



ENCIRCLE

Enabling Circular Value Chains via Production Digitization and Human Empowerment

Deliverable D5.1 “Consumer mobile app and product traceability via the DPP 1st version”

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HISTORY OF CHANGES

VERSION	PUBLICATION DATE	CHANGE
0.1	20/01/2026	Initial deliverable structure and Table of Contents
0.2	14/02/2026	Description and use of blockchain
0.3	19/02/2026	REST API endpoint structures and descriptions
0.4	28/02/2026	Presentation and explanation of the mobile app
0.5	17/03/2026	Content structure of the DPP and explanation
0.6	24/03/2026	Worldline Iberia revision
0.7	31/03/2026	ZinQ review and updated by Fraunhofer
0.8	31/03/2026	CERTH review and updated by Worldline
0.9	01/04/2026	QC by RINA
1.0	01/04/2026	Final version

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ABBREVIATIONS AND ACRONYMS

AAS	Asset Administration Shell
AI	Artificial Intelligence
API	Application Programming Interface
AR	Augmented Reality
CE	Circular Economy
CV	Computer Vision
dApp	Decentralized App
DTL	Distributed Ledger Technology
DPP	Digital Product Passport
ESPR	Ecodesign for Sustainable Products Regulation
IAM	Identity and Access Management
ID	Identifier
ISO	International Organization for Standardization
JSON	JavaScript Object Notation
MQTT	Message Queuing Telemetry Transport
OAuth 2.0	Open Authorization version 2
QR	Quick Response
REST	Representational State Transfer
UX	User Experience
WLI	Worldline Iberia
WP	Work Package

SUMMARY

This document presents the initial design, architecture and basic components for the Digital Product Passport (DPP) component developed within the framework of the ENCIRCLE project. It describes the technical plan development that enables the traceability, security and transparency of product characteristics throughout their lifecycle, thereby reinforcing the principles of the circular economy.

The architecture is based on a decentralised system and the use of blockchain technology, specifically Hyperledger Fabric. This type of technology guarantees data integrity, security and controlled access for authorised stakeholders. This document presents and explains the functionality of the chaincode, a key element of the blockchain that complements its architecture and defines the terms of use for its methodology. It also defines interaction flows and other elements necessary for the blockchain network. This chaincode describes and implements the various operations offered by the DPP API.

Various backend services and REST APIs have also been described, which will be used to interact with the blockchain layer. This abstracts the use of the blockchain, providing easy, secure and standardised communication for clients that need to utilise it. One such client that must communicate with the backend is the mobile application (dApp), which is consumer-focused and is also described in this document. The dApp functions as a "DPP wallet," empowering users not only to access detailed product information (e.g., carbon footprint, materials) but also to utilize value-added services like smart fault diagnosis and end-of-life management, thus promoting active consumer engagement. It also describes the content and definition of the DPP based on the Asset Administration Shell (AAS), within a JSON format that facilitates efficient storage on the blockchain.

This project is being carried out in collaboration with different partners. Worldline Iberia is responsible for the blockchain design and the backend, FORTH for the mobile app, and Fraunhofer for the data modelling.

1 INTRODUCTION

1.1 OBJECTIVES AND SCOPE OF THE DELIVERABLE

This document presents the technological framework supporting the Digital Product Passport (DPP) of the ENCIRCLE project, with a specific focus on blockchain-based traceability and the consumer-facing frontend apps.

The main objective of this document is to describe the **design, architecture, and core concepts** of the blockchain framework that enables product traceability throughout the product lifecycle, as well as its integration with the consumer mobile application and related backend services. This includes the definition of the main components, interaction flows, and responsibilities of the involved systems, laying the foundations for subsequent development and validation phases.

We can summarize the content in the following points:

- The concept and architecture of the ENCIRCLE project.
- The role of Hyperledger FABRIC blockchain technology in development.
- The integration of blockchain services in the creation of APIs for the DPP, identifying the components and how they are consumed by apps or frontends.
- The definition of the data flow related to the DPP, its creation, registration, and life cycle.

1.2 INTEGRATION OF THE DELIVERABLE IN ENCIRCLE

Blockchain technologies are key to the development of this project, as the architecture must meet a series of requirements:

- Data storage must be secure and reliable for DPP data.
- Products must be traceable and have ownership management at different stages of the life cycle.
- Interoperability between different backend products that communicate with the blockchain layer.

This document is part of a series of technical and functional deliverables that explain the different data models, data flows, and different consumer applications for the user or customer.

Document D5.1 explains the role of blockchain technologies in it, so that it can be effectively integrated with DPP data management, its impact on the market, and the future usability of its services.

1.3 ROLES AND RESPONSIBILITIES OF THE INVOLVED PARTNERS

The development of the ENCIRCLE project, more specifically the DPP, involves different parties responsible for creating its various parts, contributing according to their technical expertise and responsibilities.

- Worldline Iberia is responsible for the design of everything related to the blockchain, including the definition of the overall architecture, workflows, and interaction, as well as the creation and integration of backend services and APIs. This also includes the responsibility of configuring and deploying all of this, including everything related to the blockchain layer.
 - FORTH is responsible for developing a mobile application for customers, including user interaction and the app's functions that interact with DPP data.
-

- Fraunhofer is responsible for analysing the use cases and based on that analysis, defining the DPP data model and the data storage and format requirements.

Due to this division of responsibilities, we have a very clear separation of functions, which is expected to allow for seamless integration between the different parts, such as the blockchain, data services, and user-oriented frontend.

2 THE ENCIRCLE BLOCKCHAIN FRAMEWORK

2.1 BLOCKCHAIN TECHNOLOGY

2.1.1 Analysis of blockchain technologies and selection criteria

Digital Product Passport (DPP) [1] from ENCIRCLE [2] project requires a secure and trusted system for data management. Product storage requires traceability throughout its life cycle, as well as assurance that the data has not been altered. To achieve these objectives, various ledger technologies (DLTs) [3] have been researched.

Blockchain technologies offer us decentralized data management in which we can track the creation and modification of objects, in addition to requiring participants to have specific trust certificates. Within the blockchain world, we can find different paradigms and products with differences in scalability, ownership, privacy, and energy efficiency. For this reason, we must be careful in selecting the technology that best fits the development of the DPP and the requirements of the ENCIRCLE project.

In general, blockchain technologies can be classified into two distinct groups: public and permissioned. Public blockchains are freely accessible, without participation restrictions, and their consensus mechanisms are open. Permissioned blockchains, on the other hand, are networks that restrict participation and require identification and authorization, providing access control and governance mechanisms.

The DPP infrastructure is required to ensure:

- Control over trusted participants.
- Data integrity and traceability of the lifecycle of entities.
- Selective access to data with protection and confidence in its accuracy.
- High energy efficiency and low environmental footprint.
- Integrity with existing platforms and systems through standard service layers [4].

Based on these requirements, we can conclude that a permissioned platform is needed for this project. With this type of platform, the blockchain can be used to manage the traceability of entities through trusted agents. These architectures enable governance models aligned with consortium-based projects, support compliance with regulatory and data protection restrictions, and facilitate integration with enterprise-level identity and access management mechanisms.

2.1.2 Introduction to Hyperledger Fabric

Hyperledger Fabric [3] is an open-source blockchain platform designed for enterprise environments, characterized by its modular architecture, high confidentiality, scalability, and performance. It was developed under the Hyperledger project conceived by the Linux Foundation [5] [6] and focused on business or industrial use cases that require control of network participation, data trust, and specific governance mechanisms.

Hyperledger Fabric operates on an authorized network where all participating entities must be known, authenticated, and permitted within it, using an internal platform to guarantee all of this. This differs greatly from the general mindset or understanding of public blockchain platforms. This allows for a high level of

access security and precision, resulting in the creation of certificates for entities with specific roles and permissions that are used for interaction between those entities.

Fabric has a modular feature that allows us to have backup in block transactions, as well as order and commitment in its data consistency and trust. This modular feature allows us to support different contexts and mechanisms. Components can be created for management and cryptographic services that adapt to different governance policy implementations.

A concept of communication channels is also introduced, which provides communications between different participants in that channel, being a private and confidential communication on the blockchain network. This feature is very important in use cases where highly sensitive data is handled that must only be shared between authorized entities and at the same time must offer integrity between platforms.

Fabric contracts between entities are called chaincode and encompass logic that governs the lifecycle of entities and their state changes. The creation of this chaincode provides control that ensures transactions are validated according to a set of rules or policies agreed upon by network participants before being recorded in the ledger.

These features make Hyperledger Fabric the ideal platform for those who need data change traceability, controlled access, and system integrity, thanks to certificates that comply with the other features of blockchain platforms.

2.1.3 Hyperledger Fabric in ENCIRCLE

Within the ENCIRCLE project, Hyperledger Fabric is the central axis that underpins the creation of the digital product passport (DPP) and all its internal mechanics. The blockchain layer offer a reliable infrastructure for recording events for internal products and their respective life cycles, as well as managing other transactions between Fabric network operators concerning those products.

Fabric is responsible within ENCIRCLE for ensuring that the information contained in the DPPs is managed securely, cannot be manipulated, and is transparent. At the same time, it must be accessible in a controlled way, in accordance with established regulatory requirements and confidentiality. Rather than acting as a general-purpose storage system, the blockchain layer is focused on traceability, state change logging, and unambiguous reporting of data properties. On the other hand, data and services must be managed outside the blockchain.

There are interactions with the Fabric network in various parts of the DPP component, including backend APIs, identity and access management services, and applications. In this context, the blockchain layer interacts with:

- Backend services that manage DPP data and lifecycle.
 - Parts responsible for identity management that identify users and systems interacting with the blockchain network.
 - Other components that interact with the application layer and other parts of the backend. There is a IAM backend component for generating and managing certificates that enable access to the various entities involved in the channel's internal communication.
-

This allows the project to guarantee the reliability and immutability of data through blockchain technology, with the flexibility and scalability of conventional architectures. By leveraging the Fabric model, information management is based on contracts, participation by identified parties, and detailed access control. This provides us with all the necessary requirements to create a digital product passport.

This lays the technological for developing the DPP component of the project within an environment in which the benefits of using this type of blockchain, interactions on the network, and the participation mechanisms of the participating entities are implemented, validated, and demonstrated.

2.2 BLOCKCHAIN ARCHITECTURE

2.2.1 Components

In the DPP system we have different interconnected components to connect and use the blockchain layer, each with a specific purpose within the ecosystem. The project follows a modular approach to its architecture, which allows for specific responsibilities to be guaranteed and facilitates integration between the different modules or between other systems or services within the project. In Figure 1 we can get a view of the architecture.

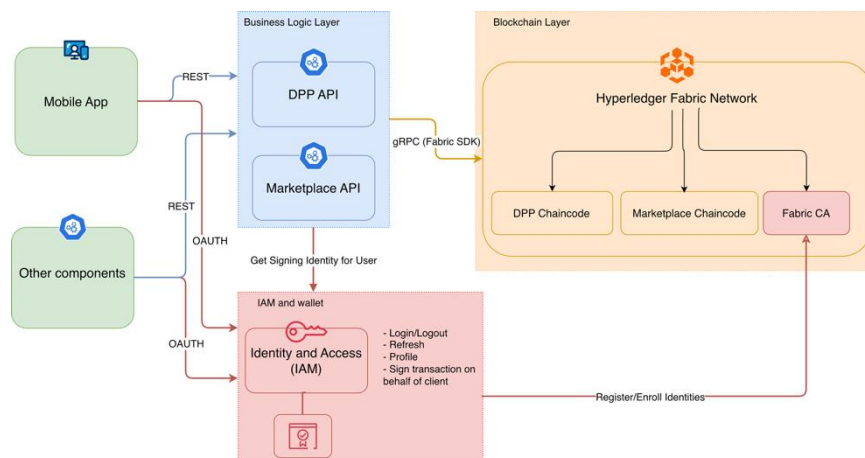


Figure 1. Blockchain Architecture

The blockchain network is the core of the blockchain system, which provides us with a distributed infrastructure to operate, store, and manage the data of Digital Product Passport (DPP). This component is responsible for ensuring the immutability, integrity, and privacy of the data or events related to it throughout its life cycle. It is also responsible for recording the traceability of products or their metadata.

Backend services are components that interact directly with the blockchain network and perform any operations related to the blockchain. These services offer application programming interfaces (APIs) and provide business logic, validation, and identification checks, offering a gateway to external applications or different types of clients. We can see these qualities in the components called DPP API and Marketplace API, which we can see in the diagram.

On the other hand, there is another backend service that communicates with the Fabric network, called Identity and Access Management and Wallet (IAM and Wallet). This architectural component is a key element for blockchain management. It identifies network users, stores credentials and certificates, and signs transactions. It can also contain user role systems or specific permissions, allowing for controlled access to blockchain services.

At the application level, we have consumer-oriented applications that interact with the APIs we purchased earlier. These apps interact with the backend and allow consumers and related services to operate on their DPP entities. This allows users to access information about their products, register new products, or even add modifications or information, thereby participating in the circular economy that we want to offer to entities. By not allowing them direct access to the infrastructure, we can guarantee the security and data integration policies that we want for the project.

All these components together form a strong, cohesive architecture, and thanks to flexible and scalable blockchain technology, we can achieve the support and guarantees we need within the ENCIRCLE project.

2.2.2 Flow diagrams

Within the blockchain component, there are different data flows from applications to APIs. These flows demonstrate the interaction between the various system components involved in blockchain operations. These mechanisms can also be used by other parts of the ENCIRCLE project, always acting as consumers at the beginning of the flow. Below are two explanatory and illustrative examples in which we can observe the flow of data between the components.

Create new DPP

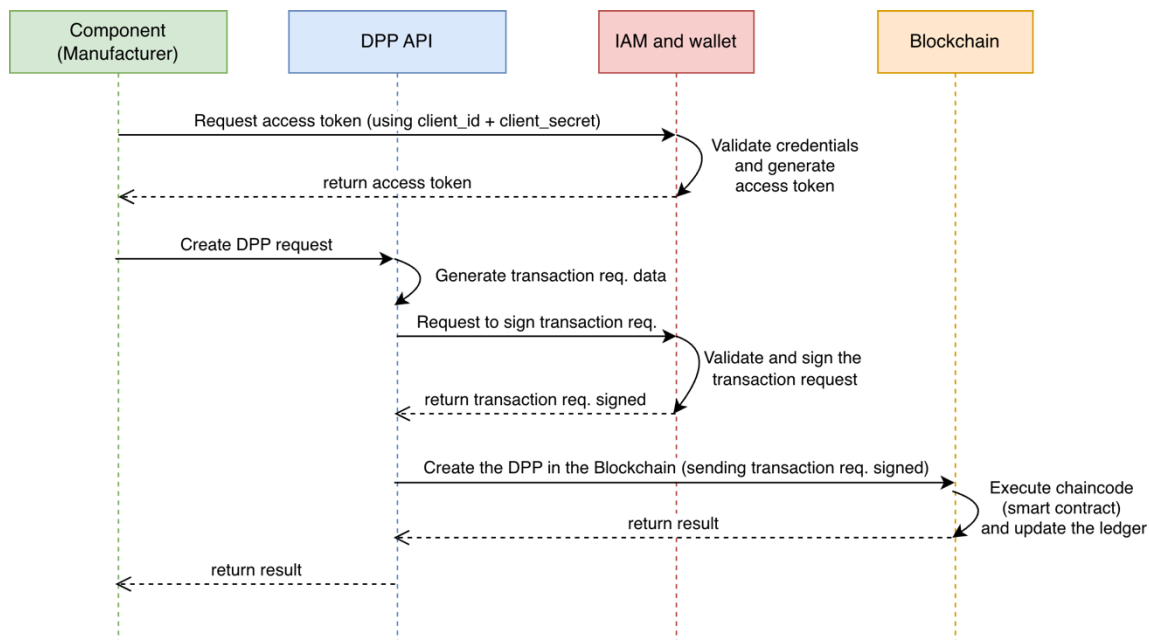


Figure 2. Blockchain Flow: Create new DPP

In the flow shown in the Figure 2, we can see the creation of a new digital product passport (DPP) entity by a manufacturer. We initiate communication through the application layer, for example, an interface focused on the manufacturer, which communicates with the backend services that validate the request, obtain authorization, and perform the corresponding transaction on the Fabric network.

At a high level, we can see how the manufacturer identifies themselves with its certificates to the component that manages the certificates, which is IAM and Wallet (IAM in the figure). This acquires a token to create the entity. The application communicates the creation request to the DPP API, which validates the identification token with the IAM. Once authorization is obtained and verified, DPP sends the request to create the DPP entity with all its information to the Fabric network. The ledger records the data and returns a unique identifier to the person who initiated the request. This ID accompanies the entity throughout its lifecycle and will be used for future transactions involving it.

Client registers a product

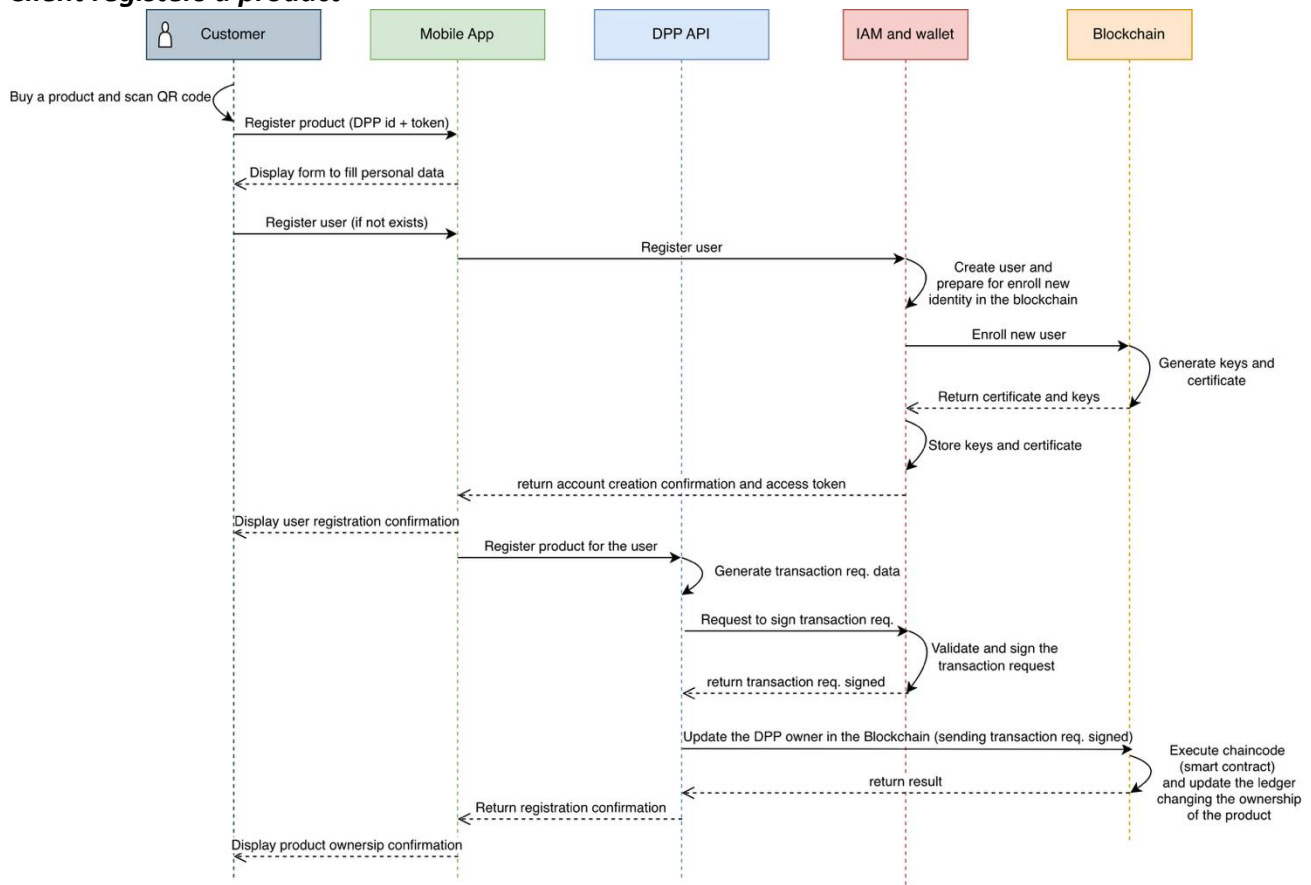


Figure 3. Blockchain Flow: Client register a product

In this other flow, we can see (Figure 3) the process that a customer goes through when purchasing a product and registering it as its property. To do this, the customer starts the transaction from the app by scanning the QR code that contains the product ID information, which they use to register their ownership.

The process is carried out in collaboration with the backend services, and in this example, we see how the user is also new to the system and must register. The app first exchanges communication with IAM, the

customer fills in the registration details, and IAM creates the user, returning an identification token. Once the user has been created, they can start registering the product. We start by communicating with the DPP API, providing the identity and the product ID. DPP checks the identification token by communicating with IAM. Once the customer has been identified, DPP sends the order to update the entity in the network, using all the chaincode and the policy proposed therein.

The flow ensures that events are reliably recorded and that every transaction has a security requirement with authentication and authorization.

2.2.3 Blockchain APIs

This section of the document presents the different methods of the API endpoints to interact with the blockchain component. This section presents the components belonging to the IAM, the Wallet, and the DPP. Market creation is not covered in this section, although this aspect will be addressed in a future deliverable, specifically in Work Package 6.

IAM and wallet API

- **POST /auth/signup**: This service will register a new user in the system. This implies the generation of a new certificate to work with the blockchain. The body of the request must contain: email, password, first_name, last_name. The response will confirm the registration.
- **POST /auth/login**: This service will authenticate a user. The body of the request must contain: email and password. The response will include an authentication token to be used for subsequent requests to the IAM and wallet API, DPP API and the Marketplace API.
- **GET /account**: This service will return the user account data. The body of the response will contain: email, first_name, last_name and phone_number.
- **PUT /account**: This service will update the user account with the provided data. The body of the request must contain: first_name, last_name, email and phone_number. The response will contain the updated data.
- **POST /account/change-password**: This service will change the user password with the provided data. The body of the request must contain: current_password, new_password. The response will confirm the password change.
- **GET /account/preferences**: This service will return the user preferences (Push notifications options, Privacy settings options, etc.). The definition of the arguments still needs to be specified and is subject to change in the future. The response will contain the data.
- **PUT /account/preferences**: This service will change the user preferences (Push notifications options, Privacy settings options, etc.). As with the previous one, there are no arguments yet and it must be addressed in the future. The response will contain the updated data.

DPP API

- **POST /product**: This service will allow the manufacturer to create a new product DPP in the blockchain with the data provided. The body of the request must contain the DPP data to be displayed in “General information”, “Components”, “Carbon footprint”, etc. in addition to a Product
-

Serial number (serial_number) that will be used by the customer to register the product. The response will contain an autogenerated identifier (dpp_id).

- **PATCH** /product/{dpp_id}: This service will allow the manufacturer to update some specific product DPP data during its lifecycle. The data that this method should supply and return must be established; for example, it is proposed that there is some status data for the entity.
- **GET** /product: This service will retrieve a list of products that belong to the authenticated customer, with some attributes from the DPP data stored in the blockchain of each product, in JSON format. The response will contain a list of products with the following attributes: dpp_id, title, serial_number, main_image_url, status_code.
- **GET** /product/{dpp_id}: This service will retrieve the DPP data stored in the blockchain for the given dpp_id in a JSON format. The response will include all the data to be displayed in “General information”, “Components”, “Carbon footprint”, etc. The response will not include any additional information such as recommendations, annotations, etc.
- **POST** /product/{dpp_id}/check_register: This service will check if the customer has provided a valid serial_number for the product. The body of the request must contain the Product Serial number (serial_number). The response will return a confirmation if the serial_number is valid.
- **POST** /product/{dpp_id}/register: This service will change the ownership of the DPP to the customer that is registering the product. The body of the request must contain the Product Serial number (serial_number). The response will confirm the registration (ownership change).
- **POST** /product/{dpp_id}/annotations: This service will add an annotation linked to the product DPP. Annotations are product-related data entities that can be added throughout the product lifecycle, for instance, diagnosis items, 3D model data items. The body of the request must contain the annotation data and the type of annotation. The response will confirm the addition of the annotation. The annotation format needs to be defined for each specific annotation type (such as diagnosis, 3d_model).
- **GET** /product/{dpp_id}/annotations: This service will retrieve all annotations associated with the given dpp_id. The response will include a list of annotations with several attributes so that the mobile app can show a list of items to the customer and the annotation_id of each item. This service will filter annotations by type by using a query param, such as: /dpp/{dpp_id}/annotations?type=diagnosis to get all diagnosis performed on a product.
- **GET** /product/{dpp_id}/annotations/{annotation_id}: This service will retrieve all the annotation data associated with the given annotation_id.

Swagger DPP API and IAM wallet api

The API also comes with documentation provided via Swagger, a set of open-source tools based on the Open-API specification, which enables the design, development, documentation and use of RESTful APIs in a standardized manner.

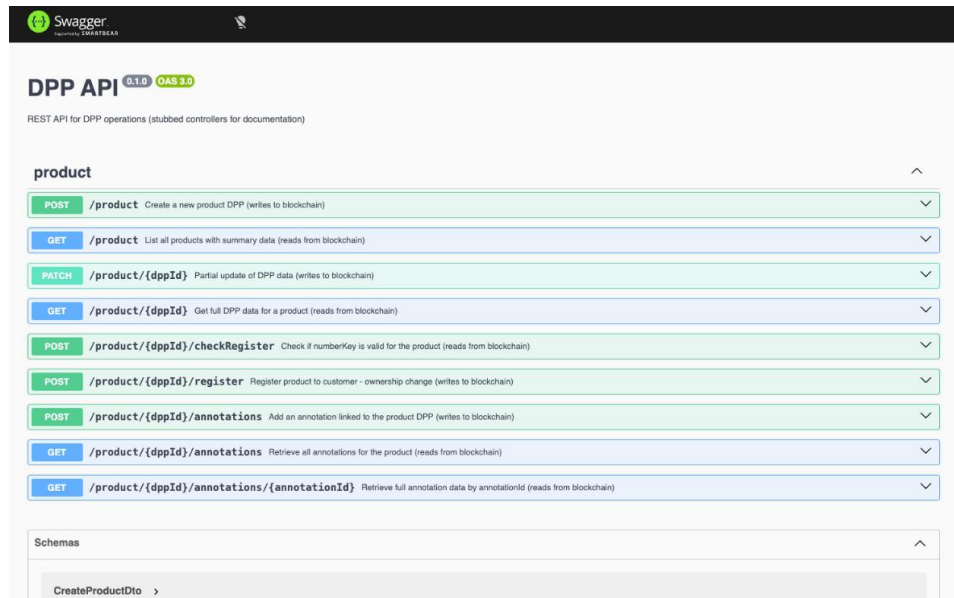


Figure 4. DPP API Swagger

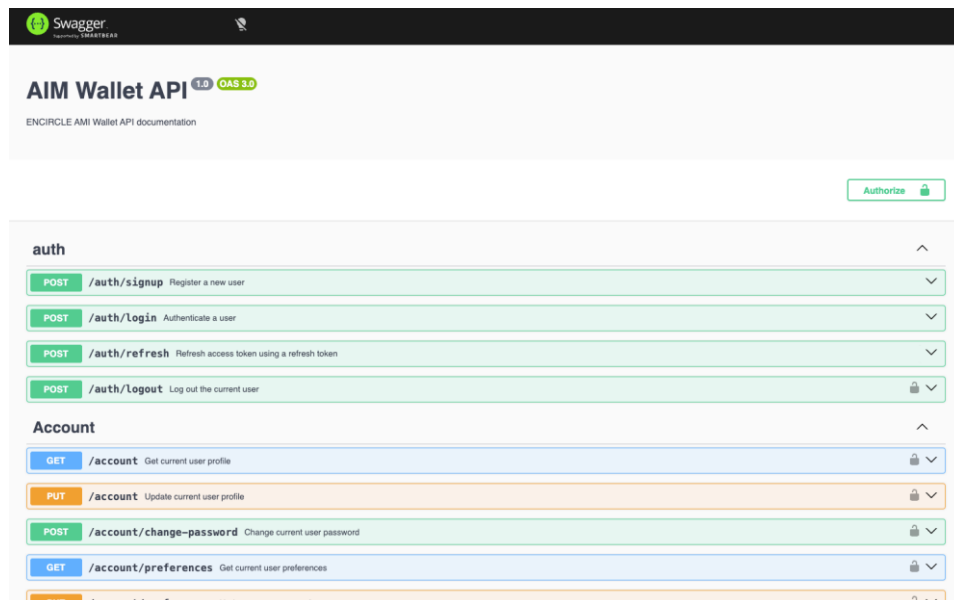


Figure 5. IAM Wallet API Swagger

Figures 4 and 5 show a screenshot of the website's main page.

2.2.4 Chaincode

In the architecture of the ENCIRCLE project, the blockchain is responsible for encapsulating the business logic that governs the operations that can be performed with the Digital Producer Passport (DPP). Any transaction that you want to perform with the DPP, whether it is creating or modifying it within the ledger, must be implemented within the blockchain and ensure that this code satisfies all the qualities we want for the DPP. Consistency and security must be guaranteed among all participants using the chaincode.

This chaincode must have a finite and well-defined repertoire of different operations that manage the entities and the traceability of the DPP. These operations include the creation of new records, validation, or modification, always based on unique identifiers that allow us to unambiguously locate the information. It also has a record of events related to ownership throughout the product's life cycle.

Instead of external applications being responsible for communicating with the blockchain, the blockchain always is invoked by backend services, the APIs we have already seen in previous sections. Therefore, at the application level, we have validation, authorization checks, and logic, but on the other hand, the blockchain is responsible for integrating internal transactions.

This blockchain is responsible for representing the data and manages a representation of the entities contained in the DPP, including their identifiers, status information, characteristics, and the references necessary for traceability. Product detail data is managed off chain by other parts of the system or architecture defined in ENCIRCLE.

The minimum requirement for the chaincode at the project is to support the creation, registration, and traceability of DPP. Additional functions required by the code will be added in the future, as these are advanced options related to lifecycle, iterations, or validation. We will be able to see them in future project deliverables.

2.3 DPP DATA AND ARCHITECTURE

The Digital Product Passport (DPP) in ENCIRCLE WP5.1 was originally modelled using the Asset Administration Shell (AAS) framework. For each pilot, ZINQ, Arçelik/Beko, and Alumil a dedicated AAS instance was created to represent the respective product as an asset. Each AAS comprises the standard AssetInformation element, in addition to a dedicated DPP submodel that captures the passport content in a structured and semantically consistent manner. The thematic categories defined in WP2 Deliverable 2.1 [7], which were inspired by the Battery Pass model, DIN SPEC 99100, and aligned with the Ecodesign for Sustainable Products Regulation (ESPR) [8, 9], were directly translated into SubmodelElementCollections within the AAS. To illustrate this point, consider the Alumil case, in which collections such as GeneralProductInfo, CarbonFootprint, PerformanceAndDurability, MaterialComposition, and LabelsAndCertification structure contain production

and sustainability-related data. Figure 6 illustrates the corresponding lifecycle phases and the associated data collected across them, including both dynamic and static data elements.

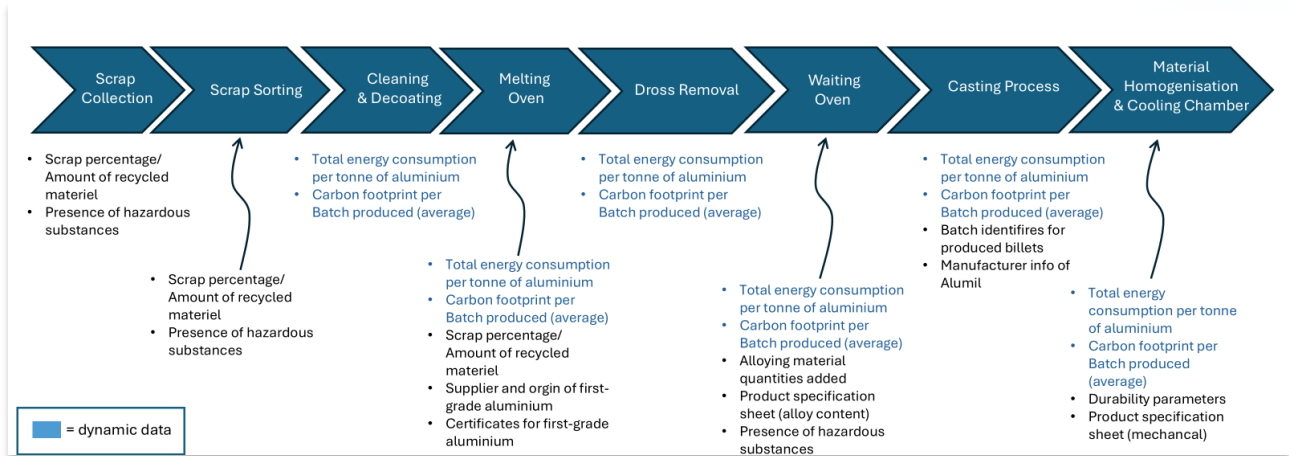


Figure 6: Lifecycle-based mapping of Alamil processes and associated DPP data

In the Arçelik implementation, collections such as GeneralProductInfo, CarbonFootprint, Circularity, PerformanceAndDurability, MaterialComposition, and LabelsAndCertification reflect the product lifecycle and conformity aspects. The associated data and lifecycle relationships are shown in Figure 7. In the ZINQ case, collections such as GeneralProductInfo, CarbonFootprint, Circularity, PerformanceAndDurability, MaterialComposition, DueDiligence and LabelsAndCertification capture environmental, traceability, and certification-related information. The structure of these data elements and their relationship to lifecycle stages are illustrated in Figure 8.

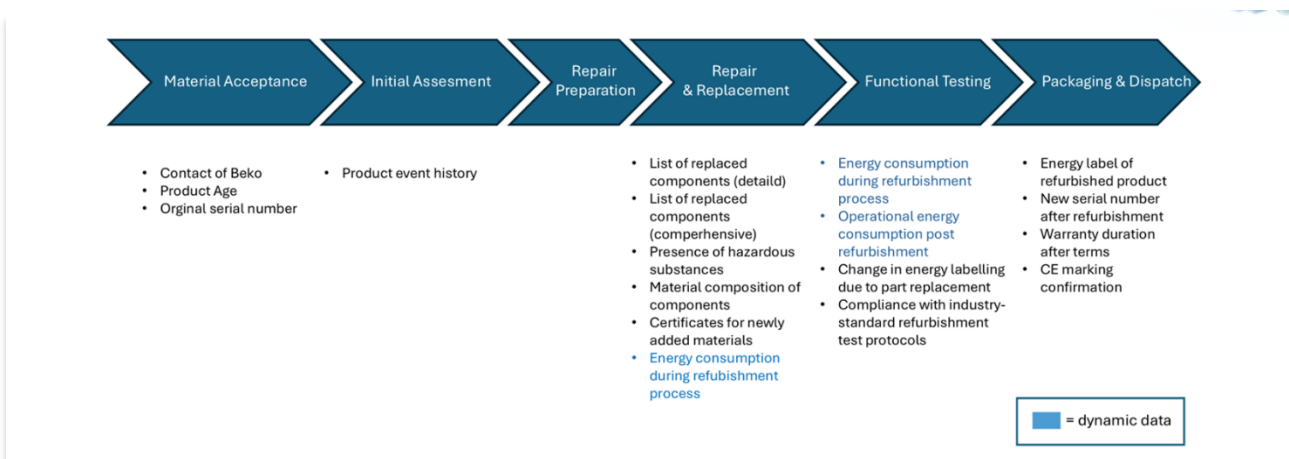


Figure 7: Lifecycle-based mapping of Arçelik/Beko processes and associated DPP data

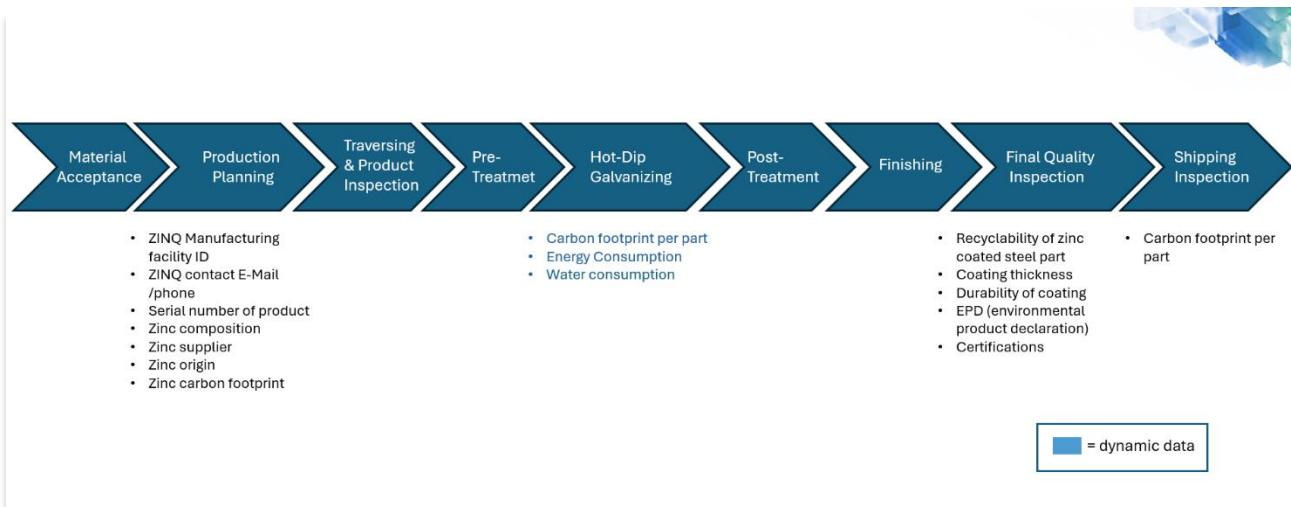


Figure 8: Lifecycle-oriented mapping of ZINQ processes and associated DPP data elements

Each individual DPP attribute defined in the WP2 tables was implemented as an AAS Property within the corresponding collection. Where applicable, physical units such as kgCO₂e, kWh, liters, or micrometers were explicitly defined at the property level, ensuring semantic clarity and machine interpretability within the AAS meta-model.

To enable integration with the blockchain infrastructure, which requires a deterministic and lightweight serialization format, the AAS-based DPP structure was exported into a JSON-based representation. This JSON structure preserves the hierarchical logic of the AAS model while transforming it into a format suitable for blockchain storage and processing. The mapping is structural rather than conceptual: the DigitalProductPass root object in JSON reflects the AAS instance, thematic JSON blocks correspond to submodel collections, and JSON fields represent AAS properties, including unit metadata where required.

Importantly, the JSON representation is not an independently designed data model but rather a direct serialization of the AAS implementation. The AAS therefore remains the semantic source of truth, while JSON serves as the technical representation required for distributed ledger integration. This layered approach preserves semantic rigor, implementation control, and infrastructural compatibility within a unified DPP architecture.

The DPP structures for all three pilot use cases were implemented and visualized using AAS Explorer. Each instance contains the complete AAS structure, including the AssetInformation section and the dedicated DPP submodel.

Figure 9 presents the AAS structure for the Alumil use case. The DPP is implemented as a submodel containing several SubmodelElementCollections, such as GeneralProductInfo, CarbonFootprint, PerformanceAndDurability, MaterialComposition, and LabelsAndCertification. Each collection groups

logically related DPP attributes, which are modeled as Properties within the AAS. This structure reflects the production-oriented and environmental characteristics of the aluminum billet lifecycle.

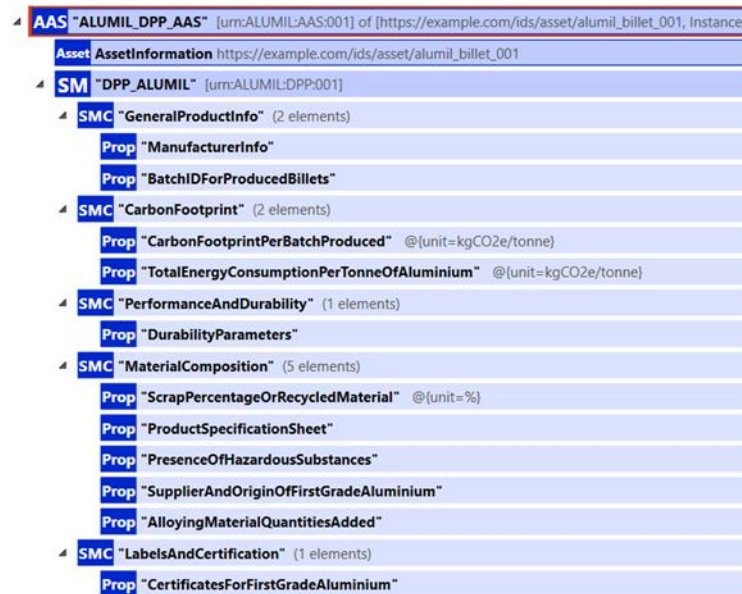


Figure 9: ALUMIL DPP in AAS Structure

In the Arçelik/Beko case, The DPP submodel is structured into collections such as GeneralProductInfo, CarbonFootprint, Circularity, PerformanceAndDurability, MaterialComposition, and LabelsAndCertification. These collections capture product identity, testing results, refurbishment and repair data, conformity

information, and energy-related indicators. The hierarchical structure visible in AAS Explorer demonstrates how lifecycle and compliance data are semantically organized within the AAS framework (Figure 10).



Figure 10: Arçelik/Beko DPP in AAS Structure

The ZINQ implementation follows the same modeling principle, with collections covering environmental impact, traceability, and certification data. Quantitative properties include explicitly defined units, ensuring consistency and interpretability across the model (Figure 11).

Across all three figures, the DPP follows the same modeling principle: a dedicated AAS instance represents the product, and a DPP submodel structures the passport information into thematic SubmodelElementCollections containing typed Properties. These AAS implementations serve as the semantic foundation from which the JSON-based representations used in the blockchain layer are derived.

4	AAS	"ZINQ_DPP_AAS"	[urn:ZINQ:AAS:001] of [https://example.com/ids/asset/1242_2121_8052_3280, Instance]
	Asset	AssetInformation	https://example.com/ids/asset/1242_2121_8052_3280
	SM	Missing Aas.Submodel for Reference!	-> AasCore.Aas3_0.Reference
4	SM	"DPP_ZINQ"	[urn:ZINQ:DPP:001]
4	SMC	"GeneralProductInfo"	(6 elements)
	Prop	"ManufacturingFacilityID"	
	Prop	"FacilityName"	
	Prop	"FacilityAddress"	
	Prop	"ContactMail"	
	Prop	"ContactPhone"	
	Prop	"SerialNumberOfProduct"	
4	SMC	"CarbonFootprint"	(3 elements)
	Prop	"CarbonFootprintPerPart"	@(Unit=kgCO2e)
	Prop	"EnergyConsumption"	@(Unit=kwh/tonne)
	Prop	"WaterConsumption"	@(Unit=L/tonne)
4	SMC	"Circularity"	(1 elements)
	Prop	"RecyclabilityPercent"	@(Unit="%")
4	SMC	"PerformanceAndDurability"	(1 elements)
	Prop	"CoatingDurability"	@(Unit=years)
4	SMC	"MaterialComposition"	(5 elements)
	Prop	"ZincComposition"	
	Prop	"ZincSupplier"	
	Prop	"ZincOrigin"	
	Prop	"ZincCarbonFootprint"	@(Unit=kgCO2e/kg)
	Prop	"CoatingThickness"	@(Unit=um)
4	SMC	"DueDiligence"	(1 elements)
	Prop	"EPDReference"	
4	SMC	"LabelsAndCertification"	(1 elements)
	Prop	"Certifications"	

Figure 11: ZINQ DPP in AAS Structure

3 THE DPP WALLET DAPP

3.1 MOBILE APP DESIGN AND AR FEATURES

This section describes the overall design approach and the user experience principles shaping the design and development of the ENCIRCLE Digital Product Passport (DPP) Wallet mobile application. It describes the conceptual, functional, and visual design foundations of the application, ensuring that technological solutions are presented through clear, intuitive, and user-friendly interfaces. The design considers how users interact with the application in everyday scenarios, recognising mobile interactions, patterns and constraints. The design described in this section is applicable to all the ENCIRCLE Use Cases, however, it is exemplified through mockups depicting the Arcelik use case.

Furthermore, this section outlines how the design approach supports alignment with circular economy services by enabling users to easily understand sustainability-related data, evaluate circular options, and actively participate in circular value chains. The DPP Wallet application is positioned not only as a technological tool but also as an interface that encourages informed decision-making and sustainable consumption behaviours.

3.1.1 Design rationale

The ENCIRCLE DPP Wallet Application is designed as a mobile-first application that allows users to register, manage and interact with their products throughout their lifecycle, access DPP information, and take circular actions (repair, reuse, recycle, resale) with minimal effort. The application design is aimed at ensuring clarity, usability, and meaningful user engagement. Users are expected to engage with the application in short, task-oriented actions, often within real-world environments (e.g., at home, near appliances, or during maintenance activities).

Mobile-First information architecture

The information architecture adopts a mobile-first approach, focusing on the main tasks and interaction needs of users. Basic modules are organized around key user actions, including product registration, product management, circular actions, marketplace interaction, and user account access. This structure enables users to reach essential functionalities quickly and with minimal navigation effort. Information and features are grouped according to user goals, integrating product interactions, circular services, and sustainability data into clearly organised sections. This reduces interface complexity and supports ease of use.

Navigation model for one-handed use

A persistent bottom navigation bar provides direct access to the primary modules of the application, including the homepage, registered products page, DPP wallet information, marketplace, and user account. This approach ensures that key functionalities remain continuously accessible, reducing navigation effort and supporting rapid context switching.

The navigation structure follows commonly used mobile interaction patterns and is specifically designed to support one-handed use. Primary interactive elements are positioned within the “thumb zone”, referring to the areas of the screen that can be comfortably reached by the user’s thumb while holding the device. These regions typically correspond to the bottom and central sections of the display.

Visual hierarchy and layout

Mobile screens offer limited space and are often used in dynamic contexts. For this reason, the interface adopts card-based layouts that improve scanability and allow users to quickly review products and available options. A clear visual hierarchy is achieved through consistent typography, spacing, and grouping, allowing users to quickly identify key information such as product identity, status indicators, and primary actions.

Gradual information reveal

The interface presents information in a structured and layered manner, ensuring that users are not overwhelmed by a lot of data. Key information, such as product name, status, and primary actions, is immediately visible, while more detailed attributes remain accessible through secondary pages. This gradual information reveal approach allows users to focus on relevant information without unnecessary complexity.

Action-oriented design to support circular behaviours

The user interface prioritises actions over information, because circularity requires participation. Circular lifecycle options, including maintenance, repair, resale, and recycling, are integrated as primary interface elements. This design choice ensures that sustainable actions are directly accessible and naturally embedded within user workflows.

In summary, the design applies mobile UX principles, simplicity, speed, consistency, gradual information reveal, and action-first interaction to make DPP application concepts usable in everyday life. The app is designed to turn product information into practical circular actions, thereby supporting ENCIRCLE's objective of increasing consumer participation in circular value chains.

3.1.2 High-fidelity prototypes

The following section presents representative high-fidelity mockups illustrating the visual design, interface structure, and overall experience of the ENCIRCLE Digital Product Passport (DPP) Wallet mobile application demonstrated through the Arcelik's use case. The mobile application is designed to enable users to register, manage, and interact with their products throughout their lifecycle. The application provides access to product-related information retrieved from the Digital Product Passport system, supporting transparency and informed decision-making. Through the application, users can perform key lifecycle actions, including product registration, product inspection, smart diagnosis, maintenance, resale, and recycling. The system supports circular economy services, enabling users to actively engage in reuse, repair, and recycling processes. Additionally, the application facilitates engagement with the digital marketplace, allowing users to explore circular value chain opportunities. By combining product information, lifecycle services, and user-centered interaction mechanisms, the ENCIRCLE DPP Wallet supports sustainable consumption practices and circular economy objectives.

As shown in Figure 12, the splash screen (first from the left) serves as the initial entry point of the application, while the login and sign-up screens provide access to user authentication and registration functionalities.



Figure 12: High Fidelity Mockups - DPP Application

a. Starting Page, b. Sign-In Page, c. Sign Up page

Figure 13a presents the Homepage of the application, acting as the main gateway for the most common user actions. This page provides users with immediate access to the main system functionalities. At the top of the screen, the application header presents the system’s visual identity. Directly below, a prominent “Add Product” action enables users to quickly initiate the product registration process. The homepage further provides immediate access to key lifecycle-related services, which, for example in the Arcelik use case, include Smart Diagnosis and Recycling Pickup, allowing users to trigger product maintenance and circularity actions. The Registered Products section displays the appliances associated with the user account. Products are presented using a structured card layout, highlighting attributes and status indicators, as a preview of product details. The Recommended Circular Actions area guides users toward sustainability actions, such as maintenance recommendations and recycling options. The Marketplace Offers section provides visibility into available circular economy opportunities, facilitating user engagement with reuse and resale mechanisms. Finally, a persistent bottom navigation bar enables seamless navigation across the main modules of the application, including the homepage, products page, marketplace, and user account. In addition, from the bottom menu’s central button the interface provides direct access to camera-based functionalities, enabling users to perform actions such as product registration, QR code scanning, and augmented reality functionality, as shown in Figure 13b.

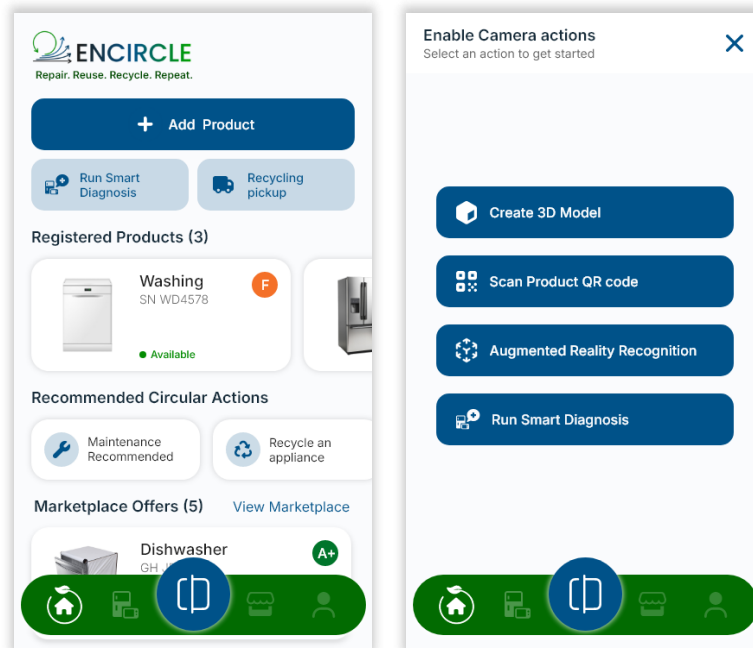


Figure 13: High Fidelity Mockups - DPP Application - Arcelik Use Case

a. Homepage b. Camera Functionality

Figure 14 illustrates the Add Product functionality of the ENCIRCLE DPP Wallet application. This interaction sequence enables users to register new appliances within the system through multiple input options. Figure 14a presents the Add Product options. The interface provides users with alternative registration options, including manual serial number entry, QR code scanning, and augmented reality recognition. This multi-option approach increases flexibility and serves different product identification scenarios. Figure 14b depicts the Serial Number Registration interface. Users can manually enter the product's serial number, supported by guidance explaining the purpose and location of the identifier. A dedicated Product Authentication action initiates the validation process. Figure 14c presents the Product Confirmation page. Once the product is successfully identified and retrieved from the DPP system, key product information is displayed for user verification. Users can either confirm the registration or cancel, ensuring interaction transparency and user control. Upon confirmation, the product registration process is completed.

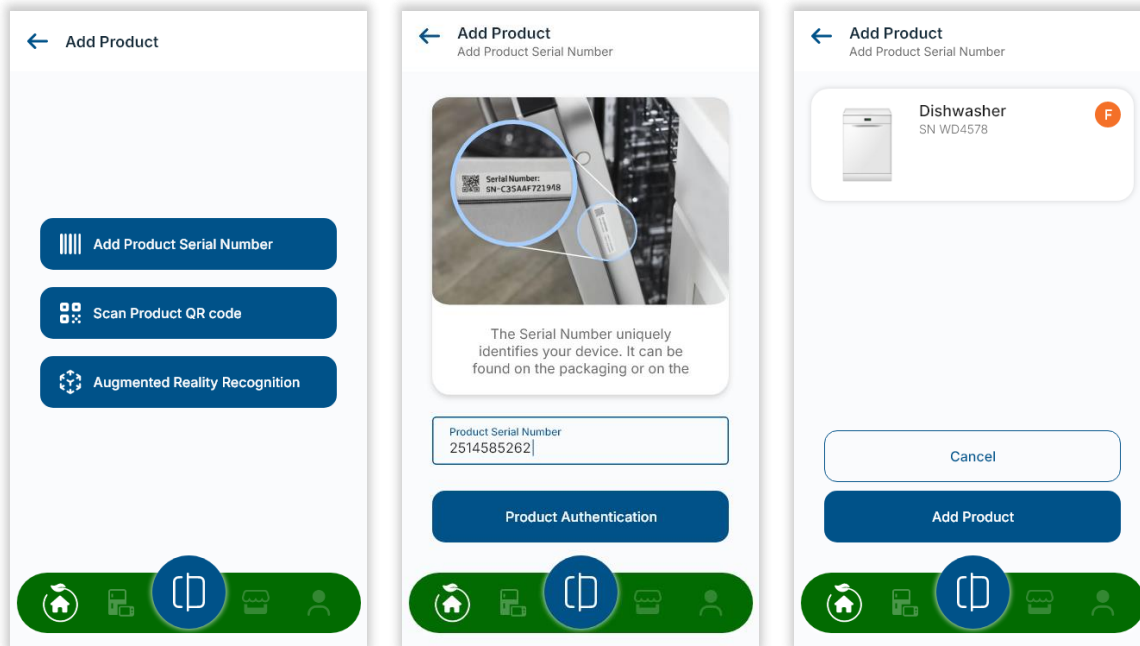


Figure 14: High Fidelity Mockups - DPP Application - Arcelik Use Case
a. Add product input options, b. Serial Number Registration, c. Add Product Confirmation

The Registered Products page is depicted in Figure 15a. This interface displays all products associated with the user account, providing an overview of registered appliances. Products are presented using a structured card-based layout that highlights essential attributes, including product identity and status indicators. Visual cues allow users to quickly assess the lifecycle condition of each appliance (e.g., availability, repair status). The interface incorporates search and filtering functionalities, enabling efficient product retrieval and navigation within the user's products. Each product card also provides direct access to detailed product information.

Figure 15b depicts the page with detailed information about a registered product, providing a detailed view of a selected appliance. This interface presents comprehensive product information retrieved from the DPP system. Key product attributes, such as product status, serial number, model, warranty information, and lifecycle data, are organized into clearly defined sections. The interface also provides direct access to primary product-related actions, including Smart Diagnosis and Recycling Pickup. Information is structured using tab-based navigation (e.g., general information, components, environmental footprint), enabling users to explore detailed data without overwhelming the interface.

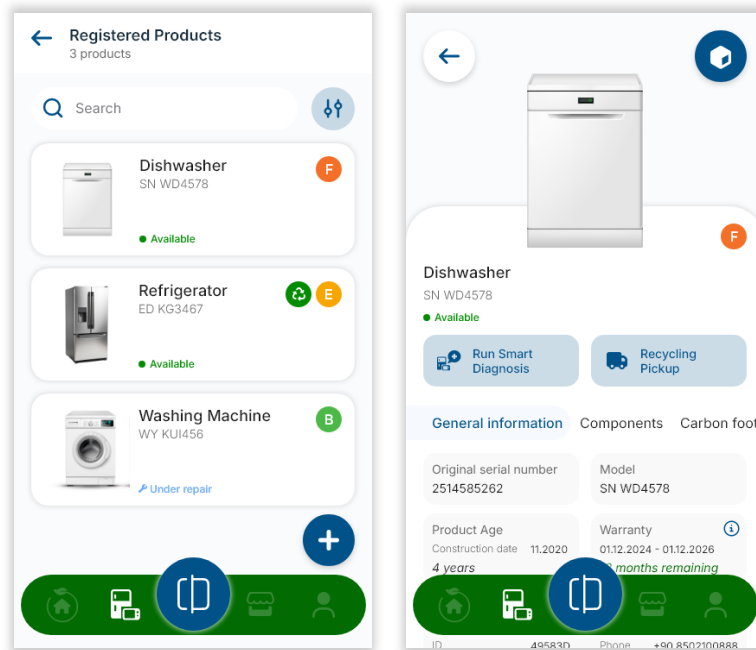


Figure 15: High Fidelity Mockups - DPP Application - Arcelik Use Case

a. Registered Products Page b. Registered Product Page

Figure 16 illustrates the 3D Model Creation process. This interaction sequence enables users to generate a digital representation of a registered product through guided image capture. The initial screen informs the user about the absence of a 3D model and provides a dedicated Create 3D Model action. The application activates the device camera and guides the user through a structured capture sequence. Clear instructions guide the user to capture images from specific viewpoints, such as the front side, interior, and control panel, in the case of a dishwasher. Visual guides assist users to correctly position the appliance within the capture area. Following each capture step, the interface provides validation options, allowing users to keep or retake images. This mechanism ensures image quality while maintaining user control over the process. The captured images are processed to generate the product's 3D digital model. Once the model is created, the interface enables interactive exploration, allowing users to inspect product components, access associated DPP information, and visualise relevant lifecycle attributes.

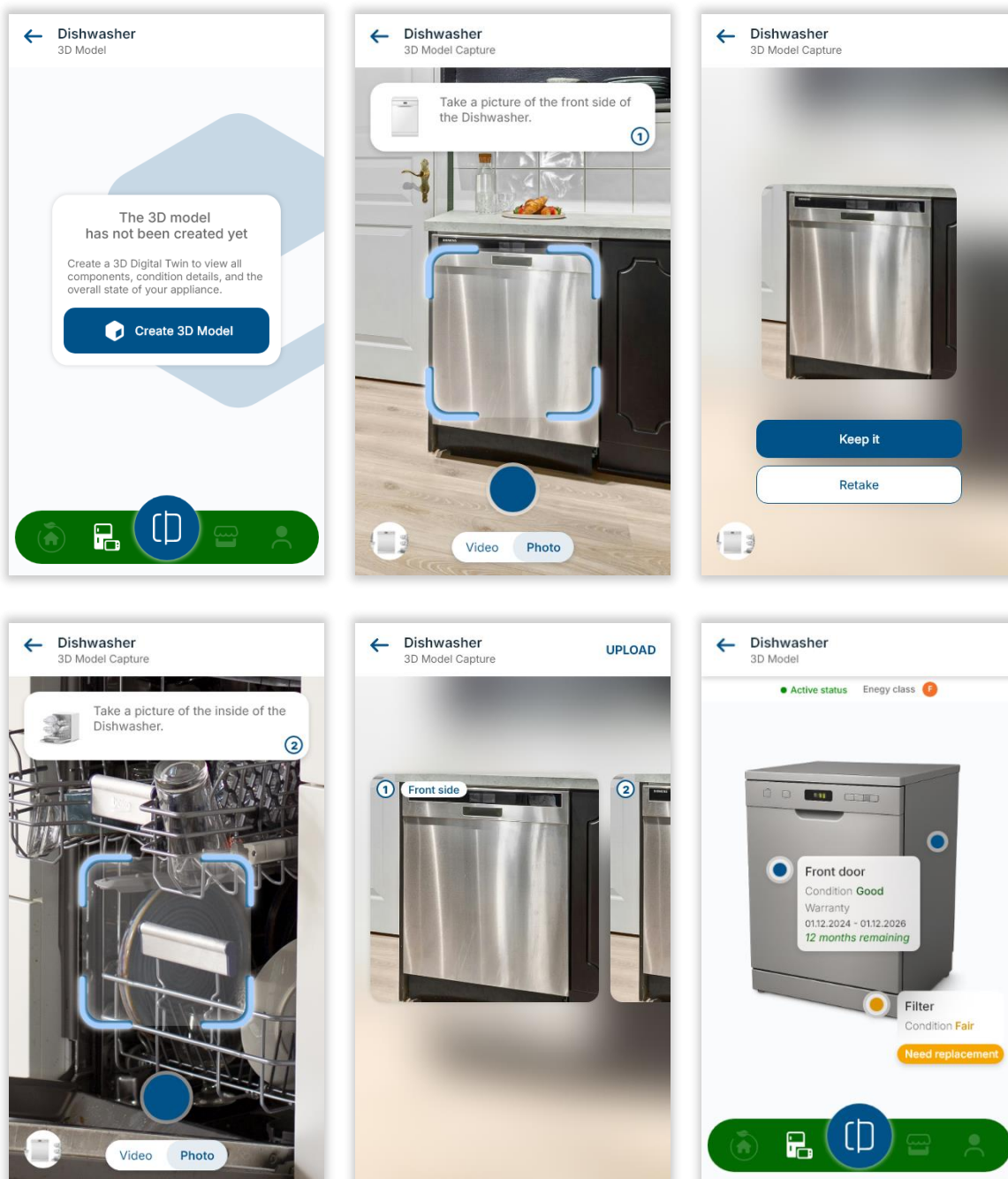


Figure 16: High Fidelity Mockups - DPP Application - Arcelik Use Case

3D Model Creation process

In Figure 17, the Smart Diagnosis process is depicted. This feature enables users to assess potential product issues through a guided interaction process. The initial screen introduces the Smart Diagnosis functionality, explaining its purpose and benefits. Users may then select the appliance for which the diagnostic process will be performed. The interface provides step-by-step guidance, directing users through the required preparation actions, such as verifying device status. Clear instructions ensure that users can easily follow the process

without technical expertise. During the diagnostic procedure, the application utilises the mobile device’s microphone. Users are guided to position the device appropriately and initiate the recording process. Visual feedback elements communicate system status and progression. Once the data capture is completed, users are provided with options to review or submit the recording. The system processes the input and presents diagnostic insights, including identified issues and recommended corrective actions.

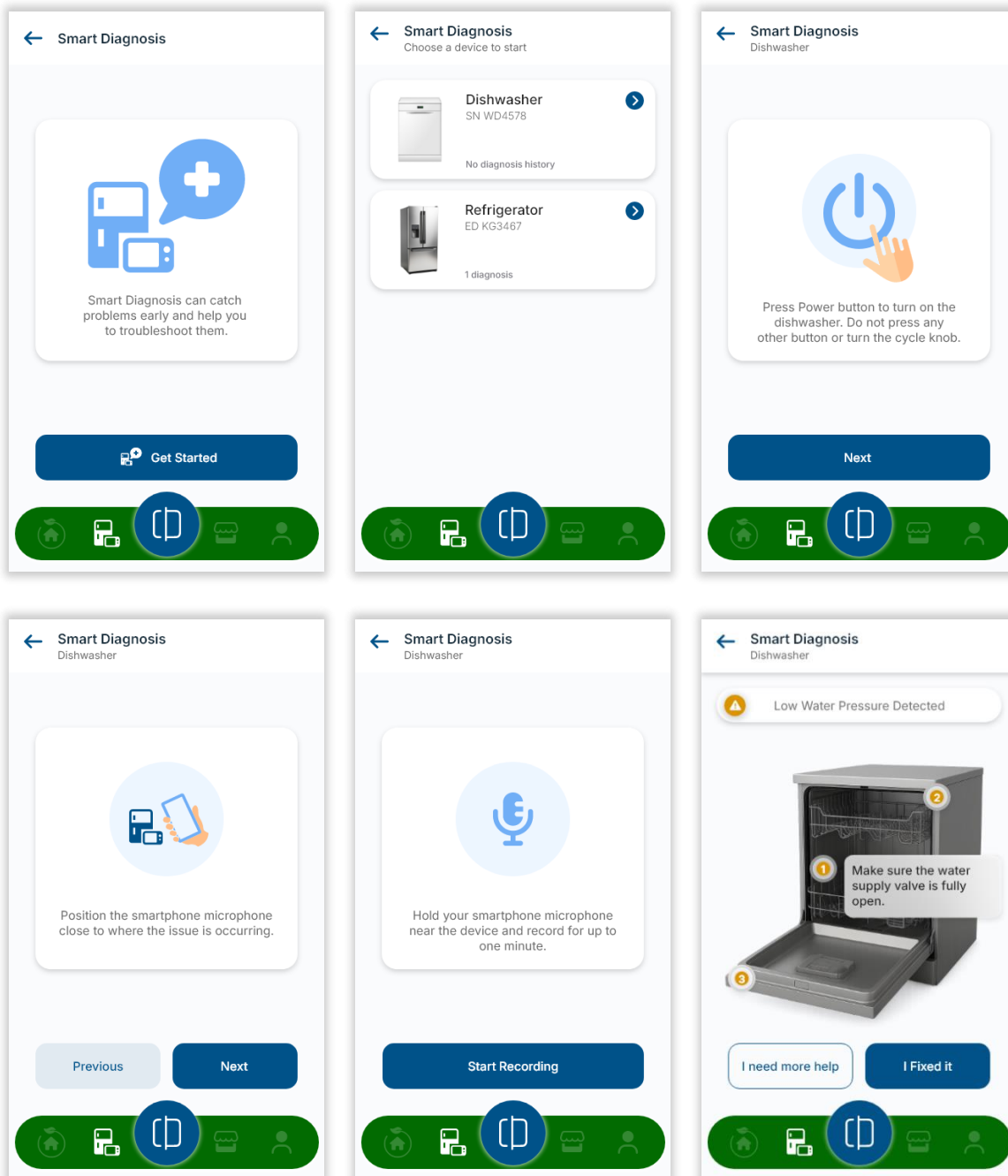


Figure 17: High Fidelity Mockups - DPP Application - Arcelik Use Case

Smart Diagnosis Process

Figure 18 presents the Recycling Pickup interface. This view enables users to initiate recycling action for a selected appliance. The interface clearly presents the purpose of the action, emphasising both the environmental and the user benefit. A prominent call-to-action allows users to submit a recycling pickup request, triggering the appropriate service. Once the request is submitted, users can track and manage their recycling requests through the User Account section.

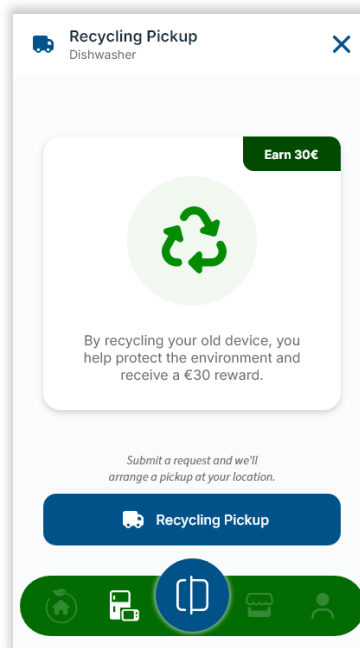


Figure 18: High Fidelity Mockups - DPP Application - Arcelik Use Case
Recycling Pickup

Figure 19 presents the Marketplace interface. This section enables users to explore available products within the circular economy ecosystem. The interface displays listed appliances using a structured card-based layout, presenting key attributes such as product identity, pricing information, and sustainability indicators. Search and filtering functionalities support efficient product discovery and navigation. Each product entry provides direct access to a detailed product view. The Marketplace Product Page presents product information retrieved from the DPP system, including product specifications, lifecycle data, and relevant metadata. Users are provided with clearly defined interaction options, such as accepting an offer or contacting the seller. Overall, the Marketplace is designed to facilitate user participation in reuse and resale mechanisms, supporting circular value chains and sustainable consumption practices.

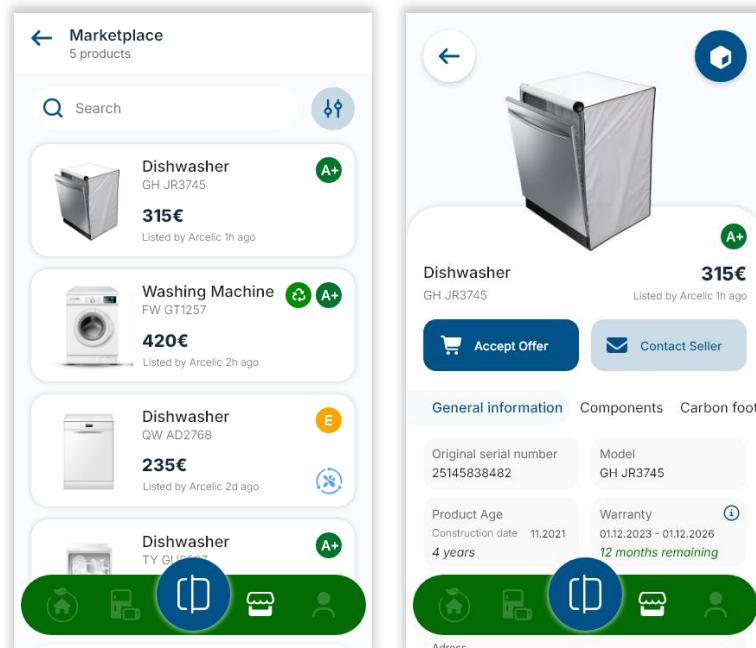


Figure 19: High Fidelity Mockups - DPP Application - Arcelik Use Case
Marketplace Section

Figure 20 presents the User Account section. This interface provides user controls, including profile management, transaction history, Smart Diagnosis access, application settings, and support functionalities. Dedicated pages support actions such as editing profile details, password management, and privacy settings. The notification icon provides access to the **Notifications** page interface, where users can view updates about marketplace activities, product changes, and system alerts. The User Account section also enables users to track transactions and requests. The interface presents transactions in a list, displaying key information such as product identity and status indicators. Visual cues assist users in quickly understanding the state of each transaction, while search and filtering options support easy navigation and retrieval of transactions.

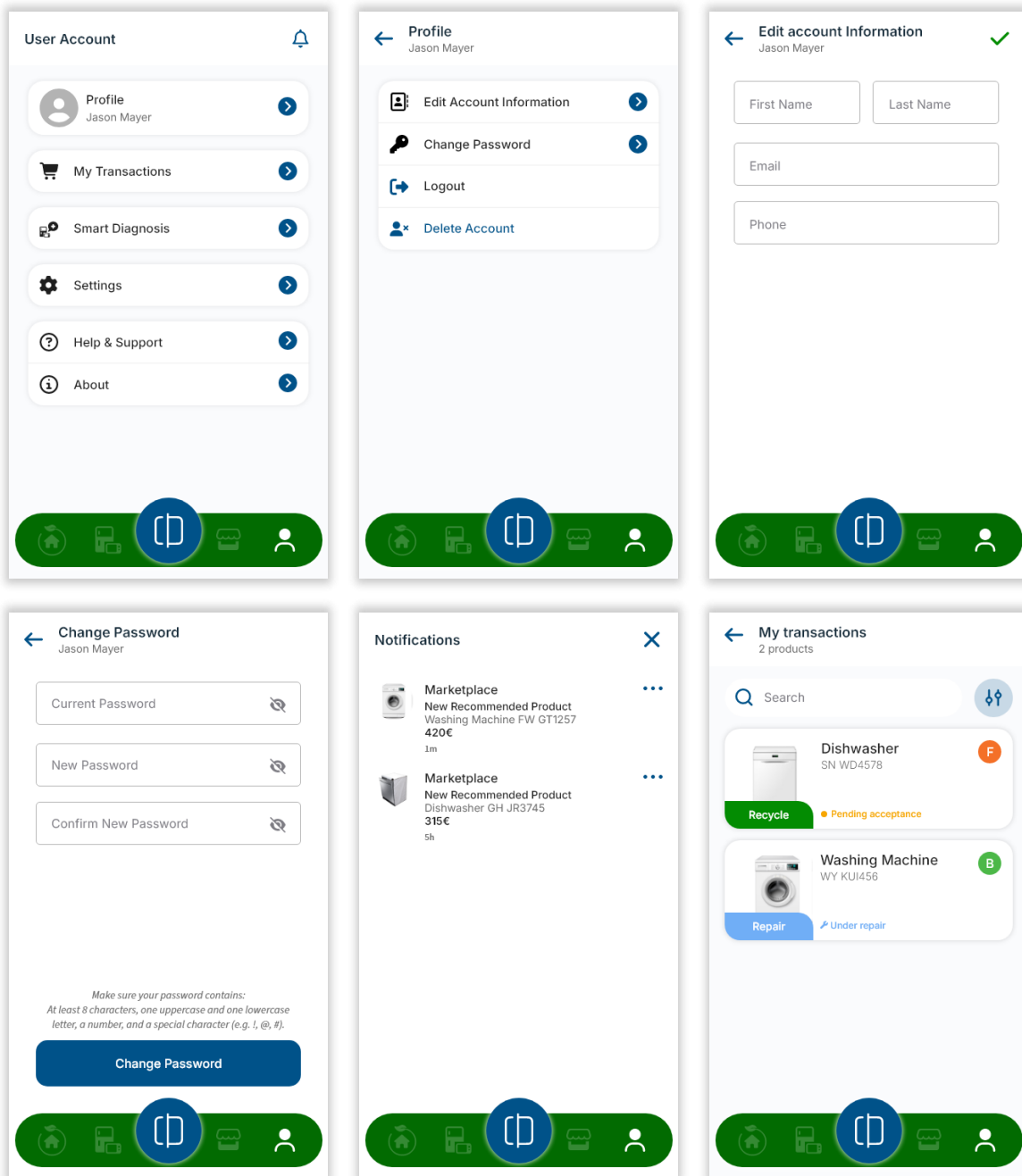
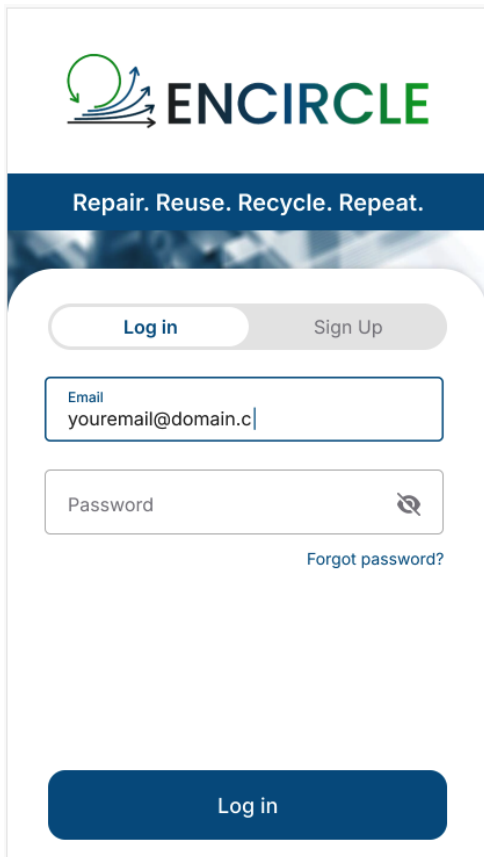


Figure 20: High Fidelity Mockups - DPP Application - Arcelik Use Case

User Account section

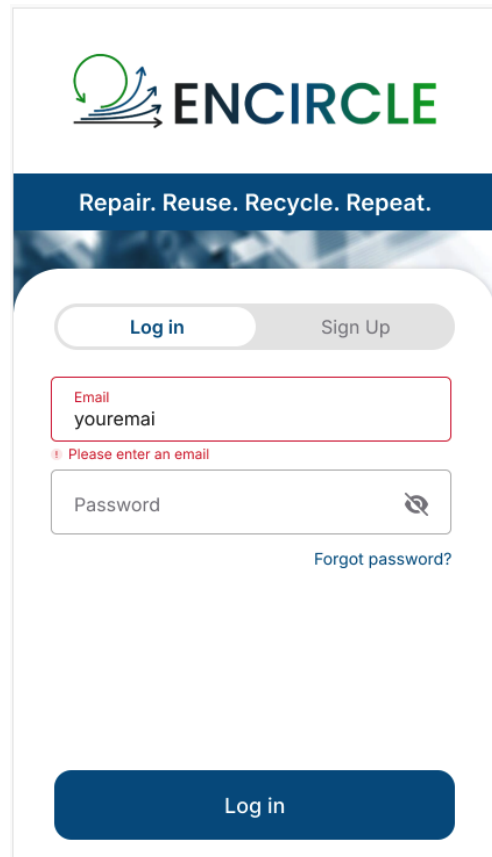
3.2 BLOCKCHAIN API CALLS

Previously, we presented the methods of the different API endpoints and the design of the mobile application. This section presents the relationship between these two parts of the project. A corresponding window of the mobile application is shown and a series of methods from the endpoints of the two APIs explained is linked. Everything related to the Marketplace application will be postponed for future deliberations, as previously mentioned.



The login screen features the ENCIRCLE logo at the top, followed by the tagline "Repair. Reuse. Recycle. Repeat." in a dark blue banner. Below this is a white rounded rectangle containing a "Log in" button and a "Sign Up" button. The email input field contains the text "Email" and "youremail@domain.c|". The password input field contains the text "Password" and a toggle icon. A "Forgot password?" link is located below the password field. At the bottom is a large blue "Log in" button.

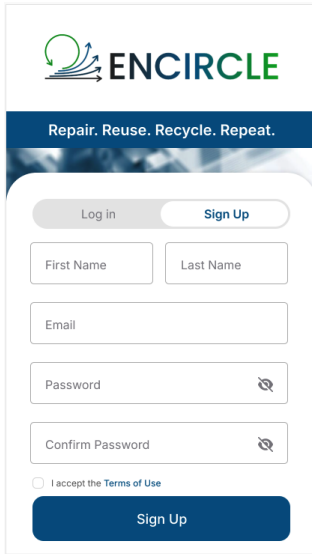
Figure 21. Log in screen



The login error screen is identical to the login screen but includes a red border around the email input field and a red error message "Please enter an email" below it. The "Log in" button at the bottom is still blue.

Figure 22. Log in error screen

IAM and wallet API:
POST /auth/login



ENCIRCLE
Repair. Reuse. Recycle. Repeat.

Log in Sign Up

First Name Last Name

Email

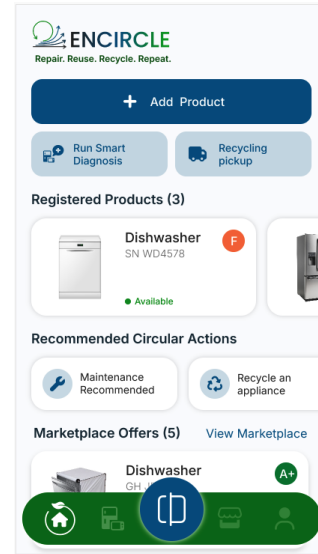
Password

Confirm Password

☐ I accept the Terms of Use

Sign Up

Figure 23. Sign up screen



ENCIRCLE
Repair. Reuse. Recycle. Repeat.

+ Add Product

Run Smart Diagnosis Recycling pickup

Registered Products (3)

Dishwasher
SN WD4578
Available

Recommended Circular Actions

Maintenance Recommended Recycle an appliance

Marketplace Offers (5) View Marketplace

Dishwasher
GH
A+

Figure 24. Main screen logged in

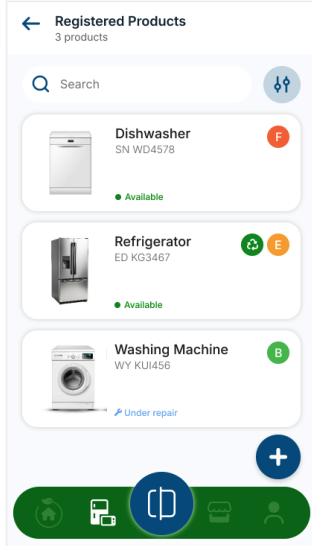
IAM and wallet API:
POST /auth/signup

DPP API:

- GET /product

Marketplace API:

- GET /offer?dpp_id={dpp_id}
- GET /offer?dpp_id=false
- GET /recommendation?dpp_id={dpp_id}



Registered Products
3 products

Search

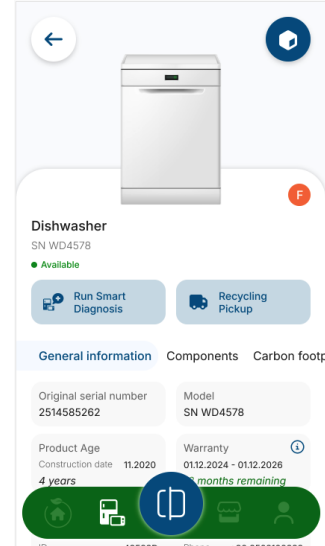
Dishwasher
SN WD4578
Available

Refrigerator
ED KG3467
Available

Washing Machine
WY KUJ456
Under repair

Figure 25. Registered products screen

DPP API:
GET /product



Dishwasher
SN WD4578
Available

Run Smart Diagnosis Recycling Pickup

General information Components Carbon footprint

Original serial number
2514585262

Model
SN WD4578

Product Age
Construction date
11.2020

Warranty
01.12.2024 - 01.12.2026
4 years 12 months remaining

Figure 26. Product view screen

DPP API:

- GET /product/{dpp_id}
- GET /product/{dpp_id}/annotations

Marketplace API:

- GET /offer?dpp_id={dpp_id}
- GET /recommendation?dpp_id={dpp_id}

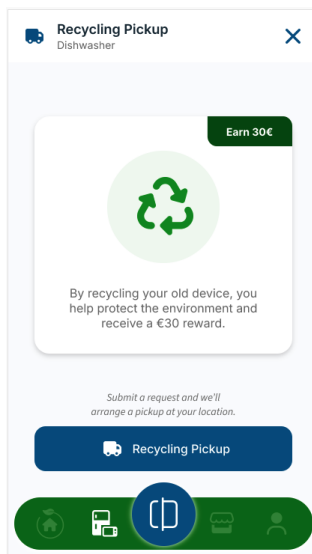


Figure 27. Recycling pickup screen

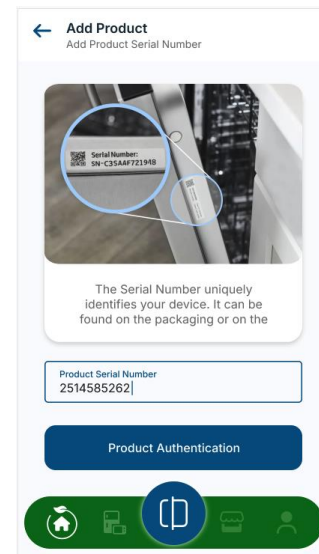


Figure 28. Add product serial number screen

Marketplace API:

- GET /offer/{offer_id}
- POST /offer/{offer_id}/accept

DPP API:

- GET /product/{dpp_id}
- POST /product/{dpp_id}/check_register

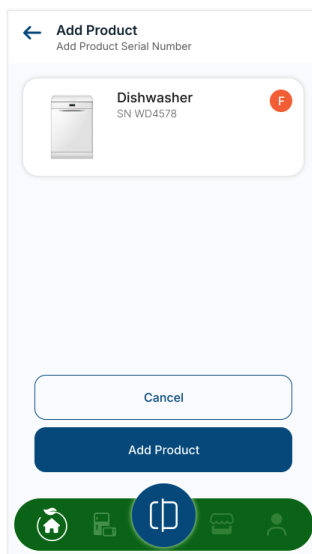


Figure 29. Finish adding product

DPP API:

- GET /product/{dpp_id}
- POST /product/{dpp_id}/register

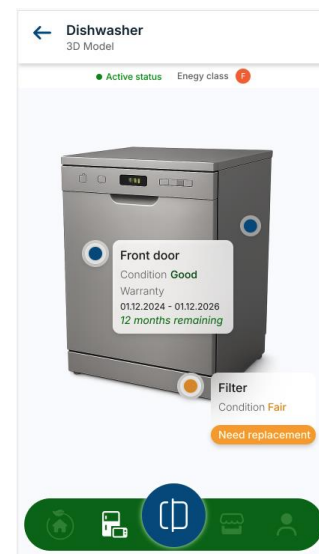


Figure 30. Select parts 3d model screen

Marketplace API:

- POST /product/{dpp_id}/annotations

Clarification: The 3D Model can be stored as an annotation. WLI will provide the needed services to manage the 3D Model generated data (store, retrieve), but won't provide functionalities to generate the 3D Model.

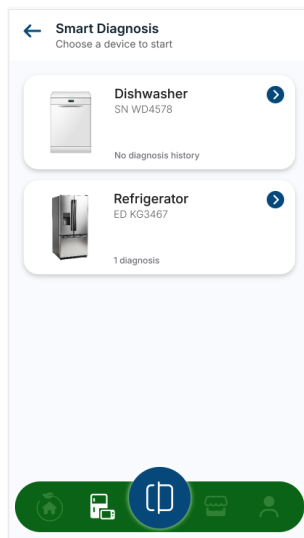


Figure 31. Smart diagnosis screen (Product selection)

DPP API:

● GET /product



Figure 32. Smart diagnosis screen (Result)

Marketplace API:

● POST /product/{dpp_id}/annotations

Clarification: The Smart Diagnosis can be stored as an annotation. WLI will provide the needed services to manage the Smart Diagnosis generated data (store, retrieve), but won't provide functionalities to generate the Smart Diagnosis.

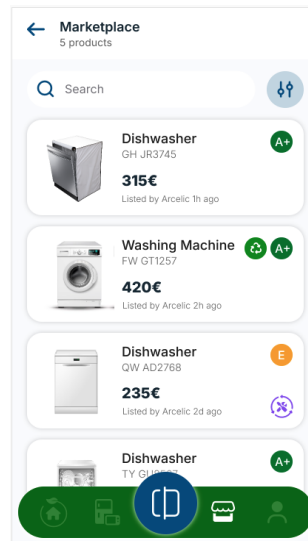


Figure 33. Marketplace screen

DPP API:

● GET /product

Marketplace API:

- GET /offer?dpp_id={dpp_id}
- GET /offer?dpp_id=false

Clarification: The APIs will provide services that allow the app to show offers related to the products that belong to the user and offers to buy other unrelated products

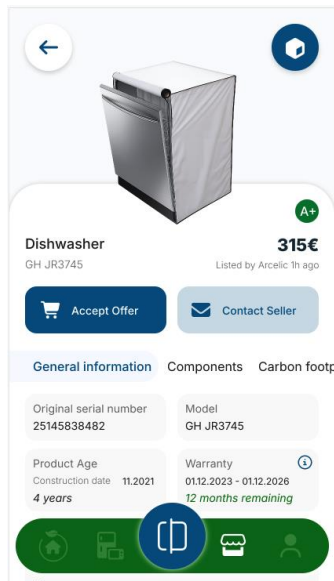


Figure 34. Description marketplace product screen

DPP API:

GET /product/{dpp_id}

Marketplace API:

GET /offer/{offer_id}

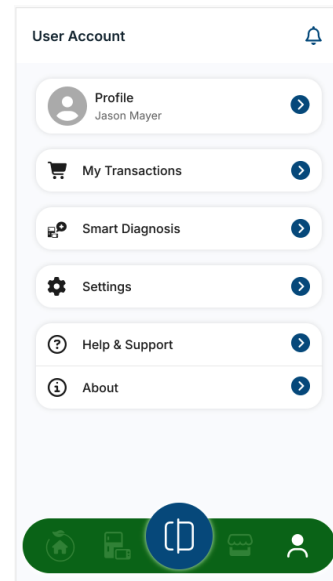


Figure 35. User account screen

IAM and wallet API:

GET /account

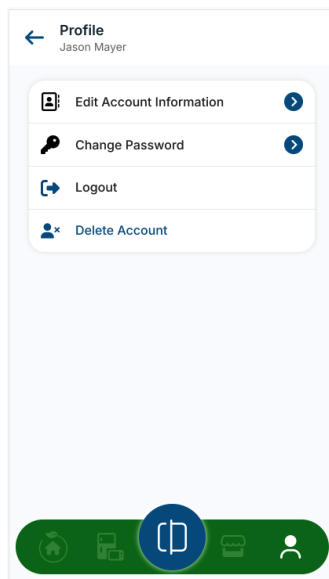


Figure 36. Profile options screen

IAM and wallet API:

GET /account

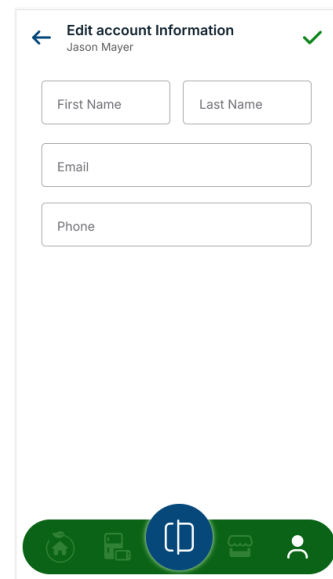


Figure 37. Edit account information screen

IAM and wallet API:

GET /account

PUT /account

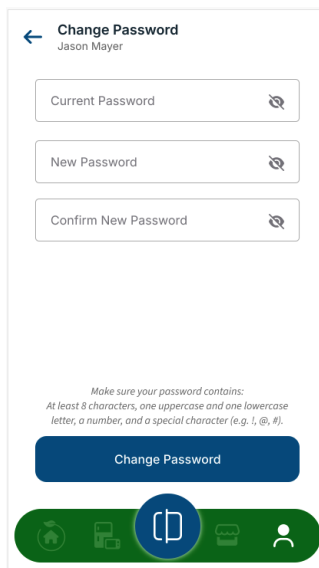


Figure 38. Change password screen

IAM and wallet API:

POST

☐ /account/change	☐ password
---------------------------------------	--------------------------------

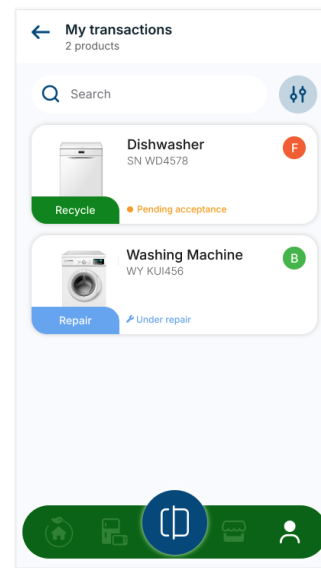


Figure 39. Transactions state screen

Marketplace API:

- GET /transaction
- GET /transaction/{transaction_id}

Clarification: The service that provides all the details about a transaction would be used if a user selects a specific transaction on this screen.

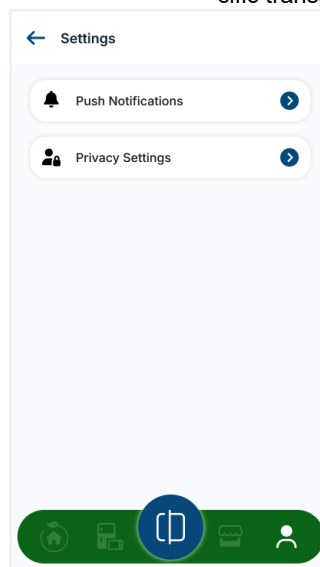


Figure 40. Setting account screen

IAM and wallet API:

- GET /account/preferences
- PUT /account/preferences

Clarification: The exact preferences need to be defined.

4 CONCLUSIONS AND NEXT STEPS

4.1 SUMMARY OF THE ACHIEVEMENTS

The work that is presented in this paper is proof of the benefits which the Digital Product Passport (DPP) built on blockchain technologies brings within the ENCIRCLE project. It shows its potential in creating a circular economy for products and services supporting specific policies guarantees privacy, transparency, and scalability.

ENCIRCLE utilizes different cutting-edge technologies in a harmonized and coherent setup that may include blockchain, DPP, and consumer applications ensuring traceability as well as addressing issues of privacy, ownership, and decisions over the entire product lifecycle. Running these technologies together under one common framework enables the project to tackle the circular manufacturing challenges whereby it eases reliable access to information while respecting confidentiality together with regulatory constraints.

This deliberative framework lays the foundation for trust and auditability among various stakeholders, including manufacturers, consumers, and service or product providers, establishing interaction roles between product data and processes. The use of a permissions-based approach and specific governance ensures transparency and access control within ENCIRCLE, a fundamental requirement in the industry.

Also, the use of blockchain technologies connected to the utilization of applications directed to consumers supports the ambition of involving end users or customers in the circular economy flows for products and services. By making product lifecycle information available through these easy-to-use apps, this project will help push more customer awareness about product lifecycle and possible attitude shift on sustainable consumption.

Overall, the foundations established in this document demonstrate the viability and relevance of the ENCIRCLE approach. It is, in short, a practical and forward-looking reference for the implementation of Digital Product Passports in industrial and regulatory contexts.

4.2 ROADMAP FOR THE UPCOMING DEVELOPMENT PHASES

Now that we have established the roadmap for tackling the project and solidifying its architecture, the current focus is on its development. This involves different development approaches, progressing gradually on each front to ensure the project matures evenly. These areas are distributed among the various project contributors. They range from defining the entities that represent the products to creating and adapting the chaincode, the backend APIs, and building applications for customer usability.

The chaincode and the rest of the backend utilize the definitions established and revised in this document regarding the entities and the different API endpoints to formalize a minimal chaincode that establishes the necessary basic methods. Based on these methods, technologies are being used to create the APIs and adapt them to the needs of transactions. Independently of the backend, progress is being made on other fronts, such as the creation of the mobile application. All this development is carried out in close collaboration among the various contributors to ensure optimal adaptation of the developments.

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