Member States to report and inform the Commission of progress under the Strategy can be supported by centralised database solutions – policy mechanisms would therefore not be enhanced through a Blockchain based solution. The number of actors involved and national reporting requirements does not warrant introduction of Blockchain technology to exchange and secure the information.

Table 11 Effort Sharing Regulation (EU) 2018/842

Criteria	Scoping analysis: Effort Sharing Regulation
Summary	*Objective:* The Effort Sharing Regulation (ESR) sets binding annual GHG targets for Member States for the period 2021-2030 for sectors that fall outside of the EU ETS. It requires that emissions are reduced by 40% by 2030 compared to 2005 levels. The ESR recognises Member States ability to act based on their level of GDP and therefore seeks to allocate cuts 'fairly'. *Scope*: The ESR accompanies the EU ETS by covering sectors not in the scope of the EU ETS (although the proposed extension of the EU ETS will cover transport and buildings – see above). The sectors in scope of the ESR concern transport, buildings, agriculture non-ETS industry and waste.
Relevance	*Actors in scope*: The actors in scope include national authorities that are mandated to perform designated tasks under the regulation. *Compliance activities and centralised database:* Member States must report on the emissions for the sectors in scope by gathering data (e.g. fuel sales, energy use etc.) and performing calculations. The Commission has a role in quality reviewing the reports submitted. Member States must engage with the Union Registry to manage their emissions allowances as defined under the EU ETS. These allowances may be 'used', 'banked', 'borrowed' or 'transferred'. Ultimately, allowances must be manged each year to ensure appropriate balancing of their emissions with their emission targets. In addition, the ESR interfaces with the LULUCF (Land Use, Land Use Change and Forestry) regulation. Here, Member States, for compliance purposes vis-a-vis the emissions targets, may consider through carbon accounting the net removals and net emissions from the relevant types of land. See more details on the LULUCF elsewhere in the report. *Relevance*: The number of actors involved in the process is limited to Member State authorities. However, since they are engaged in managing emission allocations, there may be benefits in exploring the use of Blockchain - this technology can likely improve the traceability and verification of allowances and also potentially in supporting accounting and traceability vis-a-vis the LULUCF.

Table 12 LULUCF Regulation

Criteria	Scoping analysis: Land Use, Land Use Change, and Forestry (LULUCF) regulation (EU) No 2018/841
Summary	*Objective:* (LULUCF) sets rules for accounting for greenhouse gas (GHG) emissions and removals related to land use, land use change, and forestry. *Scope:* The Regulation covers emissions and removals of GHG on several land accounting categories such as afforested land, deforested land, managed cropland, managed grassland, managed forest land and managed wetlands.
Relevance	*Actors in scope*: Member States are designated to perform activities under the Regulation.

	Compliance activities and centralised database: The regulation requires Member States to provide accounts and perform accounting activities concerning emissions and removals of GHG from the designated land categories – this includes a record of all data used. Member States need to submit two compliance reports between 2021 and 2030 to the Commission showing the balance of total emission's and total removals. To facilitate data collection, land use should be monitored using geographical tracking, corresponding to national and EU data collection systems. This can include programmes such as Copernicus and Galileo. All data used should be verifiable. *Relevance*: There is some relevance for further exploring the use of Blockchain under the LULUCF. While information exchange only occurs between public sector actors at national and EU levels, there is a need to ensure verifiable monitoring of land use. Blockchain may lend itself to improving the security of the record keeping of selected land pockets but this requires further investigation.

Table 13 EU Ozone Regulation – Regulation (EC) 1005/2009 Protecting the Ozone layer

Criteria	Scoping analysis Protecting the ozone layer
Summary	*Objective*: The objective of the EU Ozone Regulation (Regulation (EC) No 1005/2009) is to protect the Earth's ozone layer by controlling the production, use, import, export, and placing on the market of substances that deplete it. The regulation aims to ensure that ozone-depleting substances (ODS) are phased out and replaced with more environmentally friendly alternatives. *Scope:* The EU Ozone Regulation covers a wide range of ODS, including, among others, chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), halons, carbon tetrachloride, and methyl chloroform. The regulation sets out requirements for the placing on the market, use, recovery, and destruction of these substances, as well as the certification and training of personnel involved in handling them. *Proposed reform*: In 2022, the EU Commission proposed to amend the Ozone Regulation to increase the efficiency of existing measures in order to achieve additional emission reductions and ensure a more comprehensive monitoring of ODS.
Relevance	*Actors in scope:* The EU Ozone Regulation involves a range of actors at the EU and national level, including EU and national authorities responsible for enforcing the regulation, industry stakeholders involved in the import, export, production, destruction, use and placing on the market of ODS and products and equipment containing or relying on ODS. *Compliance activities and centralised database*: The EU Ozone Regulation sets out requirements for compliance activities, such as the certification and training of personnel involved in handling ODS, the completion of administrative formalities, and the submission of verifiable details of the undertakings registered in the ODS licensing system and some personal data of registered users. The regulation also requires the reporting of ODS production and consumption data by industry stakeholders to a centralised database, which is managed by the European Environment Agency (EEA) and made publicly available in the form of an online report with aggregated

data at EU level (the single reports submitted by the undertakings are confidential).

Transactional activities and centralised database: The EU Ozone Regulation also involves transactional activities, such as the import, export and placing on the market of ODS and products containing or relying on ODS. Art. 10(6), 14 and 16 set out the rules and procedures of the allocation and transfer of quotas for the production and import of ozone depleting substances. Article 15 and 17 define the import and export licensing requirements, respectively. Article 27 requires undertakings to report on ODS to the European Commission. In particular, the regulation requires that companies engaged in the production, destruction, import, export, feedstock use and process agent use of ODS report this information to the EC on an annual basis. Per-shipment licences are used for bulk substances and most types of products and equipment containing or relying on ODS; such licences must include information on the quantities, type and intended use of the ODS, as well as the parties involved in the transaction. There are also bulk licences that concern only products and equipment for the aviation sector; such licences can be used multiple times and contain a more limited set of information compared to the per-shipment licences.

Relevance: It may not be immediately clear whether investing in blockchain technology is necessary for the EU Ozone Regulation. While the regulation does involve a range of actors and activities, the existing centralised databases and reporting systems appear to be functioning effectively in meeting the requirements of the regulation.

Blockchain technology could potentially offer benefits such as increased transparency, security, and efficiency in managing compliance and transactional activities. One potential application could be in the tracking and verification of the production and trade of ODS. In particular, it would be possible to create a transparent and secure record of every transaction involving these substances, from production and import to export and consumption. Another potential application could the in the management of quotas and licenses for the production and import of ODS. This would improve the accuracy and efficiency of the system reducing the risk of errors or fraud and making the enforcement more effective.

However, there may not be a pressing need to invest in blockchain for the EU Ozone Regulation if the existing systems are already meeting the necessary requirements. Moreover its implementation would require a careful consideration of the technical and regulatory challenges involved.

Table 14 Regulation (EU) No517/2014 (F-gas Regulation

Criteria	Scoping analysis Fluorinated gases ("F-Gases")
Summary	*Objective*: The European Union has issued a concrete regulatory plan on F-gases. The May 2006 regulation imposes emission reduction standards for certain fluorinated GHGs in Europe. The 2006 regulation was repealed by F-gas Regulation 517/2014, which intends to reduce the EU's F-gas emissions by two-thirds by 2030 compared with 2014 levels. The regulation sets out rules on the production, use and trade of F-gases, in particular: a) a phase-down of the amount of f-gases that can be placed on the EU market, b) bans on the use of certain f-gases in specific applications, c) requirements for leak checking, maintenance and servicing of equipment that contains f-gases, d) certification requirements for personnel who handle f-gases, e) reporting requirement for producers, importers and exporters of f-gases. Some restrictions on use and marketing are in place for certain applications of F-gases, notably the ban on the use of certain f-gases (HFCs, PFCs, SF6) in new equipment, applications. *Scope*: F-gases cover Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride (SF6) Proposed reform: In April 2022, the European Commission made a legislative proposal to update Regulation (EU) No 517/2014 (the 'F-gas Regulation'). Currently, the co-legislators in the European Parliament and the Council are negotiating the proposal. With this revision the European Commission intends to: › Deliver higher ambition › Ensure compliance with the Montreal Protocol › Improve enforcement and implementation › Achieve more comprehensive monitoring
Relevance	*Actors in scope:* The F-Gases regulation involves a range of actors at the EU and national level, including EU and national authorities responsible for enforcing the regulation, industry stakeholders involved in the production and import, use of F-gases. Other stakeholders may also be involved, such third-party verifiers and certification bodies who provide independent verification of compliance with the regulation. *Compliance activities and centralised database:* Prior to carrying out any activities that fall under Regulation (EU) 517/2014 the 'F-gas Regulation'), all companies have to register in the F-gas Portal & HFC licensing system. This is mandatory for companies to receive a quota, for importers of equipment containing HFCs, and for all entities supplying or receiving exempted gases such as those hydrofluorocarbons (HFCs) imported for destruction, for use as feedstock, directly exported in bulk, as well as for use in military equipment, in semiconductor manufacture or for metered dose inhalers (MDIs). All companies that report on F-gas-related activities must register in the F-gas Portal & HFC Licensing System in order to enable access to the reporting forms. As regards activities related to imports and exports of fluorinated gases and imports of equipment pre-charged with HFCs, this registration constitutes an import or export license.

	This license is a necessary step, but not sufficient condition for being allowed to import into and export from the EU. Other conditions also apply, notably when imported goods are being placed on the EU market. These conditions include labelling requirements (Art. 12 of the F-gas Regulation) and requirements related to the HFC quota system (Art. 14 and 15 of the F-gas Regulation). *Transactional activities and centralised database:* The online mechanism for transferring bulk quota from one company to another is available in the F-gas Portal & HFC Licensing System. Quota of f-gases allocated to manufacturers and importers can be traded within the EU. The system of tradable quotas is known as the "phase down mechanism" and aims to reduce the quantity of f-gases placed on the EU market. Imports of all HFC pre-charged refrigeration, air-conditioning and heat pump equipment require a quota authorisation, unless an annual threshold of 100t CO2 equivalent is not exceeded or the HFC was previously placed on the market in the EU. Manufacturers and importers of f-gases are allocated an annual quota of f-gases that they can place in the EU market. If they need more than their allocated quota, they can purchase additional quota from other manufactures or importers who have a surplus. The verification has to be carried out by an independent auditor.[33] *Relevance:* Blockchain technology could potentially offer benefits such as increased transparency, security, and efficiency in managing compliance and transactional activities. In terms of traceability, it would be possible to track f-gases throughout the supply chain. When it comes to the quota system under the f-gases regulation, blockchain technology could be used to create a transparent and secure ledger of all f-gases transactions between different manufacturers and importers. It could also reduce fraud and automate certain compliances activities. However, there may not be a pressing need to invest in blockchain for the F-Gases Regulation if the existing systems are already meeting the necessary requirements.

Table 15 Funding for Climate Action Innovation Fund

Criteria	Scoping analysis: Funding for Climate Action: EU Innovation Fund
Summary	*Objective:* Raised from Horizon 2020, the Innovation Fund is the successor to NER300. The programme was born out of the EU's commitments under the Paris Agreement and aims to bring innovative low-carbon technologies to market. The Innovation Fund supports up to 60% of the additional capital and operational costs of large-scale projects and up to 60% of the capital costs of small-scale projects. The EU ETS is providing the revenues for the Innovation Fund from the auctioning of 450 million allowances from 2020 to 2030, as well as any unspent funds from the NER300 programme. *Scope:* Calls for projects target several areas of the Climate sector: › Renewable energies

[33] https://climate.ec.europa.eu/eu-action/fluorinated-greenhouse-gases/f-gas-portal-hfc-licensing-system-quota-allocation-authorisation-and-reporting_en

	› Carbon capture, use and storage (CCUS) › Energy-intensive industries, including substitutes › Energy storage Projects are assessed according to five award criteria on their ability to: 1. Demonstrate highly innovative technologies, processes or products 2. Significantly reduce or avoid greenhouse gas emissions 3. Guarantee sufficient maturity 4. Demonstrate high potential of scalability 5. Present high cost-efficiency There have been 3 calls for proposals so far. *Proposed reform:* This is not a reform but the third call for large-scale projects was launched on 3 November 2022. With a budget doubled to EUR 3 billion thanks to increased revenue from the auctioning of EU Emissions Trading System (ETS) allowances, this third call counts four topics, three of which are part of REPowerEU: › Innovative electrification in industry and hydrogen › Clean tech manufacturing (supporting manufacturing of components and final equipment such as electrolysers and fuel cells, innovative renewable equipment, energy storage, or heat pumps), (budget: EUR 700 million) › "Mid-sized pilots" projects for validating, testing and optimising highly innovative solutions (budget: EUR 300 million) › General decarbonisation, which is available to all projects eligible for the Innovation Fund except those which fall under dedicated RePowerEU topics (budget: EUR 1 billion)
Relevance	*Actors in scope:* **The European Commission,** assisted by the implementing bodies CINEA and EIB, is tasked with the overall management of the Innovation Fund Beneficiaries are European (including Norway and Iceland) companies which promote large or small scale innovative) projects (see scope above.) CINEA checks that proposals are admissible and eligible. Proposals that fulfil the admissibility and eligibility conditions are evaluated by external evaluators against the award criteria. CINEA is in charge of: › Managing the calls for proposals and all related procedures › Managing the project proposal submission and evaluation processes, including eligibility checks › The signature of grant agreements › The disbursement of the Innovation Fund grants › Monitoring the technical/financial management of projects in the Innovation Fund portfolio › Monitoring and controlling projects ex-post, including management of recoveries

- Ensuring visibility of the programme, available funding, results and achievements via communication actions and products, including events

CINEA reports regularly to the Commission and provides feedback on general orientations for further development of the Innovation Fund.

The European Investment Bank is responsible for the provision and management of the Project Development Assistance (PDA) support. The EIB is also in charge of the monetisation of the Innovation Fund allowances and the management of the Innovation Fund revenues. The EIB reports regularly to the Commission.

Member States actively participate in the implementation of the Innovation Fund. They are consulted on key decisions, including:

- Decision to launch the call for proposals
- Maximum amount of the Innovation Fund support to be made available for the PDA
- List of pre-selected projects for PDA support and
- List of pre-selected projects for the Innovation Fund grants, prior to the award of grants

Compliance activities: The necessary collected projects information (the five award criteria listed above) is used on one hand to provide policy feedback and on the other to support fellow Innovation Fund projects, industrial stakeholders and future applicants.

Detailed data can include GHG Emissions Avoidance, degree of innovation (calculation of any additional benefits, technical, business, financial and operational risks and their mitigation measures, project implementation timeline, a defined strategy for off-take agreements in place etc.

Some data take long a time to be collected and verified: The application preparation requires expertise on greenhouse gas (GHG) emission avoidance calculations which leads a 3 months delay.

The Innovation Fund Project Portfolio Dashboard is an intuitive and interactive reporting platform, allowing the viewer to discover the Innovation Fund signed projects. The aim of this dashboard is to facilitate data sharing, providing public access to real-time programme data in an easy, flexible and user-friendly manner. The Innovation Fund Project Portfolio Dashboard refers to the portfolio of projects that have signed grant agreements and consists of two main pages (sheets):

- Portfolio of signed projects
- Page for self-service

Centralised database: There is an inventory of projects funded in the last calls for projects. In accordance with Article 23(6) of Delegated Regulation (EU) 2019/856 of 26 February 2019 supplementing Directive 2003/87/EC of the European Parliament and of the Council as regards the detailed rules for the operation of the Innovation Fund (hereinafter the "Delegated Regulation"), the Commission shall report annually to the Council and the European Parliament on the progress made in the implementation of the Fund.[34]

[34] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/home

	Relevance: The application preparation requires expertise on greenhouse gas (GHG) emission avoidance calculations which leads a 3-month delay. Blockchain technology can provide greater transparency about how the data is collected and reported and how the combination of parameters leads to the determination of GHG reductions. It can therefore speed up the application process. *Transactional activities and centralised databases: N/A*

Table 16 Funding for Climate Action: EU Modernisation Fund

Criteria	Scoping analysis of the EU Modernisation Fund[35]
Summary	*Objective*: The Modernisation Fund is a dedicated funding programme to support 10 lower-income EU Member States in their transition to climate neutrality by helping to modernise their energy systems and improve energy efficiency. *Scope*: The Modernisation Fund support investments that help to modernise energy systems and improve energy efficiency. It includes: › Generation and use of electricity from renewable sources › Improvement of energy efficiency › Energy Storage › Modernisation of energy networks › Support to a just transition in carbon-dependent regions in the beneficiary Member States The Modernisation Fund operates under the responsibility of the beneficiary Member States, who work with the EIB). The Investment Committee set up for the fund and the European Commission. Just transition in carbon-dependent regions: redeployment, re-skilling and upskilling of workers, education, job-seeking initiatives and start-ups To obtain financing, the beneficiary Member State has to: › Demonstrate that the investment complies with the ETS Directive requirements › Have sufficient funds available on its Modernisation Fund account › Provide evidence that the investment proposal is in line with the State aid rules › Confirm that the investment complies with any other applicable requirements of Union and national law › Confirm that there is no double funding of the same costs with another Union or national instrument. The Modernisation Fund is supported by revenues from the auctioning of about 2% of the total allowances for 2021-30 under the current EU ETS as well

[35] https://modernisationfund.eu/how-it-works/

	as additional allowances transferred to the Modernisation Fund by some of the recipient Member States. *Proposed reform*: not subject to reform
Relevance	*Actors in scope:* The beneficiary Member States are Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia. Ministries of environment or energy are generally the representative entities for each member state. The Member States are responsible for: › Implementing the Modernisation Fund in their territory › Selecting the investment proposals they would like to support from their Modernisation Fund share › Submitting the investment proposals for confirmation to the EIB and the Investment Committee, and providing the information needed for their assessment › Paying off the support to the project proponents or scheme managing authority(ies) upon the disbursement decision of the Commission › Participating in the Investment Committee › Monitoring and submitting annual reports on the implementation of the Modernisation Fund investments › Auditing the project proponents or scheme managing authorities, submitting the results of these audits to the EIB and the Commission › Taking appropriate measures to ensure that the financial interests of the Modernisation Fund are protected. The EIB confirms if the investment is a priority investment as defined by the ETS Directive. For non-priority investments, the EIB conducts a technical and financial due diligence assessment and the Investment Committee assesses the proposal and makes its recommendation on its financing. The Commission takes a disbursement decision once an investment is confirmed as priority by the EIB. The EIB transfers the resources to the beneficiary Member States in accordance with the decision. *Compliance activities and centralised database*: Compliance activities are managed by the EIB.EIB conforms if the investment can be considered as a priority. Once the investment is confirmed as a priority, the EIB transmits the funds to the member country concerned, usually within 2 weeks. However, there is no certification system. All data are centralized on the Modernisation fund website. It includes the type of investment, type of proposal, Status, Date of Confirmation, requested amount, priority area. For each year, the member States publish annual Reports to the European Commission that summarize the investment provided by this fund. *Transactional activities and centralised database*: N/A *Relevance:* Given the limited market actors, and the fact those subject to the legislation are public entities the application of blockchain would have a limited potential.

Table 17 International action on climate change: Voluntary climate markets

Criteria	Scoping analysis of voluntary carbon markets (International action on climate change)
Summary	*Objective*: Voluntary Carbon Markets /Art. 6: The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at COP 21 in Paris in December 2015 and entered into force in November 2016. Its goal is to limit global warming to well below 2, preferably to 1.5 degrees Celsius. The Paris Agreement reaffirms that developed countries should take the lead in providing financial assistance to countries that are less endowed and more vulnerable, while for the first time also encouraging voluntary contributions by other Parties. Article 6 of the Paris Agreement opens the door to countries to use international carbon markets to meet their nationally determined contributions (NDCs). More than two thirds of countries intend to use carbon markets to meet their NDCs, and a number of countries are investing in state-of-the-art digital infrastructure to enable participation in international carbon markets. It is estimated that trading in carbon credits could reduce the cost of implementing NDCs by more than half. Carbon markets exist in two forms. In compliance markets, regulated entities obtain and surrender emission permits (allowances) or offsets in order to comply with an imposed regulation or a regulatory act. In contrast, the voluntary carbon market (VCM) is a market where carbon offsets are not purchased to be used in an active regulated market but rather 'with the intent to re-sell or retire to meet carbon neutral or other environmental claims. *Scope*: Corporate participants range across various sectors. Carbon credits can be grouped into two large categories or baskets: avoidance projects (which avoid emitting GHGs completely therefore reducing the volume of GHGs emitted into the atmosphere) and removal (which remove GHGs directly from the atmosphere). Those include renewable, forestry management projects etc. *Proposed reform*: not subject to reform
Relevance	*Actors in scope:* Participants in the voluntary market range across companies, governments and private individuals aiming to reduce their carbon footprint. *Compliance:* VCMs operate outside governmental regulatory schemes, which naturally raises concerns about the validity and the quality of carbon credits sold. For such a credit to be credible a lot of information needs to be put on that certificate and that information needs to be transparent to all market participants, especially buyers. Currently, offsets are legitimised by accredited independent third-party bodies, while carbon credit registries record the carbon offset's retail chain to track the existence of the credits. There is no database in the EC. There are platforms managed by private groups (ex: The Gold Standard…). The global voluntary carbon market is fragmented. The key players in the global voluntary carbon market include NRG Energy, Inc. (Green Mountain Energy); Just Energy Group Inc. (TerraPass); Ambipar Group; South Pole; EcoAct; ClimatePartner etc. *Transactional activities and centralised database:* When verified, credits are issued, entered into a registry and made available for trade. The registry records and labels the credit, tracks the owners, and makes information about

	credits on offer publicly available through a ledger. However, currently there is no centralized market for all voluntary carbon credit. Project developers can sell credits directly to buyers, through a broker or an exchange, or sell to a retailer who then resells to a buyer. The large and likely increasing number of voluntary carbon market actors strengthens the rationale for investment in a Blockchain system that could potentially provide benefits around the compliance and transactional activities that are currently supported by centralised database systems. Blockchain has the potential to improve verifiability and reduce transaction costs. blockchain can ensure that carbon credits are only issued once, and that the credits are retired once they have been used.

Table 18 International Action on Climate Change: Climate Finance

Criteria	Scoping analysis of climate finance
Summary	*Objective*: The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at COP 21 in Paris in December 2015 and entered into force in November 2016. Its goal is to limit global warming to well below 2, preferably to 1.5 degrees Celsius. The Paris Agreement reaffirms that developed countries should take the lead in providing financial assistance to countries that are less endowed and more vulnerable, while for the first time also encouraging voluntary contributions by other Parties Climate finance refers to local, national or transnational financing—drawn from public, private and alternative sources of financing—that seeks to support mitigation and adaptation actions that will address climate change. *Scope*: Adaptation and mitigation projects *Proposed reform*: In 2021, the European Commission committed €2.50 billion to developing economies, with a significant share (almost 40%) going to funds climate adaptation activities. Furthermore, while 20% of the whole EU budget for 2014-2020 was spent on climate-related projects – this target has become 30% for 2021-2027. In addition, the European Investment Bank provided €2.56 billion in climate finance to developing economies in 2021.
Relevance	*Actors in scope:* › Recipient countries (mainly developing countries) › Private and Public entities › Concerning the European Regional Development Fund, recipients are companies, local authorities and citizens › The European Commission: In 2021 the EC provided €2.50 billion to developing economies, with a significant share it (almost 40%) going to funds climate adaptation activities. › Numbers of European funds are involved in climate finance such as Global Climate Change Alliance+, the European Fund for Sustainable Development Plus (EFSD+), *Compliance activities and centralised database:* The European Commission and many Member States actively contribute to initiatives improving reporting

methodologies and data availability on financial support to developing countries.

Such initiatives include the OECD Development Assistance Committee, Technical Working Group, OECD Research Collaborative on Tracking Finance for Climate Action and International Aid Transparency Initiative, GCF Database.

Compliance activities are managed by each entity. Each fund has its own eligibility and verification criteria. Let's take an example with EIB. Compliance is an integral part of the Bank's ethical and professional approach and the way it does business. The Compliance function is co-responsible for the identification, assessment, monitoring and reporting of non-financial risks. The Bank adheres to the Basel Committee on Banking Supervision's definition of compliance risk. Almost all Activities eligible for EIB financing must be in line with the European Taxonomy.

Climate finance landscapes (comprehensive studies mapping financial flows dedicated to climate change action and energy transition.) landscapes draw the picture of how the financial value chain links sources, intermediaries, project managers and the end-investment. Those landscapes managed by independent organisation.

Third part: Corruption plays a role in climate finance or in development aid, but it is the bureaucracy that hinders development and leads to a decrease in efficiency.

Transactional activities and centralised database: As with compliance activities, transactional activities are managed by each fund. Each fund has a database to track funding.

Relevance:

Overall tracking of international funding, including a clear reference to participating donors, could be enabled by executing funding decisions along pre-defined conditions recorded on distributed ledgers.

Blockchain networks enable the tracing of climate finance in such a way that all participants of a given project can follow (almost in real time) the flows from donor to recipient via a universal ledger. Applying smart contracts to such a network would add an additional level of transparency to the process.

Blockchain eliminates the need for trusted third parties and, these parties are the cause for slowing down development and efficiency. Investors or grand recipients will enjoy a much higher degree of credibility from their stakeholders just by using blockchain-based processes.

Blockchain technology could contribute to both transparency and linking payments with impacts. It could be used by governments as a platform where the results of a given climate policy are registered, making it available for oversight by society. This would help ensure transparency, accountability, security and quality of data. A Blockchain-based solution could also facilitate the link of payments to concrete results via a decentralized platform.

Table 19 EU Sustainable Products Initiative

Criteria	Scoping analysis of Sustainable Products Initiative
Summary	*Objective:* The Sustainable Products Initiative (SPI): In March 2022, The EC introduced a package of European Green Deal proposals to make sustainable products the norm in the EU. The EC has highlighted new rules to make most of physical goods on the EU market closer to the circular, and energy efficient throughout their whole lifecycle (from the design phase through to daily use, repurposing and end-of-life). Product-specific information requirements will ensure that consumers know the environmental impacts of their purchases. All products from priority sectors (ICT, textiles, steel, cement…) will have Digital Product Passports. It will be implemented from 2024. This will make it easier to repair or recycle products and facilitate tracking substances of concern along the supply chain. Labelling can be introduced as well. The Regulation (which is the revised Regulation on Eco-design) offers digital solutions to reduce administrative burdens, particularly on SMEs, including a construction products database (in addition to the digital passport). *Scope:* Current priority sectors include electronics, information and communications technology (ICT), textiles, furniture and high-impact intermediary products such as steel, cement and chemicals. Further product groups will be identified based on their environmental impact and circularity potential. *Proposed reform:* The proposed Regulation on Ecodesign for Sustainable Products aims at replacing the Ecodesign Directive.
Relevance	*Actors in scope:* EC; Consumers; Producers and importers in the fields listed above. *Compliance activities and centralised database*: As the traditional passport, digital product passports contain a range of information to track products throughout their entire lifecycle from production to end-of-life disposal. This information can be used to ensure proper sourcing of materials, monitor sustainable manufacturing practices and facilitate product lifetime extension. For instance, consumers could see how long a product is expected to last or to which extent a product can be repaired. At the end of use, a digital product passport is invaluable for the disposal of products to increase the efficiency of material recovery and the reduction of waste. Digital product passports can also be used to engage with or reward stakeholders and customers for sustainable practices and behaviours. › Material traceability data – Data on the supply chain or value chain, or product ingredients/ raw material and inputs › Sustainability data – Data on how sustainable the production process and distribution of the product is. › Product-specific data – Traditional product information, such as name, make, model, brand, etc. *Transactional activities and centralised database*: *Relevance:* Building digital product passports on public blockchain technology provide immutable records of ownership, origin and usage,

	increasing trust and transparency in complicated supply chains. The implementation of digital product passports accelerates steps toward a green society and circular economy, although stakeholders may be concerned about the security of such a database, especially if it is centralized. This is where decentralized blockchain-based ecosystem solution comes to the rescue. It is a secure, transparent and fast process that guarantees security for both companies and consumers.

Table 20 Regulation 2019/631 emissions performance standards for vehicles

Criteria	Scoping analysis Efficiency standards for vehicles
Summary	*Objective:* The Regulation 2019/631 on Co2 emission performance standards for new passengers cars and for new light commercial vehicles set EU fleet-wide CO_2 emission targets applying from 2020, 2025 and 2030 and included a mechanism to incentivise the uptake of zero- and low-emission vehicles. The regulation established a number of other measures to promote vehicle efficiency and reduce emissions. In July 2021, as part of the 'Fit for 55' package, the Commission presented a legislative proposal for a revision of the Regulation (EU) 2019/631 setting CO2 emission performance standards for passenger cars and light commercial vehicles. The co-legislators reached an agreement in October 2022. The Coreper endorsed the agreed text on 16 November 2022, and the ENVI Committee approved it on 1 December 2022. Pending a formal adoptions, the co-legislators agreed: › New cars: 55% Co2 emission reduction target compared to 2021 levels › New light commercial vehicles: 50% CO2 emission targets by 2030 compared to 2021 levels › Both new cars and vans: 100% CO2 emission target by 2035 *Scope:* light vehicles, heavy-duty vehicles, Car labelling *Proposed reform:* N/A
Relevance	*Actors in scope:* The key actors in scope of the regulation are primarily manufacturers of new cars and light commercial vehicles sold in the EU. National authorities in EU MS are also involved in implementing and enforcing the regulation, they are also responsible for monitoring compliances and imposing penalties on manufacturers who fail to meet the emission standards. *Compliance activities and centralised database*: Manufacturers are required to ensure correspondence between the CO2 emissions recorded in the certificates of conformity of their vehicles and the CO2 emissions of vehicles in-service. Type-approval authorities verify this correspondence in selected vehicles, as well as the presence of any strategies artificially improving the vehicle's performance in the type-approval tests. On the basis of their findings, authorities ensure the correction of the certificates of conformity and may take additional measures, set out in the Type Approval Framework Regulation. Type-approval authorities can report any deviations to the Commission, who takes them into account for the purpose of calculating the average specific emissions of a manufacturer. Manufacturers are required to submit compliance plans outlining how they will meet the emission targets, which must be approved by national authorities in each Member States. A

	centralised database to facilitate the monitoring and report of emission data was set up. The database contains information on the Co2 emissions of each new vehicle model sold in the EU, as well as other data related to vehicle characteristics and fuel consumption. Data related to the CO2 emissions from cars and light vehicles are gathered in the DICE (Database Inter-European Collector of Emissions). Only Type Approval Authorities and Technical Services are authorized to request access.[36] *Transactional activities and centralised database*: no relevant activities *Relevance:* Blockchain Technology could enhance transparency and security of the platform for recording and tracking and reporting emissions data. It also could be used to track emission data throughout the supply chain, from raw materials to finished vehicles. This could enable the identification of emission hotspots in manufacturer's value chains. However, there may not be a pressing need to invest in blockchain for the Regulation considered the limited role of centralised database, and no relevant transactional activities.

Table 21 Carbon Removals

Criteria	Scoping analysis of Sustainable carbon cycles (carbon removals and carbon capture)
Summary	*Objective*: Carbon removals from forests, agricultural practices or technological solutions play a growing role in achieving climate neutrality by 2050, and will become the main focus of action thereafter, when negative emissions will be needed to actively reduce concentration of CO2 in the atmosphere and stabilise the climate. In December 2021, the Commission adopted the "Sustainable Carbon Cycles" Communication, which presents an action plan on how to develop sustainable solutions to increase carbon removals. It highlights key challenges and proposes short- to medium-term actions to tackle them. Carbon Farming: by 2028 every land manager should have access to verified emission and removal data, and carbon farming should support the achievement of the proposed 2030 net removal target of 310 million tonnes of CO2 equivalent (Mt CO2eq) in the land sector, as presented in July's package on delivering the European Green Deal. *Scope:* On 30 November 2022, the European Commission adopted a proposal for a Union certification framework for carbon removals. The proposal shall boost innovative carbon removal technologies and sustainable carbon farming solutions and contribute to the EU's climate, environmental and zero-pollution goals. It shall significantly improve the EU's capacity to quantify, monitor, and verify carbon removals. For this purpose, the European Commission shall develop tailored certification methods for carbon removal activities delivering on climate and other environmental objectives. *Proposed reform*

[36] Microsoft Word - user manual_v75 (europa.eu)

Relevance	*Actors in scope:* Farming, agriculture companies; industrial companies, certification schemes, certification bodies, national accreditation bodies, the Commission *Compliance activities and centralised database*: Carbon farming and industrial projects that invest in carbon removals today should have a prospect of a future robust accounting and certification framework that ensures comparability and recognition of the action started already on the ground. This aims to ensure the transparent identification of carbon farming and industrial solutions that unambiguously remove carbon from the atmosphere. The Commission is developing an EU certification system for carbon removals. To receive certification, the carbon removals need to be correctly quantified, deliver additional climate benefits, strive to store carbon for a long time, prevent carbon leaks, and contribute to sustainability. The EU certification of carbon removals is developed in two steps. Firstly, the Commission sets up high-level quality criteria under the Regulation. Secondly, the Commission approves detailed certification rules for the measurement, monitoring, reporting and verification of carbon removals from both industrial and nature-based activities. Certification bodies appointed by certification schemes shall be accredited by a national accreditation authority pursuant to Regulation. - *Relevance:* The certified carbon removal must employ a set of prescribed, high-integrity accounting principles. This includes preventing double-counting or double claiming and certifying on an ex-post. Blockchain could have a significant impact to help to track GHG emissions. It could also have an impact if a database is created. *Transactional activities and centralised database*: There are numbers of carbon removal certification schemes managed by independent private entities.

Table 22 Carbon Border Adjustment Mechanism

Criteria	Scoping analysis of Carbon Border Adjustment Mechanism
Summary	*Objective:* The CBAM[37] puts **an emissions tariff on imports of goods** with a high risk of carbon leakage from countries which are not members of the EU Emissions Trading System (ETS). CBAM will begin to operate from October 2023 The CBAM system will work as follows: EU importers will buy carbon certificates corresponding to the price of carbon that would have been paid if the goods had been produced under EU carbon pricing rules. Conversely, once a non-EU producer can demonstrate that it has already paid a price for the carbon used in the production of the imported goods in a third country, the corresponding price can be fully deducted for the EU importer. The CBAM will help reduce the risk of carbon leakage by encouraging third country producers to green their production processes. *Scope:* **The CBAM applies to goods produced in non-EU countries**. CBAM will initially cover a number of specific products in some of the most carbon-

[37] https://taxation-customs.ec.europa.eu/green-taxation-0/carbon-border-adjustment-mechanism_en

	intensive sectors: iron and steel, cement, fertilisers, aluminium, electricity and hydrogen, as well as some precursors and a limited number of downstream products. Indirect emissions would also be included in the regulation in a well-circumscribed manner. *Proposed reform:* not subject to reform
Relevance	*Actors in scope:* EU importers that buy carbon certificates corresponding to the carbon price that would have been paid, had the goods been produced under the EU's carbon pricing rules. Non-EU exporters The EC is in charge of developing the CBAM *Compliance activities and centralised database*: Importers will have to register with national authorities before importing the goods. The application must include information such as certification by a tax authority, declaration on honour and the volume of goods imported. They will declare annually the number of goods imported and their integrated emissions (by 31 May of the year preceding the import). The declaration must include data on the number of goods, the total integrated emissions and the total quantity of CBAM certificates; and obtain the necessary quantity of CBAM certificates. The certificates must offset the reported embodied emissions. Because of the complexity and traceability of carbon in GVCs, the mechanism is likely to be applied to standardised products. It is more practical to assess the CO2 content of a product like steel than of a finished product. The latter requires by definition more intermediate consumption, in a context of strong fragmentation of value chains, with production systems with variable energy efficiency. *Transactional activities and centralised database*: Information on embedded emissions for goods subject to the CBAM should be provided to EU registered importers by third country producers. In cases where this information is not available at the time of importing the goods, EU importers will be able to use default values (even once the final scheme is in operation) for the CO2 emissions of each product to determine the number of certificates they need to purchase. Importers will nevertheless be able to demonstrate actual emissions in a cross-checking procedure, and surrender the appropriate number of CBAM certificates accordingly. *Relevance:* Due to the complex nature of modern supply chains, this might bring challenges associated with the inaccessibility of information, confidentiality concerns, errors, and lack of scalability. The issue will become more prominent when the European Commission adds indirect emissions which demand wide-scale data exchange between supply chain actors. Digital traceability solutions make the emissions accounting process for the CBAM easier. The use of blockchain has great potential to better track information on embedded emissions for goods, which will better determine which external products should be taxed.

Analysis of existing use cases

This section provides details on the analysis of existing use cases with a focus on the challenges addressed by the Blockchain solutions introduced by public sector bodies or by organisations that have used Blockchain to tackle environmental or social challenges: The policies included in the scoping analyses were as follows:

11. European Blockchain Services Infrastructure
12. Carbon Credit Management: Energy Blockchain Labs (IBM)
13. Swedish Land Registry
14. Danish Vehicle Wallet
15. Made In Italy
16. Maritime Insurance Supply Chain
17. Dutch Blockchain Coalition
18. Portuguese Blockchain Alliance
19. Smart City Vienna
20. Blockchain Estonia

Table 23 European Blockchain Services Infrastructure (EBSI)

Criteria	European Blockchain Partnership: European Blockchain Services Infrastructure
Objectives and case description	*Objective:* In April 2018, EU Member States and Norway signed a Joint Declaration creating the European Blockchain Partnership (EBP) and initiating cooperation on the establishment of a European Blockchain Services Infrastructure (EBSI) that will support the delivery of cross-border digital public services, with the highest standards of security and privacy. Since the initial signature of the Joint Declaration in April 2018, several new Member States have joined the partnership and at present, the Partnership includes 27 Member States, Norway and Liechtenstein. The objective of EBSI is to provide a common, shared, and open European services infrastructure based on blockchain technologies aimed at providing a secure and interoperable platform that will support and enable the development of cross-border digital services in the public sector. It should meet the highest available standards, e.g., in terms of security, privacy or sustainability. Different use cases have been defined and are in the process of implementation on EBSI to illustrate the potential of such a reliable cross-border infrastructure for public agencies as well as private organizations and citizens. The most relevant EBSI use cases for EU climate policy implementation are document traceability (DT) as well as trusted data sharing (TDS).
Challenges and solutions	*Lack of trust:* Tracking and tracing of documents with proof of authenticity in cross-border transactions with different authorities and jurisdictions involved can be very cumbersome. Proof of ownership, identity and identifiers, or accurateness and validity of certificates issued by authorities in another country is a known barrier for cross-border transactions based on a lack of trust and transparency of documents exchanged. *Solution*: In order to promote cross-border cooperation and provide easy access to information of public/private institutions in EU regulated markets, the TDS use case is developing a platform that offers a single view for such information currently stored within different member states' infrastructures. The DT use case implemented on EBSI allows for document traceability as it

validates or "notarises" documents and related metadata by recording their hashes on EBSI. That data record can be used at a later stage as immutable proof of authenticity/integrity of a given file.

Transactional History: Approving and re-accreditation of documents necessary in cross-border exchanges requires notarization agencies, translators and auditing experts, as well as employees in the public sector validating the authenticity of documents issued by other authorities abroad. The process is mainly paper-based and slow, and often requires physical documents with signatures shipped. process not being digital, entries in the land registry can be missing, incomplete, or wrong.

Solution: The EBSI-based DT and TDS use cases support a set of cross-border digital public sector services that require certificates and documents as specifed by the European Court of Auditors that are now EBSI-registered and thus auditable if necessary.

Transactional costs: The existing process is slow and involves significant investments of time and effort for document preparation, authentication, and verification. It is assumed, that EBSI may allow for reducing the number of steps and gateways currently required to trace and authenticate documents by 40% in the case of VAT ID sharing between taxation and customs authorities once using EBSI. It is fair to assume that other cross-border process may reduce in complexity and thus transactions costs at a similar rate.

Solution: The EBSI-based DT and TDS use cases can support different cross-border scenarios and application areas. In case of cross-border VAT fraud, EBSI can ensure sharing and availability of VAT identities and enable the authorization of trading partners' identity as defined by the EU import schema one-stop-shop regulation as issued by the taxation authorities of the member states.

Fraud: VAT fraud due to faked invoices or the reimbursement of taxes that were never paid in the cum-ex and cum-cum tax scandals, as well as identity fraud and forget ("photoshoped") certificates of degrees and diplomas are a huge problem not only in Europe. As physical documents and certificates issued by authorities in other countries cannot cross-validated easily, existing loopholes and possibilities to act fraudulently are exploited by criminals.

Solution: EBSI-enforced public sector processes relying on tamper-resistant and authenticated documents such as diplomas, passports, trade documents, tax declarations etc. allow for cross-border transactions validated by the issuing authorities and the EBSI-deploying member states. As citizens do not have to authenticate themselves again in a foreign state but can do so via their authentication system in their home country (single sign on), the validity of documents, identities, and ownership rights can be instantly verified by the issuing authorities. This will allow for fewer attack vectors criminals can exploit in their attempt to commit fraud.

Verification: The verification of documents and certificates such as physical passports of shipping documents is very cumbersome and failure prone. In addition, physical forms of verifications, such as paper-based documents, might be expired, or the rights accompanied with such documents might be revoked in the meantime. It is nearly impossible in an offline verification situation, e.g., when arriving at customs at an airport to verify in real-time if the passport and identity of a person is still valid. Thus, apart from being able to

	verify rights or identities, which is challenging already, it is even more challenging to identify if a document or credential is still valid. *Solution:* EBSI is providing mechanisms for cross-border verification of identities, verifies identifiers, and can verify the integrity of all kinds of other documents and certificates. In addition, EBSI allows for sophisticated revocation mechanisms that combine high privacy and GDPR conformance with high scalability. This can be achieved using zero-knowledge proofs (ZKPs). While ZKP signatures are still in the process of approvement, privacy preserving ZKP-based revocation of verifiers will most likely be part of EBSI at some point.

Table 24 Carbon Credit Management Energy Blockchain Labs Inc.

Criteria	Carbon Credit Management: Energy Blockchain Labs Inc.
Objectives	Energy-Blockchain Lab, a Beijing-based collaborative initiative on energy and environment blockchain applications, has partnered with IBM to create a carbon credit management platform that uses the permissioned DLT Hyperledger Fabric. The initiative has completed proof of concept in 2016. In response to meeting the Paris Agreement, the Chinese government established Carbon Emission Reduction quotas, which fix carbon emissions limits to enterprises and individuals. Those quotas can be traded as a carbon asset: in practical terms, high-carbon emitting enterprises can buy the equivalent of their reduction quotas from low-emission enterprises and use those funds to invest in greener technology. Energy-Blockchain has created a carbon asset development platform to help organizations more easily comply with the Chinese government mandated CER quotas. IBM Blockchain technology is the foundation, providing a general, immutable distributed ledger. The platform builds a seamless data bridge between the green economy and all of its stakeholders, including the emission enterprises, governments, local governments, central governments, carbon asset exchanges, third-party inspections and certification bodies, companies.
Challenges and solutions	*Security:* Carbon markets has been the subject of cyber-attacks, and there has been multiple instances, where some allocated quotas have been stolen. (EU ETS 2011)[38] *Solution*: The platform will provide a seamless bridge between regulators, industry, energy exchanges and inspectorates, by providing a single view into the precise origin and verifiable ownership of carbon credits, and an immutable transaction history record. *Fraud:* The Chinese carbon emissions trading system has been prone to fraud, where the authority has uncovered a cluster of cases involving falsification of CO_2 emission figures, fake samples etc.[39] *Solution:* Energy Blockchain Labs integrates the carbon asset development ledger with a broader universal distributed ledger—also based on IBM Blockchain technology—that records and quantifies the environmental

[38] Austria Recovers Stolen Carbon Allowances Found in Sweden - Bloomberg

[39] China uncovers fraud scheme in carbon emission reporting | Upstream Online

	impact of participants' energy production and consumption activities; helps store that information securely and provides transparency to all stakeholders. *Transactional history:* The conventional carbon market faces lack of transparency, as the records of the carbon credits are not documented. *Solution:* The immutable distributed ledger has a record of all transactions, which helps to ensure that all data is traceable, transparent and visible in real time to all stakeholders. Monitoring challenges: Regulators face difficulties monitoring the emissions from the actors in the market. *Solution:* The distributed ledger records enables regulators to easily monitor progress against quotas to ensure that participants meet carbon reduction goals. *Transactional cost*: The carbon assets development cycle has a heavy administrative burden due to the large amount of administrative steps with many actors[40]. *Solution:* The blockchain technology will reduce the cost of carbon assets development by 20 to 30 percent, enabling cost-effective development of a large number of carbon assets[41].

Table 25 Swedish Land registry

Criteria	Pilot project: Swedish Land registry
Objectives and case description	Objective: The Swedish mapping, cadastral and land registration authority (Lantmäteriet) has concluded the third phase (full demonstration) using blockchain technology together with several other actors in the Swedish private and public sectors as partners. It remains to be seen if Lantmäteriet decides to fully implement it. The project has utilized blockchain to verify the transfer of real property between parties by registration in the Swedish land registry, with the goal of saving both time and costs from an administrative perspective, by exploiting the built-in transparency and security of the blockchain technology. The intent was to reduce the time between the signing of a contract to purchase and the registration of the property title from four months to a few days; this was to be achieved through the elimination of steps in the process and by reducing delays brought about by mail and the need for repeated checks and physical signatures.
Challenges and solutions	*Lack of trust:* Under the existing land registry system, the Lantmäteriet is only involved relatively late in the transfer process: when the buyer's bank sends the title registry application, bill of sale, and any application for a new mortgage to Lantmäteriet. As a result, the transfer does not become visible within the registry until long after contracts are signed – and given that the authority is the most trusted actor in the process, its absence from earlier phases reduces the transparency and the trust. *Solution*: The blockchain solution increases trust in the transfer of title taking place since all necessary information is captured by the system and visible to all parties before signing.

[40] World Bank Document (ercst.org)

[41] Energy Blockchain Labs Inc. | IBM

Transactional History: The land registration has been digitized since the 1970s, the efficiency and accuracy of the existing land transfer process have been held back by legacy processes and legislation mandating paper transactions and physical signatures. The process currently involves numerous paper documents that must be physically signed and exchanged via regular mail. In addition to the land transfer process not being digital, entries in the land registry can be missing, incomplete, or wrong.

Solution: The blockchain entails a cloud-based storage which functions as a central register, where information about the purchase price and the property can be made public, which provides security for the Buyer and Seller. The blockchain technology will make it possible to release verification records for documents, registries, and more outside of firewalls without jeopardizing the security of the original documents.

Transactional costs: The existing process is slow and involves significant investments of time and effort for document preparation, authentication, and verification: processing a real estate sale from the signing of a contract to purchase to land transfer takes an average of four months.

Solution: The application of blockchain will reduce the time between the signing of a contract to purchase and the registration of the property title from four months to a few days; this was to be achieved through the elimination of steps in the process and by reducing delays brought about by mail and the need for repeated checks and physical signatures.

Fraud: The existing system has the potential to encompass fraudulent behaviour among actors, as it is not ensured that the 'right' people are the ones that fills out the documents. In addition, the files could have the potential to be manipulated.

Solution: A central part of the system is the identification of the actors who will have rights to act in the system. For this, a secure ID solution is required. This solution makes it harder to tamper with the transaction, and conduct fraudulent behaviour, since the identities can easily be traced. Digital signatures provide a significantly greater level of security that the correct people will be filling out the documents rather than using an all-paper process. Since digital signatures are provided with the same application at several instances, the risk of errors and fraud is reduced. The process involves multiple contact points and multiple signatures by the parties involved.

Verification: The Swedish authority 'Lantmäteriet' is relatively late in the process. Prior to that, it is primarily the agent who checks the land registry to check the ownership of the property. There are several disadvantages with this system. Lantmäteriet is the actor with the highest credibility, and if Lantmäteriet is involved earlier, the confidence and transparency in the process increases.

Solution: The blockchain saves the verification records of documents such as the bill of sale and the purchasing contract, all signatures etc. Storing the original documents and their verification records can be performed by an external party, but can also be stored digitally by each party in the agreement, the bank, buyer, seller, agent, etc.

Table 26 Danish Vehicle Wallet

Criteria	Danish Vehicle Wallet
Objectives and case description	*Objective:* Vehicle Wallet was a concept project based on a partnership between payment service providers, the Danish Tax Administration and the National Motor Registry and aims to reduce fraud. It is a supply chain management tool that uses Blockchain. Data on a vehicle is saved on one distributed ledger and creates one agreed and shared record of the vehicle history as the product goes through its life cycle from manufacturing to scrapping (data stored includes manufacturing, registration, tests, repairs, loans, insurance, changes in ownership, vehicle controls, and scrapping). The project remains a proof of concept.
Challenges and solutions	*Lack of trust:* Buying and selling a car is a matter of trust, not least when it comes to used vehicles. In Denmark, a three-week period typically follows the transaction, during which the buyer and the seller would formerly settle the paperwork with their insurance companies and other parties, often by manual processes and traditional mail. During this time, the seller is registered as the legal owner or user of the car until the buyer has notified the motor vehicle registration authorities, and is thus potentially exposed to parking tickets, speeding fines etc. In a few instances, the buyer, unbeknownst to the seller, never notifies the authorities of the change of ownership. *Solution*: Using blockchain technology shifted the process of registering car ownership onto a blockchain-based setup. A blockchain-based concept could give SKAT and many other stakeholders a full overview of the life cycle of the vehicle, from the moment of import right through to decommissioning – when VAT and duties are initially paid at licensing and registration, until it is sold from a car dealership – every step of the way, the tax authorities would know be able to identify the rightful owner of the vehicle. This would limit the risk of fraud and enhance the level of trust throughout the process. *Transaction History*: For the owner of a car, it could be an advantage to know the full history of the vehicle and be certain there are no unresolved issues or claims related to it, in the current system this information is not available. In addition, it is not known whether any accidents or subsequent repair by a registered garage are registered. *Solution:* Storing all relevant documents in an open ledger, paired with cloud-based technology, enables several parties to access the data which could lead to highly efficient automated processes. This would make it possible to eventually add yet another layer of activities related to the lifecycle management of the car and registering the related documentation such as registration tax, green taxes, a notice to take the MOT test to renew certificates, a list of licensed garages performing MOT, etc. *Fraud:* In the transaction of used vehicles, there has been several incidents where the seller of the vehicles hasn't been the rightful owner of the vehicle. In addition, it is a known fact that the milage indicator is prone to be tampered with by the sellers to manipulate the selling price, and as a result buyers of vehicles may be buying a car of less value than they expect – do to a higher milage record. *Solution:* Storing all relevant documents in an open ledger, paired with cloud-based technology, enables several parties to access the data which could lead to highly efficient automated processes and thereby enhance the transparency. This would make it possible to eventually add yet another layer

	of activities related to the lifecycle management of the car and registering the related documentation such as registration tax, green taxes, a notice to take the MOT test to renew certificates, a list of licensed garages performing MOT, etc. This would in turn limit the risk of fraud.

Table 27 Made in Italy

Criteria	Made in Italy blockchain for traceability across value chain (Italy)
Objectives	*Objective*: To support Made in Italy branding across various Italian produce by introducing novel ways or tracking products across the value chain; ensure that forgeries are not branded as, and subsequently diminish the value of, Made in Italy brand. In the context of blockchain, this takes the form of different projects exploring the benefits of blockchain as a tool for traceability to allow efficient tracking of the product life cycle.
Challenges and solutions	*Type of challenge*: Verification. The Italian Ministry of Economic Development (MISE) is looking into ways blockchain technology can be used to leverage product traceability and verification of the origin of products and product components. The interest is ensuring that products labelled as Made in Italy can be 100% certified to be of Italian origin. The interest in blockchain ranges from the agri and food industry to textiles. *Solution*: MISE has launched several projects (Blockchain to change textile industry[42], Agri-Food TRACK[43]) to explore the application of blockchain to track products across the value chain. These projects are developed in partnership with IBM, overseeing the technical side and have involved industry consultations and workshop to analyse the needs and challenges associated to the introduction of blockchain as a traceability tool. In 2019 this resulted in a feasibility study exploring the potential of wider deployment in Italy in association to Made in Italy branding.[44] By December 2022, as part of the Agri-Foot TRACK project, funded by MISE, a data platform using blockchain technology was launched allowing for the traceability of Made in Italy agri-food products. *Type of challenge*: Lack of trust. This could be considered a pre-emptive challenge whereby MISE seeks to ensure industry and consumer trust in the Made in Italy branding. *Solution*: Part of the proposed solutions for blockchain use is in the development of shared platform which enables specific traceability functions to certify the quality, origin, ethics, etc. of registered products. The information would be made available to companies and consumers alike, meaning there is verifiable proof regarding Italy as the country of origin for the products in question. Efforts in this regard have led to use of blockchain in the traceability and verification system used for the Agri-Food TRACK platform, which, at least in Italy, is the first time that use of blockchain in traceability showcases environmental and socio-economic sustainability indicators of the traced product. The traceability indicators for Agri-Food TRACK were developed with

[42] Italian Ministry of Economic Development (2019). Blockchain per la tracciabilità del Made in Italy. Available at: https://www.mise.gov.it/index.php/it/normativa/notifiche-e-avvisi/blockchain-per-la-tracciabilita-del-made-in-italy

[43] Second Tempo (2022). Agri-Food TRACK: la blockchain per seguire le tracce del Made in Italy. Available at: https://secondotempo.cattolicanews.it/news-agri-food-track-la-blockchain-per-seguire-le-tracce-del-made-in-italy

[44] Italian Ministry of Economic Development (2019). PREMESSA: PROTEGGERE IL MADE IN ITALY CON LA BLOCKCHAIN. Available at: https://www.mise.gov.it/images/stories/documenti/IBM-MISE-2019-BC.pdf

	the lead of Catholic University of the Sacred Heart (Università Cattolica del Sacro Cuore) and based on the VIVA ministerial certification system, the Single Standard of Sustainability of the Wine Sector and the National Quality System of Integrated Production (SQNPI). Through these measures it is hoped that Made in Italy branding would solidify trust in both industry and consumer bases, creating trust in the branding.

Table 28 Marine Insurance Supply Chain

Criteria	Marine insurance supply chain
Objectives	*Objective:* Marine insurance has not kept up with the digital era. Marine insurance, a critical component of the global trade ecosystem, is still an industry based on the certainty of paperwork, emails, weather forecasts and a large amount of guess work. Insurwave, a commercialised system, built by a joint venture between EY and Guardtime, leverages blockchain and distributed ledger technologies Microsoft Azure infrastructure and ACORD data standards. The platform was also developed in collaboration with MAERSK and broker Willis Towers Watson and insurers MS Amlin and XL Catlin). The aim of the platform is to integrate information from clients, brokers, insurers and third parties with insurance contracts in a standardised, secure and transparent format[45]. By connecting participants in a secure, permissioned private network with an accurate, immutable audit trail and services to execute processes, the platform establishes a first of its kind digital insurance value chain. The platform was launched in 2018 and is supposed to support more than half a million automated ledger transactions and help manage risk for over 1000 commercial vessels in the first year of its activity (EY, 2018). As of now the platform is used to insure 3375 assets with an insured value of $583bn corresponding to 8 pct of the global marine fleet[46]. › Claims to be paid in hours, not years › Premiums to be agreed and settled in seconds › Shippers to track assets and share data with brokers and insurers › Brokers to focus more on servicing clients and less on administration › Insurers to track their exposures in near real-time
Challenges and solutions	*Security*: Vast amount of paper contracts and a vast number of actors involved can lead to unauthorized access and editing of the contracts. *Solution:* Blockchain facilitates the secure capture and sharing of data among chosen participants in real time with an immutable audit trail – which increases the security of the process, as there is no way to manipulate the data without a trail. *Transactional history*: Because there's no common record of all transactions, there is no immutable audit trail. These factors can result in potential gaps in coverage and both underpayment and overpayment of claims. They can

[45] ey-marine-blockchain-pov.pdf

[46] Insurwave: view your assets, understand your risks, protect your business.

	also create problems with billing and invoice reconciliation that generate unnecessary credit risks. *Solution:* As blockchain provides an immutable audit trail, actors with access to the database can easily verify the data. Also, the blockchain-enabled platform helps to address connects clients, brokers, insurers and third parties to distributed common ledgers that capture data about identities, risks and exposures and integrates this data with insurance contracts. *Lack of trust:* The vast amount of paperwork, as well as multiple actors can lead to errors, which ultimately will lower the level of trust in the transactions. *Solution:* The visibility and transparency created by the blockchain-enabled platform generates a greater level of trust between all companies in the value chain, opening the door to more collaboration and innovation. *Transactional costs:* The Marine insurance market is weighed down by complex paper chains that prevent transparency, compliance and accurate exposure management. There is significant duplication of information across multiple parties, particularly regarding risk, exposure, premiums and claims. Companies rely too much on poorly integrated manual processes. *Solution:* The blockchain-enabled platform helps to address these structural issues. It connects clients, brokers, insurers and third parties to distributed common ledgers that capture data about identities, risks and exposures and integrates this data with insurance contracts – which drives down the errors and lack of transparency and thereby creating a more efficient and rightful process of insurance claims.

Table 29 Dutch Blockchain Coalition

Criteria	The Dutch Blockchain Coalition
Objectives	*Objective*: The Dutch Blockchain Coalition (DBC) is an association that brings together representatives from government, experts from the public and private sector. The overall objective of DBC is to: "increase both knowledge and use of blockchain in the Netherlands, thereby speeding up the decentralise of digital infrastructure. In that context, the DBC is primarily a catalyst and a facilitator, activating and connecting an extensive public-private network."[47] Across its six areas of interest (internationalisation, standardisation, Human Capital Agenda (HCA), research and innovation, Self-Sovereign Identity (SSI) and cryptoeconomics), DBC has a number of example initiatives of supporting blockchain-based services introduced in the Netherlands aiming to ensure the country is progressing in the digitisation of services and is a proactive player in novel technology development and application.
Challenges and solutions	*Type of challenge*: Transactional costs. Even after registration, businesses must apply to access documents when trading in economic transactions (i.e., opening a bank account, entering a commercial relationship, etc.). The process necessitates investment from businesses and the process could be made simpler and more efficient through digital technologies.

[47] Dutch Blockchain Coalition (2023). About us. Available at: https://dutchblockchaincoalition.org/en/about-us

Solution: The Dutch Blockchain Coalition, together with the Dutch Tax Authorities and several other partners (KNB, KVK, ABN AMRO) are piloting the use of Self Sovereign Identity (SSI) and blockchain technology to develop a system for businesses to register and gain access to the required documentation necessary for their economic activity.[48] It is expected that the pilot will leverage blockchain technology in creating a digital environment to register a company and support subsequent management of data.

Type of challenge: Fraud and Poor enforcement. DBC is working on the challenges faced by the marine shipping sector in enabling smoother, more transparent and secure process of billing and documentation. Digitisation and automation of the processes could lead to huge savings for the industry as well as increased trust in the shipping sector.

Solution: DBC is partnering with the Port of Rotterdam Authority, Blocklab, Rabobank, Hoogwegt and Duch and Singapore government agencies for the development of tradable digital bill of lading (e-BL). By leveraging blockchain technology, the partners expect to create a paperless system for the transfer of ownership documents. The potential economic impact of this approach is noted by the Digital Container Shipping Association (DCSA), which forecasts that a 50% take-up for the e-BL could lead to $4 billion annual savings for the marine industry. The project is currently engaged in the so-called Global Showcase Digital Transfer of Ownership of the Bill of Lading where the potential of the technology is being piloted (and demonstrated) between the Netherlands and Singapore. In the future, the adoption of this technology is expected to strengthen the Netherlands position as a maritime operator.[49]

Type of challenge: Regulatory uncertainty and Poor enforcement. The Dutch Government recognises that citizens, companies, public organisations, etc. may not always be aware of the full set of regulations, benefits that are applicable to them when engaging with various services. Furthermore, beyond potential benefits, subsidies that might be available to different stakeholder groups, there is also the risk of localised interpretations of complex legislation that might lead to incorrect assumptions (made not out of malicious intentions but rather incomplete understanding of the regulatory environment).

Solution: DBC is working together with the Government IT foundation ICTU, various Government agencies, the Netherlands Organisation for Applied Scientific Research TNO on the project Compliance by Design – a project that aim to develop a: "method that allows legally compliant, accessible and explainable e-services to be created for members of the public and companies."[50] The project entered its piloting phase in 2018 and by 2021 the Dutch Government greenlight nationwide scaleup. The principle of Compliance by Design is to use blockchain technology towards automatically executable rules and regulations across various public e-services (i.e., automatic use of subsidies for which the stakeholder is eligible). Through the system, different regulatory structures are able to communicate and enable

[48] Dutch Blockchain Coalition (2023). Company Passport. Available at: https://dutchblockchaincoalition.org/en/use-cases-2/entrepreneur-passport

[49] Dutch Blockchain Coalition (2022). Succesvolle kick-off Global Showcase Digital Transfer of Ownership of the Bill of Lading. Available at: https://www.dutchblockchaincoalition.org/nieuws/kick-off-global-showcase-digital-transfer-of-ownership-of-the-bill-of-lading

[50] Dutch Blockchain Coalition (2023). Compliance by design. Available at: https://dutchblockchaincoalition.org/en/use-cases-2/compliance-by-design

	better compliance and increased benefits for stakeholders interacting with public services.

Table 30 Portuguese Blockchain Alliance

Criteria	Portuguese Blockchain Alliance
Objectives	*Objective*: The Portuguese Blockchain Alliance is an organisation bringing together members of Portuguese public and private sector with the goal: "to develop an ecosystem of Portuguese enterprises, academia, and public organizations in order to provide the Portuguese economic system the right knowledge tools on Blockchain."[51] It acts as an awareness building platform that is attempting to support capacity building in Portugal, to ensure that organisations from different sectors are prepared for the opportunities offered by blockchain technology. To that end, the Portuguese Blockchain Alliance offers a view into the different initiatives to introduce blockchain into the public and private sector in Portugal. This is achieved through various challenges that target different sectors to submit proposals on the development of blockchain solutions.
Challenges and solutions	*Type of challenge*: Transactional costs. Redes Energéticas Nacionais (REN) has been appointed by the Government of Portugal as the concession holder of the National Electricity Transmission Grid (RNT) and the National Natural Gas Transportation Grid (RNTGN). In its pursuit towards greater use of renewable energy and opening up the energy sector to more firms, REN launched a call for proposals to explore the potential application of blockchain technology in the Portuguese energy sector, offering consumers greater choice in their energy providers and source of energy. The objective of this actions was to identify partner organisations that could develop a platform for negotiating the purchase and sale of energy where micro and mini producers can have an additional source of income and consumers the option of choosing the cheapest supplier through the use of Blockchain technology.[52] *Solution*: The Portuguese Blockchain Alliance launched a project on behalf of REN "REN Energy Challenge" to fund exploring the use of blockchain technology to enable consumers greater access and choice for the energy market, with a focus on supporting renewable energy. The winning project "Blockbird.energy +" (proposed and subsequently managed by Blockbird Ventures) will be developing a platform where consumers can use Ethereum ERC-721 token to purchase and sale of energy, including capacity to choose the method of energy product (i.e., solar energy, wind energy, etc.). Ensuring energy consumers have access to make choices about their energy providers and the costs they are willing to pay. On the energy producer side, it would allow small and medium energy producers better access to the market and the consumer base by enabling them direct competition with larger providers. *Type of challenge*: Fraud and Monitoring challenges. Lisbon Municipal Enterprise of Mobility and Parking (EMEL) launched a challenge to identify blockchain based solutions to accurately monitor car ownership and parking

[51] Portuguese Blockchain Alliance (2023). The Alliance. Available at: https://all2bc.com/en/alliance

[52] Macedo C. (2018). REN premeia solução de Blockchain que pode mudar setor energético em Portugal. Available at: https://www.ambientemagazine.com/ren-premeia-solucao-de-blockchain-que-pode-mudar-setor-energetico-em-portugal/

	within the municipality of Lisbon. Additionally, it is expected that accurate integrated records of car parking will allow city planes make better predictions regarding parking needs. *Solution*: The challenge was awarded to Marionete which proposed a blockchain registry that collects, processes and shares parking information between different public transport organisations. The solution improves the monitoring of parking by integrating different data sources (car ownership, owner data, parking disc data) through blockchain verification.

Table 31 Smart City Vienna

Criteria	Smart City Vienna
Objectives	*Objective*: The Smart City Vienna was conceived back in 2011 with the city examining the potential of novel technologies to be deployed towards various different urban initiatives that would lead to energy, cost, time, etc. savings and improve the livelihood of Viennese citizens. The efforts culminated in 2014 when the first iteration of the Smart City Vienna strategy was published, with its mission remaining the same since then – to ensure ""High quality of life for everyone in Vienna through social and technical innovation in all areas, while maximising conservation of resources."[53] Under the strategy various different projects have been launched, leveraging new digital technologies in urban development and planning, sustainability, energy, public administration and others. Among these technologies blockchain is being utilised for its potential to ensure data protection.
Challenges and solutions	*Type of challenge*: Monitoring challenges, Security. Under Smart City Vienna the municipal administration explored the potential of using digital technologies to reduce the bureaucratic strain on various public services. It was envisioned that blockchain could be leveraged to create a more efficient system of monitoring, validating and securing Vienna's Open Government Data. A particular focus was given to public transport routes, train schedules and voting results. *Solution*: As part of the larger DigitalCity.Wien initiative (itself under the overarching Smart City Vienna), the city partnered with EY in late 2017 to start developing a pilot project to automate administrative processes. Blockchain is being utilised to help digitise and secure the city's administrative information on blockchain networks that store hashtags of the city's administrative data sets. As the utilised blockchain networks are public, both employees in the city's municipality, various public agencies and ordinary citizens are able to review these official documents and check their authenticity, the date of creation and modification. It took four months for IT specialists employed by the city to develop the Open Government platform while EY managed the work and ensured the integration of blockchain networks into the platform. By 2020 the team managed to store 350 administrative data sets with optimism from the city's municipality regarding the efficiency of the new system and

[53] Smart City Vienna (2023). Smart Climate City Strategy Vienna – our way to becoming a model climate city. Available at: https://smartcity.wien.gv.at/en/strategy/

	predictions that this approach could be taken to the national level and help digitise and secure the documentation of the Austrian Government.[54] *Type of challenge*: Transactional costs. Part of the development challenges being addressed through Smart City Vienna are related to the energy sector – ensuring greater access to the market for consumers and producers and involving greener energy to the overall supply. VIERTEL ZWEI urban development area in Vienna's Leopoldstadt was implementing the Urban Pioneers Community project which was piloting various neighbourhood or community driven approaches to test application of digital technologies with the hopes of scaling them up in the future. *Solution*: In early 2018 Wien Energie partnered with Riddle & Code to create a blockchain infrastructure for the VIERTEL ZWEI urban development area. The blockchain would allow residents direct access to novel opportunities to engage with the energy sector while Wien Energie could test new business approaches in how energy is supplied and purchased by citizens. Through blockchain, Wien Energy has the capacity to harmonise different energy suppliers and offer greater access and choice to consumers regarding their energy needs and source (i.e., a resident of VIERTEL ZWEI could choose the source of energy used to charge their electric car at a public charging node). The unique approach enabled by Smart City Vienna means that the residents of VIERTEL ZWEI are active participants in the testing and developing new solutions for the energy sector.[55]

Table 32 Blockchain Estonia

Criteria	Blockchain Estonia
Objectives	*Objective*: To support the digitisation of Estonian public sector and services by enabling a secure digital environment where personal data is protected and any potential breaches in data can be detected fast and accurately pinpointed.[56] Blockchain is now used to manage records across health, property, business and succession registries, court system and the State Gazette.[57]
Challenges and solutions	*Type of challenge*: Security. A safe digital environment for data is seen as paramount towards citizen trust and confidence in the government services. *Solution*: With piloting efforts starting in 2008, Estonia was the first country to employ blockchain technology in public services (utilising it before the term "blockchain" was even in use). By 2012 blockchain in Estonia was being used to protect national data, e-services and smart devices. Estonia developed its KSI Blockchain – the same blockchain technology used by NATO. The principle of ensuring data protection and trust is that no actual data is stored on the blockchain itself; rather, the blockchain records a digital "fingerprint" of data recorded. This way the blockchain does not allow access to sensisitive

[54] ITU (2020). Vienna rolls out blockchain platform to reduce bureaucracy. Available at: https://www.itu.int/hub/2020/05/vienna-rolls-out-blockchain-platform-to-reduce-bureaucracy/

[55] Smart City Vienna (2023). Wien Energie as a pioneer in the energy sector. Available at: https://smartcity.wien.gv.at/en/blockchain-in-the-energy-sector/

[56] PWC (2019). Estonia – the Digital Republic Secured by Blockchain. Available at: https://www.pwc.com/gx/en/services/legal/tech/assets/estonia-the-digital-republic-secured-by-blockchain.pdf

[57] Blockchain-based application at a governmental level: The case of Estonia

personal data but it does instantly show whether data has been tampered with and precisely which parts of the data in question. This is due to the data "fingerprint" being mismatched with the change in the original data. The digital "fingerprint" stored on the blockchain is immutable and enables mathematical proof whether changes were made to the original.[58]

Type of challenge: Reporting delays. Typically, when errors are made in documentation, or are otherwise tampered with, it can take a significant amount of time for these changes to be noticed, traced, verified and corrected, creating the need for significant time investment on behalf of public service providers.

Solution: By deploying blockchain to ensure the security of its public services, Estonia is also creating considerable time savings for the tracking of errors. According to Estonian authorities, it can take up to 7 months to discover the breach or misuse of data under normal circumstances. By securing public data on the blockchain, Estonian authorities report that such breaches, errors, misuses, etc. can be detected almost instantly. While this does mean that blockchain itself is not a preventative measure from error or fraud, it is a highly effective tool in detection.

[58] E-Estonia (2020). Estonian blockchain technology. Available at: https://e-estonia.com/wp-content/uploads/2020mar-nochanges-faq-a4-v03-blockchain-1-1.pdf

Analysis of the potential of Blockchain to address key climate EU policy challenges

This section provides an analysis of the potential of Blockchain to be introduced to selected EU climate policies considering the challenges of implementation and the possible solutions that Blockchain may provide in reducing or removing those challenges. The policies included were as follows:

The policies included in the scoping analyses were as follows.

No	Legislation / Policies
1	EU Emissions Trading System (ETS) Directive 2003-87-EC
2	ETS Implementing Regulation No 601/2012 (Monitoring, Reporting and Verification).
3	Effort Sharing Regulation (EU) 2018/842
4	Land use, land use change and forestry (LULUCF) Regulation 2018/841
5	EU 'Ozone Regulation' – Regulation (EC) 1005/2009
6	Regulation (EU) No 517/2014 (the 'F-gas Regulation')
7	EU Sustainable Product Initiative
8	Proposed EU Carbon Removal Certification
9	The Carbon Border Adjustment Mechanism (CBAM)

Table 33 EU ETS and MRV

Criteria	Analysis of challenges and solutions under the EU ETS and MRV
Challenges and possible solutions	*Transactional costs*: financial intermediaries and centralised databases are currently used to facilitate the allocation and exchange of carbon allowances. *Solution*: Blockchain could lower transactional costs and make exchanges of allowances more efficient through the provision of peer-to-peer transactional arrangements. *Solution*: IoT combined with Smart Contracts could be used to automate carbon allowance exchanges in response to operator emission thresholds, therefore improving the efficiency of the market and compliance. *Fraud:* There have been claims of fraudulent sales of carbon allowances including the duplicated selling of the same allowance to several parties. *Solution*: Blockchain can offer traceability of ownership and confirmation of sales through the use of cryptographic methods (i.e., unique hash codes), immutable records, and an algorithmically enforced consensus model to validate that a transaction occurred. *Regulatory uncertainty and enforcement*: The identified fraud has been made possible in parts due to fragmented national regulatory systems, and inconsistent inspection of markets by national authorities.[59] *Solution*: Smart contracts in combination with Blockchain can provide a consistent and uniformly enforced set of rules to support exchange of

[59] Trading of CO2 certificates: Blockchain as a solution - Lexology

	allowances, along with the security benefits mentioned above of using blockchain for transactions. *Compliance challenges*: There is a risk that centralised databases are hacked, or fraudulent activities take place such as submission of emissions reports that have not been verified. *Solution:* The role of accredited verifiers could be enhanced using unique hash codes and consensus mechanisms to indicate verification of the monitoring plan and annual emissions report – thus providing secure and accurate signalling to Member State authorities of the status of the needed documents and information. *Accurate emissions monitoring*: Emissions monitoring based on estimated calculations are complex to implement and may be at risk of underestimating the true level of emissions. *Solution*: Blockchain combined with other technologies could be used to strengthen compliance. For example, emissions could be monitored precisely and in real-time using sensors and IoT to gather data and update reported measures via the blockchain.

Table 34 Analysis of challenges and solutions: LULUCF

Criteria	Analysis of challenges and solutions LULUCF
Challenges and possible solutions	*Transactional costs*: Consistent data about GHG emissions from LULUCF processes on member state level is costly to aggregate, as different models are used to calculate and aggregate such data on national and subsequently, EU level. For example, two forestry models are used in parallel (G4M and EFISCEN). *Solution*: While blockchain itself cannot solve the problem of lacking unified aggregation and measurement models, in the light of blockchain-based potential efficiency increases, the pressure on harmonized models may help and ultimately lower transaction costs. *Fraud:* Illegal logging and related trade constitute other significant issues. Paperwork is being faked and people are being bribed. *Solution*: Blockchain can offer traceability of logging activities, e.g., in combination with hashed and archived proof of deforestation based on satellite pictures. Cash flows in the context of regenerative finance can be audited when based on blockchain, which minimizes the ability of kick-back payments or other types of bribery. *Regulatory uncertainty and enforcement*: While LULUCF are providing the regulatory framework and thus relative certainty, the enforcement across member states and their implementation in national jurisdiction remains an issue. *Solution*: Smart contracts in combination with Blockchain can provide a consistent set of rules enforced cross-border. While national data sovereignty can be guarantee wherever needed using ZKP signatures, the uniform enforcement of LULUCF rules can be secured. *Compliance challenges*: For enforcing compliance in LULUCF activities various reporting obligations must be fulfilled, following the Common

	Reporting Format (CRF). However, not all CRF tables contain sufficient detail in their default structure to meet compliance requirements. *Solution:* The CRF tables needed for enforcing compliance in LULUCF activities can be codified in smart contracts as well as data format standards enforced by blockchain, to allow for uniform application and compliance regimes in all Member States. *Accurate emissions monitoring:* Emissions monitoring for LULUCF activities is compiled and stored centrally on national level. Improvement or accuracy testing is also performed nationally. Due to delays in reporting and differences in the quality of monitored data, an EU-wide emission monitoring can be compromised. *Solution*: Blockchain combined with other technologies could be used to develop an EU land use database that would substantially improve transparency, connectivity, and accessibility for all member states.

Table 35 Analysis of Voluntary carbon market (VCM)

Criteria	Analysis of challenges and solutions under Sustainable carbon cycles (carbon removals certification)
Challenges and possible solutions	Carbon farming and industrial projects that invest in carbon removals today should have a prospect of a future robust accounting and certification framework that ensures comparability and recognition of the action started already on the ground. *Verification*: The main difficulty is to obtain viable data on carbon removals as it is very difficult to measure. There are key issues in document verification are in storage, retrieval and access to data. The high degree of confusion by incorrectly defining certain CO2 emissions reductions as carbon removal is also a common mistake that must be better controlled. We should avoid double-counting, accounted only once, separately from emission reductions, in national greenhouse gas inventories. *Lack of trust*: An issue is that many stakeholders do not trust carbon removal certificates because certificates may be generated through unreliable certification processes which certify activities that are not delivering strong sustainable benefits. To tackle this problem, certification schemes should set up more transparency and strongest rules and procedures to mitigate the risks that the certification process is not able to detect low-quality removals, that the carbon removal projects are not actually delivering the removals as planned, and that the same project is certified and used twice. Another issue is that the providers of carbon removals could face barriers to access finance. This is due to the fact that there is number of ways to use carbon removal certificates (through voluntary carbon markets, public funding, voluntary labels). This diversity creates transaction costs for those that want to have their carbon removal activity certified, such as research costs (the time and effort spent to understand the quality of the certification procedures of a given scheme) and switching costs (the cost of trying to raise other complementary or alternative types of funding, which is likely to require changing their operations and providing a different set of evidence and information).

	Fraud: decision makers must remain vigilant to the risk of compromising environmental integrity to expand market access to more market participants (including both carbon removal providers and carbon removal purchasers) An explicit requirement that not just the generation of carbon removal certificates, but also the end fate of all carbon removal units, be tracked on the registry. *Monitoring*: Carbon removals need to be correctly quantified; ensure a continuous monitoring throughout the duration of the project, as well as after the project has ended to detect potential reversals. *Transaction*: Transaction is linked to fraud challenge. Traceability improvement is one of the main challenges. In Carbon removals market, once the supplier sells an removals tonne to a buyer, it becomes non-transferable, and can never be sold again. No longer can buyers of these certificates claim emissions reductions that were paid for by someone else. The CO2 Tonne owner is the entity who can claim publicly that they've been responsible for removing a tonne of CO2. The same goes for suppliers. It is often the case that suppliers count their projects that reduced carbon emissions for themselves, and then sell offset credit to a buyer who also counts the emissions. After a supplier sells a tonne, they no longer own it, and cannot claim that they have removed CO2 in their own emissions report.

Table 36 Analysis of F-Gases

Criteria	Analysis of challenges and solutions of Fluorinated gases ("F-Gases")
Challenges and possible solutions	*Transactional costs*: centralised databases are currently used to facilitate the allocation and exchange of quota. *Monitoring challenges:* F-gas regulation requires extensive reporting and record-keeping, which can be time-consuming and complex to manage. *Verification:* it can be difficult to verify the certifications and licenses of the personnel and equipment involved in the production, import, export sale and disposal of f-gases. *Fraud:* the limited visibility into the F-Gas supply chain can make it difficult to prevent and identify non-compliance, fraudulent activities, and illegal trade (e.g. 'single used cylinders' being top-up multiple times). *Enforcement challenges:* enforcement can be complicated due to a range of challenges such as the number of actors subject to compliance obligations and differences in national enforcement frameworks.

Table 37 Analysis of the EU Sustainable Product Initiative (the Digital Product Passport)

Criteria	Analysis of challenges and solutions under the EU Sustainable Product Initiative (the Digital Product Passport)
Challenges and possible solutions	*Security:* Finding a balance between information-sharing and protecting personal and corporate data. *Lack of trust:* A lack of funds or skills may prevent small and medium-sized enterprises (SMEs), start-ups, waste operators and consumers from using DPPs.

	Verification: Full supply chain traceability still needed. Especially complex products or those developed with composite materials from numerous suppliers are difficult to trace back upstream to the raw materials. Textile and clothing industry is one such example that requires traceability implementation to address prevailing problems of information asymmetry and low visibility. *Fraud:* information can be easily falsified by producers/sellers. Blockchain technology allows segmented access to relevant data for all parties involved in the procurement cycle, without compromising each other's data. It also allows to triangulate data from different supply chain parties to ensure veracity of the information provided. *More generally:* In most cases, the only major thing companies are missing is the infrastructure for an open, standard, interoperable format for the digital product passport data, that is also machine-readable, structured, and searchable, (per the essential requirements included in Article 9 of the proposed Ecodesign for Sustainable Products Regulation11). But thanks to the rapidly evolving world of blockchain, decentralized systems will be able to meet these requirements and provide key product information to the parties who value it most. The digital product passport requires proper technological support as its success relies on the availability of accurate data. IT leaders will need technology that can collect and manage sustainability data from many different sources and systems and make it easily sharable; and most importantly, sustainability data needs to be trustworthy. Setting up unified/distributed blockchain system, with product information (digital), with interoperable data services, and with supply chain partners' sustainability/ESG certificates.

Table 38 Analysis of the EU Ozone Regulation

Criteria	Analysis of challenges and solutions under EU Ozone Regulation
Challenges and possible solutions	*Monitoring challenges:* verifying compliance with the EU Ozone Regulation can be a complex and time-consuming process, particularly when dealing with cross-border transactions. *Fraud:* It can also be challenging to detect and prevent illegal activities, such as the illegal production and trade of ozone-depleting substances. Stakeholders, in particular in the chemical industry, have expressed great concern about growing importance of illegal trade, e.g., duplicating quotas to place ODS on the market. *Enforcement challenges:* The EU Ozone Regulation applies to all Member States. However, enforcement can be complicated by differences in national regulations and enforcement procedures, as well as by the involvement of third-party countries in the trade of these substances.

Table 39 Analysis of the CBAM

Criteria	Analysis of challenges and solutions under the Carbon Border Adjustment Mechanism (CBAM)

Challenges and possible solutions	*Verification*: The main difficulty is to obtain viable data on products supply chain as it is very difficult to measure. There are key issues in document verification are in storage, retrieval and access to data. The high degree of confusion by incorrectly defining certain CO2 emissions reductions as carbon removal is also a common mistake that must be better controlled. *Fraud*: information can be easily falsified by producers/sellers. Blockchain technology allows segmented access to relevant data for all parties involved in the procurement cycle, without compromising each other's data. *Tax evasion*: Blockchain's unique features could offer a new way to automate tax collection, limit corruption and better identify ownership of tangible and intangible assets allowing for better taxing mobile taxpayers, the resolution claims.

Analysis of the pros and cons of the introduction of Blockchain to EU climate policies

This section provides an analysis of the potential of Blockchain to be introduced to selected EU climate policies, across several criteria namely disintermediation, stakeholder uptake, reporting and compliance, technological maturity, cross jurisdiction, international implications, and strengthened political cooperation. The policies included for analysis were as follows.

No	Legislation / Policies
1	EU Emissions Trading System (ETS) Directive 2003-87-EC
2	ETS Implementing Regulation No 601/2012 (Monitoring, Reporting and Verification).
3	Effort Sharing Regulation (EU) 2018/842
4	Land use, land use change and forestry (LULUCF) Regulation 2018/841
5	EU 'Ozone Regulation' – Regulation (EC) 1005/2009
6	Regulation (EU) No 517/2014 (the 'F-gas Regulation')
7	EU Sustainable Product Initiative
8	Proposed EU Carbon Removal Certification
9	The Carbon Border Adjustment Mechanism (CBAM)

Table 40 Analysis of the pros and cons of Blockchain in EU ETS

Criteria	EU ETS and EU MRV
Disintermediation	*Pros EU ETS and EU MRV:* Disintermediation using a DLT based system **does not undermine** the objectives of the EU ETS since a bespoke permissioned DLT system could be developed that allows continuation of dedicated roles and responsibilities of key parties (verified accreditors, authorities, and operators). Overall, regulatory scrutiny could be made tighter, and enforcement eased, specific examples are mentioned below. *Pros EU ETS*: Disintermediation can improve **security, tracking** and **verification** of ownership of allowances. Due to the quasi-immutable nature of any transaction recorded on a ledger, a consistent history of ownership and transfer of allowance would help to prevent fraud, theft and tax avoidance. This would enhance trust in peer-2-peer transactions and reduce issues around the authenticity of allowance certificates. *Pros EU MRV:* With complementary software solutions, enforcement should be eased if emissions and reporting compliance were made more transparent – see the reporting section below. *Cons EU ETS and MRV*: The **feasibility** of introducing a DLT based system for peer-2-peer based transactions would need to be explored considering that the Union Registry is established and regarded as working well by some. The Union Registry is part of the international registry architecture under the Kyoto registry. The International Transactions Log checks each transaction of allowances to ensure compliance with Data Exchange Standards. Similarly, the European Transaction Log (EUTL) verifies the compliance with the EU ETS rules and monitors the transactions. Carbon allowances may need to be 'migrated' from one system to another to support peer-2-peer

	trading and systems would need to be developed to align with existing commitments.
Stakeholder uptake	*Pros ETS and MRV:* There have been calls for some time to encourage Blockchain adoption via the EU ETS. Steps in this direction would not be surprising to many stakeholders due to the challenges identified *and the* markets would likely be strengthened due to increased levels of trust and confidence in the system. Possibly, the value of allowances would increase as a result. *Cons ETS and MRV:* There is a **lack of knowledge and skills** generally around Blockchain, and authorities and stakeholders would need to undergo training or awareness raising. *Cons ETS and MRV:* The Union Registry is well established and there would be some resistance to changing it significantly. Blockchain applications possibly could be developed to work alongside the existing system but this would require significant elaboration.
Reporting and compliance	*Pros EU MRV*: Disintermediation can support improvements in the secure **validation** of emission plans and annual emission **reports**. This would be based on a DLT based and interoperable validation step (vis-a-vis the Union Registry) accessible by accredited verifiers using cryptographic methods (hash codes) to validate the reports, with access to the system granted using Decentralised Identifiers (DIDs). Alternatively, storing of files (plans and reports) on a DLT based database system could also strengthen security by encrypting the files and requiring private user keys to open them. Sharding between nodes concerning the storage of files (i.e. partitioning the storage of a single file across the DLT) could further strengthen security. *Pros EU MRV*: IoT based monitoring of emissions could be used to gather more accurate data on emissions and provide real time transparency. This would require an ambitious plan to roll-out a monitoring system that would interface with the real world with a view to gathering data to feed into compliance reports. *Cons EU MRV:* The Union Registry would need to ensure **interoperability** with a DLT based verification step accessible by third parties. Alternatively, a DLT based system that allows development of additional applications such as file storage could be used thus replacing the Union Registry. While not impossible, the feasibility of these options need to be explored. *Cons EU MRV:* IoT based monitoring could be subject to implementation challenges given the scale of sectoral coverage. Fraudulent activities may persist.
Technologica l maturity	*EU ETS Pros*: Several DLT based systems already exist to support peer-2-peer trading of carbon credits and are believed to be reaching maturity.[60] *EU ETS and MRV Cons*: However, opinions are split around feasibility of using IoT and blockchain in an integrated way for emissions trading. Some of the focus group experts and literature has indicated that there are some bottlenecks concerning emerging DLT credit trading systems integrated

[60] Blockchain solutions for carbon markets are nearing maturity | Elsevier Enhanced Reader

	with IoT.[61] Moreover, regardless of the maturity of the technology, regulation would be needed to mandate adoption of the IoT system to ensure uptake.
Cross jurisdiction	*Pros:* Blockchain based trading has been hailed as a solution to reduce the regulatory uncertainty between Member States. This is around the traceability of ownership as mentioned.[62] *Cons:* Common standards for allowances and rules could be developed and implemented in smart contracts to support exchange of allowances internationally. However, there will likely need to be agreement on the specific scope. Carbon allowances currently have different legal bases (e.g. around administrative rights and tradeable property rights) in different countries and this would likely need to be ironed-out.[63]
Strengthened political cooperation on EU Climate Policy and International implications	*Pros:* The EU could provide leadership in introducing Blockchain to EU ETS, encouraging other world regions to do similar, thus allowing for international network integration. The ability of Blockchain to enhance compliance and trust in the system could facilitate an increase in international transactions. *Cons*: Possibly, there could need be consideration of how an EU blockchain based system would impact investors operating in other global markets outside the EU. This would require some investment in exploring the potential affects.

Table 41 Analysis of the Pros and Cons of Blockchain in LULUCF

Criteria	LULUCF Regulation
Disintermediation	*Pros:* Disintermediation using DLT based systems such as EBSI **would strengthen the willingness** of Member States to implement LULUCF regulations in national jurisdiction, as well as enforce the rules. This can be achieved as DLT systems can be designed in a way that **sovereign** entities such as Member States can stay in control of their national data while sharing only proofs that certain objectives have been achieved, or providing only access to data that must be shared, thereby enforcing the principle of data scarcity. It also **allows to integrate non-Member-States of the European Union**, while making sure that the LULUCF regulations are enforced there as well. *Cons*: Implementing decentralized systems such as DLT-based LULUCF enforcement applications are **complex undertaking**s. National systems must be connected, and further standardizations of methods and data quality levels would still be required.
Stakeholder uptake	*Pros:* Specifically with the roll-out of EBSI as instantiation of a **European Digital Infrastructure**, it becomes more tangible and thus realistic that Blockchain and DLT systems are providing technical possibilities other technologies did not provide, which convinces more and more stakeholders, independent of the ups and downs in the cryptocurrency markets. The importance of **"proof of green"** is increasing, and LULUCF

[61] Ibid

[62] Trading of CO2 certificates: Blockchain as a solution - Lexology

[63] Ibid.

	enforced on blockchain seems to be a promising application area. EBSI has the potential to enforce sustainable management practices while maintaining the productivity and regenerative capacity vital to the LULUCF sector. *Cons:* There is a **lack of knowledge and skills** generally around Blockchain, and authorities and stakeholders would need to undergo training or awareness raising.
Reporting and compliance	*Pros*: Disintermediation with polycentric governance is considered as viable solution to global commons problems, meaning that non-excludable, open-access, and unregulated **Common Pool Resources** (CPRs) are often overexploited. LULUCF is a regulation of CPRs, that depends on **digital monitoring, reporting, and verification** (dMRV). With dMRV data for reporting and compliance, tokenization of CPR as real-world assets to attribute value to the underlying material reality of the resource in the form of community currencies or ground regenerative NFT collections, social tokens, and other innovative financial and market applications, enabled by blockchain solutions. MRV for LULUCF compliance can be combined with monitoring land registries and ownership for enforcement. It would also correspond to the Effort Sharing Regulation (ESR) where land credits can be used to offset national carbon emissions. Blockchain could combine reporting and compliance needs by supporting tokenized certificates for emissions as well as removal of emissions and corresponding credits. In combination with geo satellite data, MRV based on blockchain could run semi-autonomously to fulfil the regulatory demands of LULUCF, land registry, and ESR. *Cons:* Interoperability is a critical concept and challenge for decentralized reporting and compliance applications in the context of LULUCF. While blockchain systems promises to improve interoperability and exchange of dRMV data, the **complexities of connecting on-chain and off-chain community activities** and subsequently assuring any interoperability needed between and across different blockchain systems has not been implemented and evaluated in large scale operational systems.
Technological maturity	*Pros*: Different blockchain implementations exist illustrating that the market readiness is given. An example is EBSI again. Several other implementations typically refer to as "**blockchain for good**" that enforce UN SDG goals also illustrate that the **technology is capable to support heterogeneous networks** of independent or sovereign entities. Tokenized certificates and credits are managed on blockchain already today, and in combination with IoTsolutions such as geo satellites as oracles for MRV data, the technology is already in place to develop such "blockchain for good" systems, enforcing climate mitigation and adaptation regulation on the LULUCF sector. The DLT-systems are also mature enough to enforce new incentive mechanisms supporting agroecology and agroforestry in coherence with the Union's biodiversity strategy objectives. *Cons*: In contrast to other applications such as in the field of carbon emission certificate trading in the context of EU ETS, there are **fewer pilots in place** that could inform the implementation of LULUCF on a DLT system in parts or completely. Some DLT projects focus on soil fertility and biodiversity, while also aiming to reduce carbon emissions in the agriculture industry. Thus, it seems to be challenging to learn and adapt from these projects to inform the design and roll out of LULUCF regulation on DLT systems.

Cross jurisdiction	*Pros:* In order to be effect and impactful, LULUCF regulations must be enforced cross-border and in different Member States simultaneously. While this also means to potentially spread across different jurisdictional spheres within and outside the EU, **encoded rules in form of smart contracts** for MRV LULUCF activities promise to be effective instruments. *Cons*: Transactions relevant for LULUCF might involve multiple DLT systems with different jurisdictional regimes enforced. Such a **"system of systems" interoperability** may lead to new possibilities to disguise potentially fraudulent activities, as well as may make accountability enforcement challenging, as legal implications of how to manage the resulting situation may be different between jurisdictions. Blockchain systems generally are designed to avoid this scenario, however it may arise when different jurisdictions and/or blockchains are governed differently but collectively involved in LULUCF enforcing systems.
Strengthened political cooperation on EU Climate Policy and International implications	*Pros:* The EU could provide leadership by designing and implementing DLT-based LULUCF systems that **allow Member States to stay sovereign** and in control of their data. As such systems would also provide autonomy, as they are collectively governed and not by a single entity or country, **such a system might also be supported by non-EU Member States**, as in the case of EBSI, where Liechtenstein and Norway partake, and Ukraine is observer. DLT-based system could enforce European values on a global scale, as other countries might join. For example, efforts to reduce deforestation and forest degradation to promote sustainable forest management as demanded by LULUCF regulation could be enforced and made transparent across all Member States, and support could be provided where needed based on reliable and accurate information from a DLT-based system. *Cons*: Coopetition models where states working together while competing at the same time have illustrated that cooperation between independent nations is complex, and the agreement on common rules enforced on DLT systems as in the case of LULUCF **could take too much time** in order to be effective. The level of transparency provided by a DLT-system enforcing LULUCF aims may not be desired by all Member States and thus could lead to a weakening of political cooperation in Europe.

Table 42 Analysis of the Pros and Cons of Blockchain in Sustainable Product Initiative

Criteria	Sustainable Product Initiative
Disintermediation	*Pros:* DLT could assist in setting-up a decentralised system, pooling data together from many sources, and in which every stage of a product's life cycle would be digitally identified to record information on the product to enhance its overall sustainability (e.g., performances, content, recyclability). Every stakeholder in the value chain could log the information, which could be tracked and made accessible to everyone, while ensuring companies to maintain control over their data. DLT could enhance transparency and traceability. *Cons:* The implementation of DLT could raise concerns over data privacy and industrial competitiveness. A right balance between data sharing and data protection should be found. Sensitive data may need to be recorded in the system, but only made accessible to selected stakeholders.

Stakeholder uptake	*Pros:* Digital product passport could provide meaningful information throughout the entire product life cycle, including to support stakeholder engagement in the green transition. Combined with DLT, it can improve product traceability and value chain transparency. Zero-knowledge proofs, smart contracts, and other cryptographic strategies can be used to protect data privacy, enabling transparency and trust without giving away any sensitive or confidential data. *Cons:* A lack of funds or skills may prevent small and medium-sized enterprises (SMEs), start-ups, waste operators and consumers from using DPPs. Immutability of data may have compatibility challenges with privacy agreements or trade secrets etc. This could result in stakeholder resistance to launching DLT systems. Further, availability of information in a user-friendly manner is key for stakeholder uptake.
Reporting and compliance	*Pros:* Under a unified enterprise blockchain system, product information would be available electronically via interoperable data services. Each product and component would have unique digital identifiers containing valuable information (e.g., hazardous content, durability, recyclable content, carbon footprints, proof of due diligence in sourcing raw materials). DLT has a potential to increase trust and transparency in complex supply chains, by providing immutable recordings on ownership, origin and use of product. *Cons:* DLT cannot fix the quality of the data entered. While, DLT can offer immutability, without specific considerations or checks, poor quality or fraudulent information can form part of the record history. The risk of erroneous data on the origin of products is to be considered. Further, attention should be put on not adding unnecessary administrative burden on businesses regarding data disclosure and reporting.
Technological maturity	*Pros:* DDP based on DLTs technologies seem to be the most appropriate. The digital product passport requires proper technological support as its success relies on the availability of accurate data. IT leaders will need technology that can collect and manage sustainability data from many different sources and systems and make it easily sharable; and data needs to be trustworthy. *Cons:* Implementation of DLT raise concerns on the overall scalability and implementation timeline, especially for complex products. Three sectors are currently considered for implementation for 2024-2026 (apparel, batteries, consumer electronics
Cross jurisdiction	*Pros:* DLT can improve transparency and trust, by anchoring recording from every value chain stakeholder in a same system. *Cons:* Some high-tech products (e.g. the smartphone) are built with many components from different countries. Country legislation may differ regarding the disclosure of information on these components, which may hinder the relevance of the information on the DPPs. International collaboration is needed to support the uptake of standards and interoperability across multiple value chains and geographical areas.
Strengthened political cooperation on EU Climate	*Pros:* EU could provide leadership by designing and implementing DLT-based DPPs. It has the potential to provide incentives at the global level towards better product sustainability and circularity. It was assessed that

Policy and International implications	the overall SPI framework could lead to primary energy savings equivalent to the EU's import of Russian gas (132mtoe in 2030)[64]. *Cons:* the level of transparency provided by a DLT-system enforcing DDP may not be desired by all Member States (due to the full transparency) and thus could lead to a weakening of political cooperation in Europe. To ensure transparency, the development of global standards is needed, and the uptake of such digital tool require the use of international fora (e.g., G7, OECD, UN).

Table 43 Analysis of the Pros and Cons of Blockchain in Carbon Removal Certification

Criteria	Carbon Removal Certification
Disintermediation	*Pros*: DLT could enhance transparency and traceability. DLT could assist in setting-up a decentralised system, pooling data together from many sources, and in which all the removal duration would be digitally identified to record information. Concerning VCMs where carbon removals scheme could be exchanged: Disintermediation can improve security, tracking and verification of ownership of allowances. Due to the quasi-immutable nature of any transaction recorded on ledger, a consistent history of ownership and transfer of allowance would help to prevent fraud, theft and tax avoidance. This would enhance trust in peer-2-peer transactions and reduce issues around the authenticity of certificates. *Cons:* Implementing decentralized systems such as DLT-based forestry enforcement applications are complex undertakings. National systems must be connected, and further standardizations of methods and data quality levels would still be required.
Stakeholder uptake	*Pros:* With the growing number of players involved in VCMs, it is becoming more tangible and therefore realistic that blockchain and DLT systems offer technical possibilities that other technologies did not. *Cons:* A lack of funds or skills may prevent small and medium-sized enterprises (SMEs), start-ups, from using DLT for their carbon removal activities.
Reporting and compliance	*Pros:* IoT based monitoring of emissions could be used to gather more accurate data on emissions and provide real time transparency. A robust monitoring system is essential for the long-term credibility of carbon removals. It is imperative to ensure a continuous monitoring throughout the duration of the project to detect potential reversals. When a validation process is needed before a project is deployed to assess the amount of carbon that can be reliably sequestered, available historic data (such as satellite imagery) should be used to verify that the land use has not been changed prior to the beginning of the project, in order to establish ground-truthed baselines. *Cons:* IoT based monitoring could be subject to implementation challenges given the scale of sectoral coverage. Fraudulent activities may

[64] https://commission.europa.eu/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/sustainable-products/ecodesign-sustainable-products_en

	persist. A lack of skills by certification bodies can affect the assessment through DLT. DLT has no discerning function of its own and is consequently susceptible to the classic "garbage in, garbage out" problem. Blockchains are typically meant to work as decentralized accounting ledgers and have no ability to differentiate between 'good' and 'bad' data linked to credits. It can, however, put the ability to monitor and verify data in the hands of individuals — empowering them to make informed purchasing and investment decisions.
Technological maturity	*Pros:* Blockchain has the potential to improve verifiability and reduce transaction costs, and to a lesser degree address the additionality and permanence concerns of forestry projects. Blockchain complements REDD+ projects too. Not only do blockchain projects pay farmers to plant trees and enhance other ecosystem services, but the technology also has a wide range of further applications, among them the integration of renewable energy into grids as well as promoting regenerative agriculture. *Cons:* Blockchain based project are still margin. As for the EU ETS, regardless of the maturity of the technology, regulation would be needed to mandate adoption of the IoT system to ensure uptake.
Cross jurisdiction	*Pros:* In order to be effect and impactful, carbon removals regulations must be enforced cross-border and in different Member States simultaneously. *Cons:* difference in jurisdictions and enforcement framework may create challenges since a standardised DLT cannot accommodate different requirements.
Strengthened political cooperation on EU Climate Policy and International implications	*Pros:* There is currently no voluntary, centralised market in Europe for carbon removals certification. However, if this were to be set up one day, then The EU could provide leadership in introducing Blockchain to VCMs encouraging other world regions to do similar, thus allowing for international network integration. The ability of Blockchain to enhance compliance and trust in the system could facilitate an increase in international transactions. *Cons:* there could need be consideration of how an EU VCMs system would impact investors operating in other global markets outside the EU. This would require some investment in exploring the potential affect.

Table 44 Analysis of the Pros and Cons of Blockchain in Cross Border Adjustment Mechanisms

Criteria	CBAM
Disintermediation	*Pros:* DLT could assist in setting-up a decentralised system, pooling data together from many sources, and in which every stage of a product's life cycle would be digitally identified to record information to better identify the products subject to CBAM. *Cons:* The implementation of DLT could raise concerns about data privacy and industrial competitiveness. A balance needs to be struck between data sharing and data protection. Sensitive data may need to be stored in the system, but may only be accessible to certain stakeholders.
Stakeholder uptake	*Pros:* Data sharing could be enhanced, since DLT can facilitate more efficiency data sharing.

	Cons: CBAM might bring challenges associated with the s. The issue will become more prominent when the European Commission adds indirect emissions which demand wide-scale data exchange between supply chain actors.
Reporting and compliance	*Pros:* The use of blockchain has great potential to better track information on embedded emissions for goods, which will better determine which external products should be taxed.
Technological maturity	Pros: To enable full supply chain traceability, DLTs technologies seem to be the most appropriate. IT leaders will need technology that can collect and manage sustainability data from many different sources and systems and make it easily sharable. *Cons:* If every single product off EU needs a DLT-based traceability system, there would be billions, if not trillions of nodes, negatively impacting the data storage requirements and associated energy consumption.
Cross jurisdiction	*Pros:* DLT can improve transparency and trust, by anchoring recording from every value chain stakeholder in a same system. *Cons:* Difference in jurisdictions and enforcement framework may create challenges since a standardised DLT cannot accommodate different requirements.
Strengthened political cooperation on EU Climate Policy and International implications	*Pros:* The EU could provide leadership in introducing Blockchain to CBAM, encouraging other world regions to do similar, thus allowing for international network integration. *Cons:* The level of transparency provided by a DLT-system enforcing some off-EU product may not be desired by all States (due to the full transparency).

Table 45 Analysis of the Pros and Cons of Blockchain in F-gases regulation

Criteria	F-gases regulation
Disintermediation	*Pros*: Disintermediation can improve transparency and traceability. By removing intermediaries, DLT can increase the transparency of the supply chain, and enabling to track f-gases quotas from production to end use. This can reduce the risk of fraud and non-compliance. In terms of efficiency, it could reduce transaction costs and increase the speed of the data sharing. *Cons*: the introduction of DLT would require a significant investment in technology and infrastructure, which can be particularly challenging for smaller business. The feasibility of introducing a DLT based system for peer-2-peer based transactions would need to be explored.
Stakeholder uptake	*Pros:* data sharing could be enhanced, since DLT can facilitate more efficiency data sharing between stakeholders in the f-gases supply chain. *Cons:* There is a lack of knowledge and skills generally around DLT, and authorities and stakeholders would need to undergo training or awareness raising. In particular, the regulatory landscape around DLT is still evolving,

	and there might be uncertainty on how to comply with regulations that apply DLT systems.
Reporting and compliance	*Pros*: Disintermediation can support improvements in reducing errors and inaccuracies while reporting. DLT can also automate some reporting processes and make it easier and faster to monitor the compliance. *Cons:* The EU central database would need to ensure interoperability with a DLT based verification step accessible by third parties. There are currently few standards for interoperability between different systems, hence the effectiveness could be limited. Alternatively, a DLT based system that allows development of additional applications such as file storage could be used thus replacing the central EU database. While not impossible, the feasibility of these options needs to be explored.
Cross jurisdiction	*Pros:* DLT could increase collaboration between different stakeholders and regulatory bodies across different jurisdiction. This could help to improve coordination around compliance and reduce complexity of reporting requirements. *Cons:* however, difference in jurisdictions and enforcement framework may create challenges since a standardised DLT cannot accommodate different requirements.
Strengthened political cooperation on EU Climate Policy and International implications	*Pros:* The application of DLT in the f-gases regulation can set a positive example for other countries on how to implement effective climate policies. Capacity to verify trusted supply chain partners and avoid fraud and illegal trade. *Cons:* Further assessment should be then channelled in understanding how DLT would impact investors operating in other global markets outside the EU.

Table 46 Analysis of the Pros and Cons of Blockchain in Ozone Regulation

Criteria	Ozone Regulation
Disintermediation	*Pros*: Similar to the f-gases analysis, disintermediation can improve transparency and traceability. By removing intermediaries, DLT can increase the transparency of the supply chain, and enabling to track ODS from production to end use. This can reduce the risk of fraud and non-compliance. In terms of efficiency, it could reduce transaction costs and increase the speed of the data sharing. *Cons*: the introduction of DLT would require a significant investment in technology and infrastructure, which can be particularly challenging for smaller business. The feasibility of introducing a DLT based system for peer-2-peer based transactions would need to be explored.
Stakeholder uptake	*Pros:* adopting DLT could provide a more transparent way of recording transactions and sharing data, which could increase trust among stakeholders. *Cons:* There is a lack of knowledge and skills generally around DLT, and authorities and stakeholders would need to undergo training or awareness

	raising. In particular, the regulatory landscape around DLT is still evolving, and there might be uncertainty on how to comply with regulations that apply DLT systems.
Reporting and compliance	*Pros*: Disintermediation can support improvements in reducing errors and inaccuracies while reporting. DLT can also automate some reporting processes and make it easier and faster to monitor the compliance. Additionally, DLT could enable real-time reporting and monitoring of quotas and licenses, thus saving time between data collection and reporting. *Cons:* The ODS licensing system would need to ensure interoperability with a DLT based verification step accessible by third parties. There are currently few standards for interoperability between different systems, hence the effectiveness could be limited. Alternatively, a DLT based system that allows development of additional applications such as file storage could be used thus replacing the central EU database. While not impossible, the feasibility of these options needs to be explored.
Cross jurisdiction	*Pros:* DLT could increase collaboration between different stakeholders and regulatory bodies across different jurisdiction. This could help to improve coordination around compliance and reduce complexity of reporting requirements. *Cons:* however, difference in jurisdictions and enforcement framework may create challenges since a standardised DLT cannot accommodate different requirements.
Strengthened political cooperation on EU Climate Policy and International implications	*Pros:* The application of DLT in the ozone regulation can set a positive example for other countries on how to implement effective climate policies. *Cons:* Further assessment should be then channelled in understanding how DLT would impact investors operating in other global markets outside the EU.

8.2 Task 2 appendixes

CASE STUDY 1. Carbon removals certifications

The Introduction

This case study provides a high-level overview of the potential of Decentralised Ledger Technology (DLT) to support the implementation of the proposed EU Regulation on Carbon Removal Certification.
The case study involved desk research of EU laws and Blockchain reports, a series of workshops with the European Blockchain Services Infrastructure (EBSI),[65] and interviews with certification schemes, carbon removal auditors and other experts including:

- Minespider – a Blockchain supply chain sustainability software provider;[66]
- Agreena and Puro Earth – carbon removal certification bodies;
- Verra and Gold Standard –carbon removal certification schemes;
- World Bank – Climate Action Data Initiative.[67]

The case study is organised as follows:

- A policy background is provided setting-out the objectives and implementation approach to the proposed Regulation;
- The rational is outlined for the selection of the proposed Regulation for DLT case research;
- A general assessment highlights the pros and cons of different DLT technological options;
- A detailed assessment explores the implementation of two alternative DLT models;
- Finally, conclusions are provided on the pros and cons of the implementation of the models.

Policy Background

Introduction to the proposal

The European Climate Law requires the EU to achieve climate neutrality by 2050. This is defined as a balance between any remaining emissions of the main greenhouse gases (carbon dioxide, nitrous oxide, methane and the fluorinated greenhouse gases) and removals of CO_2 from the atmosphere. It further sets a target for the EU to reduce net GHG gas emissions by at least 55% by 2030, compared to 1990 levels. To keep temperature rises within 1.5°C as outlined in the Paris Agreement, and prevent the worst impacts of climate change, the world needs to reach net-zero carbon emissions by around mid-century, while removing and storing as much carbon dioxide as possible.

On 30 November 2022, the European Commission adopted **a proposal for a Union certification framework for carbon removals**. The main thrust of the proposal is to promote, within a voluntary and harmonised framework, high quality carbon removal practices with unambiguous climate benefits, thus contributing to the EU's climate neutrality, environmental and zero-pollution goals.

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[65] ESBI is a European Commission initiative supporting the introduction of

[66] The leading supply chain traceability solution | Minespider

[67] About : Climate Action Data Trust

More specifically, the objective of the proposal is to facilitate atmospheric or biogenic carbon removal by operators or groups of operators. This is to be achieved within geological carbon pools, biogenic carbon pools, long-lasting products and materials, the marine environment, or the reduction of carbon release from a biogenic carbon pool to the atmosphere.

To meet climate policy objectives, removing several hundred million tonnes of CO_2 out of the atmosphere will become increasingly necessary every year. Carbon can be removed and stored in three broad ways:

1. Permanent storage: industrial technologies such as BECCS (bio-energy with carbon capture and storage) or DACCS (Direct Air Capture with Capture and Storage), capture carbon from the air either indirectly (through the processing of biomass in the case of BECCS) or directly (in the case of DACCS) and store it in a stable form.
2. Carbon farming: carbon can be naturally stored on land through activities that enhance carbon capture in soils, forests and coastal areas (e.g. agro-forestry, forest restoration, better soil management), and/or reduce the release of carbon from soils to the atmosphere (e.g. restoration of peatland). Carbon farming activities contribute to achieving the EU's ambitious target of -310 Mt of CO2 net removals in the Land Use, Land Use Change and Forestry (LULUCF) sector.
3. Carbon storage in long-lasting products: atmospheric carbon captured by biomass or industrial technologies can also be used and stored in long-lasting products and materials, such as wood-based or carbonate-bonded construction materials

In doing so, the Regulation establishes a voluntary Union framework for the certification of carbon removals by laying down: (a) quality criteria for carbon removal activities that take place in the Union; (b) rules for the verification and certification of carbon removals; (c) rules for the functioning and recognition by the Commission of certification schemes.

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Under the Commission proposal, carbon removals must bring clear benefits to the climate and preserve or strengthening other environmental objectives. To that end, the certification framework for carbon removal activities will be guided by four **QU.A.L.ITY** criteria:

1. **Qu**antification: The benefits realised through carbon removals should be measured against a baseline and is net of supply-chain emissions;
2. **A**dditionality: Carbon removal activities go beyond standard market practices and what is legally required at the level of the operator
3. **L**ong-term storage: Operators need to ensure long term storage of carbon. Clear distinction between permanent storage from temporary storage
4. Sustainabil**ity**: Carbon removal activities do not harm the environment but can positively result in co-benefits for other environmental objectives such as biodiversity.

Governance arrangements

To permit independent verification, credibility and transparency, the proposed implementation of the Regulation is provided through third party certification. This approach sets out specific requirements and roles for:

- Operators conducting carbon removals;
- Certification bodies conducting audits and issuing certificates;
- National accreditation of certification bodies and monitoring thereof by Member States;
- Recognition of certification schemes by the Commission;

- Certification schemes ensuring correct auditing and issuing of certificates, and making certificates publicly available and register the certified carbon removals units in a certification registry.

To obtain a certificate of compliance, operators should submit an application to a certification scheme providing a comprehensive account of their removal activity and application of the certification methodology necessary for compliance.

The certification body should perform audits to verify the information provided. Where removal activities are determined as compliant, certification bodies may issue an audit report and certificate – these documents are to be made publicly available via a registry. To ensure ongoing compliance, the certification bodies are to perform periodic re-certification audits resulting in the issuing of updated reports and certificates.

Annex 2 of the Proposal

Carbon removal certificates shall include the following minimum information:

a) name and type of the carbon removal activity, including the name and contact details of the operator or group of operators;
b) the location of the carbon removal activity, including geographically explicit location of the activity boundaries, respecting 1:5000 mapping scale requirements for the Member State;
c) start date and end date of the carbon removal activity;
d) name of the certification scheme;
e) name and address of the certification body and logo;
f) (unique) certificate number or code;
g) place and date of issuance of the certificate;
h) reference to the applicable certification methodology referred to in Article 8;
i) net carbon removal benefit referred to in Article 4(1);
j) carbon removals under the baseline referred to in Article 4(1), point (a);
k) total carbon removals referred to in Article 4(1), point (b);
l) increase in direct and indirect greenhouse gas emissions referred to in Article 4(1), point (c);
m) breakdown by gases, sources, carbon sinks and stocks with regard to the information referred to in points (j), (k) and (l) of this Annex;
n) duration of the monitoring period of the carbon removal activity;
o) any sustainability co-benefits referred to in Article 7(3);
p) reference to any other carbon removal certification.

Certification bodies appointed by certification schemes shall be accredited by a national accreditation authority pursuant to Regulation (EC) No 765/2008 of the European Parliament and of the Council.[68] Certification bodies needed to be judged as competent to fulfil their activities and independent from operators conducting carbon removals. Member States are tasked with supervising the correct operation of certification bodies and must be granted access to all necessary information held by certification bodies.

[68] Regulation (EC) No 765/2008 of the European Parliament and of the Council of 9 July 2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products and repealing Regulation (EEC) No 339/93 (OJ L 218, 13.8.2008, p. 30).

Certification schemes used by operators should be recognised by the Commission and aligned with the requirements of the Regulation. These should operate using reliable and transparent rules and procedures, in particular with regard to internal management and monitoring, handling of complaints and appeals, stakeholder consultation, transparency and publication of information, appointment and training of certification bodies, addressing non-conformity issues, and development and management of registries.

Certification schemes shall verify if the information and data submitted by operators were subject to independent auditing and if the certification of compliance was carried out in an accurate, reliable, and cost-effective manner.

Certification schemes shall publish, at least annually, a list of the appointed certification bodies, stating for each certification body by which entity or national public authority it was recognised and which entity or national public authority is monitoring it.

Registries

Certification schemes shall establish and maintain a certification registry to ensure that audit reports, certificates of compliance are publicly available and to register certified carbon removal units. Those registries shall use automated systems, including electronic templates, and shall be interoperable.

Rationale for selection for DLT case research

Risk of double counting

The main reason for the selection of the proposed Carbon Removals Certification Regulation for the possible application of Decentralised Ledger Technology (DLT) case research stems from the potential for fraudulent activities especially double counting and double sale of certified carbon removal units.

A key concern is that operators may fraudulently request their removal activities to be certified under different certification schemes, thus leading to the same removal activity being falsely registered twice. Similarly, there is a risk that the same carbon removal unit, or a token based on a single carbon removal unit, is incorrectly sold twice, for example, as part of offsetting schemes. These are significant risks to the Regulation that would seriously undermine its credibility if detected.

Moreover, it should be recognised that any strategy to mitigate fraudulent activity should not result in serious administrative burdens especially for small and medium sized operators that make-up significant parts of the farming and forestry sectors.

For these reasons, the proposal requires the establishment of registries that offer transparency, automation and interoperability.

Potential relevance of DLT for the proposed Regulation

DLT is relevant for carbon removals certification due to its potential to mitigate the main risks around double counting while at the same time offering transparency, automation and interoperability. These features are explained in more detail in the following sections, however, some of the key technological principles that address the risks around fraudulent activities are as follows:

Intrinsic to DLT is that it operates as a decentralised ledger maintained by multiple participants or nodes in a network. Each node has a version of the entire ledger and allows multiple writers to develop the ledger – thus providing transparency to all parties involved. DLT solutions prevent double counting. Using, a consensus mechanism, any update to the ledger must be subject to prior approval – therefore, validation is needed to ensure authenticity, integrity and compliance with the predefined rules of the DLT system.

Once the decentralised ledger has recorded the entry, the results are immutable thus removing the risk of fraud. Any further attempts to edit the ledger are also recorded and require approval. This ensures that the history of the ledger is permanently recorded making all key information traceable.

General reflection on the pros and cons of alternative DLT systems for carbon removals certificates

Using interviewee feedback, this section provides a general reflection of the pros and cons of alternative DLT systems for carbon removal certificates. This general exploration was conducted to frame the definition of two different DLT models for detailed investigation in the context of the proposed Regulation – see the following section.

As one would expect, the selection of different DLT options would impact the operation and performance of the proposed Regulation, and therefore prior general assessment of key principles was conducted to gauge how stakeholders felt about these possible choices.

Disintermediation is often associated as a potential benefit of DLT systems. Disintermediation involves the removal of the role of intermediaries. In processes that involve centralised databases, depending on the context, intermediaries typically have the role of facilitating financial transactions or validating information. With respect to cryptocurrency, DLT has been used to eliminate financial intermediaries therefore lowering transaction costs – this is enabled through peer-to-peer transactions.

Table 47 DLT options around disintermediation

Broad DLT options around disintermediation	Possible issues for carbon removals T
1. Possibility to produce efficiencies via disintermediation by reducing the role of or removing intermediaries from managing transactions between parties or providing updates to ledgers; 2. Include intermediaries in the governance and operation of the DLT.	• Roles of bodies responsible for third party system and enforcement to be reinforced through DLT

However, some stakeholders assumed that the approach to the DLT system would not necessarily lead to disintermediation of intermediaries essential to a regulatory or third-party implementation context. Rather, it was suggested that the DLT system would enhance the possibility for the different actors to fulfil their proposed legal obligations i.e. operators, certification bodies, certification schemes, accreditation bodies, authorities, and the Commission. Therefore, it was suggested that any proposed DLT system would need to establish a governance framework that is well aligned to the rules and roles set in the proposed Regulation.

Different **methods of network access** notably **permissionless** and **permissioned DLT systems** have been well discussed in the DLT literature and were seen as a key consideration in the context of the proposed Regulation.

Table 48 DLT options around network access

Broad DLT options around network access	Possible issues for carbon removals
1. Permissionless systems that do not use security controls or centralised governance bodies; 2. Permissioned systems that lay down system access procedures, and are limited to selected or approved nodes and a centralised governing body.	• Permissioned systems would allow the introduction of a governance framework aligned with the spirit, requirements and security needs of the Regulation.

Permissionless systems are often associated with decentralised networks where typically anyone can join with the necessary hardware, software and technical skills. These systems do not have a centralised governing body for management or maintenance, and therefore require internal incentivisation to preserve the database and add new information. Participants can operate with the same or similar level of rights as other participants, and benefit from or contribute to the development of the ledger. While methods differ, permissionless systems often emphasise the privacy of participants and therefore establish minimal entry requirements such as authorisations or documentation, and persons may be allowed to operate using pseudonyms. Some stakeholders suggested that a possible benefit of this approach would be integration of carbon markets through connection to other blockchains registering carbon certificates and greater market volume and liquidity – although this approach would be exposed to greater technical complexities and risks of fraud.

Generally, the stakeholders interviewed anticipated a **permissioned** approach for DLT implementation under the proposed Regulation. Permissioned systems are typically owned by a defined governing body, which can be one or more entities organised in a consortium model.

In this instance, a more centralised governing body typically has the role of approving user access to the system. This would typically involve establishing the identity of organisations and individual users, for example, using legal identifiers such as registration documents, certification, passports, credit scores, digital certificates etc.

While not having some of the flexibility associated with permissionless systems, a key benefit of permissioned systems when compared to centralised databases is that of **immutability** and **transparency** – i.e. all updates and edits to the registry are visible to all and permanently recorded – and **security** – since by distributing the database across nodes, there is no single point of failure. However, this system requires trust in the controlling governing body and framework since the management of the ledger is less decentralised.

With respect to the **consensus mechanism** used to support approval of updates to the ledger, DLT systems offer several possibilities.[69]

Table 49 DLT options around consensus mechanisms

Broad DLT options around the choice of consensus mechanism	Possible issues for carbon removals
1. Proof of Stake (PoS) where updates to the ledger are approved by owners of a significant number of credits / certificates / token. 2. Proof of Authority (PoA) updates to ledgers are approved by verified organisations that operate as nodes;	• Proof of Authority (PoA) would best align with the logic of the third party system established by the proposed Regulation.

The consensus mechanism, **proof of stake (PoS)**, that is used by cryptocurrency such as Ethereum and has the benefit of being more energy efficient than other methods such as proof of work (PoW) – see footnote.

In this case, the participants that act as validators are pre-selected to validate updates to the ledger based on their significant 'stake' in the system, such as the value of their cryptocurrency holding, or number of tokens etc. Since the interests of those with significant stakes is to ensure the correct and true functioning of the system, especially with respect to cryptocurrency, it is assumed that those selected as validators will act with integrity – and often this is ensured with the stake of validators acting as collateral and forfeited if malpractice is later identified. When participants are selected as validators, they are tasked with validating transactions, updating the ledger and communicating the results with other validators selected to cross-check the updates.
Consensus mechanisms like PoS are more closely associated with permissionless systems where there is a need to incentivise users to ensure correct updating to the database in absence of a centralised body.[70]

However, stakeholders interviewed were not sure how proof of stake would work in the context of the proposed Regulation. Importantly, operators that hold certificates should not be tasked with updating or validating the ledger even if they have a 'high stake' based on the extent of certificates owned. Rather, considering that the proposed Regulation is based on third party approval, it was felt that approved independent validators would be tasked with approving updates to the system.

For this reason, **proof of authority** was deemed as the most anticipated option. Again, this consensus mechanism uses a significantly lower amount of energy compared to proof of work. In this case, the validators are approved by a central governing body. The validators are

[69] Bitcoin, a cryptocurrency, is associated with the proof of work (PoW) consensus mechanism. However, this consensus mechanism was not discussed since it is associated with high levels of energy usage, and has been heavily criticised for this reason, and would therefore be inappropriate for implementation in EU climate laws. This involves participants, know as miners, to compete against each other to solve a computational puzzle. When the correct value is identified, the successful miner communicates the result and this is validated by other participants in the network. If valid, the ledger is updated and the miner is rewarded with Bitcoin.

[70] Incentives are given to participants (nodes) who process data and maintain the database in a number of ways, such as payment in cryptocurrency (also referred to as 'gas'), or in-kind (processing a transaction in exchange for posting a transaction, as in DAG). Where cryptocurrency is used as the incentive for public maintenance, each transaction is subject to a service fee, so if transaction volumes are high or if there are internal market failures, use of public DLT can be prohibitively expensive. Systems using PoW are also energy intensive given the computational requirements. Where in-kind incentives are used, data storage often becomes non-linear and the "single source of truth" and auditability is lost, so double counting of transactions becomes a risk.

chosen to add new entries to the ledger. The validators are pre-selected for their competences and reputation, and have an interest in ensuring the integrity of the system since their role would be discontinued otherwise. Hence, this system would seem to be suited to a regulatory system involving authorities and third-party oversight and approval activities.

In comparison to PoW and PoS, the PoA mechanism offers potential for a faster network (requests per second), more security (given that nodes are vetted and can be held accountable for misconduct) and lower operating costs (since fees can be set at fixed rates or even zero-rated).[71]

Stakeholders were also convinced that a DLT system could offer automation with the use of **smart contracts** that can automate the execution of contractual terms by encoding conditions in computer code. Importantly, this could support Monitoring, Reporting, Verification, and Revocation (MRVR) under the proposed Regulation, for example, through verifying the true identity of participants, automatically notify operators when re-certification is needed, and revoking certificates when expired etc.

A further item discussed was the issue of **tokenisation** – this involves representing assets as digital tokens that can be later exchanged and traded using smart contracts. Under the proposed Regulation, stakeholders envisaged connections between the issuing and management of certificates, with the sale of offsetting tokens linked to the certificates – again this would also benefit from an appropriate DLT system that could offer accessibility and scale transactions while ensuring the authenticity and integrity of the system by preventing double selling of the same certificate / token.

Table 50 DLT options around fractionalization

Broad DLT options around fractionization of certificates for offsetting	Possible issues for carbon removals
1. Fungible tokens are identical, interchangeable and can be broken down into divisible units; 2. Non fungible tokens are unique, and often show verifiable ownership of a specific physical object i.e. an entire carbon removal site.	• Fungible certificates would generate more market interest around offsetting but may be associated with greater compliance, security and traceability risks. • Alternatively, NFTs could be established based on a non-divisible unit like a carbon tonne.

A key issue for carbon removal markets is the degree of **fractionization** of carbon removal units used with broad choices around the use of **fungible tokens** that could be linked to specific carbon removal sites but are identical and represent a designated unit of carbon removed, and **non-fungible tokens** that are based on indivisible assets and are therefore unique.

At first sight, while more challenges were anticipated, fungible tokens would seemingly offer greater benefits, largely by boosting market liquidity which in turn could lead to greater investment in carbon removal projects. However, the supporting DLT system would need to offer sufficient protection from fraudulent activity and cybersecurity risks, along with the necessary robust regulatory oversight.

[71] Moreover, permissioned DLT systems are complemented well with PoA consensus mechanisms because all participants are trusted and could therefore be operated without incentives; specifically, incentives or fees are not an implicit requirement for the operation of the network, though it they can be introduced as compensation to organisations offering node services.

However, to solve the issue of divisibility for NFTs, they could be issued according to the most logical minimum unit of trade, for example, one tonne. In cases where projects yield several units, multiple NFTs could be issued. This could provide middle ground in improving security and traceability while encouraging liquidity.

Furthermore, issues around **interoperability** of DLT registries were discussed. It was highlighted that interoperability in the context of DLT should not be understood in the same way as interoperability of centralised databases. A DLT system should be seen as a network of databases that keep track of the same data. There is a common language that allows these databases to talk to each other and ensure data accuracy. This makes interoperability between separate DLT systems challenging and can result in issues around trust and traceability. Different DLT protocols have different architectures and consensus mechanisms, and interoperable blockchains are subject to greater security risks.[72] Cross chain protocols and significant industry coordination are needed to accommodate such differences.

Exploration of the pros and cons of specific DLT implementation model(s)

Based on the above mentioned analysis the different DLT systems and stakeholder feedback, the following models for implementation are examined in more detail:

Model 1: European Blockchain Services Infrastructure (EBSI)

EBSI functions and capabilities

The EBSI is an Open Ethereum based network, specifically built on Hyperledger Besu and a PoA consensus mechanism. As of early 2023, it is distributed across 40 nodes[73] (at least one from each EU member state, Norway, Liechtenstein, and the European Commission itself). The network is operational, though currently open only to limited use cases and pilots. It will become fully available on a utilities basis to both public and private organisations between 2024 and 2026. It is important to note that EBSI is decoupled from cryptocurrency markets, and the risks of crypto exchanges have therefore not been developed here.

Consensus and storage techniques

Hyperledger Besu (the main DLT protocol in use by EBSI) is using while it is worth mentioning that EBSI us a multi-chain infrastructure, capable to handle other DLT protocols as well) offers a balance in that it distributes responsibility for database updates and maintenance across a network of pre-approved participants (nodes). The consortium can vote to add new nodes according to automated rules, e.g., through simple majority or two-thirds majority, or even a single validator. The consortium can also choose to make their database publicly visible or restrict visibility to vetted parties.
As a multi-chain infrastructure, the EBSI is also capable of handling other DLT protocols.

[72] Why is blockchain interoperability hard to reach? (minespider.com)

[73] https://doi.org/10.3390/bdcc7020079

Digital Wallets, Verifiable Credentials (VCs) and compliance with EU data privacy and sovereignty rules

The EBSI network is capable of running smart contracts, which introduce the possibility of complex instructions attached to transactions, and APIs, which connects EBSI and the public internet and allows for interaction between the two. This permits individuals and organisations to hold digital wallets on their phones, computers or in a cloud, which they can use to view and access their digital assets (such as digital identifiers) or exchange value (such as the trade of CRCs). Digital wallets are the tools used to sign the transactions executed on a blockchain, so that all transactions are traceable to the wallets from which they originate.

EBSI allows the issuance of digital identifiers which are compliant with EU regulations related to data sovereignty and privacy, such as the European self-sovereign identity framework (ESSIF). Combined with digital wallets, these VCs provide auditability and accountability within EBSI that can greatly reduce the administrative burden of processes that currently take place off-ledger. However, an important consideration for the application of digital wallets is that they are not inherently capable of interacting. While the use of a single blockchain greatly contributes to the standardisation of protocols, users have a range of wallet providers to choose from even within EBSI's environment. This is why the European Blockchain Partnership (EBP) has started a certification programme allowing wallet providers to get EBSI ready, if they meet certain minimum security and privacy criteria.
Regarding VCs, as part of this system, EBSI currently offers two kinds of decentralised identifiers (DIDs); one for legal entities, and one for natural persons[74]. The legal entity DID is a public identifier which can be enforced by means of a DID registry. On the other hand, to preserve privacy, the natural persons DID is pseudonymous and not registered and thus requires more complex governances and processes of verification which shall not be elaborated here. In all cases, VCs involve designated authorisation, accreditation, issuance and verification bodies, and processes, all of which are backed by EBSI[75] to create a decentralised system of trusted digital IDs.

Smart contracts and NFTs

Smart contracts also enable the tokenisation of unique assets in the form of NFTs (non-fungible tokens). Where coins are a unit of accounting that is tracked in the ledger, NFTs add a layer of information which allows them to represent virtual versions of other assets. For example, tokens can represent trees, so that the exchange of 'tree' tokens represents the exchange of trees in the real world. NFTs can be part of an accounting system i.e., they can be added or subtracted, but in the context of CRCs, each NFT will hold unique certificate data or a link to a unique certificate. There is an important distinction between an NFT which holds certificate data in its metadata, and an NFT which 'points' to a certificate that is stored externally (off-ledger). The former is as immutable as the underlying DLT but is limited in the size of the data it can store, whereas the latter has a low storage impact but could allow for modification of the certificate data (which could lead to tampering and diminish the DLT's security). However, modifications could still be detected as the NFT's associated hash will change in response to changes in the data it points to, potentially breaking the chain or causing pre- and post-modification checksums to be unbalanced. The hash signature is therefore the main piece of

[74] https://ec.europa.eu/digital-building-blocks/wikis/display/EBSIDOC/EBSI+DID+Method

[75] https://ec.europa.eu/digital-building-blocks/wikis/display/EBSIDOC/EBSI+Verifiable+Credentials+Playbook

information that can be verified either off-ledger by an external auditor, or on-ledger by a smart contract.

Network speeds and security

At the network level, the nodes constituting the EBSI network are required to uphold strict standards of security and availability, and must themselves be compliant with EU regulations related to data and privacy. By setting minimum standards for node availability, the network's capacity to process requests is ensured, further contributing to reliability of the EBSI. The current number of nodes and API development permits approximately 4200 requests per second[76], though this will conceivably increase as improvements are made and new nodes are approved. Presently any person or organisation may apply to become a node[77], though their eventual participation in the network is subject to approval by the European Blockchain Partnership. Pre-approval of trusted organisations ensures the integrity of the PoA consensus mechanism. This external governance reduces the risk of a 51% attack, while the lack of anonymity also enhances accountability, which is a key concern for public blockchains.

Scenario 1 – multiple registries for CRCs

Scenario 1 describes a situation in which certification schemes operate their own independent CRC registries, as well as the high-level governance and components required for effective operation at the EU level. In this case, certification schemes are responsible not only for the databases that store certificate and audit report data, but also the creation and maintenance of the EBSI side-chains on which their registries operate.

Independent registries

- All actors in this carbon offset market have an EBSI-based digital wallet and a legal entity category DID (see section above for detail). The former allows actors to submit requests to the blockchain network (for trades or issuance of NFTs), while the latter ensures all on-chain events are traceable not only to a digital wallet but more crucially to a unique and accountable organisation.

- While the governance structures and process of the registries may be independent, the protocols on which their EBSI side-chains operate shall be aligned to technical standards prescribed by the Regulation to ensure interoperability.

- Carbon removal certificates originate from accredited certification bodies who in turn form part of one or many certification schemes. Given this chain of authority, implementation of a CRC registry on EBSI should mirror this as far as possible. The certification scheme shall form the general boundary of the network, with nodes consisting of representatives from each member certification body and one from the certification scheme itself. The auditing bodies responsible for monitoring the respective certification bodies as well as relevant public interest organisations should also be considered for roles as nodes to avoid collusion.

- Upon approval of successful carbon removal by a project operator, the certification body shall generate a request for a CRC NFT, to be processed by the certification

[76] https://doi.org/10.3390/bdcc7020079

[77] https://ec.europa.eu/digital-building-blocks/wikis/display/EBSI/Node+Operators

scheme's internal PoA consensus mechanism. This NFT contains pointers to both the issued certificate and the audit report, both of which are stored in a database managed by a party within the relevant CRC network. Although this data is not stored on-chain and is not strictly subject to the same benefits of security and transparency as on-chain data, the metadata contained within the NFT would be altered if any changes are made to the certificate and the audit report outside of the scope of a smart contract specifically designed to allow authorised updates. On the other hand, such an external database represents a single source of potential failure and should therefore be equipped with the necessary security and back-up systems to ensure continuous accessibility to stored data.

- The CRC NFT shall also be encoded with several programmes that prevent double counting. Unique land and geospatial credentials shall be assigned to the CRC NFT. To ensure that the NFTs issued by all independent certification schemes meet the same standards of trust in this regard, and to ensure auditability, land credentials shall be issued by an independent body at a national or regional level (with no overlap between jurisdictions). These credentials would exist on a separate EBSI-based registry that permits automated verification whenever NFT trades associated with operators from that region take place, and flags if unrelated trades occur for the same land area. By having a single registry per non-overlapping jurisdiction (instead of relying solely on the geospatial data contained in the NFTs of independent networks), this mechanism mitigates the possibility of independent registries being 'invisible' to audit queries due to interoperability issues.

- For the issue of double claiming, the tokenisation of certificates prevents the existence of an NFT in multiple wallets, so that only one digital wallet can claim the CRC NFT at once.

- In order to ensure the ability to update or revoke certificates in the future, given the immutable nature of DLT, CRC NFTs shall also be linked to smart contracts that authorise these actions. The use of smart contracts permits an auditable record of changes.

- The certificate and audit reports shall remain on the assigned external database, while the associated NFT shall be issued to the digital wallet of the project operator. From there, the project operator may trade the NFT according to whatever rules have been assigned to the NFT via smart contract. For example, the certification scheme may choose to limit trade of their certificates to organisations in certain regions or sectors. This kind of capability is enhanced by EBSI's VC frameworks.

- To enable CRC NFT trade and verification across all digital wallets operating on EBSI, wallet providers will require standardisation of protocols at a system level. Similar standardisation will be required for the issuance of CRC NFTs, so that auditing bodies and verifiers can make automated system requests capable of interpreting and aggregating certificate and audit report data.

The role of complementary networks and VCs

- The complementary networks in the highly decentralised Scenario 1 are a critical factor for auditability and trust in the system. Both primary (taking part in the carbon offset supply chain) and secondary actors (public interest and watchdog organisations) should be included as nodes, should possess digital wallets or should have independent EBSI-based networks for their respective functions. For example, the accreditors of certification bodies will ideally maintain their own ledgers which store certification body data, visible to the public. Their network could consist of other accreditors in the EU who work together to maintain standards of accreditation; or alternatively their network could constitute NGOs and national government departments who hold accreditors accountable for maintaining high standards. Another example of an important complementary network in Scenario 1 is the land credentials registry. Such a registry must be maintained by organisations with no jurisdictional overlap, such as national or local governments, respectively, so that any project location runs no risk of occurrence on a number of similar registries. By linking this network to that of the certification scheme(s), double counting of contributions from a single parcel of land is avoided.

- VCs also play an important role in maintaining the integrity of the system, by increasing accountability and thus reducing the possibility of fraud.

Non-EBSI based systems

In the same way that Scenario 1 is more complex with respect to the number of actors and processes required to ensure trust than Scenario 1, a non-EBSI based system presents additional complexity by order of magnitude. For example, whereas EBSI has existing protocols in place for DIDs which must be adhered to by all participants, any external system would require the design of new protocols and a governance structure capable of enforcing them. These protocols would also need to be agreed on by all participants affected by the proposed Regulation. At the financial level, any non-EBSI based solution may be subject to market conditions for transaction requests[78], whereas at the technical level the interoperability issue is likely to be exacerbated by the use of different chains altogether.

Future iterations and possibilities for international trade

Future iterations may include the integration of IoT with DLT-based certificate issuance. Once MRV technologies and decentralised oracle techniques have advanced sufficiently, the process of carbon removal verification can be partially automated. Oracles are the gates by which off-ledger data enters and interacts with the chain. For example, an oracle can be created to monitor rainfall in an area through local weather feeds, and once a certain threshold is reached it can trigger a smart contract to pay out insurance to farmers. Decentralised oracles aggregate multiple sources that must agree before triggering smart contract clauses. In this way, the administrative burden of the certification process can be further reduced for both project operators and certification bodies.

The scope of the draft EU carbon removal certification framework is limited to carbon removals generated in EU territory. This said, the trade of CRC NFTs with countries outside of the EU and using blockchains other than EBSI is technically possible through the use of blockchain bridges. However, several factors would need to align for any solution to be feasible:

- At the technical level, as for digital wallets, blockchain bridges require the use of standard protocols to enable the cross-chain smart contracts that would carry the CRC NFT from one system onto another while potentially maintaining cross-chain verification capabilities.
- The need for technical standardisation leads to the wider issue of international institutional cooperation and governance. Different requirements and standards for data sovereignty as well as technological inertia may present challenges to developing a system for blockchain bridging that permits global trade and verification.

In contrast, a market-based blockchain may be used instead of an EBSI-based solution, as is currently the case for the CAD Trust's non-transactional database, meaning that it stores data without creating NFTs to trade. This database uses the Chia Network and is available to

[78] https://www.binance.com/en/feed/post/489929

international users. However, such a solution could limit the ability to dictate specifications regarding the content of certificates given the commercial provider, and is also subject to international buy-in, just as the standardisation of protocols would be for the EBSI case. A commercial solution also limits the possibility of setting fees independently, which may be exacerbated if a single registry leads to a monopoly for the commercial provider. Furthermore, while the use of a non-transactional database to store data without creating NFTs may reduce interoperability concerns, the system sacrifices a degree of traceability and accountability (see Scenario 0.5).

Table 51 Desirable characteristics of a carbon removal and certifications

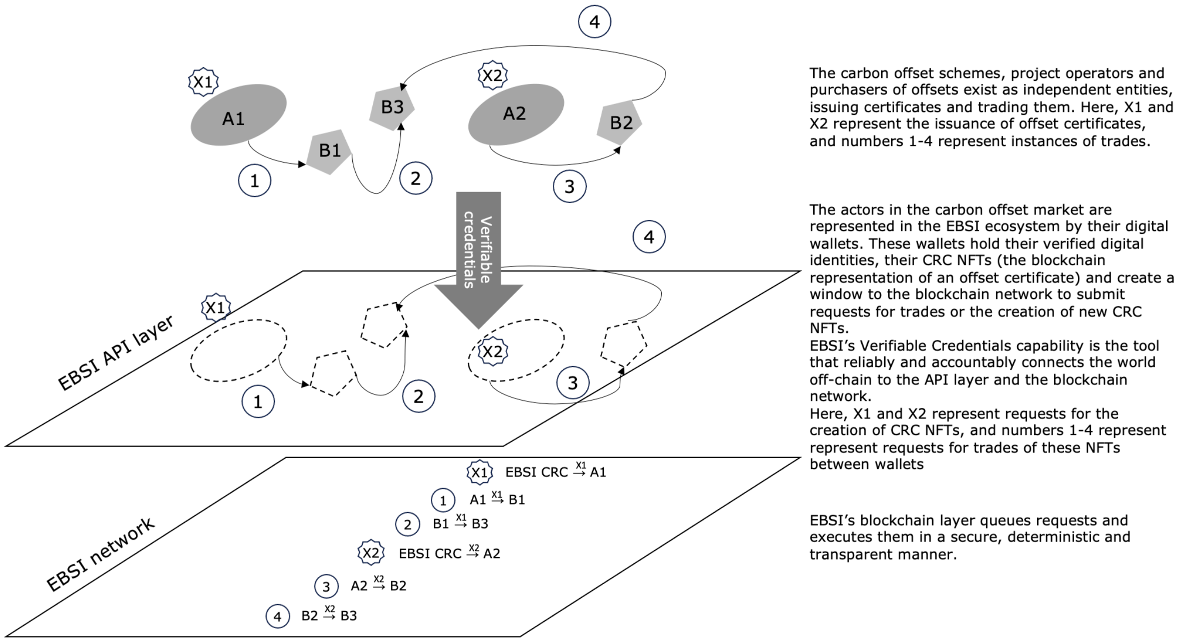
- Operators conducting carbon removals;
- Certification bodies conducting audits and issuing certificates;
- National accreditation of certification bodies and monitoring thereof by Member States;
- Recognition of certification schemes by the Commission;
- Certification schemes ensuring correct auditing and issuing of certificates, and making certificates publicly available.

Scenario 2 – single registry for CRCs

Scenario 2 describes a scenario in which certification schemes subscribe to a single CRC registry active across the EU, as well as the high-level governance and components required for effective operation at the EU level. While at the blockchain level there exists a single registry, certification schemes still operate independently, issue their own certificates and maintain their respective certificate databases. These certificate databases do not need to be based on DLT. However, each certificate is simultaneously issued as a CRC NFT on EBSI, and it is these NFTs which will be traded across a common blockchain environment.

An analogy of this setup is that of the Internet. While there may be different access providers (such as your home broadband subscription), different means of access (mobile network, wifi etc.) and different websites, they're all part of the same internet ecosystem. This allows different devices and websites to communicate while being operationally independent.

Figure 21 Layers of the carbon offset market with respect to the EBSI



- All actors in this carbon offset market have an EBSI-based digital wallet and a legal entity category DID (see section above for detail). The former allows actors to submit requests to the blockchain network (for trades or issuance of NFTs), while the latter ensures all on-chain events are traceable not only to a digital wallet but more crucially to a unique and accountable organisation.

- Carbon removal units originate from accredited certification bodies who in turn form part of one or many certification schemes. These certification bodies and schemes are all subject to the proposed Regulation at the EU level. Following this governance structure, a single EBSI-based registry dedicated to CRCs is managed by a single or federated overseeing organisation, potentially with representation from national and commercial certification organisations. This single registry shall have both transactional and non-transactional layers to accommodate market tracking.

- Upon approval of successful carbon removal by a project operator, the certification body shall simultaneously issue their report and certificate to the certification scheme and generate a request for a CRC NFT through a purpose-built app which interfaces with EBSI and is managed either by the certification scheme or the overseeing body at the EU level. This app will capture the necessary fields to ensure alignment with the Regulation and NFT requirements. The processing of NFT issuance requests shall be done through the standard EBSI network and its PoA consensus mechanism. The resultant NFT contains pointers to both the issued certificate and the audit report, both of which are stored in a database managed by the relevant certification scheme or some other party within the EU CRC network. As described in previous sections, the certificate and report data is not stored on-chain and is not strictly subject to the same benefits of security and transparency as on-chain data. However, the metadata contained within the NFT would be altered if any changes are made to the certificate and the audit report. Such an external database represents a single source of potential failure and should therefore be equipped with the necessary security and back-up systems to ensure continuous access to stored data.

- When a certificate or credit is traded, it shall remain on the database of the original carbon scheme. A change of hands shall be reflected in one of several ways; firstly, the transaction will be logged on the single blockchain registry, as the CRC NFT moves into a different digital wallet. Secondly, the certification scheme's database may obtain data from the blockchain registry to indicate the new owner, thus using the single registry to maintain records of certificate ownership.

- To prevent double claiming, the CRC shall be tokenised as an NFT. This prevents the existence of the digital asset in multiple wallets, so that only one digital wallet can claim the CRC NFT at once.

- Double counting may occur when project operators register their carbon removals with more than one certification scheme. Present measures to prevent this include guarantees provided by project operators that they will not engage in such activity, though this presents an administrative burden both for the project operators themselves and for the organisations who must enforce such guarantees. For the issue of double counting, each NFT shall be programmed with the geospatial data of the relevant land parcel on which the carbon capture has occurred. Even though certificates exist in separate databases, because their corresponding CRC NFTs are consolidated on a single ledger, origins and overlaps can be easily queried by an appropriately designed audit application.

- Wrongful issuance, another challenge experienced in the carbon removal markets, occurs when project operators request issuance of credits in cases which do not allow it. For example, carbon removals or reductions which are legally mandated or heavily subsidised may not be eligible for credit as it is another form of double counting. Current solutions rely on certification bodies to cross-check legal requirements and subsidies against individual projects. This process could be facilitated by listing the projects and entities which are subject to the abovementioned subsidies and legal requirements at a national level (each country develops and manages its own list), and then linking this data to the single registry and EBSI API layer to enable EU-wide queries and searches.

- In order to ensure the ability to update or revoke certificates in the future, given the immutable nature of DLT, CRC NFTs shall also be linked to smart contracts that authorise these actions. The use of smart contracts permits an auditable record of changes.

- The certificate and audit report shall remain on the assigned external database, while the associated NFT shall be issued to the digital wallet of the project operator. From there, the project operator may trade the NFT according to whatever rules have been assigned to the NFT via smart contract. For example, the certification scheme may choose to limit trade of their certificates to organisations in certain regions or sectors. This kind of capability is enhanced by EBSI's VC frameworks.

- To enable CRC NFT trade and verification across all digital wallets operating on the single EU registry, wallet providers will require standardisation of protocols at a system level. The issuance of CRC NFTs on a single registry should serve to standardise protocols, enabling auditing bodies and verifiers to make automated system requests capable of interpreting and aggregating certificate and audit report data.

- Lastly, given that local regulations may exist that require special data fields or market rules, the single registry should accommodate a large number of data fields which can be accounted for, verified and managed by smart contracts.

The role of complementary networks and VCs

- The key complementary network in Scenario 2 is that of DIDs, and is critical for establishing trust and accountability in the system. This is in contrast to Scenario 1 above, which requires a large number of complementary networks and governances to maintain trust across independent DLT registries.

Open-source metadata system (Scenario 0.5)

The use of a non-transactional DLT registry may achieve some of the results from Scenario 2, and a comparable system is currently in its early stages at the Climate Action Data (CAD) Trust[79]. The CAD Trust is implementing a global, open-source metadata system built on the Chia Network, which is a public blockchain. This database is not intended to enable the trade of CRCs through digital wallets. Rather, carbon schemes voluntarily upload or link their certificate data to the database by means of an application which acts as the window to the blockchain. This application also harmonises inputs to the database, so that all data transactions have the same, correct protocols. In practise, this database acts a common registry from which any interested parties such as local authorities may view carbon offset data, including geospatial information or changes to offset ownership, if such details are provided by the carbon scheme.

A similar database could be built on EBSI. In comparison to Scenario 2, the trade of carbon offsets would continue as they do now, without the need for digital wallets for exchange. Carbon schemes would link the issuance of new certificates and reports through a purpose-built application to the EBSI database without the creation of CRC NFTs. Instead, the EBSI database would statically point to the carbon scheme's certification data. The inclusion of geospatial data in certificates would reduce double counting, as auditors could run queries for overlaps within the single database. The reduction of double claiming, however, would be the responsibility of carbon schemes, who must enable their systems and processes to correctly retire claimed offsets. The matter of wrongful issuance would be solved in the same manner as for Scenario 1; by means of linking lists of projects who are subject to subsidy benefits or legal requirements to the single database to allow for system-wide queries. In contrast to Scenario 1, a degree of traceability and accountability is lost in this case due the lack of digital wallets and VCs, particularly for those actors involved in the trade and use of credits.

Conclusions

The primary consideration prior to any implementation of a blockchain solution should be to determine whether the benefits outweigh the challenges. The key benefits that DLT can offer the voluntary carbon removal markets are, firstly, the reduction of errors or fraud related to double counting, double claiming and wrongful issuance. Secondly, the reduction of administrative burdens related to auditing projects and credits, and the corresponding enforcement of regulations. It is important to note that blockchain does not eliminate the need for audit processes and authorities, it merely facilitates them. In contrast, a key concern related to DLT is that of interoperability, particularly outside of the EU, so that carbon offset schemes operating in multiple jurisdictions may be unable to participate.

This case study has presented two scenarios. Scenario 1 represents a single pan-European transactional registry which underpins and links the independently managed rules and databases (subject to a minimum level of alignment with the proposed Regulation) of individual carbon schemes. Scenario 1 represents a system in which all carbon schemes

[79] https://climateactiondata.org/about/

manage independent DLT databases which communicate directly, without the underlying single registry. Both scenarios are based on EBSI. A comparison of Scenarios 2 and 1 indicates that a single DLT registry at the EU level, based on the EBSI, is most feasible given:

- Scenario 2 involves significantly fewer actors who need to cooperate and form part of the overall process. It does not require the creation of complementary networks but can instead operate on those structures which should inherently form part of the EBSI when it is operating at scale.
- Scenario 1 poses risks to interoperability and therefore limits potential for DLT to offer its full suite of benefits.
- In both cases, carbon certifications schemes are required to adhere to the proposed Regulation in the issuance of their certificates and NFTs. Whereas Scenario 1 offers the possibility of independent governance and issuance of NFTs, it adds the burden of securing and maintaining a side-chain and the associated network, which requires more capacity and technical skill than Scenario 2.
- Both cases allow independent databases and certification conditions for each certification scheme, with some minimum amount of standardisation to comply with the proposed Regulation.

A third possibility, Scenario 0.5, is similar to Scenario 2 in that it suggests a single pan-European registry, though implemented as a non-transactional database. The lack of NFTs and digital wallets may lead to better interoperability and the potential for application beyond the EU, however, a degree of traceability and accountability is sacrificed. Quantification of the benefits of interoperability vs traceability and accountability is recommended.
More generally, the requirements for successful implementation of a blockchain system include the following:

- Awareness among potential users of the system's benefits, and also of the relevant agents across all roles. For example, users should know where to be onboarded, where to certify registry compliance, how to apply for DIDs etc.[80]
    - To find the best means of spreading awareness and understand the main areas where users require assistance, pilots could be run within a small slice of sector that involves the major components of the overall system. If value addition is measured as part of this pilot, it could be communicated to future users to promote buy-in.
- Constant alignment of off-ledger governance and certification processes with technical systems and interoperability requirements. Furthermore, the specifications for certificates and NFTs should remain stable to avoid multiple iterations of processes and apps, leading to increased sunk costs for certification schemes and public interest organisations.
- At the EBSI level, expansion and adoption of the EBSI ecosystem[81] into other use cases, such as government-backed digital IDs, will contribute to the establishment of norms which may increase buy-in and cooperation. Also, these additional use cases can be integrated into the CRC process rather than creating stand-alone, single use case structures and systems which risk duplication of effort
    - Various governments in the EU are already exploring digital identity options (Belgium, Netherlands[82], the EC itself[83]), and it is critical that these include EBSI /

80 https://doi.org/10.3390/bdcc7020079
81 https://doi.org/10.3390/bdcc7020079
82 https://www.inrupt.com/blog/flanders-solid
83 https://ec.europa.eu/commission/presscorner/detail/en/IP_21_2663

ESSIF standards and technical protocols if they are to contribute to the interoperability of EBSI functions.

While DLT presents several advantages for the reduction of administrative burdens related to reporting and auditing of the voluntary carbon market's activities, the issue of interoperability at an international level may present a risk to those certification schemes operating in countries both within and outside the EU. For blockchain infrastructures operating on fundamentally different protocols, blockchain bridges are not currently able to address this issue. In this case, political cooperation is proposed to determine minimum standards for international interoperability.

CASE STUDY 2. Ozone Depleting Substances

Introduction

This case study provides a high-level overview of the potential of Decentralised Ledger Technology (DLT) to support the implementation of EU Regulation on ozone-depleting substances (ODS). The regulation aims to safeguard the ozone layer and combat the adverse effects of substances that contribute to ozone depletion, such as for instance chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). The case study involved desk research into EU documentation, particularly recent impact assessment for the ODS licensing system, the application of DLT relevant to the ODS licensing system.

When relevant, the study examines the possibility of utilising the European Blockchain Services Infrastructure (EBSI) is a permissioned solution that is decentralized and distributed. It was born in 2018 when 29 countries (all EU members states, Norway and Liechtenstein) and the EU Commission have joined forces to create the European Blockchain Partnership (EBP). EBP's vision is to leverage blockchain to create cross-border services for public administrations, businesses, citizens and their ecosystems to verify information and make services trustworthy.

The case study is organised as follows:

- A policy background is provided setting-out the objectives and implementation approach to the EU Regulation on ozone-depleting substances.
- The rational is outlined for the selection of the proposed Regulation for DLT case research.
- A general assessment highlights the different DLT technological options.
- Conclusions discussing the pros and cons of different DLT technological options.

By harnessing the capabilities of DLT, the study seeks to discuss technological options to enhance transparency, traceability, license management, compliance monitoring, and data security in the management of ozone-depleting substances.

Policy Background

The ozone layer is a natural layer of gas in the upper atmosphere that protects humans and other living things from harmful ultraviolet (UV) radiation from the sun. UV-B has a harmful effect on all living organisms, both terrestrial and aquatic, as it alters the DNA of cells. High levels of UV-B radiation reduce photosynthesis and the growth of vegetation and crops. Scientists discovered in the 1970s that the ozone layer was being depleted. Humans will be directly exposed to the harmful ultraviolet radiation of the sun due to the depletion of the ozone layer. This might result in serious health issues among humans, such as skin diseases, cancer, sunburns, cataract, quick ageing and weak immune system. Scientific evidence has revealed that certain man-made chemicals are the cause of this depletion. These ozone-depleting substances were introduced mainly in the 1970s in a wide range of industrial and consumer applications, including refrigerators, air conditioners and fire extinguishers. In 1987, to combat the destruction of the ozone layer, the international community established the Montreal Protocol on Substances that Deplete the Ozone Layer. It aimed to reduce the production and consumption of substances that deplete the ozone layer (phase out chlorofluorocarbons (CFCs) in 1993, and by 1998 achieve a 50% reduction on 1986 consumption levels).

TSome of the most known ozone-depleting substances (ODS) are chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). The industrial production of CFCs (that started in the 1920's) caused an average reduction of the ozone layer of 3 per cent. The largest historical extent of the ozone hole — 28.4 million km² — occurred in September 2000.

Since the 1980s the European Union has taken a leading role in global efforts to phase-out ODS in order to preserve the ozone layer. A number of Council Decisions and Regulations started regulating certain CFCs and halons in the 1980s. Regulation (EC) No 2037/2000 preceded the current Regulation (EC) No 1005/2009. The objective of the EU Ozone Regulation (Regulation (EC) No 1005/2009) is to protect the Earth's ozone layer by controlling the production, use, import, export, and placing on the market of substances that deplete it. The regulation aims to ensure that ozone-depleting substances (ODS) are phased out and replaced with more environmentally friendly alternatives. The EU Ozone Regulation covers a wide range of ODS, including, among others, chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), halons, carbon tetrachloride, and methyl chloroform. The EU aims to prevent the equivalent of 32,000 tonnes of ozone depleting potential (ODP) emissions by 2050 through the implementation of new measures aimed at products in which ODS were previously used legally. The regulation requires licences for companies engaged in the import and/or export of ODS (bulk substances) or ODS containing products, as well as production authorisations (for laboratory and analytical uses) for bulk substances via the ODS Licensing System. The regulation also requires reports for companies engaged in production, destruction, import, export and/or some uses of ODS (bulk substances) via the Business Data Repository (BDR) managed by the EEA .

The ODS licensing system

Licences are issued by the European Commission with the use of a software called the ODS Licensing System. The version that is currently in use began to be progressively rolled out from 2013, and allows for the tracking and verification of ODS production authorisations, import and export licences and, when applicable, quotas (though the efficiency of the quota process has been put to question in a recent ODS impact assessment). The database is managed by the European Commission (DG CLIMA) and is accessible on a need-to-know basis to EU and national authorities, industry stakeholders, national ozone units from third countries (in the latter case, only limited information linked to the validity of a licence) and, when necessary, third parties like contractors of the Commission (subject to confidentiality agreements). Annual reporting on the activities of undertakings with ODS is performed through a tool managed by the European Environment Agency (EEA) called BDR and linked to the ODS licensing system.

A licence is required for the import/export of the substance itself, a mixture containing ODS and a product or equipment containing or relying on ODS. The system is also used to release authorisations for production of ODS for laboratory and analytical uses. To obtain a licence, the entity concerned has first to apply for registration for an ODS account, providing information such as their legal name, EORI number, address, contact person and business profile. Once they are registered by the Commission, undertakings can apply for quota and/or licences. In a per-shipment import/export licence application, that applies to bulk substances and most types of products and equi^pment, the applicant must provide the details of the exporter/importer in the third country, details of the substance/s and its use and then they can apply for a licence within this ODS account. Hence per-shipment licences for bulk substances and some products and equipment must include information on the quantities, type and intended use of the ODS, as well as the parties involved in the transaction. Such licences are to be issued for each shipment. Bulk licences for products and equipment used in the aviation sector can be used multiple times within their validity period and contain just an indication of the ODS and the type of products/equipment.

In terms of compliance, Member States' competent authorities can carry out checks regarding the compliance of undertakings with their obligations under the regulation and keep records of these checks. The checks could be carried out without warning to the undertakings. Directive 2008/99/EC on the protection of the environment through criminal law establishes that the illegal production, trade, placing on the market or use of ozone-depleting substances is a criminal offence.

Current system

Import/export licences are issued per shipment, except for products and equipment containing or relying on halons for use on aircraft. For the latter, licences can be used for multiple shipments within their validity period of up to one calendar year. The system does not cover only the release for free circulation into the EU customs territory, but also shipments under other customs procedures (like inward processing). Quotas are annually distributed to import ODS for feedstock uses, process agent uses and critical uses of halons, as well as for import and production of ODS for laboratory and analytical uses. Only quota holders can apply for import licences and production authorisations for such purposes until the maximum annual quota that has been granted to them; the licensing system checks automatically that the licences/authorisations issued to an undertaking do not exceed the maximum annual quota.

Proposal for update the regulation

Currently, there is a proposal (ref. COM/2022/151 final) for update of the regulation. Both the licensing per shipment and the quota system are among the proposed changes to the ODS licensing system – to introduce a periodic license and remove the ODS quotas entirely. The annual quota allocation system would be abolished for the important use of exempted substances; and modernising the licensing system. Importers/exporters of ODS and products would apply for 'traders' licenses, instead of per shipment licenses. The licensing system would be interconnected with the national customs authorities' systems through the EU 'single window' for customs, so that the validity of licences would be checked automatically at customs for every shipment. These measures are expected to achieve substantial cost savings for industry and relevant authorities.

The ODS licensing system is linked to the EEA's reporting tool BDR (Business Data Repository), through which undertakings report on the production, destruction, import, export and some uses of ODS every year pursuant to Article 27 of the Ozone Regulation. The data from the BDR are then reported at EU aggregated level to the Ozone Secretariat of the United Nations Environment Programme through an online reporting system (ORS) developed by them. A machine-to-machine communication system has been established for this purpose between BDR and the UNEP ORS.

Rationale for the selection for DLT case study

The ODS licensing system has been subject of a recent impact assessment, evaluating the current approaches to its implementation and possible scenarios for improvement.[84] The report highlights that the possibility of targeting the following broad challenges[85]:

- Increase efficiency of some measures.
- Reduce gaps in monitoring.
- Ensure clarity and coherence with other rules.

These challenges demonstrate that the ODS licensing system has an opportunity to be updated through the implementation of new technology solutions. There are therefore challenges linked to improving the traceability of licences, monitoring the extension of reporting, the increase in the number of players, the correct application of legislation and the detection of fraud.

The needs and challenges for the ODS correspond to the possibilities offered by DLT solutions. Thus, in the following chapters the challenges for ODS will be presented in greater detail. This will be followed by exploring the possibility of utilising DLT system as the basis for ODS licensing, possible pathways to implementations, including leveraging EBSI.

Challenges of the policy implementation

In 2022, the EU Commission proposed to amend the Ozone Regulation to increase the efficiency of existing measures to achieve additional emission reductions and ensure a more comprehensive monitoring of ODS. For example, in the proposed revision, the European Commission considers the removal of the quota system[86], arguing they have achieved their purpose and in the future would have limited added value. Costs of the annual quota systems for import and production of exempted uses are disproportionate compared to the benefits. According to the ODS impact assessment, import and production quotas did not result in any noticeable environmental effects, although they proved to be effective at reducing the use of the relevant substance groups in the past when the EU was still reducing the general consumption and production of ODS under the Protocol's schedules. As this has now been achieved, the remaining exempted uses are allowed only to the extent that they are needed. A quota system therefore appears to be redundant.

A modernised licensing system and the elimination of antiquated quota would result in cost savings for the industry and authorities. The reporting would be expanded to include more substances and activities so that the remaining trade in ODS, their emissions, and any future hazards can be better understood.

Monitoring and enforcement challenges are connected to the reporting requirements placed on the multitude of actors that need to report their ODS-related information. Indeed, verifying compliance with the EU Ozone Regulation can be a complex and time-consuming process,

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[84] European Commission (2022). SWD (2022)99 final, Commission Staff working document, impact assessment report for regulation on substances that deplete the ozone layer and repealing Regulation (EC)No. 1005/2009. Available at: https://climate.ec.europa.eu/system/files/2022-04/ods_impact_assessment_en.pdf

[85] European Commission (2022). Initial Appraisal of a European Commission Impact Assessment Further reduction of the ozone depleting substances. Available at: https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/734694/EPRS_BRI(2022)734694_EN.pdf

[86] The Commission allocated quotas to importers and producers for the release of exempted uses. Quotas were allocated annually for the next calendar year.

particularly when dealing with cross-border transactions. The European Union and Member States - as parties to the Montreal Protocol - must report to the Ozone Secretariat of the United Nations Environment Programme on the production, import and export of ozone-depleting substances. Additionally, enforcement can be challenging due to the differences in national regulations and enforcement procedures, as well as by the involvement of third-party countries in the trade of these substances. In terms of fraud, it can also be difficult to detect and prevent illegal activities, such as the illegal production and trade of ozone-depleting substances (ODS). Stakeholders, in particular in the chemical industry, have expressed great concern about growing importance of illegal trade, placing illegally ODS on the EU market[87].

DLT could support solving these challenges by providing a secure platform for sharing information and facilitating the implementation of the regulation. EBSI is a relevant example. These opportunities are examined in further chapters. Importantly, the proposed revisions discussed in the 2022 ODS impact assessment are taken into consideration when examining the potential for the introduction of DLT technology towards reporting, monitoring, and compliance requirements.

Opportunities to use DLT

Operational cost

DLT could support solving these challenges by providing a secure and decentralised platform for sharing information and facilitating the implementation of the regulation. These opportunities are examined in further chapters. Importantly, the proposed revisions discussed in the 2022 ODS impact assessment are taken into consideration when examining the potential for the introduction of DLT technology towards reporting, monitoring and compliance requirements.

The area of Ozone Regulation (Regulation (EC) No 1005/2009) is considered for further investigation when it comes to adopting DLT. First, the adoption of DLT could translate in reduced costs. The current ODS licencingand quota systems creates excessive costs and burdens for the EU-level administration, authorities and stakeholders as a licence for import/export is not always granted automatically (some that have a low risk are). Many undertakings registering in the system are SMEs that face entry costs in understanding the legislation, becoming acquainted with the registration system and providing the right information. As explained in the previous section, the quota system is too costly.

The licensing system would be modified to eliminate the quota system according to a 2022 Commission proposal for a new regulation. The system is being interconnected with the national customs authorities' systems through the EU 'single window' for customs, so that the validity of licences would be checked automatically at customs for every shipment. These measures are expected to achieve substantial cost savings for industry and relevant authorities and could be achieved though DLT implementation.

Compliance, monitoring

Concerning reporting and compliance, benefits include, for example, reducing errors and inaccuracies by automating several reporting procedures and allowing an easier monitoring

[87] European Commission (2022). SWD(2022)99 final, Commission Staff working document, impact assessment report for regulation on substances that deplete the ozone layer and repealing Regulation (EC)No. 1005/2009. Available at: https://climate.ec.europa.eu/system/files/2022-04/ods_impact_assessment_en.pdf

of compliance. The introduction of DLT can facilitate this. Data can include imports, exports, production, destruction, process agent use, feedstock use , stocks, and data on new ODS.

Additionally, the advantage of immutable DLT records of all the changes in the beneficiaries of quota can help detecting non-compliance, although transfer of ODS quotas among beneficiaries are rare events (and quotas should be abolished according to the ODS impact assessment). In terms of cross-jurisdiction, the application of DLT could favour collaboration and coordination between stakeholders and regulatory bodies across jurisdiction.

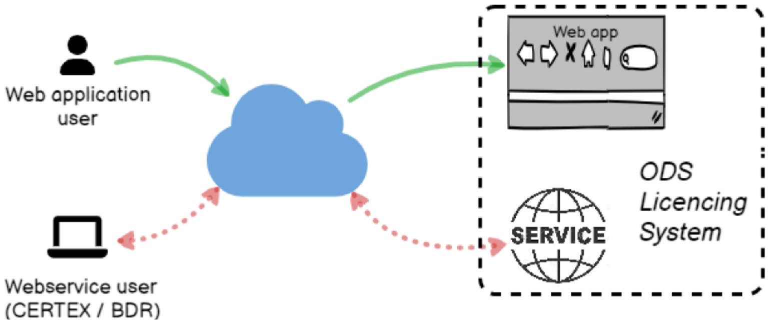
The introduction of DLT for the ozone regulation could set a positive example for other countries on effective climate policies when it comes to strengthening political cooperation. Moreover, it could find strong support among the business community looking for solutions to level the playing field against illegal trade of ODS.

Due to the close linkages between the ODS and F-gases regulations, some economies of scopes could be identified to use the same technology for similar aspects (monitoring, reporting and compliance requirement). Furthermore, the ODS licensing system could leverage EBSI as the framework to adopt DLT to manage ODS licensing.

The EU Single window Environment

The EU single Window system for customs is a digital platform enabling traders to submit information and documents related to the import and exports of goods in the EU. It provides a single-entry point and aims at streamlining and simplifying the customer clearances process. Indeed, it removes the need for multiple data entries and manual paperwork. The EU Single Window Environment for Customs will enable interoperability between customs and non-customs domains to streamline the electronic exchange of documents and information required. The framework legally establishes a centralised system to interconnect the import, export and transit systems of the Member States with Union non-customs systems that manage non-customs formalities.

Figure 22 Simplified EU Single Window schematic

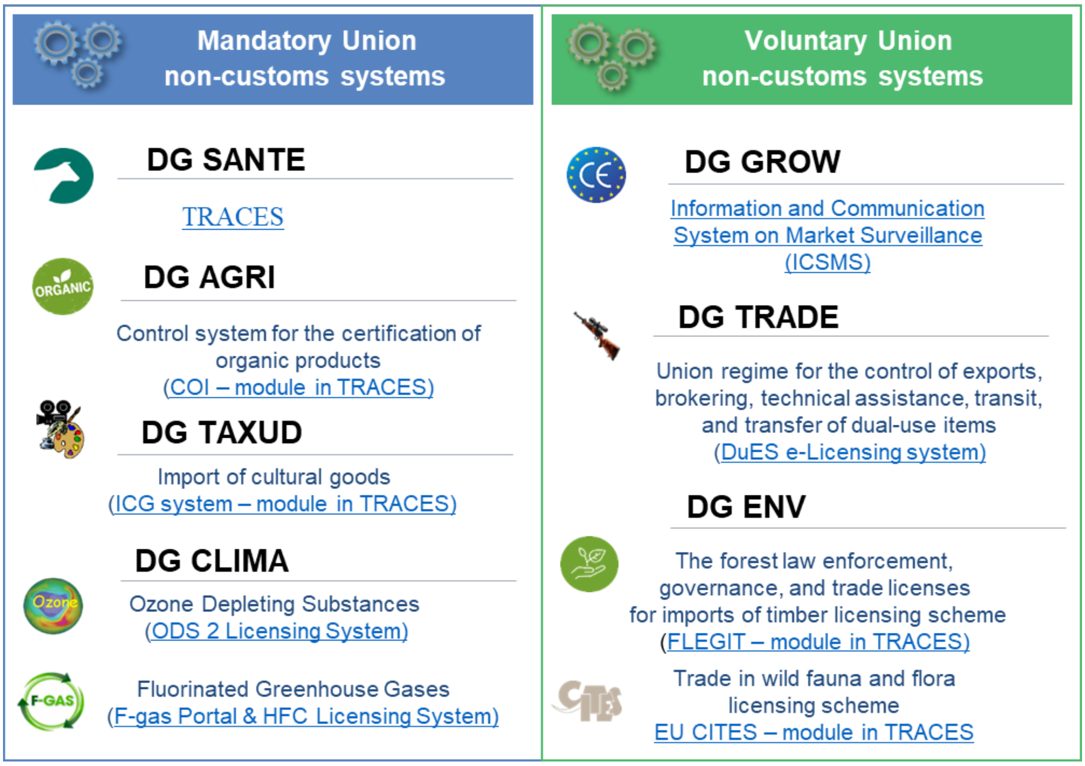


Source: Technopolis

An important component of the EU Single Window Environment for Customs is the EU CSW-CERTEX. This EU CSW-CERTEX system was launched as a pilot project with several national competent authorities. The implementation phase of the EU Single window will be done gradually, with the first phase coming into effect by 2025.

The EU CSW-CERTEX system would initially cover sanitary and phytosanitary requirements, rules governing the import of biological products, environmental requirements relating to fluorinated greenhouse gases and ozone-depleting substances, and formalities relating to the import of cultural goods. It is an electronic system managed by TAXUD and allows for information exchange. CSW CERTEX covers several non-custom documents (i.e., certificates, licenses, permits, and other formalities). This will help in reducing the risk of fraud and gaps in the enforcement of non-custom requirements. Importantly, the ODS licensing system falls under the Mandatory Union non-custom systems. These are managed by their respective agencies (DG CLIMA in the case of ODS) and are connected to and share information with CSW-CERTEX.[88]

Figure 23 EU SWE-CERTEX Union non-customs systems



Source: European Commission (2022). The EU Single Window Environment for Customs

In the context of DLT compatibility with CSW-CERTEX, the main challenges would be the flexibility of CSW-CERTEX to accommodate different system environments, the administrative burdens for the agencies managing the mandatory and voluntary non-customs systems and ensuring smooth, efficient transfer of data between them and CSW-CERTEX.

Technical applicability of DLT to ODS licensing system within EU Single window

Exploration of specific DLT implementation use cases

The following chapters present a discussion on possible use cases for DLT. The first two use cases present those that will be further elaborated upon during Task 3, including discussing the

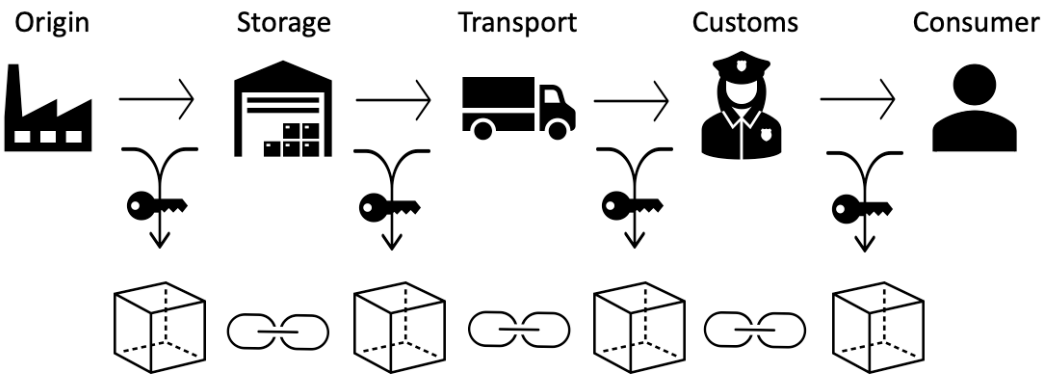
[88] Source: European Commission (2022). The EU Single Window Environment for Customs. Available at: https://taxation-customs.ec.europa.eu/eu-single-window-environment-customs_en

specifics of their implementation within the ODS framework. A further three additional uses cases are presented in the appendix of this document. These additional cases offer argument for possible future benefits of DLT system utilisation should the European Commission be interested in revisiting this topic.

Use case 1: Monitoring and Reporting

The objective of DLT based monitoring is to provide authorities, stakeholders, and the general public with a greater understanding and overview of ODS-related trade and use. By leveraging the transparency and immutability of DLT, it becomes possible to optimise audit processes and accountability within the industry, thereby reducing incentive for misclassification. In particular, as all data transactions on a DLT system are stamped with the unique "address" of the digital wallet that originated the request, the digital wallet can be used as a tool to promote or even enforce accountability. For example, only the digital wallets of those organisations possessing valid licenses and registrations could be permitted to log ODS transactions onto a DLT based supply chain system (see figure below). Simultaneously, the association of these licenses and registrations with a unique digital wallet ensures that ODS transactions from the supply chain system can be traced directly to an accountable party. The record of these transactions would also be safe from tampering and manipulation. By making such a supply chain system visible to stakeholders, including regulatory bodies, their verification activities can be simplified. The inspection process could be incorporated into the DLT based system and enhanced by smart contracts that could trigger alerts and run origins checks whenever real-world inspection data does not match on-chain classification data. Each transaction related to the movement or handling of ODS can be recorded on a dedicated supply chain DLT system which is linked to complementary databases (such as those which hold and issue licenses and registrations) via smart contract. This integrated system could create an audit trail that captures the entire lifecycle of the substances along with all associated actors and their designations.

Figure 24 Simplified schematic of how ODSs could move through a DLT based supply chain monitoring system



A blockchain based supply chain monitoring system can be used to provide real-time updates regarding the status and location of ODSs. For example, each time an ODS is manufactured or changes hands, these actions can be logged by the relevant actors onto a single network. The logging of information can be automated through IoT or other digital applications to further reduce administrative intervention. Authorisation to submit updates to the system can be regulated directly, or by the integration of complementary systems such as those which grant licenses and registrations.

Source: Technopolis Group

Supply chain systems like the one described above are already in use in industry to allow actors in the logistics business to automate workflows, predict bottlenecks and view shipment activity in real-time[89].

Use case 2: Security

Increasingly stringent requirements on data protection and security is expected to drive administrative costs at the European level (Commission and EEA). Data protection consists of different aspects for which a DLT system can offer varying degrees of utility. The primary aspect of data protection involves the preservation of information against damage, loss or corruption. DLT application in this area depends on whether this sensitive information is stored on-chain or whether instead the data transactions 'point' to data stored externally. The former case is highly secure, as all nodes in the network would have a copy of the data which could be recovered should any of the other nodes suffer damage. However, this method of storage would also require larger data transaction sizes and therefore impose higher storage and computational requirements on every node in the network. The latter case is less data-heavy for the network itself and requires only a single database to which the network 'points', but this database is at risk of being a single point of failure should it be damaged or compromised. In such an instance the data would not necessarily be recoverable, but the DLT system would still detect any changes in information stored externally as the hashes generated for each block incorporate the metadata from externally stored files. Therefore, even when data is stored externally, DLT is ideal for detecting whether data has been tampered with.

Another aspect of data protection relates to data sovereignty. Public DLT systems promote data sovereignty as their networks are maintained and updated in a decentralised manner. Consequently, their data does not belong to a centralised organisation. However, as data transactions can be requested anonymously, public DLT systems also lack accountability. Consortium or private DLT systems can solve this issue by limiting participation in the network to trusted parties but may do so at the expense of data sovereignty in the same way that centralised digital systems do. Some DLT systems are addressing this, for example, EBSI has GDPR and other European privacy and sovereignty regulations built into it, and node operators must be compliant. Therefore, given a well-designed system, DLT can be used to simultaneously promote accountability and data sovereignty.

Consortium DLT systems are also applicable for cybersecurity, as the right to modify or view data can be restricted to trusted parties. And as a further assurance, a hash value representing the state of the DLT system at a particular point in time can be periodically saved on an external, public DLT system. While this process does not actually report or save the database itself, it creates a record of the state of the DLT system that cannot be altered by the actors in the consortium.

Technological alternatives

Non-DLT databases and digital systems may be implemented to achieve similar outputs to those described above, albeit with certain drawbacks. In cases where standardisation of laws, rules and protocols cannot be agreed for political or other reasons, non-DLT digital solutions are simpler to retrofit or connect to new processes, given that their structure is potentially less

[89] Urwin M. (2023). Blockchain and Logistics: 19 Examples of the Technology. Available at: https://builtin.com/blockchain/blockchain-supply-chain-logistics-uses

strict than that of DLT. However, immutability is sacrificed as a result. Should standardisation of blockchain protocols take place at the EU or international levels this issue may be eliminated.

Furthermore, whereas a non-DLT system may require verification or intervention at several steps along a process, a well-designed DLT process requires verification only at the origin of new data. Once data has entered the DLT system, its architecture protects its integrity and, in this way, reduces the administrative burden linked to audit and enforcement processes.

Conclusions

A well-designed DLT system can address several of the current issues faced by ozone regulation processes in the EU. For the case of licensing it has been demonstrated how DLT is applied in similar instances by the private sector, and how these could be carried over to ODS licensing. Similarly, the application of DLT to the ODS supply chain could improve monitoring and reporting processes and provide real-time data on the status and location of goods. It has also been shown how a DLT system can enhance data security by limiting access, by drastically reducing the ability to change historical on-chain information and by providing an immutable log of data and any changes to data.

The use of verifiable digital identities or license keys, particularly for legal entities, to stamp data transactions on the DLT system improves auditability and reduces the possibility for ODS supply chain actors to create and use false identities within the system. This in turn reduces the possibility of exceeding quotas and license terms and increases the likelihood of accurate reporting across the ODS system.

Though DLT can offer several improvements to current and future processes, it remains important to leverage existing systems like EBSI and consider how changes to the ODS licensing system will affect its integration with the EU Single Window. The integration of these systems will require consideration of each component's relative strengths and weaknesses and must weigh these against investments already made and the system's readiness for change. In this regard, it is possible to achieve similar outputs using non-DLT systems, though with potentially higher administrative input.

Next steps in relation to this case study on ODS, is laying down the potential preliminary implementation strategy focused on the role of European Commission's administrative capacity to enable blockchain implementation and how this affects the requirements for blockchain and the impacts that can be achieved.

CASE STUDY 3. F-gas

Introduction

This case study provides a high-level overview of the potential of Decentralised Ledger Technology (DLT) to support the implementation of the f-gases regulation.

The case study involved desk research of EU laws and Blockchain reports, interviews with European Commission policy officers working on f-gases regulation, ODS regulation, and on the EU single window environment.

The case study is organised as follows:

- A policy background is provided setting-out the objectives and implementation approach to the proposed regulation.

- The rational is outlined for the selection of the proposed Regulation for DLT case research.
- An overview of the system in place and the EU single window environment is provided.

Policy Background

F-gas Regulation (EU) No 517/2014 aims to reduce the EU's F-gas emissions by two-thirds by 2030 compared with 2014 levels. The regulation sets out rules on containment, use, recovery and destruction, the placing on the market and the use of F-gases and it establishes quantitative limits for their placing on the market. It also establishes reporting requirement for producers, importers and exporters of f-gases, companies destroying f-gases or using them as feedstock, for companies that place f-gases in products or equipment.

Prior to carrying out any activities that fall under Regulation (EU) No 517/2014 the 'F-gas Regulation'), all companies shall register in the F-gas Portal & HFC licensing system. This is mandatory for companies to receive a quota, for importers of equipment containing HFCs, and for all entities supplying or receiving exempted gases such as those hydrofluorocarbons (HFCs) imported for destruction, for use as feedstock, directly exported in bulk, as well as for use in military equipment, in semiconductor manufacture or for metered dose inhalers (MDIs). All companies that report on the annual F-gas-related activities must register in the F-gas Portal & HFC Licensing System to enable access to the reporting forms. This F-gas Portal & HFC Licensing System is managed by the European Commission (DG CLIMA) and is accessible on a need-to-know basis to EU and national authorities, the companies themselves, and, when necessary, third parties like contractors of the Commission (subject to confidentiality agreements). Annual reporting on their activities with F-gases by undertakings is performed through a tool managed by the European Environment Agency (EEA) called BDR and linked to the F-gas Portal & HFC Licensing System.

As regards activities related to imports and exports of fluorinated gases and imports of equipment pre-charged with HFCs, a valid registration constitutes an import or export license.

The new proposed regulation

A revision of the F-gas Regulation (Com(2022)150 final) is currently being negotiated by the co-legislators. The objective of the revision is to deliver higher ambition, improve enforcement and implementation of the regulation and achieve more comprehensive monitoring of f-gases placed on the EU market. In particular, the revision is intended to set a tighter quota system for hydrofluorocarbons (HFC) gases and introduce additional restrictions for the placing on the market.

It introduces important changes regarding trade, with important provisions such as: custom controls; monitoring of illegal trade; restrictions on imports and exports with states, organisations, and territories not signatories of the 2016 Kigali Amendment of the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer ('the Protocol'); and price per tCO_2e for quotas.

It is important to mention that the proposed revision does not significantly change the functionality of the F-gas Portal & HFC licensing system, reporting requirements.

Rationale for the selection for DLT case study

There is rationale for the use of DLT solutions in combination with other digital technologies such as traceability systems (e.g., QR codes, RFID, etc.), for the easy of compliance to the new proposed provisions of the regulation.

Firstly, whilst shifting from free to prices quotas may allow to reduce illegal trade, it is uncertain whether the price will offset entirely the potential price difference between the EU and the world market for hydrofluorocarbons, reducing the rationale for price setting to prevent illegal trade. Moreover, quota pricing may not be a variable contributing to risk assessments by customs authorities whilst controlling the legitimacy and accuracy of the declared f-gas related trade for clearance, therefore it may not necessarily contribute to the prevention of illegal trade.

Provision 24 of the proposed revision of the F-gas Regulation (Com(2022)150 final) includes the possibility of delegating act where tracing methods may be required to reduce the potential risks of illegal trade liked to movements of gases from temporary storage to customs warehousing, free zones, or in transit, and in general to gases present in the market. The use of DLT systems in combination with other digital technologies (e.g. RFID, etc.) may allow to monitor and to autonomously update information in a distributed ledger as the products move between economic and institutional operators. There may be benefits of **improved transparency and traceability**, which may contribute for the risk assessment and management of fraud (illegal trade) and non-compliance.

The use of DLT in combination with other digital technologies and the CERTEX/Single Window, may allow for an immutable ledger of the flow of products with F-gas along their supply chain, for transparency of the origin, destination, and transit of the product, and the update of EOs quotas. Thus, a system integrating DLT (incl. traceability information) with CERTEX/Single Window may enhance **stakeholder engagement** by integrating already existing traceability systems by economic operators (e.g. with RFID) with existing f-gas quota enforcement systems by competent authorities.

Thirdly, concerning reporting and compliance, automating several reporting procedures, and allowing an easier monitoring of compliance may contribute to **reducing errors and inaccuracies.** This is related to the possibility of immutable DLT based record transfers of quotas from a holder to other companies, use of quotas by importers or by a company managing authorisations,

An interoperable and cross-architectures DLT may allow seamless real-time traceability and information access of HFCs imports and exports to verify that gases are correctly accounted for within the quota system and across jurisdictions. It is important to investigate how to make the licensing tool more secure and explore possibilities to trace F-gases throughout the economy, along the whole supply chain from import/production to end-user/ export to ensure that the history of the gas can be traced. In this context, the Single Window Environment for Customs could be considered in the analysis[90].

The introduction of DLT systems for the f-gases regulation could set a positive example for other countries on effective climate policies when it comes to strengthening political cooperation. Moreover, it could find strong support among the business community looking for solutions to level the playing field against illegal trade of f-gas.

[90] The European Commission and Member States are already on a voluntary basis working to connect the F-gas Portal & HFC Licensing System to the so-called EU Single Window Environment for Customs. The 'Single Window' will enable electronic exchange of data and documents between customs domains and the F-gas Portal & HFC Licensing System via a central EU Customs Single Window Certificates Exchange System when goods are checked for customs clearance. The use of the Single Window Environment will become mandatory. At least one MS is already piloting with exchanging data related to F-Gas formalities.

Current system

F-gas portal and HFC Licencing system

The European Commission has set up an F-Gas Portal & HFC Licencing System for placing HFCs on the market:

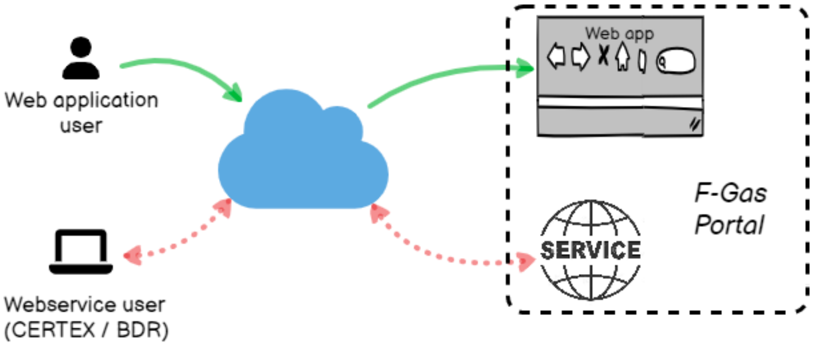
- A valid registration of an undertaking acting as importer or exporter in the F-Gas Portal & HFC Licencing System under the F-Gas Regulation is recognised as import/export licence. Such a license is however not a sufficient condition for being allowed to import into and export from the EU with undertakings also needing to fulfil other requirements, such as for example those related to the HFC phasedown.
- In practice, prior to carrying out any activities that fall under the F-Gas Regulation, all undertakings must register in the F-gas Portal & HFC Licensing System specifying their business profile. This registration request is checked by the European Commission, including as regards an undertaking's business activities and a registration can be refused, suspended, or cancelled.
- A valid registration is mandatory for companies to be allocated annual HFC quota by the European Commission, for importers of RACHP equipment pre-charged with HFCs to obtain authorisations to use quota, and for all entities supplying or receiving gases exempted under the F-Gas Regulation
- Registration is also needed to access the reporting tool to comply with the obligations of the F-Gas Regulation. All data related to individual undertakings, their quota allocations, authorisations to use quotas by importers of refrigeration, air-conditioning and heat pump equipment pre-charged with HFCs, compliance history etc., are stored in the system.
- The F-Gas Portal & HFC Licencing System also includes all necessary functionalities related to allocating quotas, transferring quotas between companies, authorising the use of quotas etc.
- For information purposes, undertakings trading with bulk HFCs or importing RACHP equipment pre-charged with HFCs can generate from their company profile in the F-gas Portal & HFC Licensing System an extract, in pdf format, of their main data stored in the System at any given time. This so-called 'Kigali Licence' shows the date of extracting the data from the system, the main company information (such as VAT number, address and ID number in the licencing system) and whether or not the undertaking has a valid registration as a bulk importer and/or as importer of RACHP equipment pre-charged with HFCs. The extract also informs whether the undertaking has or has not valid quota for the import of bulk HFCs and in the case of RACHP equipment pre-charged with HFCs, if the undertaking has enough authorisations to use quota at the time of import.
- EU Member States incl. custom authorities can check the data about a company including quota availability and/or amount of authorisations to use quota for customs clearance.
- The F-gas Portal & HFC Licensing System is linked to the EEA's reporting tool BDR (Business Data Repository), through which undertakings report on F-gas activities every year pursuant to Article 19 of the F-Gas Regulation. The data from the BDR are then reported at EU aggregated level to the Ozone Secretariat of the United Nations Environment Programme through an online reporting system (ORS) developed by them. A machine-to-machine communication system has been established for this purpose between BDR and the UNEP ORS.
- In case the proposed quota price is approved during the negations, this would mean that the European Commission will have additional obligation to collect the quota price and information on whether the company requesting the quota has paid and how much, for them to allocate the quota that was paid. This would imply additional functionalities in or related to the existing system. The proposed Regulation also includes additional provisions as regards electronic verification by independent auditors of the reported data. This is

consistent with the reporting of amounts of F-gas moving along their supply chains, and it is not providing the capability of additional documentation reporting such as invoices.

The EU Single Window Environment

The EU Single Window system for customs is a digital platform enabling traders to submit information and documents related to the import and exports of goods in the EU. It provides a single-entry point and aims at streamlining and simplifying the customer clearances process. Indeed, it removes the need for multiple data entries and manual paperwork. The EU Single Window Environment for Customs will enable interoperability between customs and non-customs domains to streamline the electronic exchange of documents and information required. The framework legally establishes a centralised system to interconnect the import, export and transit systems of the Member States with Union non-customs systems that manage non-customs formalities.

Figure 25 Simplified EU Single Window schematic

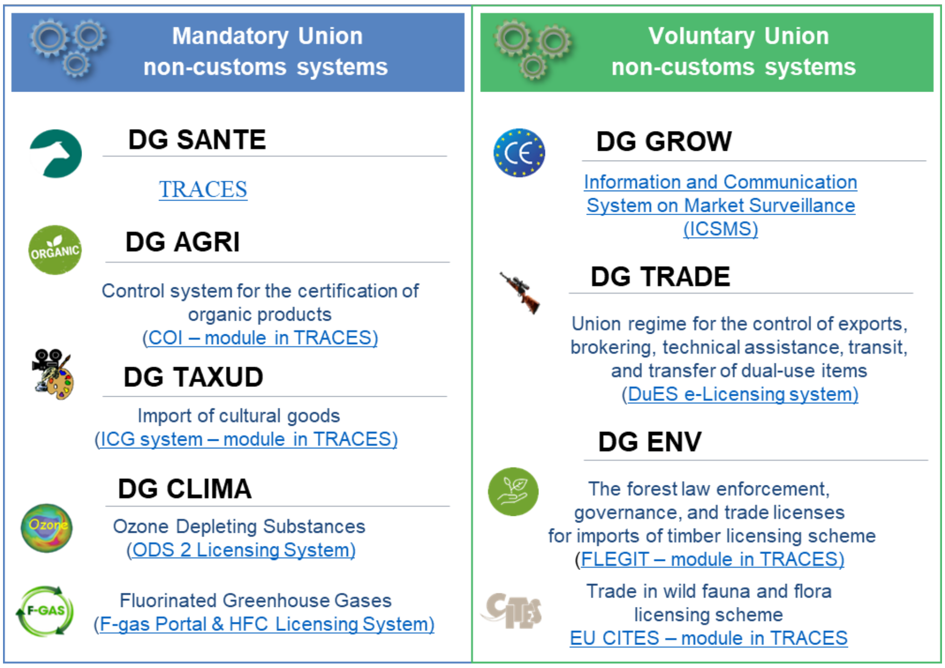


Source: DG CLIMA, FGAS' Functional description

An important component of the EU Single Window Environment for Customs is the EU CSW-CERTEX. The EU CSW-CERTEX system would initially cover sanitary and phytosanitary requirements, rules governing the import of biological products, environmental requirements relating to fluorinated greenhouse gases and ozone-depleting substances, and formalities relating to the import of cultural goods. It is an electronic system managed by TAXUD and allows for information exchange. EU CSW CERTEX covers several non-custom documents (i.e certificates, licenses, permits, and other formalities). This will help in reducing the risk of fraud and gaps in the enforcement of non-custom requirements.[91]

[91] Source: European Commission (2022). The EU Single Window Environment for Customs. Available at: https://taxation-customs.ec.europa.eu/eu-single-window-environment-customs_en

Figure 26 EU SWE-CERTEX Union non-customs systems



Source: European Commission (2022). The EU Single Window Environment for Customs

This EU CSW-CERTEX system was launched as a pilot project with several national competent authorities. The implementation phase of the EU Single Window will be done gradually, with the first phase coming into effect by 2025.

The obligatory implementation phase of the EU Single Window will be done gradually. The first phase starts in 2025 focused on intergovernmental exchanges at EU borders. Customs authorities will be able to automatically verify that non-customs formalities comply with the rules enforced by partner competent authorities. This verification will further ensure that the quantities of goods imported or exported at the EU level are properly monitored and controlled, thus reducing risks of fraud and gaps in the enforcement of non-customs requirements.

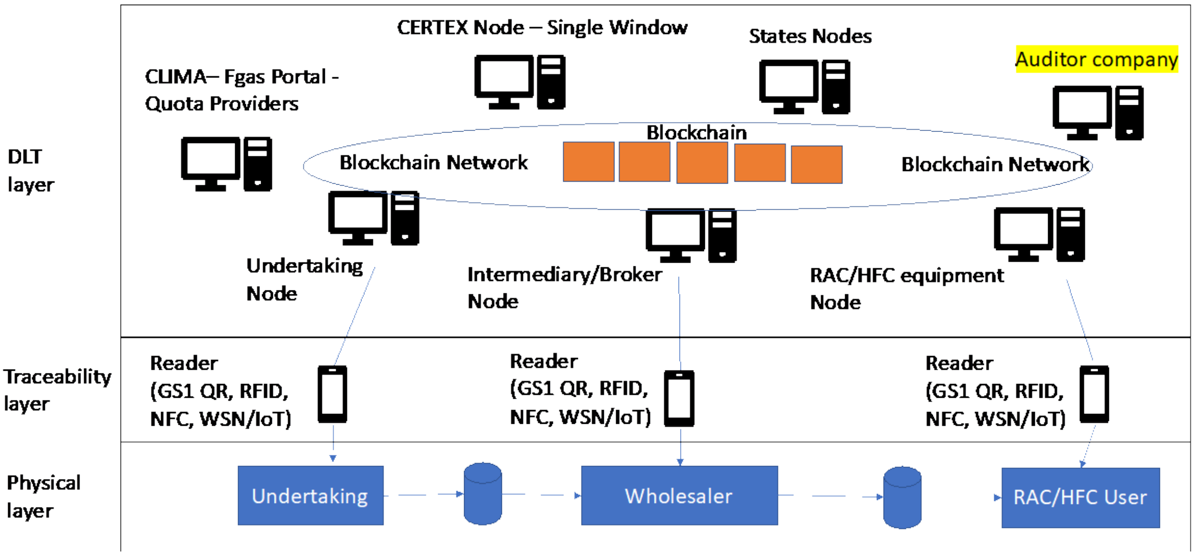
Technical applicability of DLT to F-gas portal HFC licensing system within EU single window

This section describes a potential applicability of DLT and other digital technologies for the management of quotas and a traceability system integrated with the F-Gas portal and CERTEX/Single window.

Architecture

The architecture entails three main layers, the DLT layer, traceability layer, and the physical flows of F-Gas. The next sections describe each one of the layers and their interactions.

Figure 27 DLT and Traceability System integration to the EU SWE-CERTEX



Source: Technopolis Group

DLT layer

Distributed ledger protocols such as Ethereum allow for deploying own transaction logic, e.g., in form of smart contracts which execute pre-defined rules when specific conditions are met, and records of transactions may be placed in a blockchain[92]. In this case, a distributed ledger would be comprised of nodes operated by the stakeholders and their respective roles involved in the allocating quotas, trading, customs clearance, authorising, assessing, and managing f-gas along an international supply chain, namely:

- F-gas portal role: Manages and registers transactions related to the quota management life cycle. It may also manage the verification of further compliance checks by country of origin of the Undertaking.
- Undertaking role: Manages and registers transactions related to quota authorisations and used quota authorisations. It may also manage further compliance documentation based on the origin of the Undertaking.
- CERTEX/SW role: Manages customs declarations from Undertakings. An authorised procedure is the forced interventions from customs bypassing the F-gas authorisation, activating a smart contract for automated update of the quota authorisation balance.
- Public authority role: Manages/validates licences and certificate of conformance issued by Undertakings.
- Auditor role: Access to the HFC registry without interventions upload rights. The main role of the auditor and auditor company is the ensure transparency throughout the overall system.

[92] Madhwal, Y., Borbon-Galvez, Y., Etemadi, N., Yanovich, Y., & Creazza, A. (2022). Proof of Delivery Smart Contract for Performance Measurements. IEEE Access, 10, 69147-69159. https://doi.org/10.1109/ACCESS.2022.3185634

The DLT layer connects with the physical layer through the traceability systems, which are recording real movement of F-Gas along international supply chains. The DLT layer verifies that the amount of F-Gas physically transferred between economic operators are within the limits of the quota allowances. Depending on the capabilities of the traceability system (i.e., ability to communicate bidirectionally with RFID and/IoT), upon depletion of allowances or revocation of allowances, the traceability system signals of the need to keep a F-Gas batch on hold to prevent the movement along the supply chain.

An important aspect to highlight regarding the F-gas portal features as per FGAS' functional description – Registration, which allows different operational flows according to whether the Undertaking or Auditor are from EU or non-EU states. As indicated in the rationale section of this case study, the Commission can implement Delegated Acts for the management of quotas from economic operators from states that are non-signatories to the Montreal protocol. In this line, the proposed architecture considers a possible scenario where distinctions between Undertakings from non-EU states signatories of the Montreal Protocol and non-EU states not signatories. Using smart contracts could necessitate additional criteria (compliance checks) by non-EU stakeholders.

Additional checks required to non-EU states' operating nodes could include updating their signatory status to the Montreal Protocol, as well as validation of documentation presented by Undertakings (i.e. HFC bulk, RAC importers, and Authorizing Managers).

Additional checks required to non-EU Undertaking nodes could include certification of compliance and/or documentation of valid licence to operate as F-Gas Undertaking in their respective state.

DLT infrastructure options

The architecture of F-gas interacts from a regulated industry; as such, a permissioned DLT architecture may be more suitable for the management and record of transactions, licences, certificate of conformance, etc. than permissionless DLT systems[93].

One infrastructure option in a permissioned environment is *Hyperledger Besu*. It allows for selecting from different consensus algorithms including Proof of Stake, Proof of Work, and Proof of Authority (IBFT 2.0, QBFT, and Clique)[94], and as such, it is a comprehensive permission environment for regulated consortium environments.

Another option is the use of the European Blockchain Services Infrastructure (EBSI). It is composed of three main elements: APIs, exposed on the public internet, which allow applications to connect; Smart Contracts, which act as a go-between the outside world (APIs) and the ledger; decentralised database of information that can be accessed by actors looking to complete a business process[95]. The advantage of EBSI is its ability to host multiple blockchain architectures (interoperable).

The F-Gas architecture can be hosted by the European Blockchain Services Infrastructure (EBSI) after operators meet the technical and security requirements imposed by EBSI.[96]

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[93] Eryilmaz, U., Dijkman, R., van Jaarsveld, W., van Dis, W., & Alizadeh, K. (2020, July). Traceability blockchain prototype for regulated manufacturing industries. In Proceedings of the 2nd International Electronics Communication Conference (pp. 9-16). https://doi.org/10.1145/3409934.3409937

[94] https://www.hyperledger.org/blog/2019/08/29/announcing-hyperledger-besu

[95] https://ec.europa.eu/digital-building-blocks/wikis/display/EBSI/What+is+ebsi#how-it-works

[96] EBSI (2023). What is EBSI? Available at: https://ec.europa.eu/digital-building-blocks/wikis/display/EBSI/What+is+ebsi

Traceability layer – technological options

Traceability is defined as the ability to access information – its entirety or part of it – related to the object moving along a chain of actors and business steps by means of recorded identifications. The object traced along the supply chain is called Traceable Resource Unit (TRU). There are three objectives for tracing an object: to track the history of the transactions, to assess the conditions of the object at each step of the value chain, and to track the real-time position of the TRU. To perform that, a traceability system requires access to the information related to the TRU. That access is enabled by a unique identifier for the TRU under scrutiny. The components of a typical traceability system are the following:

- Mechanisms for identifying TRUs;
- Mechanisms for recording attributes about the TRUs;
- Mechanisms for verifying conditions of the TRUs;
- And mechanisms for documenting connections between TRUs.[97]

The components described can be further classified into hardware elements (the identifier of the TRU and the reader of the identifier) and software elements, or software traceability platform, that gather the data from the identifier, run algorithms on that data, and exchange data with other software systems. In the case of the F-Gas, there is the identifier on the cylinder or equipment; the device needed to read the identifier, and software components that manage the data[98], and in case of the blockchain-based architecture move the data to the blockchain network.

Traditionally, traceability systems have used barcodes and RFID tags as identification techniques, Wireless Sensor Networks (WSN) or Internet of Things (IoT) sensor networks to capture data, and Electronic Product Code (EPC) to identify the product, gather and share product information along the different stages of the chain[99]. Generally, passive, and active RFID tags, barcodes and EPC solutions are based on GS1 standards. The information contained in a GS1-based barcode is captured across various supply chain processes and used to maintain a continuous log of ownership. At each step, the stakeholder records the possession of the product and can verify the authenticity through central data repository maintained as Global Data Synchronization Network (GSDN). The verification of authenticity and the retrieval of the information can be performed via a dedicated reader or a smartphone[100].

Near Field Communication (NFC) tags have been recently proposed as a traceability solution. Examples can be found in the pharmaceutical supply chain and in the food supply chain. The NFC Forum sees great opportunities in traceability when NFC converges with an IoT deployment[101]. The WSN or IoT network is involved in traceability solutions when conditions of the TRU need to be remotely monitored along the supply chain. For example, in the case of food or medicines, temperature, humidity and other indicators need to be assessed at each step. That can be done through an WSN or IoT network.

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[97] Olsen, P., Borit, M., "The components of a food traceability system", Trends in Food Science & Technology (2018), doi: 10.1016/j.tifs.2018.05.004.

[98] There are several commercial solutions offering F-gas tracking such as Joblogic (F-Gas Tracking Software | Book a Free Demo | Joblogic®), Service Geeni (F-Gas Data Management Tracking & Reporting Software - Service Geeni), and Click (F-Gas Tracking Software | Clik (cliksoftware.com))

[99] Bougdira, A., Ahaitouf, A. and Akharraz, I. (2019), "Conceptual framework for general traceability solution: description and bases", Journal of Modelling in Management, Vol. 15 No. 2, pp. 509-530.

[100] GS1, www.gs1.org. GS1 DataMatrix Guideline - GS1 DataMatrix Guideline | GS1

[101] NFC Forum, IoT (nfc-forum.org)

In the case of the F-gas, the choice of the traceability system depends on the tasks to perform. There is the essential task to identify the cylinder or equipment and read specific information about it that needs to be fed to the blockchain network. There is not an immediate need to sensing the conditions of the equipment. Therefore, there is no need of an IoT solution to put in place, but there is the need of a GS1-based solutions that could be a QR code, an RFID tag or an NFC tag.

Physical layer

The physical layer represents the traditional supply chain flow, where the HPC bulk producer ships bulk that places HFC in the market ships to a wholesaler, and in turn to a user of HFC applications such as RAC equipment.

Transparency and implications

Some of the implications on the implementation of a DLT increasing the transparency of the system, and with the ability of using smart contracts to execute pre-defined rules in the network to verify credentials, licences, certificates, and quotas balances, etc. can make the role of traditional auditing companies redundant.

The combination of the DLT with other digital technologies for the traceability of F-gas allows to update the quotas, balances, and summaries in real time, rather than on a periodic basis. Furthermore, traceability data provides measurable indication of the F-Gas and production level of Undertakings, which can be automatically used for following years, quota allocations.

The system does not distinguish between import and export and allows to manage outgoing flows of F-gas.

Conclusion

A DLT architecture with the combination of other digital technologies (i.e. traceability systems) allows to address the potential inclusion of provision 24 of the proposed F-gas regulation. Whilst the DLT is a new architecture being assessed, the use of traceability systems is not actually new in the industry. It is in fact a standard used to protect assets along supply chains. Thus, its adoption may be feasible from the point of view of the acceptability of the industry.

While transparency is important for monitoring trade and updating quota balances as they are used, near real time information on the status and flow of goods along international supply chains may allow customs to perform risk assessment for clearance of declared F-gases.

The proposed architecture includes the option to request additional documentation for Undertakings from non-Protocol signatory states, allowing to address the proposed provision 25. Similarly, non-Protocol signatory states are given options to update their internal procedures to ensure compliance of economic operators form their countries, allowing the Commission to evaluate and manage derogations when/if relevant.

The architecture therefore may be a tool that incentivise international stakeholder (public and private) engagement, into the efforts to carve f-gases and illegal trade.

Finally, the availability of an architecture that contributes to reduce inaccuracies, expedite validation of documentation, keep records up to date, and automatically enforce in case of throughout traceability and monitoring systems, may have impacts on the need of intermediaries previously placed to ensure transparency. Traceability systems may be subject to further or future analysis and of policy options.

Next steps in relation to this case study on F-gas, is laying down the potential preliminary implementation strategy focused on the role of European Commission's administrative capacity to enable blockchain implementation and how this affects the requirements for blockchain and the impacts that can be achieved.

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