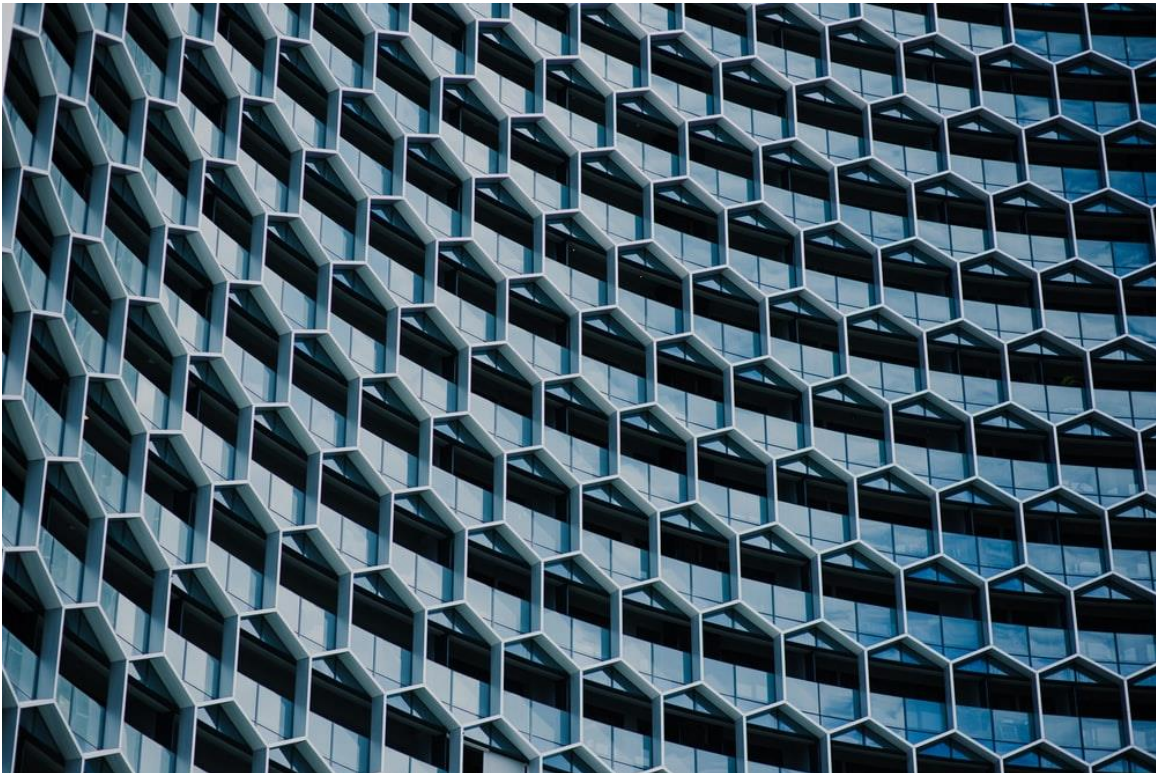BLOCKCHAIN BÜRO

south pole group

CLIMATE | LEDGER
INITIATIVE

Unlocking Climate Finance for Distributed Renewable Energy

Using blockchain and the token economy to leverage the impact of renewable energies

A real-world use case assessed in the context of the Liechtenstein Token and TT Service Provider Act (TVTG)

(May 2021)

CLIMATE | LEDGER
INITIATIVE

OFFICE FOR FOREIGN AFFAIRS
PRINCIPALITY OF LIECHTENSTEIN

I.   Introduction

In January 2020, the Law on Tokens and Trusted Technology Service Providers (Token and TT Service Provider Act; TVTG) came into force in Liechtenstein. The act allows the tokenization of assets and rights by establishing a Token Container Model. The "token" is a new legal construct which enables the transformation of the "real" world to blockchain systems while ensuring legal certainty. The act creates the premise that a token can be a package of various features: it can represent an asset such as real estate, stocks, bonds, gold, money value, a right to access or a security. To enable the tokenisation of different assets the TVTG provides guidance around newly established service providers, their registration and licensing obligations. Moreover, the act also determines how stakeholders under the TVTG are supervised. The framework is intended to create legal security for transactions with distributed ledger technologies and at the same time to strengthen customer protection.

While the creators of Liechtenstein's TVTG may have had the financial markets in mind when drafting the framework, the potential of the token economy goes way beyond the finance industry. Since 2016 the Climate Ledger Initiative (CLI) has operated at the intersection of digital technologies and climate action. The multi-stakeholder initiative examines and supports activities that combine the use of blockchain technology with climate projects. Experts confirm that the smart application of digital technologies will overcome the current limits to practicality and efficiency and the high costs associated with monitoring, verifying and reporting (MRV) the impact of climate projects (see NR1, 2018)[1]. Digital MRV systems can significantly enhance climate action by mainstreaming adoption, increasing the credibility and accuracy of reporting and encouraging better comparability and decision making.

The report at hand takes the next step of digitizing climate action and looks at the requirements and conditions needed to tokenise distributed renewable energy certificates (D-REC). The relevant system integration, including function schematics and technical feasibility of the D-REC generation and its corresponding tokenisation is explained in detail. Consequently, the token will contain the proof that a specific amount (1MWh) of renewable energy (solar home system) was generated at a unique location (here in Sub-Saharan Africa region, determined via GPS) at a given time (timestamp). According to Liechtenstein's Token Container Model, the token serves as the vehicle that contains the proof of impact (impact container) of an associated solar device.

Furthermore, the report assumes that the distribution of these impact token takes place under Liechtenstein legislation and provides an analysis of applicable provisions under the TVTG. The analysis includes the identification of potential benefits of a regulated approach for impact investors, philanthropic actors, and other relevant stakeholders.

In the context of the TVTG, the Liechtenstein Government communicated in 2019[2]…

… "it may be possible in the future to record a much broader range of assets and other rights on blockchain systems and that a number of services related to these rights will be offered. In particular, the low costs for digital transactions will, according to experts, open up new opportunities in fields such as financial services, logistics, mobility, energy, industry, media, and many more."

---

[1] See p. 33ff https://www.climateledger.org/index.html?cmd=countFile&file=CLI_Report-January19.pdf
[2] https://impuls-liechtenstein.li/en/blockchain-act-liechtenstein/

After the enactment of the TVTG, Liechtenstein's Financial Market Authority (FMA) developed an approach to determine the necessary characteristics of a system to be classified as a "Trusted Technology" under the TVTG. Throughout this report, the relevance of procedures, technology and governance will be referenced against these four characteristics of the FMA which are:

> *Characteristic 1: There is a safeguard against manipulation.*

> *Characteristic 2: There are tokens that can be unambiguously assigned to an identifier and can be used on the system in the sense of the TVTG.*

> *Characteristic 3: Technically, tokens must be transferable (it is a transaction system).*

> *Characteristic 4: User trust in the system is achieved through the use of technology.*

These points will eventually be discussed and checked for qualification.

The working hypothesis of this report is that the low costs for <u>and</u> the unprecedented transparency of digital transactions play an enabling role for unlocking new climate finance in the future.

II.   Access to Energy: Background and Market Barriers

Access to energy acts as a fundamental catalyst for the growth of developing societies and economies. Working towards universal access to affordable and clean energy for all (SDG7) is especially important as it impacts several other SDGs, is crucial to creating more sustainable and inclusive communities, and builds resilience to environmental issues like climate change. Yet, clean energy remains inaccessible for a significant portion of the population: 840 million people still live without electricity, mostly in Sub-Saharan Africa and South Asia, and an additional 1 billion do not have adequate access as of 2019[3]. This represents a fundamental barrier to progress for a sizable portion of the world's population, and impacts a range of development indicators, including health, education, food security, gender equality, income generation, livelihoods, and poverty reduction.
The lack to access energy states a problem of a global and cross-border nature where the international community jointly seeks solutions.

Despite progress in the past decade, the international community is not on track to achieve sustainable energy for all by 2030. While RE is particularly suitable for developing countries and both grid-tied and off-grid solutions are vital for achieving universal access, they must be supported by an enabling environment, e.g., by improved national and international frameworks. Off-grid energy or distributed renewable energy (DRE) in emerging markets generates significant value locally (for end users) and globally (climate impacts).

However, the sector faces several challenges:
- A significant financing gap exists to fuel the energy-access sector enterprises and the necessary ecosystem around it. It is estimated that US$33 billion in blended capital is required to achieve

---

[3] Lighting Global (World Bank) Estimates, 2020 https://www.lightingglobal.org/resource/2020markettrendsreport

SDG7 by 2030[4]. An additional US$1bn of softer early-stage funding support is required to generate a pipeline of companies that can absorb commercial investment.

● A considerable segment of the bottom of the pyramid people cannot afford even the most economical of solar home system products or services and cannot be served without subsidy.

Many incomes are sensitive even to small changes such as seasonality, rainfall, harvests, and loss of key household incomes through employment or mortality. This is a key challenge to people who initially can afford off-grid solar solutions but who may have these solutions repossessed or locked out due to temporary or seasonal changes to incomes.

Market-based instruments provide an opportunity for unlocking finance for climate action in the DRE sector. To date, financial support for climate action has utilized two primary mechanisms to underwrite sustainable activities:

● the carbon offset, which represents a reduction of 1 tonne of carbon dioxide from a "business-as-usual" case; and
● the renewable energy certificate (REC), which represents 1 MWh of energy from a qualified renewable system.

Both instruments originated from the need to comply with government regulations, but increasingly have been adopted by voluntary markets where multinational corporations and others purchase these instruments to offset their emissions and fossil fuel usage. The table below compares both instruments.

Instrument	Renewable energy certificates (REC)	Carbon offset
Certifies	1MWh of electricity has been produced by a renewable energy source	Reducing or avoiding 1 tonne of carbon dioxide or equivalent GHG
Main applications	Solar, wind, small hydro, biomass, geothermal	Carbon capture and sequestration, forestry and land conservation, biofuel, waste
Transaction Costs	Low: rapid and scalable process	High: slow, and not scalable process

Table 1: comparison between RECs and carbon offsets as environmental market instruments

Unfortunately, **existing REC market instruments are not fit-for-purpose for the DRE players in the emerging markets.** Without appropriate internationally accepted frameworks in place, corporates are unable to integrate DRE into global RE sourcing strategies and DRE project developers are unable to access clean energy markets. The latter is a pre-condition to unlock considerable finance from both the public and the private sector.

While the revenues for RE certificates like European Guarantees of Origin, US RECs or I-RECs, which vary between 0.20 USD to 2.50USD may not improve the business case for Distributed Renewables significantly, a multi-year off-take of D-RECs by a multinational company can improve the risk profile of a D-RE developer significantly, which in turn can make further debt or equity capital more affordable. This topic and the underlying economic modelling is not considered in the present report.

Innovation is urgently needed to develop enabling frameworks and catalyse new sources of capital to the DRE sector in order to achieve universal access to clean energy. This calls for joint action and innovative market mechanisms - such as customising RECs for the DRE sector in the emerging markets - which could

---

[4] Catalyst Off-grid Advisors/SF, 2017 https://shellfoundation.org/learning/achieving-sdg-7-the-need-to-disrupt-off-grid-electricity-financing-in-africa/

transform the world's energy systems and mobilise the private sector as a key player alongside other important actors such as the non-profit and public sector.

III.   Technical Perspective of D-RECs

The technical perspective of D-REC describes how Solar Home Systems and other providers of RE are to be integrated into a fully automated MRV-cycle that results in the issuance of environmental tokens. The content has been prepared by South Pole, Zurich.

South Pole, in partnership with Positive.Capital Partners, EnAccess Foundation, Shell Foundation, UNDP, the IFC, the global standards and other partners is leading a multi-stakeholder initiative to create a new REC market instrument for the DRE sector – called Distributed Renewable Energy Certificates or "D-RECs". Through the development of this new financing mechanisms and its digitised tracking and traceability process designed specifically for DRE systems, this instrument aims at providing powerful incentives for the private sector to invest in DRE projects.

*

1. Process of generating D-REC
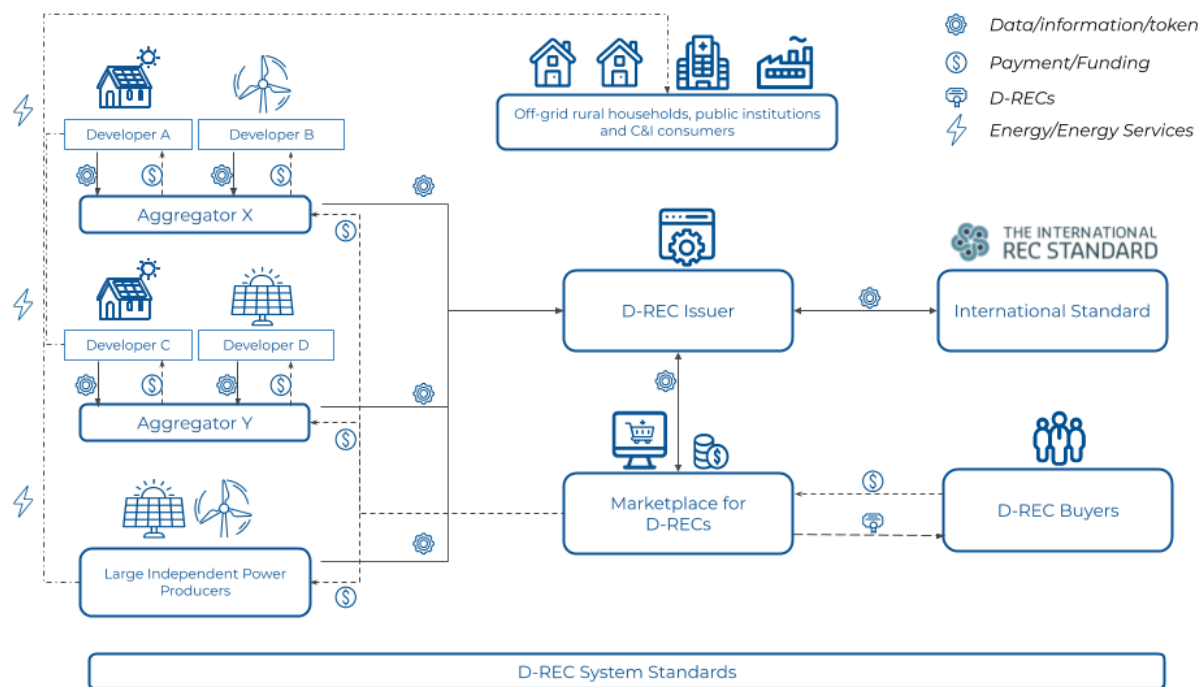
Figure 1: Schematic flow of data, funds, D-RECs and energy (Source: South Pole)

1. A solar device is installed as a Solar Home System, on a hospital, a school or SME by a local developer or system provider.
2. Renewable energy is generated and the amount that is consumed / delivered is tracked and verified digitally using statistical data assessment and reference data.
3. The record of the monitored electricity is fed to an aggregator, who provides data management services to a number of developers. If the developer's own IT backbone is capable of verifiable monitoring, no aggregator is required.
4. 4.   The monitored data is wired to the D-REC Issuer who may run additional data inspection and validation, comparing the provided evidence with the monitoring protocol of the system/installation
5. D-REC Issuer connects to International Standards to comply with the applicable regulations for issuance.

6. The D-REC Issuer emits a D-REC token that corresponds to the Standard's certificate.
7. The D-REC token is brought to the marketplace where corporate buyers purchase it, to meet their global RE / CSR commitments.
8. Local RE system providers receive revenues from D-RECs, enabling investment in new capacity, creating job opportunities and/or redistributing income to clients, making services more affordable to lowest-income households, and supporting local economic growth.

2. Monitoring and Issuance and Tokenisation

2.1 Project performance metering

Measurements for the relevant parameter are usually performed using a calibrated - meter conforming to a certain accuracy class, (installed) at a location where the complete data gets monitored transparently.

While performing the monitoring, the aspects to be considered are as depicted in the following table:

Table 2: Monitoring requirements aspects

Aspect	Details	Example
Data / Parameter	As defined by the methodology	Quantity of net electricity generated by the RE system (EG_y)
Data unit	As defined by the methodology	Wh, kWh
Metering arrangement	Measurements are undertaken at the point where the entire value (Completeness) under consideration gets measured transparently without interference	Measurements are undertaken a) using electricity meters installed at the distribution interface for electricity export to local appliances and b) using electricity meters installed at the entrance of the electricity consuming facility for supply to captive consumption
Accuracy class	The accuracy class of the meters should be in accordance with the local standards and regulatory requirements or as stipulated in the applicable national requirements	The accuracy class of the meters should be in accordance with the local standards and regulatory requirements or as stipulated in the applicable national requirements. The minimum suggested accuracy with reference to the installed capacity of the renewable energy plant is as follows: ● < 1kW should have an accuracy class of +/- 1.0% ● 1 kW - 100 kW should have an accuracy class of +/- 0.5% ● >100 kW should have an accuracy class of +/- 0.2%
Monitoring frequency	Regularly and at least monthly recording	Continuous monitoring, hourly measurement and at least monthly recording

Meter calibration	The meter(s) will be subject to regular maintenance and testing in accordance with the stipulation of the meter supplier or national requirements.	The calibration of electricity meter(s), including the frequency of calibration, should be done in accordance with national standards or requirements set by the meter supplier. If these standards are not available, calibrate the meters every 3 years. In the event, meters are found faulty they will be replaced with immediate effect by new calibrated meters
Cross-check	Apart from plausibility check, the measurement results shall be cross-checked with other available records.	The measurement results of the electricity delivered/consumed shall be cross-checked with meteorological data and records of and electricity service settlement.
Event of meter failure	The procedure for handling uncertainty in the metering system or eventually a metering system failure will be as follows: • In the event when meters are found faulty or not working, these will be replaced immediately with new calibrated meters. • In the event when meters fail to communicate for a certain period (silence period) the data recorded at the project site will be used for emission estimation purposes. • In case of missing data due to meter failure or other reasons, conservative approach will be applied.	• In case of missing data due to meter failure or other reasons, one of the following options to estimate electricity generation may be applied: (i) the conservative value as zero; (ii) the lowest daily value among the daily monitored values from the current crediting period multiplied by the number of days with missing data. However, estimation of electricity generation can only be applied if it is demonstrated that the renewable energy project is operational during the missing data period. Missing data period shall not exceed 30 consecutive days within six consecutive months.

(Source: South Pole, based on UNFCCC)

With a view on hardware requirement, further to the aforementioned aspects for automated monitoring, the recommended basic features of such (smart) meters should be as follows:

- The smart meter should have an **integrated communication module** to enable remote communication with a device over a standardised protocol.
- Ability to **provide time-stamped data** to the remote meter data acquisition system at periodic intervals or on-demand, on a standardised protocol. This data can be instantaneous data parameters as well as logged data (like cumulative energy etc., profile parameters like power/voltage/current recorded at predefined periodic time instants, and events that notify occurrence of predefined conditions, etc.).

2.2 Tamper event detection, recording and reporting

The system should be equipped with the necessary functionality to allow adequate diagnostic to be executed as well as to prevent tampering that would result in false metering.

- The meter(s) shall have appropriate security measures to prevent and detect tampering and ensure that unauthorised systems cannot access it remotely nor locally for acquiring data or modifying its configurations.

- Any form of tampering (e.g. meter bypassing or supplying electricity to the meter from a source (i.e. diesel generator) other than the one configured) must be detected and result in a system alarm, operation halt and notification report.
- Local display: the meter shall have an interface for displaying data locally and to run system diagnostics.
- Remote firmware upgrade: ideally the meter shall support in-field or remote firmware upgradation, after passing due authorisation and authentication.

2.3 Data assessment for cross-check

After measuring the project performance via appropriate metering, it is vital to assess whether the data reflects the normal operation of the project and not a manipulation thereof. To do so, the accuracy of the data obtained through the main meter reading should be assessed for correlation with alternative measurements performed simultaneously and/or associated records. The aim of cross-checking is to find proof or plausibility of the correctness of the monitored project performance. Additionally, statistical data assessment improves data coherence by eliminating data outlies and improbable system performances that might have been caused by hardware/firmware malfunctions.

Therefore, for automated monitoring, the recommended basic features for performing cross-checks are as follows:

- Parameters should be identified (as well as appropriate ways to measure them) than allow for correlation analysis between them and the project performance data.
- Cross-check information should be collected/metered under comparable aspects and requirements as the project performance data.
- If the cross-check information can be metered, the meter should ideally have either an integrated communication module to enable remote communication with a device over a standardised protocol or allow communication through a data logger.
- Periodic manual upload of sampled records / invoices (pdf format) would be required to substantiate the measured value.

Relevant for classification of TT system under TVTG by Liechtenstein FMA

Characteristic 1: There is a safeguard against manipulation.

Cross-check measurement for the example of Solar PV

Inverter

In the context of a solar PV project, in general every inverter already measures the AC yield in kWh of the PV system, so it does not need to be specifically installed for the MRV system. It is useful to reduce the risk of upfront tampering (e.g., use of diesel generators), since this secondary measurement cannot be easily manipulated. Further, each inverter has an ID that can be linked to the solar PV plant as an identifier for the MRV system.

Pyranometer

These devices can be installed directly on the solar panel or next to them to measure the solar irradiance. In the MRV system it could be used to determine the theoretical maximum energy output of the PV system, or as an automated plausibility check on the data provided by the electricity meter. For small solar PV systems, it is deemed that the costs of such a device would outweigh the benefit of this additional data source. In such cases, publicly accessible weather information (including solar irradiance) from the region where the solar PV plant is located, can be used as an alternative data source for the same kind of sanity check on the data provided by the electricity meter.

3. Issuance

3.1 The status quo of REC issuance

The process that is used by most registries today looks as follows: when owners of renewable generators request certificates for a specific device and time frame, they have to provide evidence for the amount of produced electricity during that time. Based on this evidence, the issuing body issues the right number of certificates to the device owner. The standard defines what is admissible as evidence. This is one of the central tasks of the standard. In most cases, the official document used as evidence is the 'joint meter readings' which are used as basis for the generator and the electricity off-taker (e.g. the grid operator) to settle their power purchase. It states the amount of electricity that came from the generator and was fed into the grid injection point. This document is typically provided on a monthly basis. After the document has been provided, usually in the form of a PDF, issuing bodies review it and issue the requested certificates. This exact procedure also applies to the International REC (I-REC) Standard, which is applicable in countries that do not yet have an operation energy attribute tracking system - which applies to most the geographies that the D-REC aims to address. In a D-REC system, these documents can be used for regular verification.

3.2 Issuance requirements for D-RECs

In order for the D-REC to be compliant with any of the I-REC Standard (and thus be applicable to today's major Scope 2 reporting frameworks), the best way is to align with the existing I-REC registry and it's issuance process.
At the same time, D-REC aims to allow for fully automated issuance, higher granularity in transacting and increased transparency across its value and impact chain. Features that the current I-REC system does not cater for.

For that reason, the organisations behind the D-REC development have explored ways to implement these aims and concluded that the functionality of the **Energy Web Foundation's** blockchain application *Origin* provides these exact capabilities.
The Energy Web Foundation is a non-profit organisation that aims to provide the energy sector with enterprise- grade tools that simplify the end-user experience and streamline application development and deployment, to achieve mainstream adoption of decentralized technologies.

Energy Web Origin is a family of software toolkits that support "proof-of-impact" applications for tracking, trading, and reporting energy attribute certificates (EACs) based on industry standards. Applications built using Origin can be used for
● creating a digital **registry** ecosystem of buyers, sellers, asset owners, and regulators to issue and monitor transfer of digital EACs;

- creating a digital **marketplace** to trade, claim, and report EACs that integrate with existing EAC registries, including legacy systems that do not use the EW Chain or Origin (e.g., the I-REC Standard);

For D-RECs, this will enable generation devices to self-register in appropriate registries, automatically report their operational data, and consequently access relevant EAC markets.

3.3 Certificate based Tokens

To combine the rigor and wide recognition of the I-REC with the versatility of the modern digital economy, the D-REC will achieve the best of the two worlds through a simple functional connection: the tokenisation of a certificate issued to the I-REC registry.

In practice, the production evidence will be aggregated to stacks of 1 MWh volume on the D-REC platform, and then provided to an approved I-REC issuer, who can review the generation data, run verification routines and finally issue the certificate in the central I-REC registry. Each of these certificates refers to an 1MWh stack of production, and carries a unique identification (i.e. serial number and issuance time stamp), which in turn is reference to all the data points that are included in this 1MWh stack. The full data wealth of this stack can be inspected only on the D-REC platform as the I-REC registry does not provide this level of information detail. It could be described as the Origin platform using this certificate registry as an external data oracle to mint token-certificates. The advantage of this approach is that the Origin platform is fully compliant with the I-REC standard while also offering all the advantages of a decentralized system after issuance.

D-REC's connection with the I-REC registry as certificate issuer is depicted in the figure below:
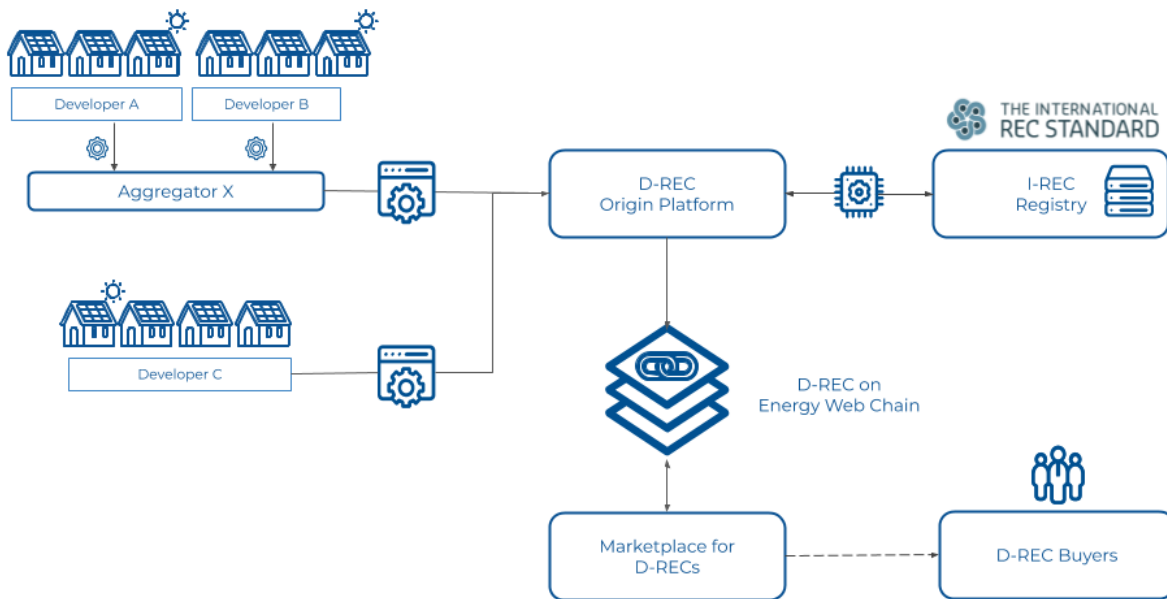
Figure 2: Issuance of certificate-based D-REC (Source: South Pole)

The request for certification is triggered automatically if the generation volume reaches the threshold of 1MWh. The request is stored on-chain but also forwarded to the I-REC registry by calling its public API. This triggers the approval process on the I-REC side, where the issuance request and evidence are evaluated. By integrating with the registry this way, the job of determining whether the provided evidence

is correct and fulfills the requirements of the standard is outsourced to the I-REC issuing body. To date, the issuers do not evaluate the generation evidence based on automated processes. It is however clear that the multitude of data points cannot be handled in an analog manner and thus specific verification protocols need to be established within the I-REC's issuer role to address this challenge.

Once verified, the certificate is created in the I-REC registry. Origin's issuer module can then query the API and retrieve the certificate information. If everything is correct, the issuance request is approved and the certificates are minted on-chain, with the reference to the I-REC certificate. The D-REC device registrant can choose in the issuance request to have the certificates minted to their own or some beneficiary's account (i.e. in the case of a multi-year off-take agreement), or transact it via a dedicated market place.

Relevant for classification of TT system under TVTG by Liechtenstein FMA

Characteristic 2: There are tokens that can be unambiguously assigned to an identifier and can be used on the system in the sense of the TVTG; and

Characteristic 3: Technically, tokens must be transferable (it is a transaction system).

---

4. Sovereign D-REC tokenisation

4.1 Non-certificate-based Tokens

One step further than tokenising certificates that have been issued through a semi-automated process, is the approach of minting D-REC Tokens directly from automatedly monitored generation.

With the functionality described in Section 3 above, the system could technically rely directly on the monitoring data and use it as the oracle without prior authorization by a human issuer. For this to be possible, an issuing module has to be connected to the platform that authorises the automatically transferred (i.e. submitted) generation data in a way that is trusted by all stakeholders.

As this scenario does not foot on any existing environmental standard, it would fall into the growing category of do-it-your-self approaches of impact assurance solutions. These however, have so far not managed to establish a sizeable user base, because most compliance or voluntary market participants that trade high volumes of results/impacts-based finance require instruments certified by a standards body for their reporting purpose. A solution to this approach would be that the *practice* of issuing sovereign D-REC tokens directly by the origin platform, should be approved and certified by a Standard organisation, to which the diligent upholding of the practice (and its software components) is guaranteed and frequently reported. This approach, to certify the assurance of algorithms, models and data processing is new to the environmental markets sector but is essential for the shift towards automated issuance.

This approach would conclusively allow breakthrough performance at low transaction cost compared to today's issuance practice of environmental certificates. For the trust in such a system to compare to the established standards' practices, the underlying technology must prevail in robustness, transparency and accuracy.
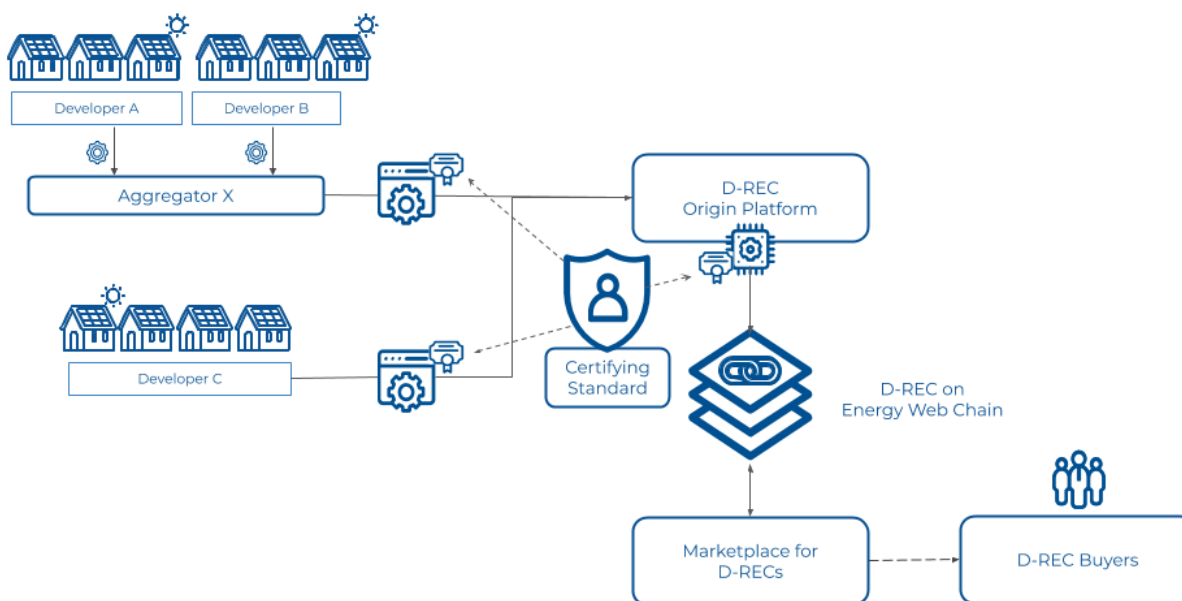
Figure 3: Issuance of sovereign D-REC (Source: South Pole)

4.2 The D-REC Token duality of fungible and non-fungible components

EW Origin leverages a specific Ethereum token standard (ERC-1155) which allows a single smart contract to govern an infinite number of tokens. This allows the D-REC to include **static information** that specifies the **origin** of the renewable energy (including metadata) along with **flexible information** that only reflects the **amount** of the electricity.

The multi-token standard ERC-1155[5] combines a non-fungible token with a fungible component. While fungible tokens are well-suited to represent a commodity that is completely interchangeable, like US-Dollars for example, non-fungible tokens are used to represent things that have distinctive characteristics that make them unique, like personal ID's. In the case of D-RECs, the device information of a DRE-installation (e.g type, location, capacity etc.) and time frame of the production are represented as *non-fungible* tokens. The electricity *volume,* that is generated from that device and in that period, is implemented as the *fungible* component, which comes with a wide range of operability possibilities: it can be transferred and split into arbitrarily small units in a very efficient manner. All the while, these volumes remain immutably bound to the specific device and generation time information.

---

[5] See the Ethereum Improvement Proposal for ERC-1155: https://eips.ethereum.org/EIPS/eip-1155

This implementation allows the D-REC token to be a robust, yet efficiently and flexibly transactable proof of origin that carries a broad amount of information.

5. Main lessons learned

Topic	Lessons learned	Remarks/ Finding regarding next step
Higher degree of resolution	A system like D-REC can carry a richer set of information at a higher degree or resolutions compared to today's REC systems	This can form the basis for new kinds of transactions and revenue streams for the DRE sector. Associated solutions like market platforms would build on this trust in the underlying technology.
Ex-ante verification	With the necessity to achieve fully automated issuance, it is inevitable to move away from the current MRV-sequence to a procedure with ex-ante verification (MRV -> VMR).	This ex-ante verification could be achieved through a periodical system-validation that assures the validity of all performance data processed through the system. This approach would have to be fully supported by the environmental standards with regards to registry processes.
Self-sovereign tokenisation	Ex-ante verification under recognition of the VRM concept would allow strong inclusiveness and ultimately a fully DLT based transaction economy of D-RECs.	Again, the standards' acceptance and support of the ex-ante verification is the key challenge here. In additional, the robust adherence to the standards issuance requirements must be referenced and transparently proven.
Trust through manipulation security	The robust and transparent technology can render manipulation effort obsolete, as automated error and temper protection can prevent manipulated data from being certified.	Requirement for public trust will be a combination of process transparency and institutional ratification

IV. D-RECs in the context of Liechtenstein's TVTG

1. Qualification for a Trustless Technology (TT) System

To determine whether a system qualifies as a trustless technology and therefore is applicable for a role under the Liechtenstein Token and TT Service Provider Act (TVTG) we have applied the definition that is used by the Liechtenstein Financial Market Authority (FMA). The FMA uses the fit of four characteristics to classify a system as a TT system. Those are:

a) There is a safeguard against manipulation.

b) There are tokens that can be unambiguously assigned to an identifier and can be used on the system in the sense of the TVTG.

c) Technically, tokens must be transferable (it is a transaction system).

d) User trust in the system is achieved through the use of technology.

These points will be discussed and checked for qualification.

The Energy Web Chain

The Energy Web Chain is an enterprise grade blockchain working as backbone for the Energy Web Origin Platform which is planned to be used to generate and transfer D-REC tokens. This blockchain is derived from the Ethereum blockchain[6] and works with a Proof-of-Authority (PoA) consensus mechanism in contrast to the original Ethereum network that uses Proof-of-Work (PoW) as of today. This means the well-known mechanisms of how the Ethereum blockchain works can be applied for the Energy Web Chain except for the consensus mechanism.

Manipulation security

Manipulation security in a blockchain system is achieved by signing entries to the database with asymmetric cryptography and coming to terms about a binding chronological order of those entries through a network wide consensus. Ethereum uses asymmetric cryptography to sign and verify transaction entries. Applying Proof-of-Authority means that new entries are confirmed by a selected group of signers who sign blocks and thus confirm the order of the entries. The finite nature of the group is in contrast to permissionless architectures but can ensure a sufficient degree of security if measures against cartelisation or collusion have been taken. The described techniques (especially asymmetric cryptography) are common practice and state of the art when it comes to trust minimized manipulation security.

Assignment of Token to an identifier

Ownership of Ether, the token of the Ethereum blockchain, or other tokens on the chain like the earlier discussed ERC-1155 is established through digital private keys, Ethereum addresses and digital signatures. A private key is at the heart of all user interaction with Ethereum. In fact, account addresses are derived directly from private keys: a private key uniquely determines a single Ethereum address, also known as account.[7] This means every token in the system is assigned to a unique address which qualifies as an identifier according to the TVTG.

Transferable tokens

Transactions in the Ethereum blockchain are signed messages originated by an account, broadcasted by the Ethereum network, and recorded on the Ethereum blockchain. Another way to look at transactions is that they are the only things that can trigger a change of state. Ethereum can be seen as a global state machine and transactions are what makes the machine run, changing its state. This change of state can assign tokens that have been owned previously by another address to an address which qualifies as a transaction in the sense of the TVTG.

---

[6] Energy Web Chain Whitepaper, https://energyweb.org/wp-content/uploads/2019/05/EWF-Paper-TheEnergyWebChain-v2-201907-FINAL.pdf

[7] Antonopoulos, Wood: Mastering Ethereum, 2019

Trust through technology

Trust through technology is meant in contrast to trust in other entities while interacting with the system. The functioning of the system and the authenticity and consistency of the entries in the database should therefore be achieved independently of trust in intermediaries, but only through trust in the technology on which the system is built. On the Ethereum blockchain, this is ensured by the fact that the digital signature (through asymmetric cryptography) can only be generated by the owner of the associated private key and this fact can be independently verified (more precisely: By using mathematical functions) by any user of the system without asking any other party for information or permission. Furthermore, the binding order of the individual entries is confirmed by a previously determined group of authorities who also sign the blocks with digital signatures. This guarantees to a certain degree that those entries can be trusted by trusting in the technology, not the authorities signing. The limits of this trust are collusion or cartelisation between the signatory authorities.

2. Obligation to register under TVTG

Service providers in a blockchain (or trustless technology TT) context often operate in close proximity to financial market law and provide similar services to traditional financial intermediaries. A TT token custodian for example, like a bank, can provide its customers with a cryptocurrency account through which they can carry out transactions. The corresponding cryptocurrencies are then taken into custody by the TT service provider. For social/environmental impact markets this becomes also more relevant the more assets like a Renewable Energy Certificate become standardized.

If the business model of a TT service provider includes services that are subject to special laws under financial market law, e.g., because a banking business is operated or a payment service is offered, it additionally requires the corresponding authorisation by the Liechtenstein Financial Market Authority (FMA) under these special laws, irrespective of its registration under the TVTG.

The registration obligation under the TVTG is intended to introduce minimum requirements for all TT service providers in Liechtenstein, which are important from the point of view of user protection, compliance with international standards and the protection of Liechtenstein's reputation.

The examination for the registration of a TT service provider has both a more limited scope and a lower examination depth than the authorisation procedure under financial market law. Moreover, TT service providers are not subject to ongoing prudential supervision like licensed financial intermediaries (e.g., transparency obligations, comprehensive reporting obligations or periodic external audits), but rather to incidental supervision. The level of client protection guaranteed by supervision thus differs from that of a licensed financial intermediary.

With the token, the Liechtenstein law on tokens and TT service providers (TVTG) introduces a new legal object to enable the mapping of the real world on TT systems in a legally secure manner and thus to open the full application potential of the token economy.

For the D-REC project, this means that one or more participants in the D-REC issuance process could register for roles presented below. Filling such a role means legal certainty and therefore protection for the renewable energy producer who receives the D-REC token from a token generator as well as for later

market participants in the market for renewable energy certificates. Furthermore, compliance with international standards is ensured.

3. Potentially relevant TVTG service providers

In the context of the TVTG there are several roles which can be applied to participants in the D-REC process flow (Fig. 4). The possible roles were discussed with FMA's regulatory laboratory to be valid for the registration process under certain circumstances. The roles are presented below.

Physical Validator

The physical validator provides the link between a physical object and its token counterpart. Because this link can't be made available in a trustless manner by the system itself, the two realms need to be bridged by a supervised actor. This kind of validation seems to be applicable on first sight because power (in electric terms) is represented in a token. But the TT Physical Validator can only be applied for objects (in the legal sense) because it was conceived having a specific use case in mind: Physically storing valuable goods and dividing them into tokens on a distributed trustless ledger so that parts of the physical objects can be transferred or traded. An often-used example here is the tokenization of a painting or diamond.

Token Generator

The party making a token e.g., programming and generating units which can be transferred later is called the Token Generator in the context of the TVTG. Minimal requirements to be registered for this role make sure that the token's functionality has been programmed by capable professionals. The **D-REC Origin platform is eligible to be qualified** as such a party. The entity providing this service (Energy Web Foundation or others using a blockchain) will be **eligible to be registered as a TT provider** with FMA Liechtenstein if requirements specified in the "Conditions" section are fulfilled.

Token Issuer

This role was created by the legislator having an entity in mind that issues securities or similar financial instruments in token form. The role of the token issuer was discussed but will not be taken in this project. The developer (producer of renewable energy) would only be qualified for this role if it has a **registered office in Liechtenstein** and the emission for the token would be a **public offer** within the meaning of the TVTG. Both conditions are not fulfilled. The platform on the other hand could qualify as an issuer if it sold certificates in the user's name which is not the case either. The role of the token issuer is therefore not relevant in the context of this project. This means that articles 30 ff (publishing of basic information or a prospect) of the TVTG act do not apply in this context.

Token Depository

A token depository is meant to take care of a token for customers. Registering this role under the TVTG means that there is minimal room for abuse and therefore greater protection for a customer that entrusts token to such a counterparty. In most cases today, the producer of renewable energy does not act as a market participant himself but makes the certificates available on the market via an intermediary (e.g., MyClimate, South Pole). This case is explained in section 2.3 of the report: During the mint process, the user (producer of renewable energy) can choose to have the certificates minted to their own or some

intermediary's account. **This type of intermediary qualifies** (or if registered in Liechtenstein, obliges) **to act as the token depository**.

Furthermore: Price Service Provider

A price service provider could be registered if there is an entity that calculates prices for the marketplace. Because of the marketplace being excluded from the consideration of this report (see: D-REC Marketplace outside system boundaries) this service provider will also not be discussed further.

4. Legal Conditions for TVTG Registration

This section lists the conditions that must be met for the relevant roles to be registered under the TVTG.

Relevant Articles of Liechtenstein's TVTG (extracts)

Art. 13 Registration Requirement

According to Art. 13 of the TVTG an entry to the TT service Provider Register requires the applicant to
a) be capable of action;
b) be reliable (described in article14);
c) be technically suitable (further description in article 15);
d) have their registered office or place of residence in Liechtenstein;
e) have the necessary minimum capital, where appropriate (CHF 100k for depositaries, no capital needed for the token generator);
f) have a suitable organisational structure with defined areas of responsibility and a procedure to deal with conflicts of interest;
g) have written internal procedures and control mechanisms that are appropriate in terms of the type, scope, complexity, and risks of the TT Services provided, including ensuring sufficient documentation of these mechanisms;
e) have special internal control mechanisms (article 17), where appropriate;

k) if they intend to conduct activity that is subject to an additional authorisation obligation in accordance with a law pursuant to article 5(1) of the Financial Market Authority Act, for which the corresponding authorisation is available.

Art. 14 Reliability

1) A natural person is excluded from rendering a TT Service if:
a) they have not been convicted by a court of law for fraudulent bankruptcy, damage to third party creditors, preferring of a creditor with fraudulent intent or grossly negligent interference with creditor's interests (sections 156 to 159 of the Liechtenstein Criminal Code), or have been sentenced to up to three months' imprisonment or a fine of more than 180 daily rates and the conviction has not been expunged; and
b) they have not been convicted in the ten years prior to their application due to severe or repeated violations of the provisions of the Law on Unfair Competition, the Consumer Protection Act or a law pursuant to article 5(1) of the Financial Market Supervision Act;
c) they have been subject to a futile seizure in the five years prior to application;
d) bankruptcy proceedings were brought against them in the five years prior to application or an application to bring bankruptcy proceedings was rejected due insufficient assets to cover the cost pursuant to article 10(3) of the Liechtenstein Bankruptcy Rules; or
e) there is another reason which creates serious doubt concerning their reliability.

2) (1) letters a) to d) also applies for foreign decisions and proceedings if the underlying action is also a criminal offence pursuant to Liechtenstein law.

3) For legal persons, the requirements under (1) must be met by members of their bodies and shareholders, partners or holders who hold qualifying holdings of 10 % or more in a legal person.

4) Upon request, the FMA may grant leniency from exclusion under (1) and (2) if committing the same or similar offence when rendering the TT Service is not to be expected in consideration of the nature of the criminal offence and the personality of the person sentenced.

Art. 15 Technical suitability

Those who are sufficiently technically qualified due to their education or prior career for the task in question shall be considered technically suitable.

Art. 17 Special internal control mechanisms

1) Applicants who intend to act as TT Service Providers pursuant to article 2(1) letters k to t must have suitable internal control mechanisms before starting their activity which ensure the following:

b) for Token Generators, the use of suitable measures which ensure that:
1. the right in the Token is correctly represented during the Token's lifetime;
2. that the disposal over a Token directly results in the disposal over the represented right;
3. a competing disposal over the represented right are excluded both under the rules of the TT system and the provisions of applicable law.
d) for TT Token Depositories:
1. establishing suitable security measures which in particular prevent the loss or abuse of TT Keys;
2. the separate safekeeping of customers' Tokens from the business assets of the TT Token Depositary; and
3. the clear assignment of Tokens to customers;
4. the execution of customers' orders in line with contracts;
5. the maintenance of the services in the event of interruptions (business continuity management);

5. Assigning the role of token generator and depositary to D-REC

The analysis of the D-REC process revealed that D-REC could register two service providers, namely the token generator and the token depositary under the TVTG. The following paragraphs discuss the pros and cons of applying Liechtenstein law to these roles.

Token Generator

The token generator has to have a registered office and substance in Liechtenstein. The right in the token must be correctly represented during its lifetime. He must ensure that the disposal or ownership change over a token results in the disposal or ownership change of the represented right. In case of a REC this means that the holder has the right of ownership of the certificate issued by I-REC. Furthermore, competing disposal over the represented right is excluded both under the rules of the TT system and the provisions of applicable law. In concrete terms, this means that after the approval process (Fig. 4, (3)) and before the minting (Fig. 4, (4)) the I-REC must be immobilized and flagged as being active on the D-REC blockchain. This ensures that change of ownership is only possible on D-REC and not on I-REC anymore.

Token Depositary

The token depositary must have a registered office and substance in Liechtenstein. According to Art. 3 of the due diligence act, SPG[8], the token depositary is also subject to due diligence. This act regulates the safeguarding of due diligence in the professional exercise of the activities subject to this act. Its purpose is to combat money laundering, organised crime, and the financing of terrorism within the meaning of the criminal code. In addition to other obligations set out in the due diligence act, the physical presence and accessibility of the SPG documents and a lockable office (i.e., no co-working space) should be emphasised as conditions. Furthermore, he must prevent the loss or abuse of TT keys. The effort involved can vary greatly depending on the blockchain infrastructure used. A clear assignment of tokens to customers is also a remarkable condition, but one that can be realised well with conventional means and technology.

Having a registered office in Liechtenstein also implies having substance within the state borders. This means owning or renting office space and having people actively working in Liechtenstein. This circumstance could be a hurdle for already existing companies. For companies registering under the TVTG, there are only indirect advantages, as this act mainly serves to protect customers. It must be carefully weighed up whether this is worth relocating or building up workforce in Liechtenstein.

6. D-REC Marketplace outside system boundaries

At this point of time, it is not clear who will take over the function of the trading platform. The options under discussion are Energy Web Zero, which wants to introduce trading with D-RECs as a pilot project, a set-up from scratch by South Pole or an application on an existing trading platform. Depending on the design of the trading platform, the entitlement to occupy a role and the conditions attached to it vary greatly. Questions have to be clarified such as

---

[8] See SPG in English, https://www.regierung.li/media/medienarchiv/952_1_17_11_2017_en.pdf?t=3

- Who is allowed to buy tokens and is this right checked on the trading platform?
- Is there a trading venue that is subject to due diligence?
- How exactly is trading conducted and interacts with the platform? Are these peer-to-peer transactions from self-managed wallets or is there a custodial function of the trading venue?

Since it is difficult to answer these questions without a concrete candidate for the role of the trading platform, the system boundary was drawn at this point for the present research and the market place was excluded for the time being.
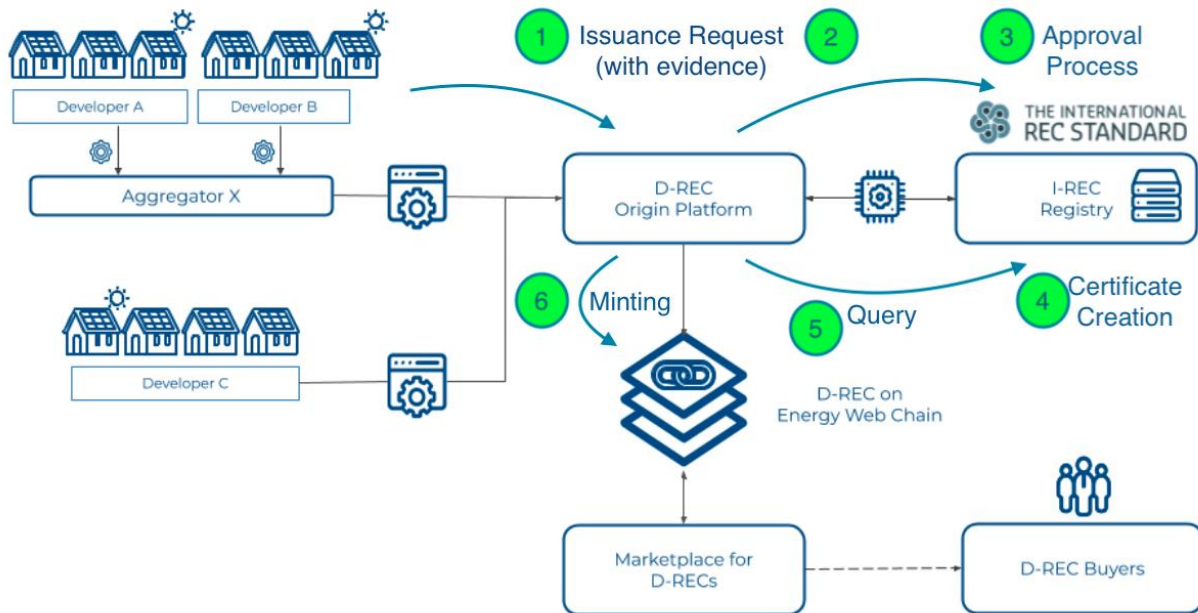

Fig. 4: Issuance process flow (Source: South Pole)

7. Lessons learned from applying the TVTG to the D-REC concept

Topic	Lessons learned	Remarks/ Finding regarding next step
D-REC can be classified as a TT system	The D-REC system qualifies as a TT system under the TVTG due to its technical characteristics and Ethereum as base system.	
TVTG roles	The roles of token generator and token depositary could be filled. These fall to the D-REC Origin Platform and an additional intermediary for D-RECs respectively. Benefits will arise primarily for the system's customers. The role holder has documentation obligation and can be held liable for his actions.	In the event of implementation, the entities wishing to fill the roles can apply to the FMA for registration.
Liechtenstein domicile for TT providers	A domicile in Liechtenstein for a role holder according to the TVTG is necessary.	Settling or relocating to Liechtenstein can be associated with considerable effort and therefore represent a significant hurdle to registering under the TVTG, especially since experience of the practical benefits of this registration is still lacking.
Narrow interpretation of the Physical Validator in the TVTG	The physical validator role can't be applied in a way to bridge the boundaries between trust-minimized systems and real-world non-physical assets like energy in this example.	A direct link between a kilowatt hour and the energy certificate for it, validated during onboarding and secured by law, could further simplify processes. This type of validation is not provided within the current version of the law. The physical validator can only link an object in the legal sense with its digital twin. An integration of non-physical real-world assets could be discussed.

V. Summary and discussion

The Liechtenstein TVTG was put in place mainly for user protection, compliance with international standards and the protection of Liechtenstein's reputation. Registering as such a service provider can help an actor in the world of trustless technologies to reassure clients and to minimize the exposure for fraudulent or criminal activities (i.e., money laundering). It has been shown that the real-world use case D-REC can be classified as using a Trusted Technology under the TVTG.

.
Moreover, by assessment within an informal meeting with the Liechtenstein Financial Market Authority (2020-12) and study of relevant parts of the TVTG it was possible to clarify which participants in the D-

REC process flow are eligible to act within the framework of the TVTG from Liechtenstein. The roles of **token generator** and **token depositary** could be filled. These fall to the D-REC Origin Platform (Figure 4) and an additional intermediary for D-RECs respectively. An additional intermediary for renewable energy certificates only comes into play if the renewable energy producer does not have the D-REC token minted to itself, but for the attention of said intermediary.

In the case of a TT Service Provider application, both entities must be registered in Liechtenstein. This can also be done in the form of a subsidiary. **Settling or relocating to Liechtenstein can be associated with considerable effort and therefore represent a significant hurdle to registering under the TVTG, especially since experience of the practical benefits of this registration is still lacking.** The author is not aware of any ongoing discussions that try to address this circumstance.

The token generator must be able to ensure, among other things, that **the right in the token is correctly represented during its lifetime**, ensure the disposal over a token results in the disposal of the represented right and that a competing disposal over the represented right are excluded both under the rules of the TT system and the provisions of applicable law. Especially the last point affects the interaction with the previous issuer of I-RECs as these must be immobilized on the I-REC platform.

The automated MRV (measurement, reporting, verification) system with self-sovereign token issuance aims at increased processing speed, high transparency, and lower transaction costs. Therefore, certain conditions need to be met on the technical site. Most of these conditions mirror the aims and objectives of the TVTG.

- Further development of TVTG should happen in close exchange with voices from the practice;

- Laid out example described how TVTG could improve the business case for environmental and social assets but underlying assumption is that a standardisation of processes improves quality – excerpting principles of standardisation frameworks (e.g. ISO) could be a promising option to further extending the practical relevance of the TVTG – A future version of the TVTG could require a TVTG service provider to provide proof that he applied specific quality principles (similar to the physical validator).