FleXible user-CEntric Energy poSitive houseS

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Responsible	Organisation	Contributing WP
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Abstract

This deliverable describes the EXCESS Blockchain and the two applications built on top of it, namely, the Objective Benefit Sharing Application (OBS App) and the Explicit Demand Response Application (EDR App) in their final version, after accommodating the feedback from the initial testing of their first version. The EXCESS Blockchain is based on an Ethereum Blockchain and provides the underlying infrastructure. The OBS App provides information and stimulation for building occupants to raise their energy awareness, offers a management system for the room comfort control, and enables prosumers to govern their community installation. The EDR App enables building occupants to understand their flexibility potential and monetize it. Occupants trade their flexibility potential with aggregators, which shield privacy information and trade the collective flexibility potentials with the local energy market. User involvement and user feedback haveled to updates of both apps during the testing phase and improvements are described in this second version of the deliverable D3.5b.

Keywords

Blockchain, energy awareness, governance, automated organisation, automation management, user-centric, consumption forecast, consumption scheduling, community investment, aggregators, local energy market, flexibility potential, flexibility profiles

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EXECUTIVE SUMMARY

The deliverable D3.5b “Block chain Infrastructure and Applications” describes the final versions of the EXCESS Blockchain infrastructure, the Objective Benefit Sharing Application (OBS App), and the Explicit Demand Response Application (EDR App), accommodating the feedback from the initial testing of the first versions.

The EXCESS Blockchain forms the basis for autonomous organisations enabling automated settlement and verification via smart contracts. It is deployed as a private Ethereum based blockchain providing a secure infrastructure enabling high level of flexibility for both applications, the OBS and EDR App, built on top of it.

The OBS App offers a user centric management system raising energy awareness and aiming at collaborative and collective energy optimization within the community. Users can set their desired level of automation for the room comfort control, for example heating and shading, schedule their consumption behaviour, resulting in a user-based energy forecast, and are motivated to optimize their consumption by multiple indicators, incentives and customized recommendations. Prosumers can access an additional management screen to govern their community installation and manage incentive strategies to further optimize user behaviour.

The EDR App enables the trading of building occupants’ flexibilities between occupants and aggregators. Aggregators monetize these flexibilities on the local energy market and subsequently remunerate the monetary gains to the occupants. The App provides flexibility information for occupants and aggregators alike, protects sensible flexibility information by shielding privacy data, and help occupants to understand the value of their flexibility potentials.

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1 INTRODUCTION

This document is part of WP3 – "Technology and user integration via ICT" that comprises 6 tasks aiming at:

- EXCESS ICT component definition
- Data Management Framework
- ICT platform service
- Flexibility and Forecasting
- Monitoring and Control
- Blockchain-enabled applications.

The latter task, T3.6 – "Block chain-enabled applications for local energy communities and flexibility trading", includes the design and implementation of the:

- EXCESS Blockchain Infrastructure (EBC)
- Objective Benefit Sharing Application (OBS App)
- Explicit Demand Response Application (EDR App)

These three components will be described in their final version in the current document D3.5b.

1.1 Purpose of the document

This document describes the direct outcome of Task 3.6 – "Blockchain-enabled applications". For this task a block chain (BC) infrastructure is required – the EXCESS Block Chain (EBC). The decision for a specific block chain technology for the EBC has been discussed. With the EBC as underlying infrastructure, two applications were developed, the OBS App and the EDR App. Both applications are designed and developed in their final version after encapsulating the feedback from the initial testing of their first version.

The EBC provides the basis for the OBS and EDR App, while these two Apps have dependencies within the project. Both Apps require access to specific sensor data via the EXCESS Data Management Platform. ICT specifications, flexibility analytics, and forecasting components are also required. Thus, Task 3.1 "Blueprint architecture design and specification of the EXCESS ICT components", Task 3.2 "Interoperable Data Management Framework", Task 3.3 "Core ICT platform services" and Task 3.4 "Flexibility analysis and forecasting component" are prerequisites. This Task 3.6, reported by the final version of the Deliverable D3.5b, will provide information for Task 4.2 "Demonstration Case Studies in main EU climatic zones" concerning the blockchain applications and their integration with MPC components for different demo sites.

This document D3.5b is led by Thomas Schwarzl, who is also the leader of the corresponding Task 3.6. S5 and VITO specified and developed the EDR App, Thomas Schwarzl is responsible for the implementation of the EXCESS Blockchain and the development of the OBS App.

1.2 Scope of the document

This document covers the final releases of the three components designed and implemented during Task 3.6:

- EXCESS Blockchain
- Objective Benefit Sharing application (OBS App)
- Explicit Demand Response application (EDR App)

The EXCESS Blockchain (EBC) provides the underlying infrastructure for both blockchain based applications, the OBS App and the EDR App. Both BC based applications are focusing on different aspects of the EXCESS concept in the demo sites of the project.

The OBS App is a dwelling and community management tool, allowing users to interact with the room comfort control, motivate and stimulate energy optimized behaviour not only for single users but on community level and allows shareholders to manage the community installation.

The EDR App is a visualization and trading tool for flexibility potentials. Building occupants are informed about their flexibility potentials and can trade them with aggregators. Aggregators, in turn, can monetize collective flexibility potentials on local energy markets and subsequently reward occupants.

1.3 Structure of the document

This document is structured in the following 6 sections:

1. In section 1, the interrelation within the project, involved partners and interconnected tasks are listed. The purpose and structure of this document is summarized.
2. In section 2, an overview is given about the current blockchain landscape. The selection process of the proper blockchain serving as the EXCESS Blockchain is discussed. The results of the EXCESS BC are described and the final release of the underlying infrastructure is explained.
3. In section 3, the final release of the Objective Benefit Sharing application is described in detail. After introducing the aim of the OBS App, the components are described. The mobile app is acting as main user interface and is presented in detail emphasizing the interplay of blockchain technology with the mobile app.
4. In section 4, the final release of the Explicit Demand Response application is described in detail. First, an overview of design and functionalities is given, followed by a detailed usage description, depicting the features.
5. In section 5, the conclusion summarizes crucial aspects of the final releases of the EBC, the OBS App, and the EDR App and gives an outlook.
6. In section 6, abbreviations, acronyms and other used terms are listed.

2 EXCESS BLOCK CHAIN (EBC)

Blockchain is a growing topic enabling new and revolutionizing existing business models. Technically, a blockchain is similar to a database where changes are stored and chronologically linked by a cryptographic fingerprint. Thus, the blockchain can be considered resistant to historic modifications of data, since a change of an historic entry requires the adaptation of all the following entries. The blockchain usually is distributed among peers, thus, becoming a shared database, often referred to as distributed ledger. Inserting, updating or deleting data in this distributed ledger is called a transaction and is subject to the consensus protocol. The consensus protocol defines how a common agreement is reached in this distributed system. Thus, it decides which transaction is valid, adding it to the shared database. The combination of historic immutability and consensus protocol can transform processes based on trust between parties into trust-less systems. This trustlessness is a major feature of public blockchain solutions. A commonly known public blockchain emerged 2009 with the crypto currency Bitcoin[1], a decentralized digital currency tradeable without intermediaries. Major progress was made by the implementation of smart contracts, which are executable algorithms within the blockchain environment. With the Ethereum[2] project, which went live 2015, a blockchain enabling the use of smart contracts was publicly available. Currently blockchain and distributed ledger technologies are highly active topics with new blockchain platforms emerging frequently. Promising blockchain platforms as candidates for the EXCESS blockchain have been assessed in the current chapter.

2.1 Existing technologies

The following blockchain and distributed ledger technologies have been evaluated as possible candidates for the EXCESS Blockchain:

- Ethereum
- Quorum
- Corda
- Hyperledger Fabric
- EOS.IO
- Cardano

The European central bank (ECB) currently explores the potential of distributed ledger technology (DLT) and blockchain, as extension to existing solutions. DLT has the potential to make certain financial processes more efficient, or even to transform them completely. The ECB has two main ongoing initiatives exploring these new technologies:

First, the EUROchain[3], an EU-wide network with national central banks, aiming at proof of concepts for the use of blockchain and DLTs for payment channels. The EUROchain research evaluates the use of central bank digital currencies (CBDC) not only for inter-bank settlements but also for individual citizens. The latest report demonstrates concepts for transaction anonymity in central bank digital currencies, building on the functionalities of Corda.

Second, the project Stella[4], a joint research project by ECB and Bank of Japan, is a set of conceptual studies evaluating DLTs for payment systems, securities settlement systems, cross-border payments

[1] https://bitcoin.org/en/
[2] https://ethereum.org/en/
[3] https://www.ecb.europa.eu/paym/intro/publications/pdf/ecb.mipinfocus191217.en.pdf
[4] https://www.ecb.europa.eu/pub/research/authors/profiles/bank-of-japan.en.html

and the balance of confidentiality and auditability. This project mentions a wide variety of blockchains and distributed ledgers in their reports: Ethereum, Quorum, Corda, Hyperledger Fabric, and others.

Ethereum is a reliable public blockchain with the second highest market-capitalization, with Bitcoin being the first. On the public chain values can directly be traded via the native crypto currency Ether (ETH), existing tokens/coins and so called stablecoins, the latter trying to link the crypto currency to fiat money. Transactions are billed with the native currency ETH and transaction costs depend on market value, current traffic and the amount of data sent with the transaction. Ethereum based blockchains can also be set up independently by creating a private chain. Private chains create the possibility to reduce transaction costs, increase transaction throughput, decrease latency and choose ecological consensus algorithms. As stated, Ethereum provides the functionality to use smart contracts, which are written in Solidity.

Quorum[5] is based on Ethereum and has been developed by J.P. Morgan as permissioned blockchain for the financial industry. Permissioned blockchains allow only authorised peers to participate in the network. Furthermore, a privacy feature was added by hiding sensitive data from transactions. This private data is only visible to selected participants, which have to be stated beforehand.

Corda[6] is also a permissioned blockchain where each peer has to be authorised to join the network. Within the network, Notary nodes validate uniqueness and define the order of transactions. Privacy can be achieved by segregating transaction records, which are only shared among authorised participants. Smart contracts in Corda separate contract storage and contract logic and can be developed in Kotlin or Java.

Hyperledger Fabric[7] is a distributed ledger platform based on permissioned blockchains. Participants are authorised by network operators and can provide peer nodes. These nodes can be part of channels, which share distributed ledger states and run smart contracts, referred to as chaincodes. Channels are segregated and only participants of a channel share data. Ordering service nodes provide double spending protection and establish the order of all transactions. Each channel requires endorsing nodes which execute and validate the transaction based on the channel's endorsement policy. Chaincodes are written in Go, Java or JavaScript (Node.js).

EOS.IO[8] is a public blockchain released in 2018 by a private company. EOS.IO aims at high transaction rates by applying horizontal and vertical scaling. Transactions are claimed to be free of charge, however, to process transactions resources within the EOS network are required. These resources are RAM, CPU, and NETwork bandwidth and have either to be purchased (RAM), or rented (CPU/NET) by staking tokens which are subject to inflation. EOS.IO enables smart contracts written in specific EOSIO canonical C++.

Cardano[9] is also a public blockchain following a scientific approach by applying peer reviewed development. Cardano provides intrinsic token settlements removing the necessity to use smart contract-based tokens. However, the smart contract functionality is still under development.

[5] https://consensys.net/quorum/
[6] https://www.corda.net/
[7] https://www.hyperledger.org/
[8] https://eos.io/
[9] https://cardano.org/

2.2 Chosen Infrastructure

The EXCESS blockchain applications might benefit from accessing external payment channels like crypto currency or stablecoins. Hence, the work by the EUROchain research network was looked into. Various blockchain and distributed ledger frameworks were evaluated and selected frameworks have been tested, especially including frameworks proposed by the EUROchain research network and the Stellar Project. However, neither project commits to a specific DLT and it is currently unclear when and how a European CBDC will be established. Therefore, we propose the use of Ethereum based blockchains, as these are proven to be versatile, robust, developed by an active community and offer the required smart contract functionality. This makes Ethereum based blockchains a future-proof choice as EXCESS blockchain.

The EXCESS BC was thus set up as a private Ethereum chain. A private chain[10] allows to place restrictions on who is allowed to participate on the network, as well as, how the network progresses. To progress the BC, blocks have to get signed by participants of the blockchain, which are the miners. The consensus model of the BC is responsible to find the signing participant. To prevent malicious behaviour, multiple measures are set in place on the Ethereum main net. One of which is the consensus model, the way new blocks are mined – "Proof of Work" (POW). With POW new blocks are signed by a random process where miners have to find a signature of a special structure. This process requires a vast number of attempts, thus, relies heavily on computing power. In a private BC, miners can be selected differently. In the EXCESS BC, the consensus model is set to "Proof of Authority" (POA). Some nodes of the network are explicitly granted the right to sign the blocks. Only those nodes are trusted and can progress the BC. Limiting the mining to only a few nodes relieve the necessity on the computation extensive POW algorithm. Thus, the often-discussed high energy consumption of the POW algorithm does not apply to the private EXCESS BC.

2.3 Infrastructure

The EXCESS BC is stored on nodes, forming the fundamental infrastructure of the BC. Nodes are connected among each other and constantly exchange new blocks to keep the BC information in sync. Nodes check the validity of new blocks based on predefined rules and decide to accept or reject them. After accepting the new block, nodes apply the state changes submitted within the block and store the block in the transaction history. Successively, the node broadcasts this transaction history to other nodes to synchronize.

Nodes perform additional tasks, aside from BC synchronization:

- Read/write access to the BC
- Mining
- Accept/reject blocks

[10] https://geth.ethereum.org/docs/interface/private-network

Nodes are the interface to BC data for read and write access. Writing data to the BC is called a transaction. Transactions are bundled into blocks signed by miners. Nodes can also act as miner but this function is optional.

The EXCESS BC infrastructure consists of 4 nodes. One node acts as high availability gateway, providing external access for read and write access. The other 3 nodes are shielded, thus, not directly accessible from external sources. These 3 nodes are authorities, acting as miner, accepting or rejecting new blocks.

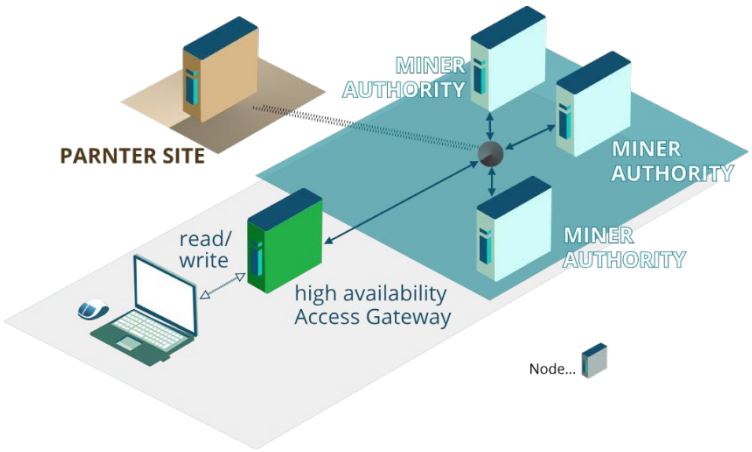

Figure 1: EXCESS Blockchain Node Structure

This infrastructure can be expanded by additional nodes on partner sites. By increasing the number of nodes, the data redundancy is increased. Future development could be a transition of the consensus algorithm from POA to “Proof of Stake” (POS), allowing to further decentralize the BC infrastructure.

2.4 Updates in final release

The EXCESS BC infrastructure is in operation in its intended form, the tests have been successful. It is functioning as expected including the possibility of expanding it with additional nodes. No changes were required for the final release.

3 OBJECTIVE BENEFIT SHARING APPLICATION (OBS App)

The Objective Benefit Sharing application (OBS App) that will be used in the Austrian demo comprises a mobile app, a privacy data server, an API server and a blockchain application. The mobile app is the key human-machine interface, enabling users to participate in collaborative and collective energy optimization at the community level by giving automation approvals and scheduling their energy consumption. The mobile app enables shareholders to govern their community investment backed by automated secured blockchain contracts. The API server provides secure and controllable data management to other software components and partners, and simplifies the use of OBS Smart Contracts on the EXCESS Blockchain. This server also handles accounting automatically based on shareholder settings and user consumption allowing to apply monetary incentives to reward users.

3.1 Purpose of the OBS App

A goal within the EXCESS project is to optimize energy consumption at community level through collaboration and collective actions. To achieve this goal, the community is structured in consumer and shareholder roles within the OBS App, but a user can take up both roles. While the consumer role targets users with pure consumption behaviour, the shareholders are the economic actors within the community. Shareholders can be financially involved in production facilities (PV, heat pumps, etc.), community infrastructure (shared spaces, shared equipment, etc.) and local business (vending machines, etc.). Both roles are independent and, thus, can be taken up at the same time. This combination of consumers and shareholders (producers) is merged into the role of the prosumer.

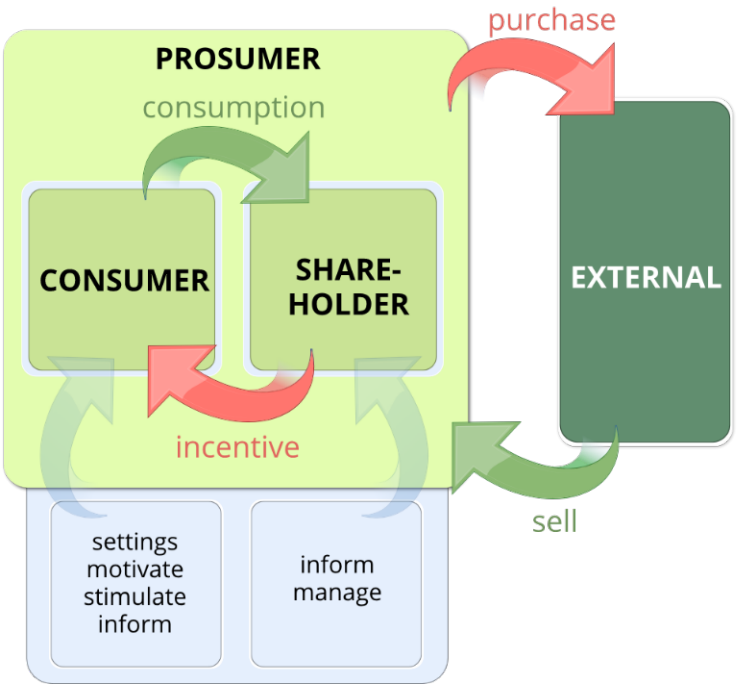

Figure 2: OBS App - Community roles (green boxes), cash flow (coloured arrows), task of the OBS App (blue boxes)

The OBS App aims to assist the participants, depending on their role within the local community:

- Shareholders get information about their investment at community level. Multiple key performance indicators (KPI) are calculated. Depending on the interest of the shareholder, a selection of these KPIs are depicted. These KPIs can be for example solar gain, cumulative energy sold internally or amortization period estimates.
- Shareholders are able to manage the property. This management system allows mapping of different governance structures in combination with sophisticated voting mechanisms.
- Consumers can manage their room comfort settings and assist the community forecasting system by consumption and usage planning.

- Consumers get information about their dwelling at community level. Depending on their interest, KPIs are selected and depicted.
- Consumer's community involvement is estimated and depicted leading to increased motivation to actively participate in the community.
- Consumers are stimulated by frequent challenges to further participate in the energy optimization process at dwelling and community level.

The user interface of the OBS App consists of three main components interlocking in a modular fashion depending on user roles:

- The home screen serves as informative component depicting KPIs depending on user role and interest.
- The modular room comfort managing system allows the user to adjust dwelling based controls. Depending on the equipment of the site different management components are available to the user. These components include temperature band settings, shading automation limits, and consumption planning in the first version of the OBS App.
- For shareholders, a governance component allows the management of community equipment based on association statutes.

To achieve the goal of optimizing energy consumption at community level, the OBS App utilizes multiple methods:

- KPIs and the management modules should raise the users' energy awareness through transparent visualization of current energy flows and the impact of personal behavior on these flows.
- Scores, awarded by different actions and settings within the app, might motivate by means of gamification.
- Rankings within the local community can increase the peer pressure and stimulate to act on behalf of tribalism.
- Various billing models, chosen by shareholders, can provide users with monetary rewards in form of cash back incentives based on scores or rankings and are automatically settled via the built in accounting system.

As other projects already demonstrated a mere financial stimulation deemed not sufficient to keep up user participation. The OBS App is designed to visualize these financial benefits but moreover exploit social and psychological triggers in order to reach a broader acceptance.

3.2 Components of the OBS App

The OBS App is structured into 4 key components:

- OBS Interface
- API Server
- Privacy Server
- OBS Smart Contracts

The OBS Interface is the human machine interface of the OBS App and was implemented as mobile app. This interface is linked to the API server and the OBS Smart Contracts on the BC. The mobile App is described in detail in chapter 3.3. The mobile app is implemented in JavaScript and utilizes the vue.js[11] framework.

The API Server handles requests from both, external and internal sources. By applying access restriction rules, the API server limits external access and allows easy to use interface to the OBS Smart Contracts. The API Server is implemented in JavaScript and is based on the Node.js[12] framework.

The Privacy Server is shielded by the API Server and the access restriction system. Here, required user data is stored in the database program MongoDB[13].

OBS Smart Contracts are the data and logic elements operating on the EXCESS BC. These smart contracts are the central part of the shareholder management system, forming a decentralized autonomous organisation, which is described in section 3.3.5. The Smart Contracts are developed in the programming language designed for Ethereum, Solidity[14] version 0.8.x.

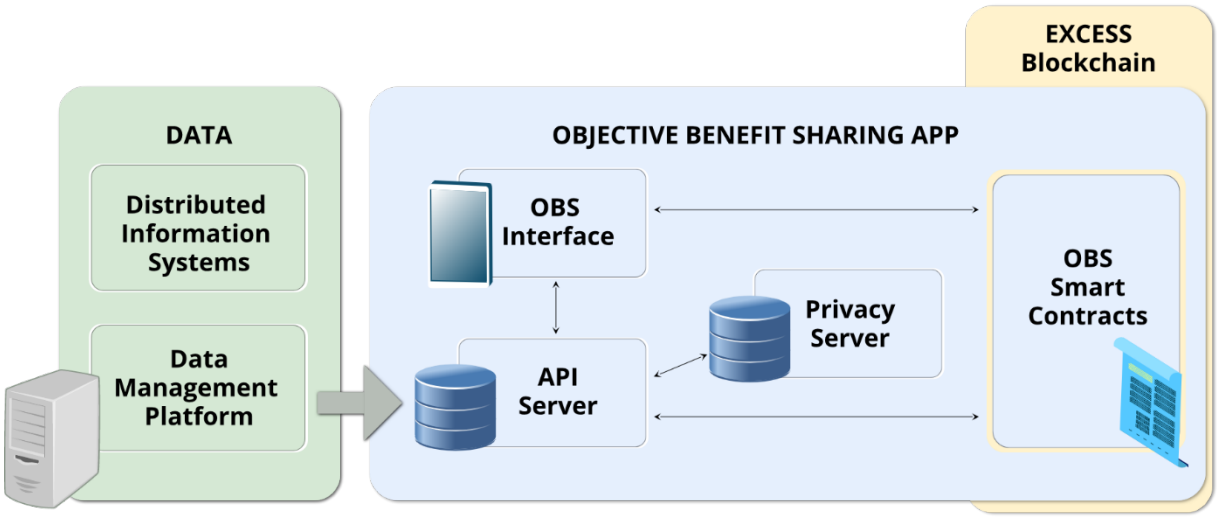

Figure 3: OBS App Components - schematic view of OBS App Components (blue), the underlying EXCESS BC (yellow), and external connection to EXCESS Data (green)

[11] https://vuejs.org/
[12] https://nodejs.org/en/
[13] https://www.mongodb.com/de
[14] https://docs.soliditylang.org/en/v0.8.0/

3.3 Mobile App

The mobile app contains multiple views with which a user can check and control the settings of their personal systems. In addition, a user might observe and participate in goals that he/she might reach or activities he/she could participate in. The following subchapters give an in-depth description on the selectable options on these multiple views.

3.3.1 Home Screen

The home screen gives an overview, depending on the role of the user's behaviour in the context of other users in order to encourage the user to interact with the system. A user can have one of two roles or can have both roles. Depending on which role he/she currently uses, the home screen shows different interaction possibilities, namely:

- Scores: Users are rewarded with points for various actions and settings within the OBS App. These points are collected in different categories: Community, Interaction, Heating, and Electrical.
- Personal information: The above scores allow an estimate of user involvement within the community and form the total score by a weighted sum. Additionally, a monetary incentive can be applied and is depicted as motivator.
- Key Performance Indicators: In this section, KPIs are depicted. Here, PV-production, self-consumption rate, consumption and feed-in energies are shown. These KPIs are tailored to meet user role and user interest.
- Recommendations: An animated leaf presents tailored tips, to enable user to further improve their behaviour.
- Radial Menu: Different management modules are accessible via this dynamic interactive radial toolbar.
- Forecast and current status: At the bottom of the screen a time-resolved daily forecast of solar gain and weather are presented and current sensor values are listed.

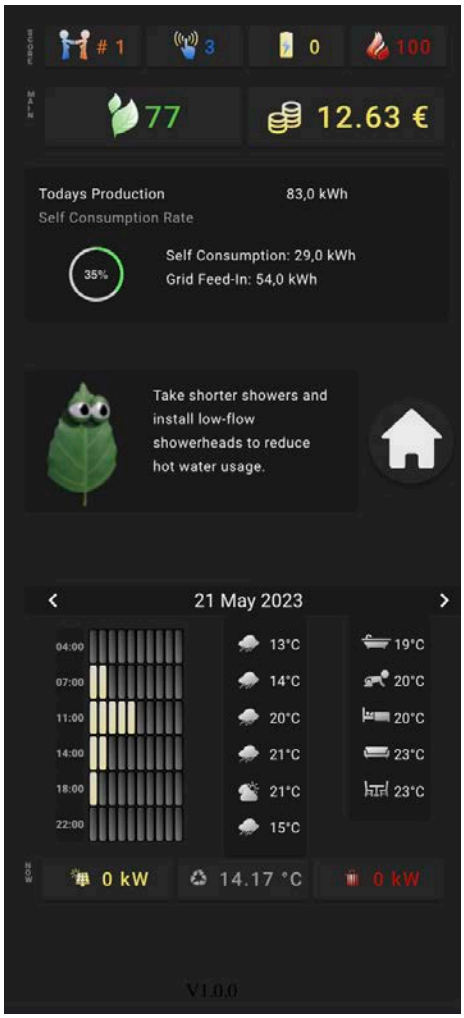

Figure 4: OBS App - Home screen.

This screen shows personal information, scores, KPIs, and links to management screens in order to inform and motivate users.

3.3.2 Electricity Planning

The management screen “Electricity Planning” contains information about any excess in-house electricity production and allows users to plan electricity consumption. Users are able to place machines in time-slots to indicate their intended use aiming to increase the self-consumption ratio of the community.

Machines are representable and configurable within the app. Especially long-running high consumption machines play a role here, like charging electric vehicles, washing machine, tumble dryer and similar. Time-slots make it easy to indicate start and duration of the machine. This planning tool helps a user to consume electricity from the building when it is available directly and/or energy consumption of the community is low. Especially in times with an excess of community energy, otherwise sold to energy market, users will be triggered by this view to use machines such as washing machines or dishwashers that can be run in the absence of a user. In the first step, users are motivated to use machine intrinsic features like “Set Starting Time” to automatically start the machine at a later time. A connection of selected machines for an automated starting by the app might be a promising future goal.

Specific profiles can be created by users for repeating energy extensive tasks like charging your electrical car or tumble dryers. In the first step, the app helps users to plan their consumption and remind them to start their machines according to their set consumption plan. These consumption profiles and this user based daily consumption forecast can be fed back to the model predictive control system.

As an optional outlook, automatic handling of selected machines by the control system might be possible. Then, this screen allows the user to approve automatic control of certain machines within specific time-slots. This is possible if the machine provides points of communication such as an API that allows a direct communication between the app and the machine.

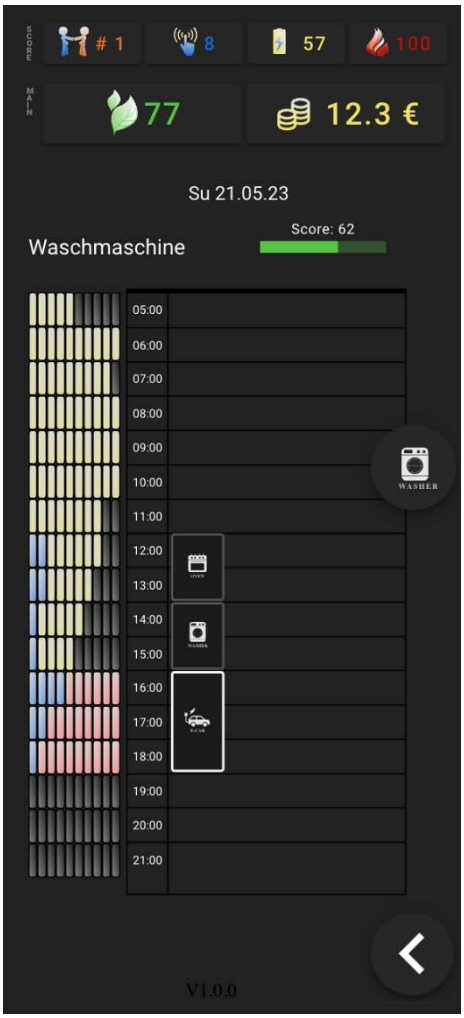

Figure 5: OBS App - Electricity Planning Screen

This screen motivates user to plan their electricity consumption of energy extensive machines in order to increase self-consumption rate and feed this user forecast back into the control system.

Interacting with this Electricity Planning screen will increase the user score, allowing a comparison of the intensity of interaction of different users and their effect on community consumption. We believe that regular interaction with the Electricity Planning tool raises the user’s energy awareness in a way that not only the user but the whole community will benefit.

3.3.3 Shading Automation

The Shading Automation screen helps a user to control to which degree the system is allowed to use automated shading. Several aspects can be controlled by the user in this view:

- Sliders allow the user to set minimum and maximum shading levels used by the shading automation per room and time-slot. Within those limits, shading can be set automatically by the system, depending on system's needs. On demand, the user can manually override shading automation to adjust the shading to meet their comfort requirements.
- Recurring pre-set profiles can be created and only deviations from these pre-sets need to be adjusted to fulfil different user's needs, for example home office days, holidays, summer or weekends.
- A score is displayed on the top to motivate the user to increase the accepted shading automation range. The score shows how many interactions a user had to optimise their shading settings and how much freedom the system is granted.

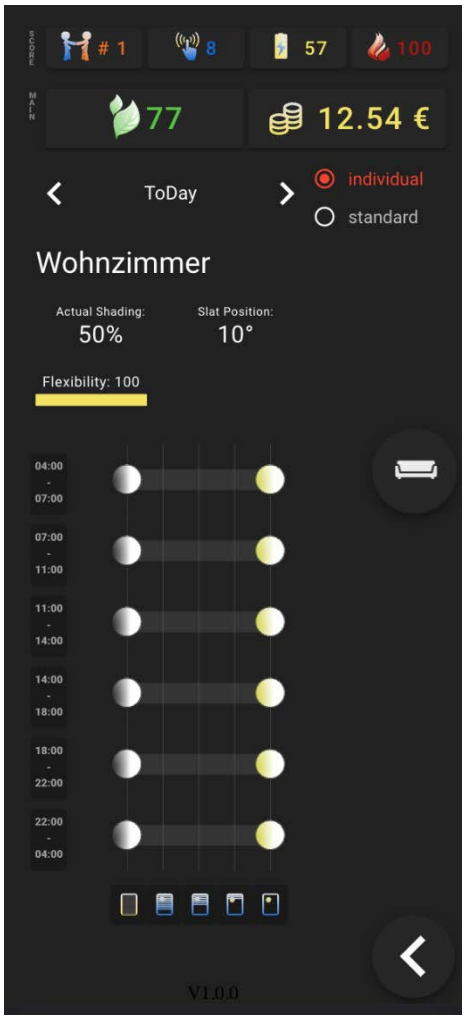

Figure 6: OBS App - Shading Automation Screenthis screen allows the user to define automation limits on a room-level for pre-defined time slots.

In dwellings with a high thermal mass, a long temperature latency, and low required heating power, overheating can occur and can become a challenge when actual solar gain deviates from solar gain forecasts. One way to keep the room temperature within the user comfort-zone is to reduce excess solar gain and thus prevent an increase in room temperature by shading. If users allow a high grade of shading automation, the required energy for cooling during summer days shall be reduced significantly as well.

3.3.4 Temperature Management

The Temperature Management screen supports a user to check and set a temperature band at a room-level. An upper and lower limit can be set per room and pre-defined time-slot so for example, a bathroom might be perceived as more comfortable if it is a bit warmer than a bedroom. So just setting the temperature to a certain set-point might not be suitable to optimize the overall community energy consumption.

As the building is in itself also a storage for heat and thus energy, it is important to use the energy in times of high energy production. By allowing the user to define a temperature band, this flexibility can be used to access thermal storage at a room-level. So having the possibility for minima and maxima might be a valuable feature to feel comfortable and raise user's energy awareness.

Another aspect is that depending on the time of year and certain habits such as home office or being on holidays, a user of the app might want to create several pre-set profiles for this temperature band. While a temperature around 23 degrees might be preferable in winter, it might be too cold for summer months. While heating should be switched on in winter, it might not be necessary to heat during the day but maybe more in the afternoon when the user wants to come to a cosy home. Night setback can be automated or a broad temperature band during daytime if the room is empty, both reducing the energy consumption.

A standardised energy pre-set profile is therefore available while other profiles can be created and switched on, depending on a user's favourite way of being comfortable and saving resources. However, a user can also always react to quick weather changes and might want to have a warmer setting in case of unexpected weather changes.

A user is rewarded in case of offering wide temperature bands, thus, having a large flexibility potential. This behaviour allows the system to be as resource optimized as possible. A larger flexibility potential allows the system to use energy when it is produced and store it directly at room-level.

Figure 7: OBS App - Temperature Management Screen:

This screen allows the user to choose and adjust pre-set profiles for temperature bands on a room level and pre-defined time slot basis.

3.3.5 Governance

The Governance screen allows to monitor community data and interact with the community to govern community installations. Shareholder access in-depth financial data about the community installation and can trade their shares and incentive tokens. Shareholder meetings can be streamlined through this Governance screen by enabling voting mechanisms and can speed up the whole management of energy communities. By utilizing blockchain technology, the governance of organisations is partially automated, secured by defined rules and executed transparently.

Underlying this Governance screen is a multitude of smart contracts developed for and deployed to the EXCESS BC. The interplay of these innovative OBS smart contracts enable the operation of a decentralised autonomous organization (DAO) at an extended level. Organizational structures such as board of directors, committees, delegates can be mapped on the BC. Different types of decision-making processes can be set-up and used, as in standard corporate contracts. Automatic evaluation of these meeting polls also enables automated implementation of the decisions made.

By utilizing BC-technology decisions made by the shareholders are applied automatically and recorded. Thus, these virtual meetings are automatically logged in a tamper proof BC environment, assisting the official role of the secretary to the board.

Decisions logged to the BC are accessed by the OBS App and are thus automatically up to date after a meeting is evaluated.

As smart contracts underly strict limits regarding size and complexity in comparison with other software environments, the development of these OBS Smart Contracts deemed to be challenging. Strategies such as splitting data and logic units in different smart contracts were used and further developed. Due to the complexity of logic units, logic elements were grouped together and split into subunits. Thus, a smart contract registry schema was applied.

The data stored in the OBS Smart Contracts are required to be as flexible as possible. Novel data classes were developed to fulfil these flexibility requirements. Interfaces to common data structures were prepared. The data itself is stored in site-based data smart contracts, allowing to update logic smart contracts, if the need arises.

Especially, the development of the OBS Smart Contracts was a balancing act between data flexibility, upgradability, complexity, and immutability.

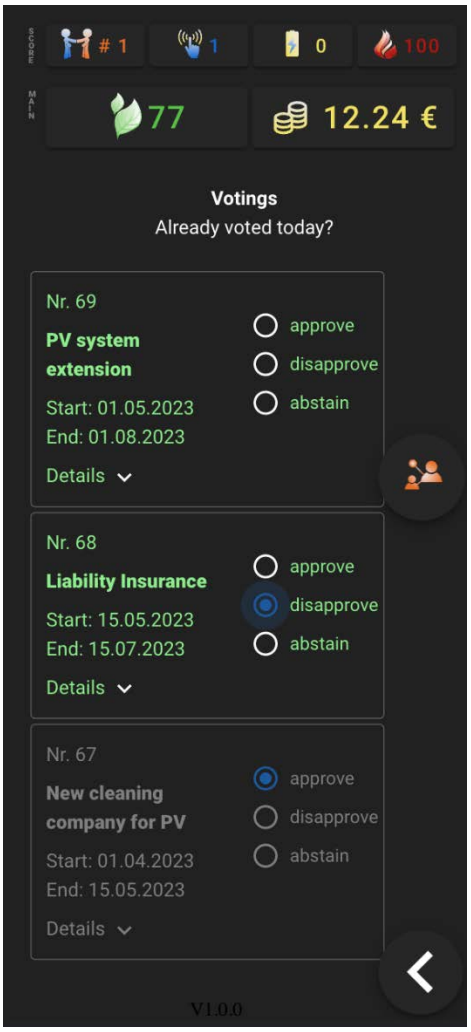

Figure 9: OBS App - Governance screen in overview mode

Shareholders are able to directly vote on selected issues. Expired decisions are greyed out.

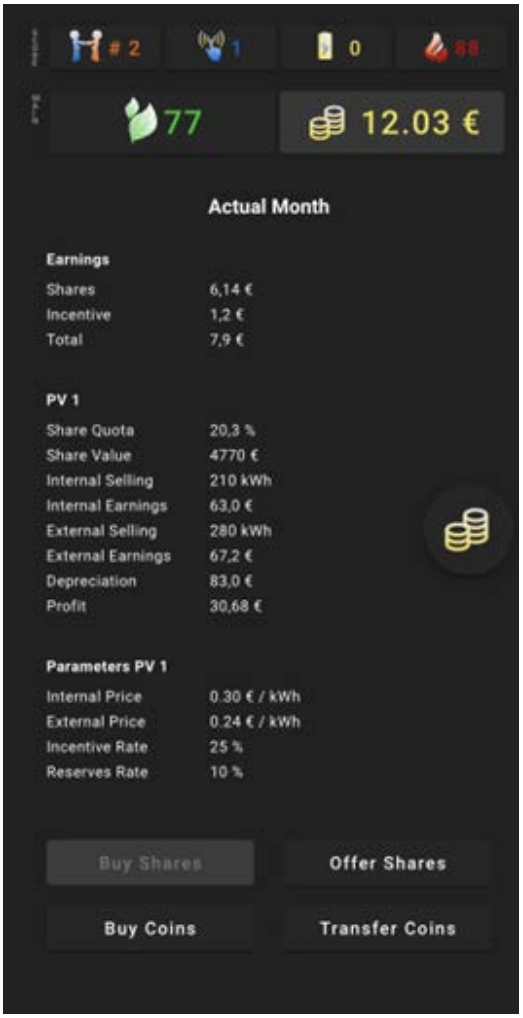

Figure 8: OBS App - Governance screen shareholder view

Detailed financial information about the community installation is shown here. Shareholder can directly see their participation and interact with the community by trading shares and incentive coins.

3.4 Updates in the final release

The interface has been completely redesigned. Due to the large number of menus and sub-menus, a traditional menu structure proved to be impractical. A novel approach using a dynamically built multi-level radial menu provides quick access to the desired sub-menu item. As a result, the app can be tailored to different levels of complexity with modules that can be turned on and off.

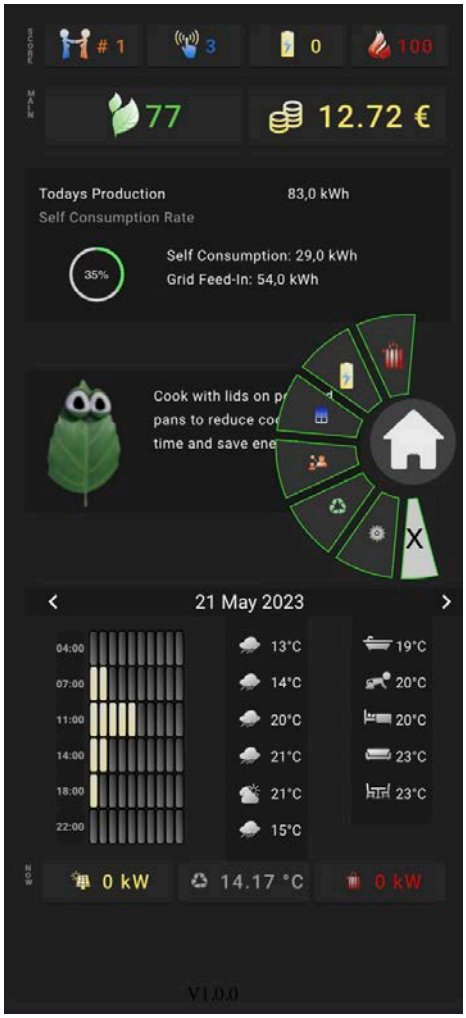

Figure 10: OBS App – Radial Menu

The radial menu allows quick access to modules of the OBS App.

Figure 11: OBS App – Multilevel Radial Menu

The radial menu is dynamically built with up to three levels

4 EXPLICIT DEMAND RESPONSE APPLICATION (EDR App)

4.1 Design and functionalities

The Explicit Demand Response Application (EDR App), which will be used in the Belgian demo, comprises the blockchain-powered component that is deployed on top of the EXCESS Blockchain Infrastructure and facilitates the interaction between the building occupants (prosumers) and the aggregators towards the trading of building occupants' flexibilities to the local energy markets by the aggregators and the subsequent monetary gains of the building occupants from such flexibilities' transactions.

More specifically, the functionalities of the EDR App are presented below:

- **Presentation of flexibilities' overview:** The EDR App facilitates both, building occupants and aggregators to view the available flexibilities that can be traded in the local energy market. Building occupants can view only their own available flexibilities, while aggregators can monitor all the available flexibilities in the building. Both users can view the details of the available flexibilities, assisting them in their decisions for the participation in flexibility trading transactions.
- **Blockchain-powered contract mechanism:** The EDR app enables the creation of flexibility contracts between the building occupants and aggregators. Through the contribution of the EXCESS Data Analytics Framework[15] of the EXCESS system, the EDR App allows building occupants to make specific flexibilities available for certain time periods. An aggregator can monitor these available flexibilities from the building occupants and make any offers for trading such flexibility clusters in the local energy market, as soon as a flexibility contract related to such clusters is signed between a building occupant and an aggregator.
- **Protection of flexibility information:** Through the signing of a flexibility contract between a building occupant and an aggregator, this contract is also written in the EXCESS Blockchain. However, towards assuring the security and privacy of transactions, no sensitive flexibility data are written in the blockchain, but only the necessary contract metadata details.
- **Elaboration of blockchain wallets:** The building occupants and aggregators are enabled by the EDR App to create corresponding wallets so that they can participate in flexibility contract transactions in the EDR App.
- **Performance monitoring of flexibility contracts:** The EDR App enables building occupants to check the performance of their flexibility contracts and understand the potential renumeration gains from them.
- **Searching of available flexibilities:** The EDR App facilitates the searching of available flexibilities through various filters in order to allow the trading operations between building occupants and aggregators.
- **User management:** The EDR App provides the necessary user interface to building occupants and aggregators in order to update their user information, while it enables the authentication and authorization of users in the application.

[15] D3.3b "EXCESS Flexibility Analytics Module" (2023)

4.2 Technologies and Tools

The EDR app is written in Python. For the frontend implementations, Vue.js[16] has been exploited, while for the backend implementations, Node.js[17] has been used. For the facilitation of searching functionalities, Elasticsearch[18] has been utilized.

4.3 Navigation to EDR App

The EDR application includes an intuitive and user-friendly interface that facilitates the monitoring of available flexibilities by the building occupants and aggregators, while enabling the trading of flexibility clusters between them. In the following subchapters, descriptive screenshots of the EDR app are presented.

4.3.1 Login

When entering the EDR App, the user is prompted to login by entering his/her credentials.

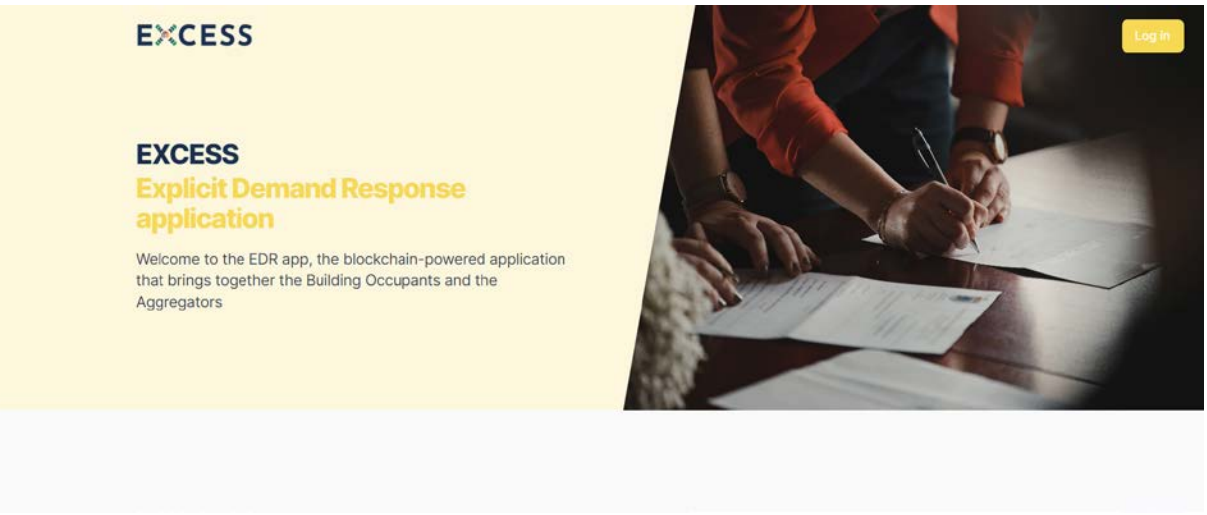

Figure 12: EDR App - Login (1)

[16] https://vuejs.org/
[17] https://nodejs.org/en/
[18] https://www.elastic.co/

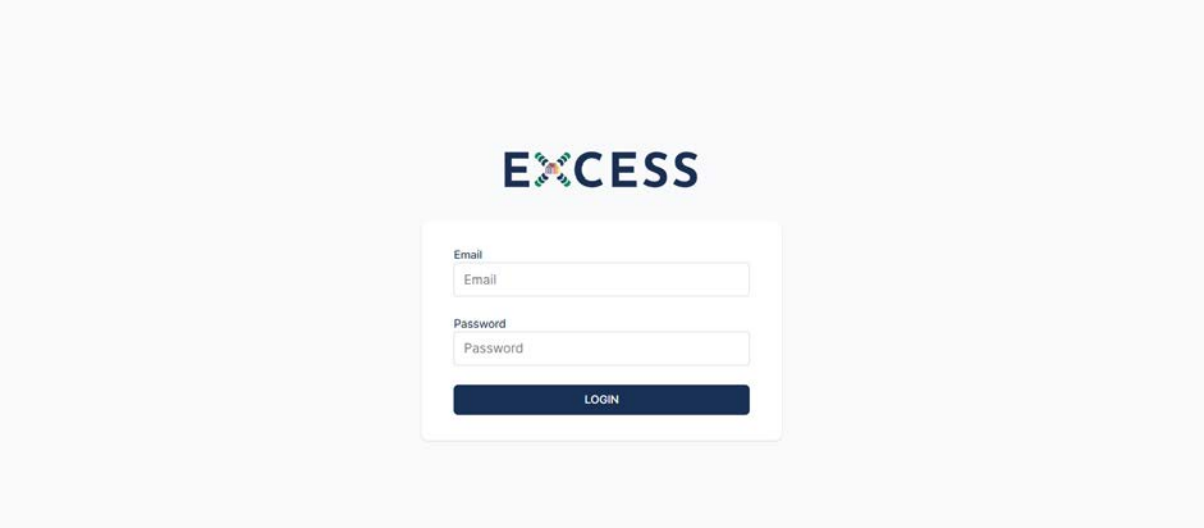

Figure 13: EDR App - Login (2)

4.3.2 Flexibilities Overview and Details – Building Occupant

The building occupant, through the EDR App "Overview" page, is able to monitor his/her available flexibilities, by searching them through various filters and navigating into their details ("View Details" option).

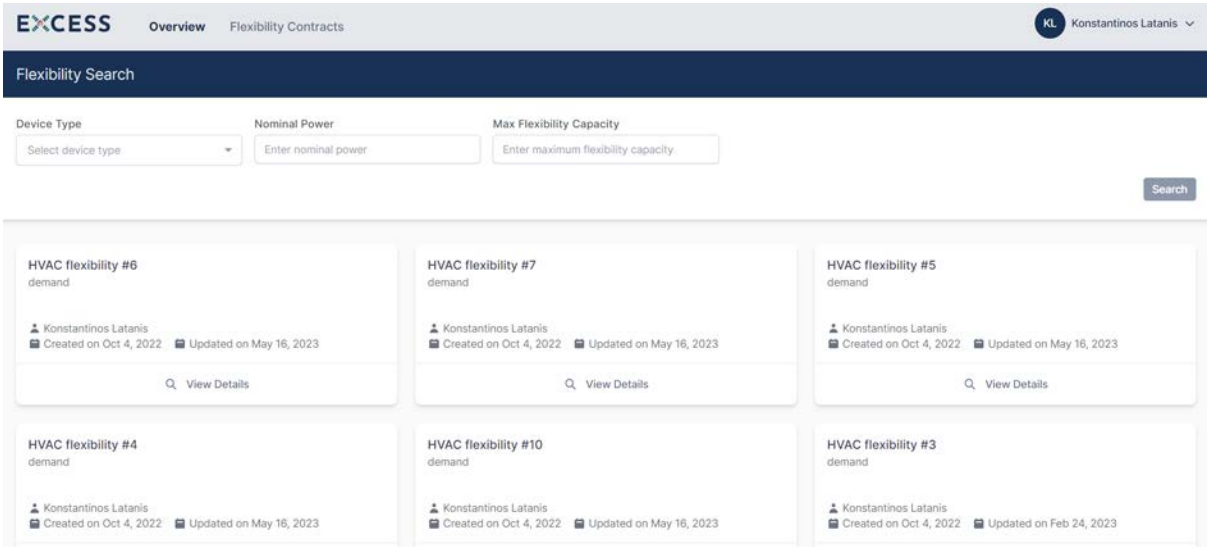

Figure 14: EDR App - Flexibilities overview - Building occupant

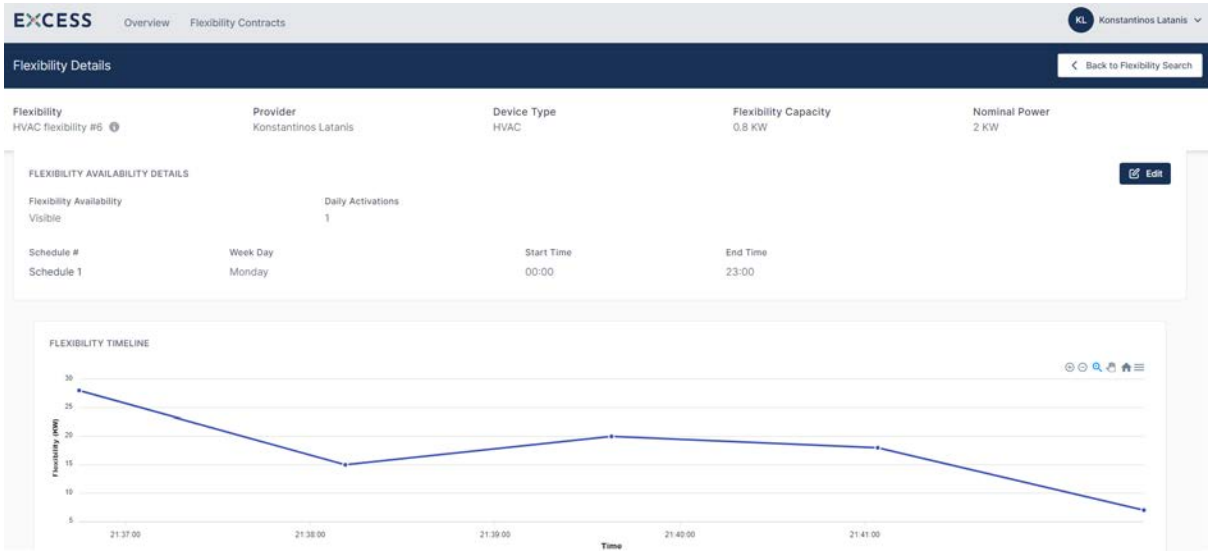

Figure 15: EDR App - Flexibility details overview - Building occupant

The flexibility details can be modified by the building occupant by clicking on the "Edit" button (see above picture) in the "Flexibility Details" page. At any time, the building occupant may change the availability of a flexibility, thus, making it visible or not for potential trading into the local energy markets by the aggregators.

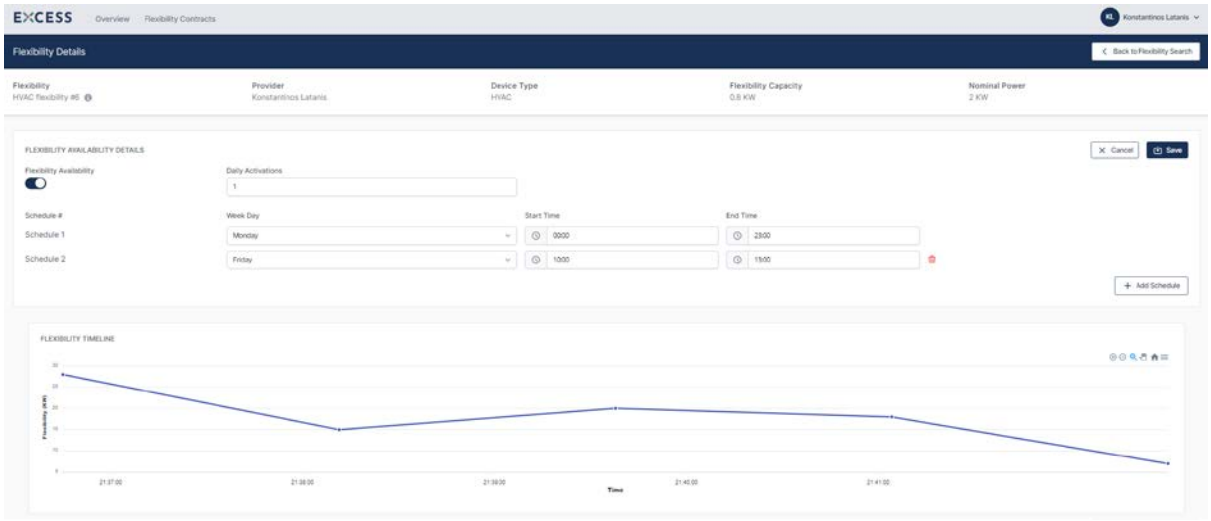

Figure 16: EDR App - Flexibility details edit - Building occupant

4.3.3 Flexibilities Overview and Details - Aggregator

The aggregator can monitor the available, by the building occupants, flexibilities in the EDR App "Overview" page, search them through various filters, select them in order to create flexibility clusters for potential trading in the local energy markets by clicking on the "Add to Cluster" (or "Remove from Cluster") option, and view their details in order to facilitate their decision making ("View Details" option).

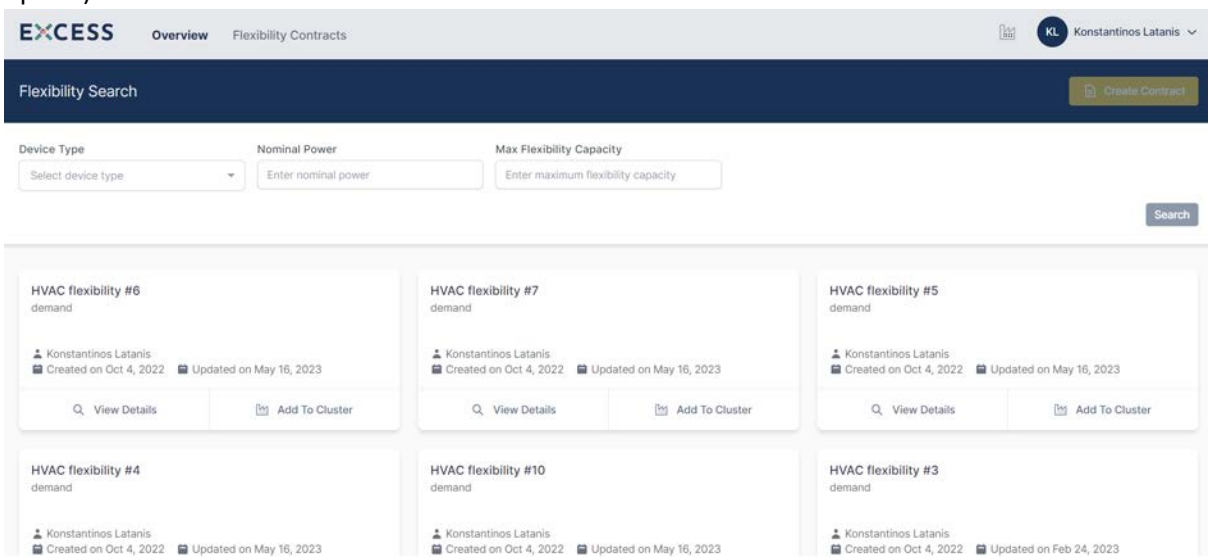

Figure 17: EDR App - Flexibilities Overview – Aggregator

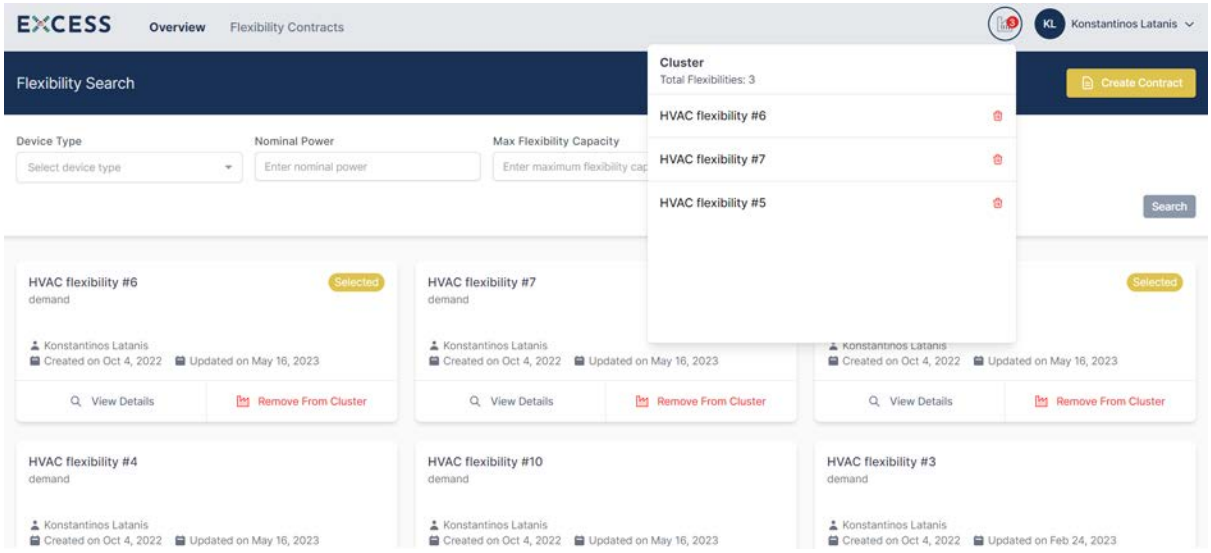

Figure 18: EDR App - Flexibilities clustering - Aggregator

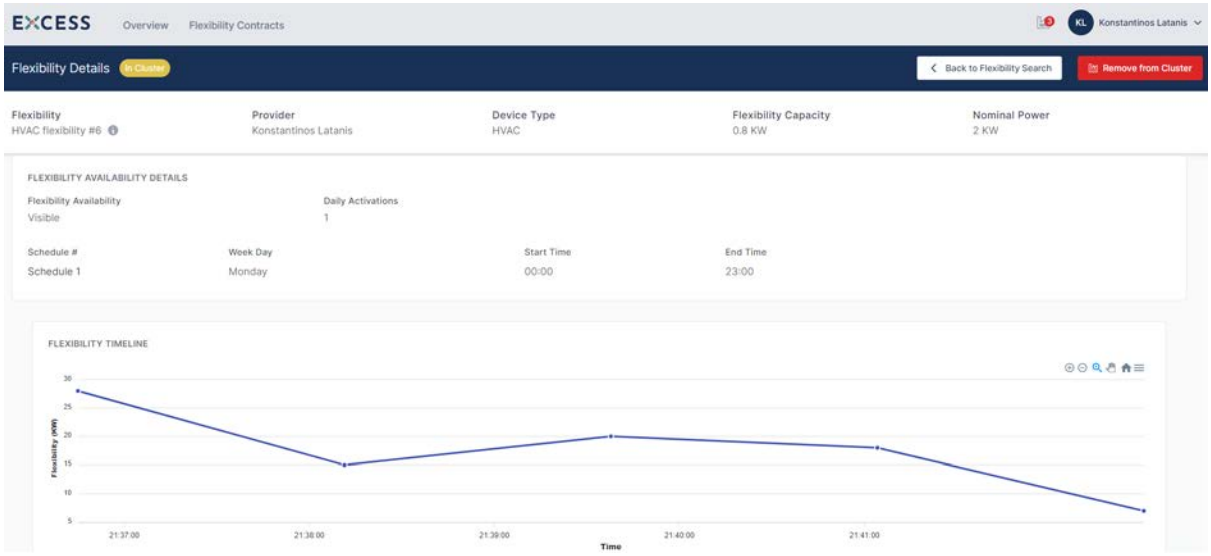

Figure 19: EDR App - Flexibility details - Aggregator

4.3.4 Flexibility contract

In the "Flexibility Contracts" page, both building occupants and aggregators can view the list of the already created flexibility contracts where they participate in.

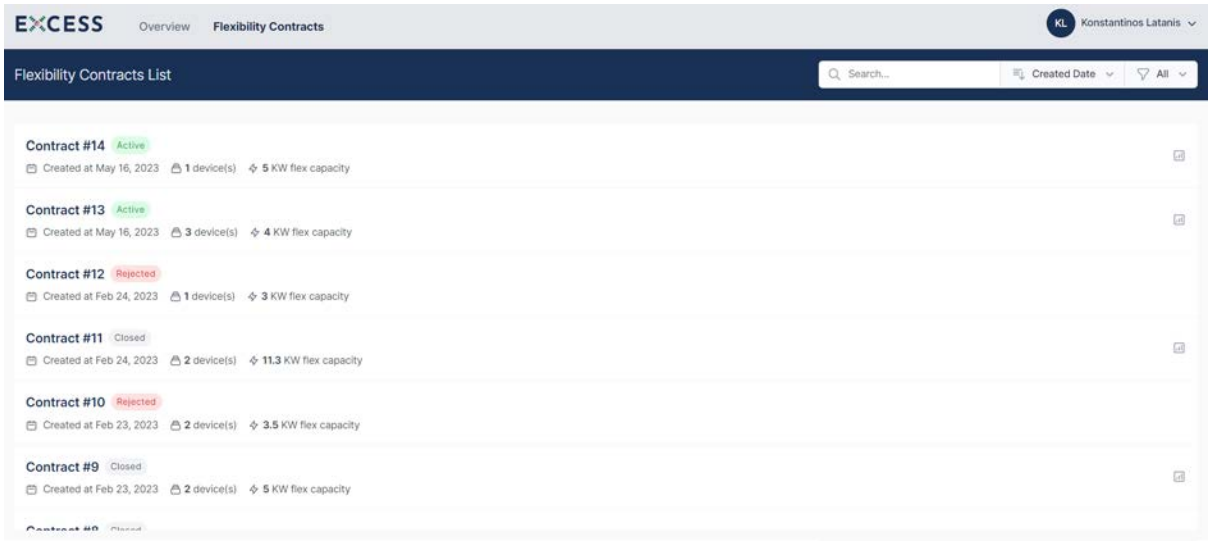

Figure 20: EDR App - Flexibility contracts list

A user may click on a contract to view its details.

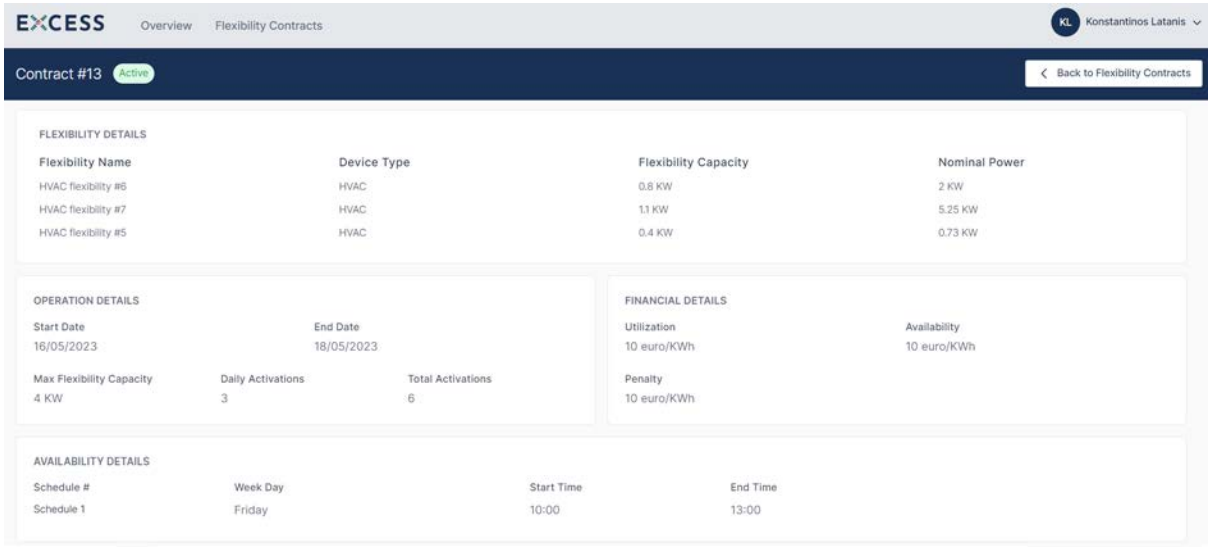

Figure 21: EDR App - Flexibility contract details

An aggregator, upon creating a flexibility cluster, can create a contract offer that will be sent to the corresponding building occupant for consideration.

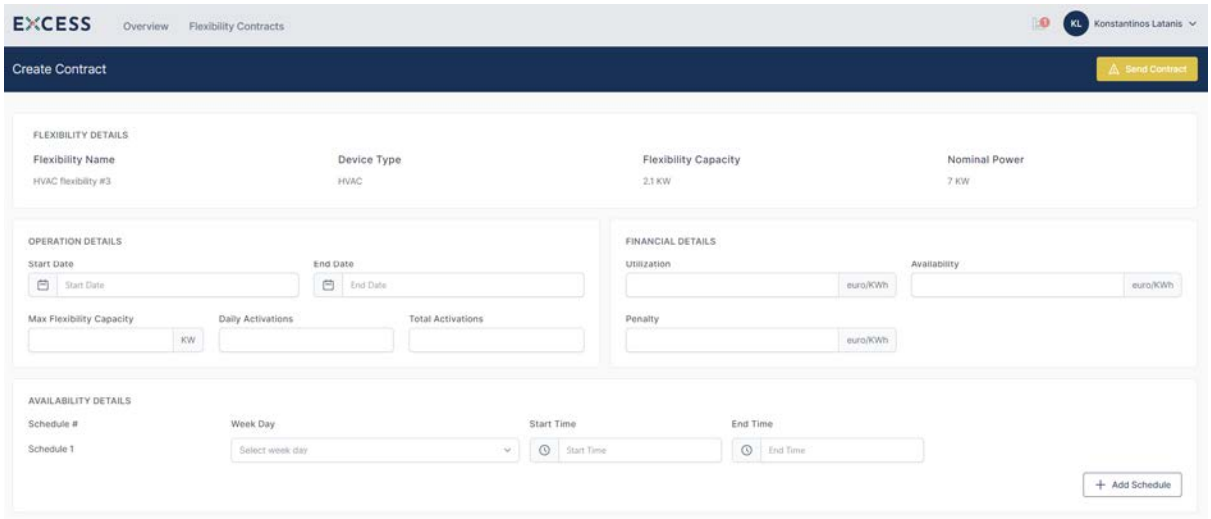

Figure 22: EDR App - Flexibility contract creation

Upon creating a contract and clicking on the “Send Contract” button, the aggregator is prompted to unlock his/her wallet in order for the transaction to be also written in the EXCESS blockchain. Then, the contract offer is displayed.

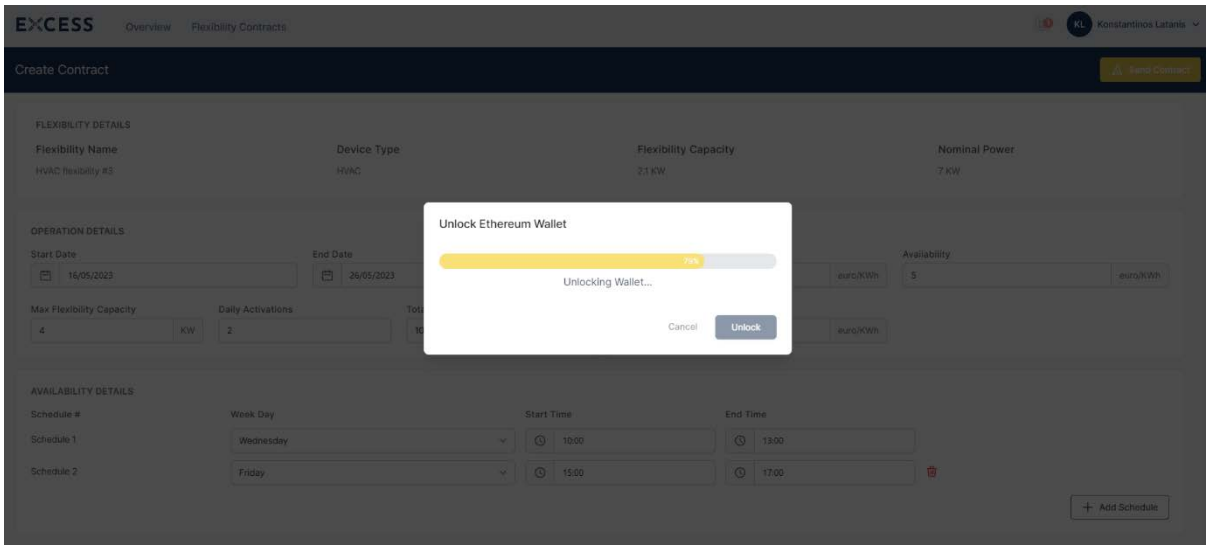

Figure 23: EDR App - Wallet unlocking and contract writing in EXCESS blockchain

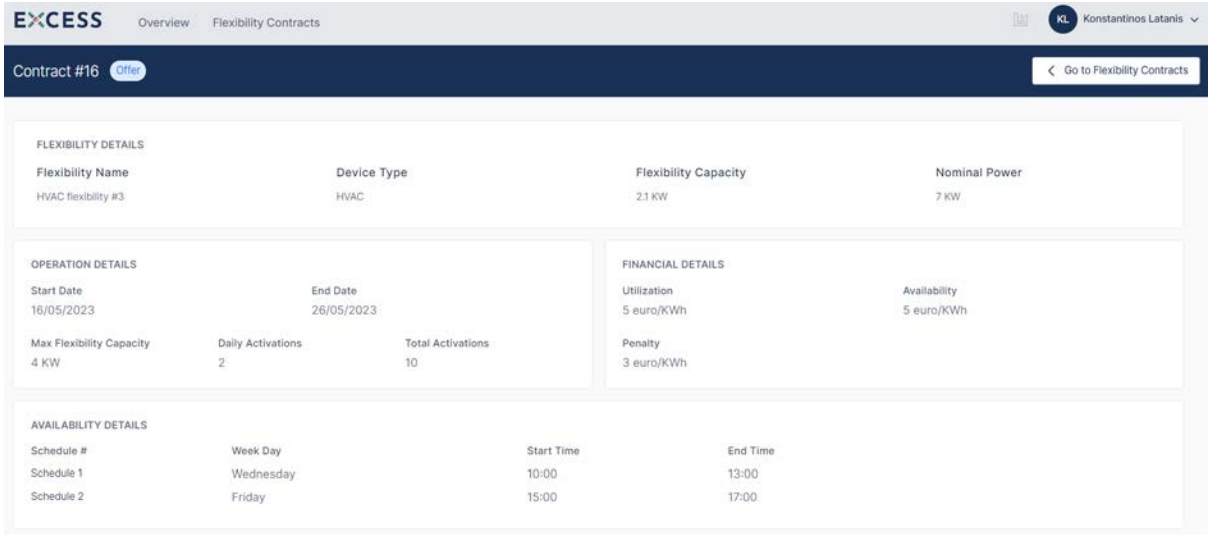

Figure 24: EDR App - Flexibility contract offer

The building occupant receives the contract offer and may accept or reject it. Upon acceptance, the flexibility contract is written as active in the blockchain and the flexibility schedule and financial details are finalized.

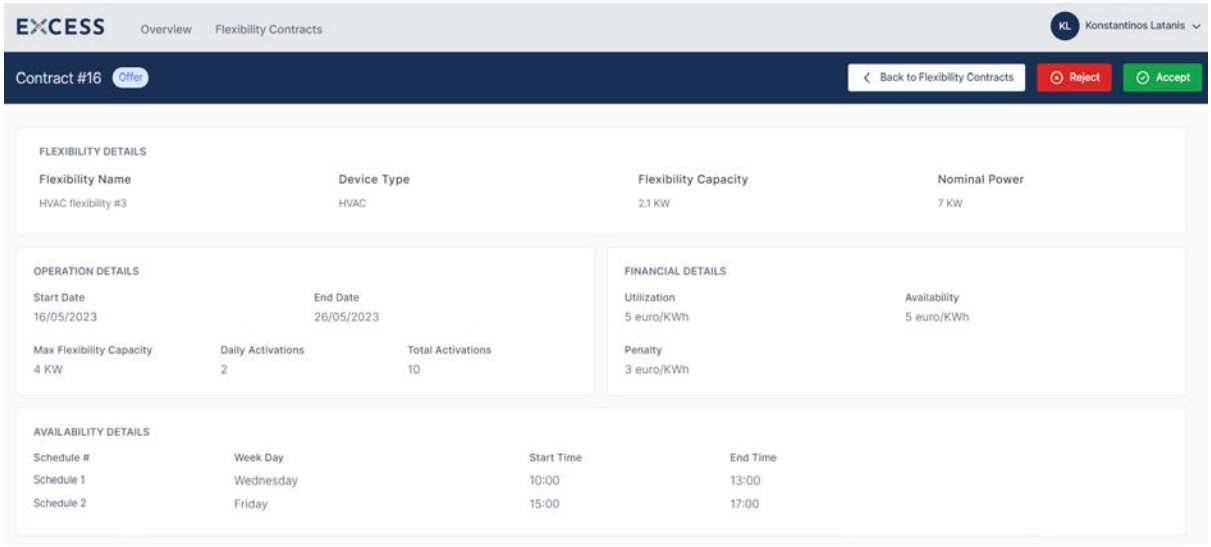

Figure 25: EDR App - Flexibility contract acceptance/rejection

4.4 Updates in the final release

During the design and development of the final release of the EDR App, the following improvements have been performed:

- Performance improvement of flexibility profiling mechanisms
- Improvements in the user interface

5 CONCLUSIONS

This document represents the final version of the EXCESS Blockchain, the Objective Benefit Sharing Application (OBS App), and the Explicit Demand Response Application (EDR App). The EXCESS Blockchain serves as the underlying infrastructure for both apps and is deployed as an Ethereum based private chain.

The OBS App serves as a management system for both users and prosumers. It is built in modular fashion, thus, it has a high level of adaptability, if need arises. Users can manage their level of automation for the room comfort control and schedule their energy consumption for a user-based energy forecast. Prosumers are assisted in governing their community installation by streamlining decision processes.

The EDR App enables prosumers to detect and exploit their flexibility potentials by offering them to aggregators. Aggregators, in turn, can monetize these collective flexibilities by trading them on the local energy market, rewarding the prosumers in the process.

The deliverable D3.5b has described the final releases of the EXCESS Blockchain, the OBS App and the EDR App, that have been designed and developed based on the feedback received from the initial testing of their corresponding first releases.

6 ACRONYMS AND TERMS

Table 1 presents the used abbreviations within this document.

Table 1: Acronyms and terms

Acronym	Full name
App	Application
BC	Block Chain
CBDC	Central Bank Digital Currency
DLT	Distrubuted Ledger Technology
EBC	EXCESS Block Chain
EDR	Explicit Demand Response
ICT	Information and Communications Technologies
OBS	Objective Benefit Sharing
POW	Proof of Work
POA	Proof of Authority
PV	Photo Voltaic
WP	Work Package