Development of User Interfaces – Platforms and Apps

D.T2.3.1

Version	Description	Author	Date
0.1	Initial draft.	Simon Verbeke (PXL), Florian Maurer, Shane Deconinck, Boy	12/2022 and 01/2023
0.2	Review + abstract + added some conclusions/future work + glossary	Ann Das	30/01/2023 08/02/2023
0.3	Final Polishment	Florian Maurer	21.02.2023

Table of contents

Abstract

In this report, we will discuss the achieved objectives within work package 2.3: Development of User Interfaces, platforms and apps. This work was divided between three partners namely FH Aachen, Howest and PXL.

The goal of this deliverable was to develop and design user-friendly interfaces in addition to the decentralized database based on the blockchain technology. Due to the different pilots, regions and their requirements, different applications will be needed. This also includes the visualisation for the user of the sold solar and wind energy from his own plant, the purchase of the still required electricity and the monitoring of the generation plants.

With these objectives in mind, FH Aachen has created a Grafana dashboard for the energy statistics that are being collected from their infrastructure. This also includes setting up the infrastructure of collecting the data. This dashboard and interface will also be used for energy dashboards at other partners, e.g. with energy data of Climate Cities, Tiorc and PXL.

Howest and FH Aachen have been working together on various interfaces and visualisations of the assets within the blockchain and the transactions that happen between users of the blockchain. Therefore, they also discussed together the implications on the underlying structure of the blockchain itself.

The FH Aachen handled the data collection and processing for the different pilots and created Grafana visualizations which are publically available as a project deliverable.

Hogeschool PXL has created visualisations of energy statistics they are collecting from the Makerspace. Makerspace @PXL/UHasselt is an open, multidisciplinary, technological "making lab" where young and old can experiment with technologies and follow guided technology workshops or refresher courses. There are different devices available like 3D printers, lasercutters etc. that can be used by various people.

The interface of the energy usage will be used to optimise the makerspace, i.e., investigate if energy efficiency can be improved and which alternative payment models would work well. There will be 3 visualisations of the same data that can be used by various audiences: one is a 2D visualisation on a webpage, another is a Grafana dashboard and the third is an AR/VR visualisation. In this part and firstly we made proof of concepts; further dashboards will be developed for the pilots of PXL.

These first interfaces and visualisations are described in this document. In a later phase of the project, the interfaces are further elaborated for the use in different pilot setups. The interfaces described below are the first visualisations created as base for later development and use in the pilots.

Introduction

Grafana Interface (FH Aachen)

In this project, we collect a large amount of measurement data on energy usage from various sources, including a public MQTT broker instance, an FTP server from partners, an InfluxDB mirror from PXL, and web crawling from public sources. The aggregation of the data is performed using a Telegraf connector, which is configured to read data from an MQTT endpoint. MQTT is a popular messaging protocol for IoT devices and allows for publish-subscribe communication between devices and the Telegraf connector. The connector then writes the data from MQTT into the InfluxDB timeseries database.

Data from different IoT devices running Shelly Firmware, Tasmota or SmartPi's can be connected at once on this instance, which required a special configuration to read the MQTT data using Telegraf. This config is provided in the source code repository on GitHub, where all results are available for the public.
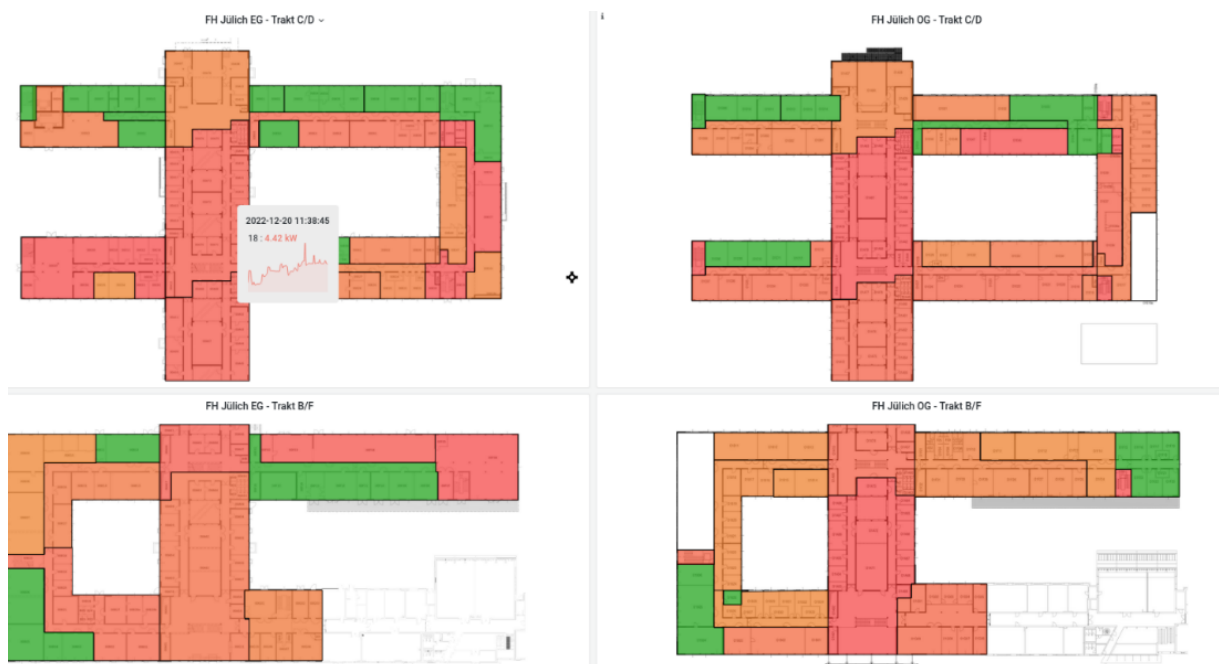

Figure 1 Floor map of Campus Jülich showing electricity consumption measurements per floor

Other data comes from different PV systems which are installed at the campus in Jülich, from the demonstrator in Eupen and the PXL Diepenbeek campus. Some are available from an FTP server, while others come by parsing csv files send on a regular basis. Special energy monitoring devices which measure the usage of different university campus facilities of the project partners are also included in the available data dashboards.

The InfluxDB timeseries database is used to store all the measured electricity usage data. This type of database is well-suited for handling time-series data and can scale efficiently for large amounts of data. In contrast to other types of databases, such as relational databases, timeseries databases are not slowed down by large amounts of data. This is achieved by sharding across the time domain, which allows for efficient querying even with very large amounts of data. However, to ensure efficient querying, all queries must include a clear time filter to operate on a subset of the data.

Figure 2 Dashboard providing stats of single measured devices as well as economic metrics (annual cost)

The Grafana interface provides a convenient way to visualize the real-time energy usage data from all connected devices and partners. This can be useful for monitoring the performance of individual devices, as well as for identifying trends and patterns in energy usage.

Overall, the project aims to collect and manage large amounts of energy usage data and provide tools for analysing and visualizing this data in real-time. By using timeseries databases and the Grafana interface, we are able to effectively manage and make sense of this data.

The Source code is publicly available on https://github.com/bc4p/smartmetering/ and can be used to set up a similar solution for monitoring of individual assets, including the Grafana dashboard at other places.

The Grafana Interface with can be viewed here :

https://monitor.nowum.fh-aachen.de/d/2cbPoSD4z/bc4p-installations ,

A separate visualization per "Demonstration suite" is made available to monitor the individual power usage in real-time.

PV data is measured from different locations, eg PV data at FH Aachen and at PXL (buildings and a private house). These graphics can be viewed in the Grafana interface.

Blockchain Explorer (FH Aachen & Howest)

A "blockchain block explorer" is a tool that allows users to view and explore the details of transactions on a blockchain. This can include information such as the sender and recipient of a transaction, the amount of a particular cryptocurrency that was transferred, and the time and date of the transaction.

Blockchain block explorers are often used to provide transparency and accountability on the blockchain, allowing users to view and verify the details of transactions on the network. They can also be used to track the movement of a particular cryptocurrency and to monitor the overall health and activity of a blockchain.

To monitor the blockchain solution described in the deliverable "Blockchain Development", we did set up a Proof of Authority (PoA) blockchain based on Ethereum running in a docker container. This solution does not have the benefits of distributed authorization as the verifying nodes are under the same trust domain, yet they provide a very good option to experience the behaviour and properties of a blockchain network and how it can be visualized.

It can be accessed through a web-based user interface and can be integrated into other applications and services.
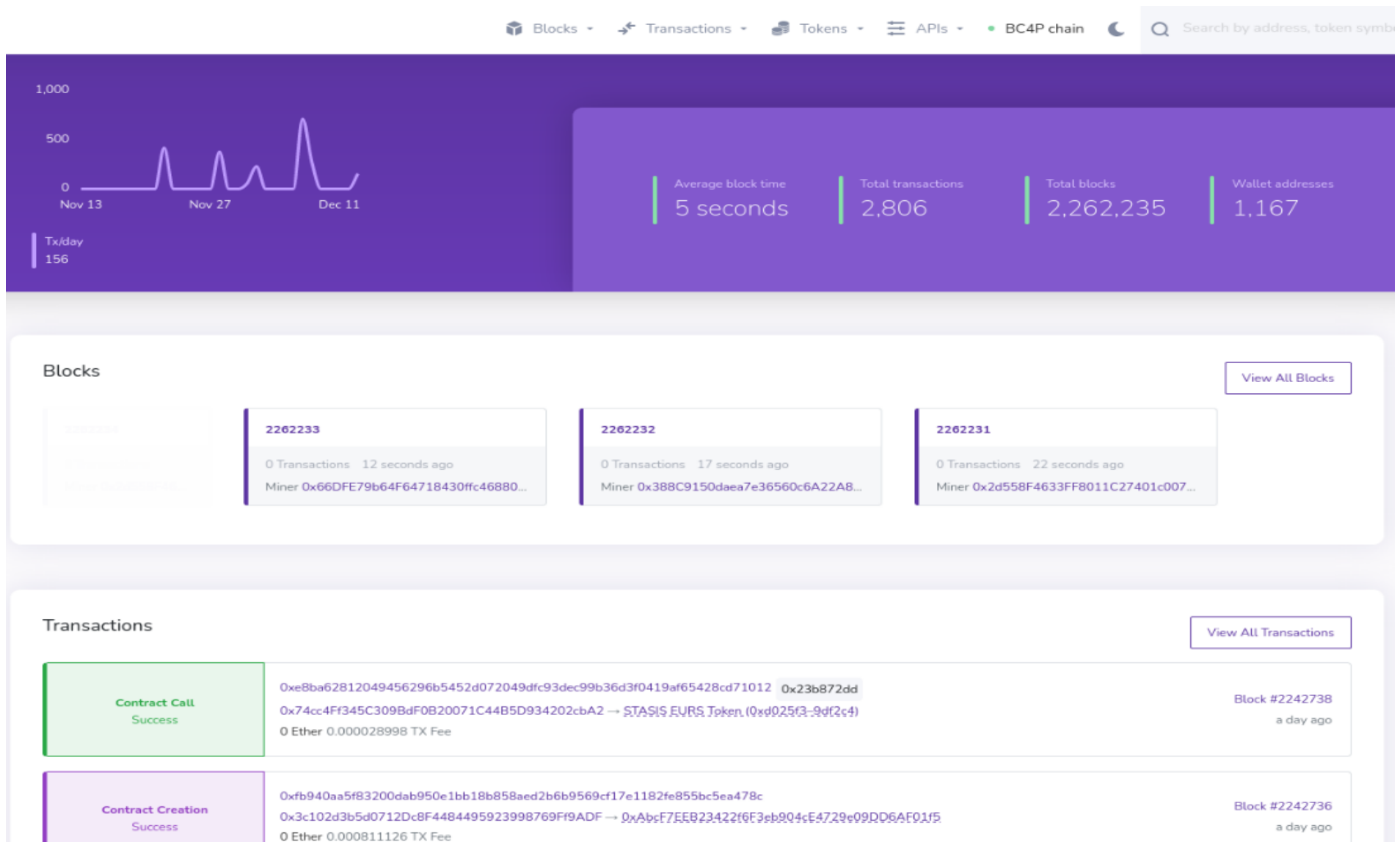
Figure 3 Blockchain explorer showing last transactions and last created blocks

To view the block explorer one can visit the public webpage at https://bc4p.nowum.fh-aachen.de/explorer

Here you can see the continuous trades of the developed energy market trading solution, which generates transactions for each event happening on the Gridsingularity Exchange platform.

Even the smart contracts which are used and described in the Deliverables "Smart Contracts" can be inspected here to provide transparency.
Therefore, you can see the ABI – so the bytecode of the smart contract which is stored on the blockchain. Still, verifying the actual behaviour of a smart contract is possible but this is a time-consuming process, not doable by everybody.

Realtime transaction and energy production interface

The real-time transaction interface is the user interface that connects the prosumer to the energy market on the Gridsingularity Exchange platform. **The interface makes it possible for prosumers to monitor the exchange.**

While the exchange prints its results when the simulation finished running, there was no possible way to get insight into the simulation while it was running. Since in a real situation the market would be running in real time, there would be no end to the simulation. This is why there is a need to visualise the simulation while it is running.

Based on expert interviews and interviews with prosumers, an interface was built to monitor the exchange.

The user interface informs the user about the market in such a way that the user can operate and monitor the market without further guidance. This is needed since not all prosumers know the necessary knowledge to operate within the market.

Next to informing the prosumer about the market, the interface shows what's happening on the Gridsingularity Exchange platform.

Because the identity management system is built within WP T3, user driven information (e.g., what a certain user produces), isn't available within the user interface yet.

Registering assets and Identity Management on the blockchain

Of great importance is the connection between the assets and the management of the identities which are allowed to trade energy on market.

This is needed as the energy system would break if unknown traders would pay for electricity which is not actually used by a physical demand. This problem is further described in our report from the T1 working package from FH Aachen, as well as in the working package T2 "Blockchain Development". This is also the main requirement why other proof mechanisms than Proof-of-Authority can not work for energy markets.

To register and create new identities, a management platform with capabilities for KYC (Know-Your-Customer) is needed. This is developed in the project and will be described in the upcoming report of T3 "Identity Management".

This interface shows how Identities can be stored on the blockchain using SSI (Self-Sovereign Identities) and evaluates their usages in the project.

MetaMask Wallet Interface

The public blockchain solution running on https://bc4p.nowum.fh-aachen.de/explorer can also be accessed through a wallet storing the private and public key to inspect the balance of the wallet.

This can be used to receive or send tokens from one address to a different one or check the current balance. To provide a better understanding of this concept, we also developed a game for P2P trading with the MetaMask wallets running on the projects blockchain, which can be seen here: https://bc4p.nowum.fh-aachen.de/game/

In this game, people can transfer energy and kWh tokens on the blockchain to trade with other people by communicating a price in person. This includes getting familiar with transactions on the blockchain and sending Tokens in the MetaMask wallet from a mobile phone.

This also includes description of how the MetaMask wallet can be set up to add our BC4P test network.

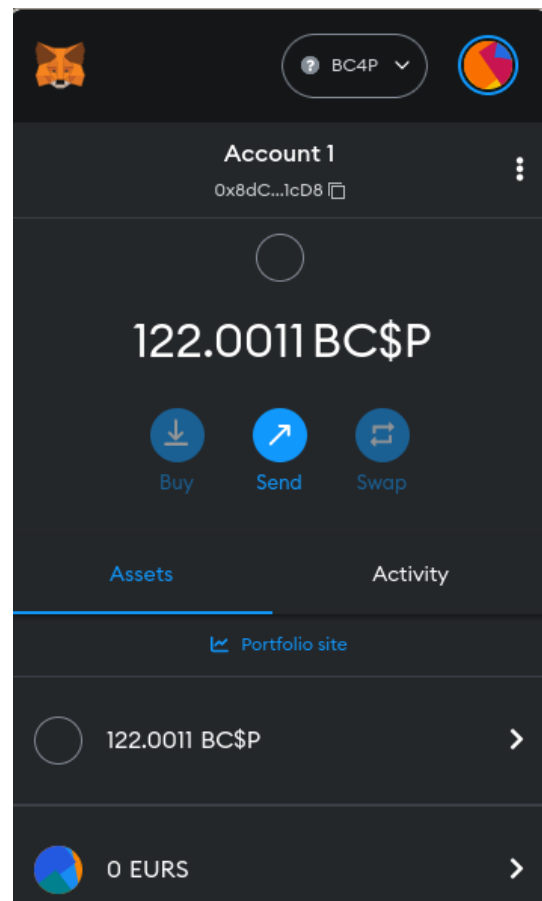It can be installed as browser extension in nearly every browser or can be used as a smartphone app.

Figure 4View of the Wallet used to trade virtual energy

The game has been played with project members, with students at PXL and during the first event of the BC4P project in October 2022.

Asset Interface (Hogeschool PXL)

For the asset interface we wanted to visualize the **energy consumption of the PXL Makerspace**. This is a space from PXL/UHasselt where colleagues and students can access various machines to produce and work together on projects. There are for example 3D printers, a laser cutter, a PCB mill (printed circuit boarding mill), an embroidery machine, etc. We are collecting energy statistics of the majority of the machines here.
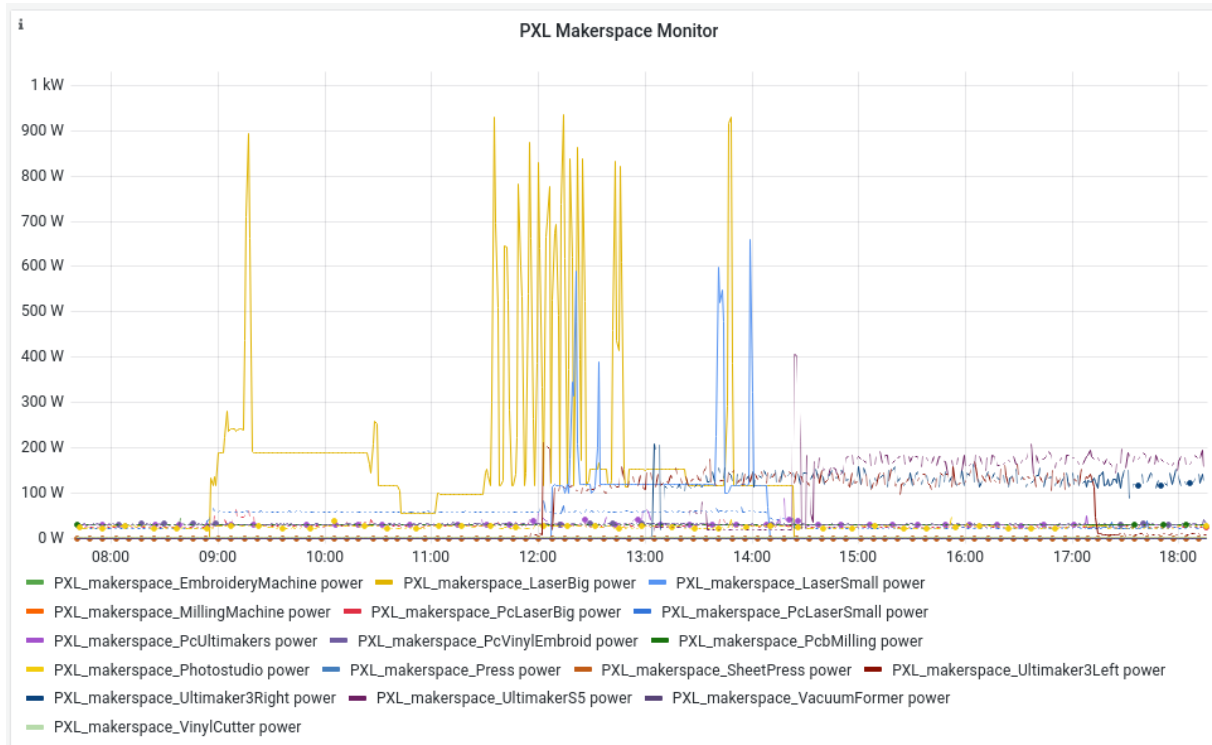

Figure 5 Grafana screenshot which visualises the current energy consumption in the Makerspace

We have 2 kind of visualisations

- Integrating PV-data of PXL and energy measurements of Makerspace in the Grafana dashboard of FH Aachen.
- Interfaces/apps that we create so that we have proof of concepts to show and discuss with a broader public (3 interfaces)

For the first interface, we setup measurements of PV-data of different buildings and sent it to the database of the dashboard of FH Aachen. For the pilots, we will build user stories around this.

The energy consumption of the devices in Makerspace is also sent to the same dashboard (with underlying blockchain solution). In this way, FH Aachen had more data to explore different kind of energy visualisations and simulate on energy trading.

For the second type of interfaces, we built separate interfaces for the Makerspace owner (on his demand) as well as other possible variants that can be used during the pilot visits, showing use case stories to a broader public. For this, the data of the PXL Makerspace is also used in three apps/interfaces. Two are created for an audience of random people. One is for the operator of the Makerspace. He has a more technical background and needs more in-depth data. The others could be used by all kind of people wanting to have a view on energy use, like private persons, companies, municipalities or the government.

We discuss the apps in detail below.

Makerspace 2D

This app is for an audience of laypeople. Its main goal is to look visually interesting for any target public that might be interested in energy usage. We followed the stylistic choices made by the communications specialist of the project, hence the minimalist neon look.

The user interface and interactions were programmed in Unity3D. This is a realtime development platform for building 2D and 3D applications, like games and simulations, using .NET and the C# programming language. The chosen database is InfluxDB because this is a timeseries database, suitable to store a lot of incoming energy measurement data.

The map of the Makerspace is visualized in blue.

Red rectangles indicate the location and the name of a device for which we collect power consumption data.

In each rectangle we show the instantaneous power consumption of the device through text. In the background we see a graph showing the past 6 hours of power consumption.
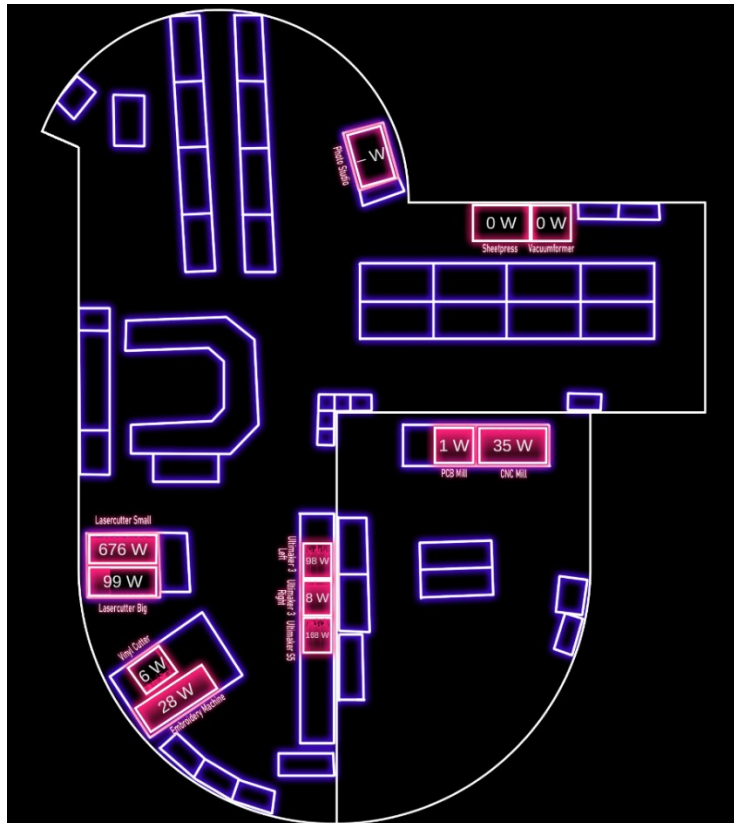

Figure 6 Makerspace 2D view made with Unity

When a user clicks on a device, they will see a 24-hour history of the instantaneous power consumption, energy consumption today, energy consumption yesterday and total energy consumption.

A user can filter on the period he wants to see.

In this figure you see an example for the lasercutter energy consumption on a random day.
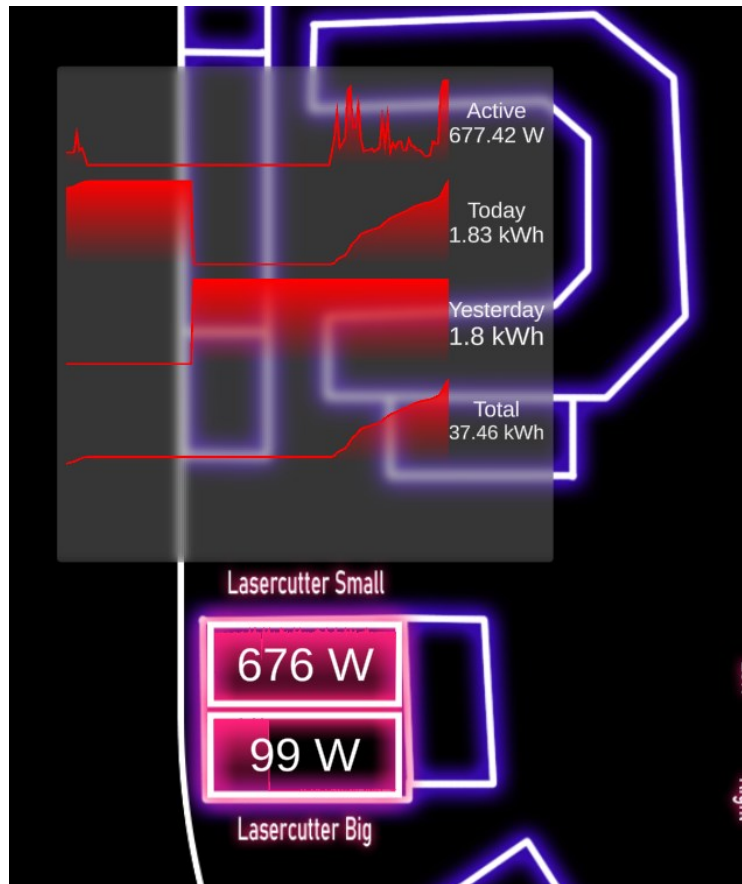

Figure 7 View on metrics in the 2D makerspace view

The use of this interface gives better insights in the energy consumption of devices in a building in a chosen period of time.

Makerspace 3D

For the 3D images we have built a proof of concept. The further development will be done for the pilot case of PXL.

The idea is to show a 3D version of the makerspace in VR. We already have a 3D scan of the space that we can use. This scan was made with Matterport, a manufacturer of 3D scanners. Unfortunately, the data format in which we can access the scan is visually not satisfactory. The meshes are very noisy.

Thus, we are essentially recreating the Matterport viewer, which does look good despite noisy data. The secret in the Matterport viewer is that the noisy mesh is only used for interaction with the mouse cursors. The displayed scene is a high resolution 360° photo. Because of the interaction with the mesh, it feels like the scene is 3D, despite being 2D.

This visualisation will be used on mobile devices. On mobile devices we're not allowed to generate code at runtime, which we need in order to read measurement data from an arbitrary database. For this reason, we have created a tool to generate the necessary code to connect to any SQL database.
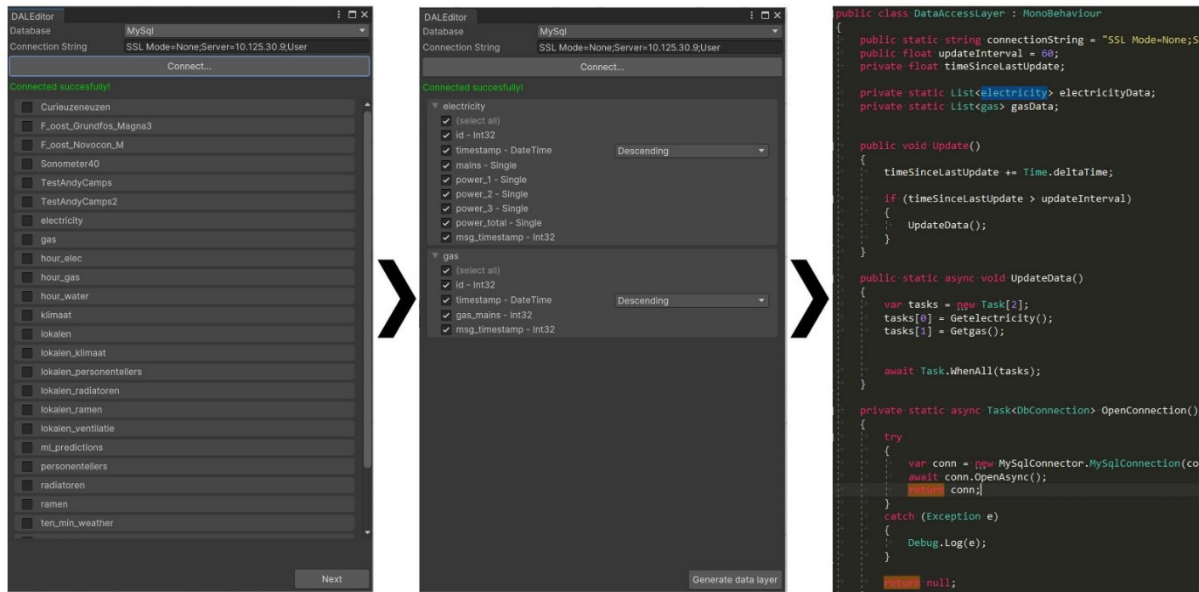
Figure 8 Object trees from the Development interface of Unity3D. Functionality is implemented in C#

Grafana Dashboard

This dashboard was made for the operator of the PXL makerspace. In the future they want to bill users by the amount of energy used. For this reason they need to be able to segment the data into jobs. Therefore we added a heatmap that makes it much easier to identify the period of a job. They can then select the job and the "verbruik in periode" ("consumption per period") chart will update to show the energy consumption in that period.

There is also the energy usage per machine for today ("verbruik vandaag") and the instantaneous power consumption per machine ("huidig verbruik").
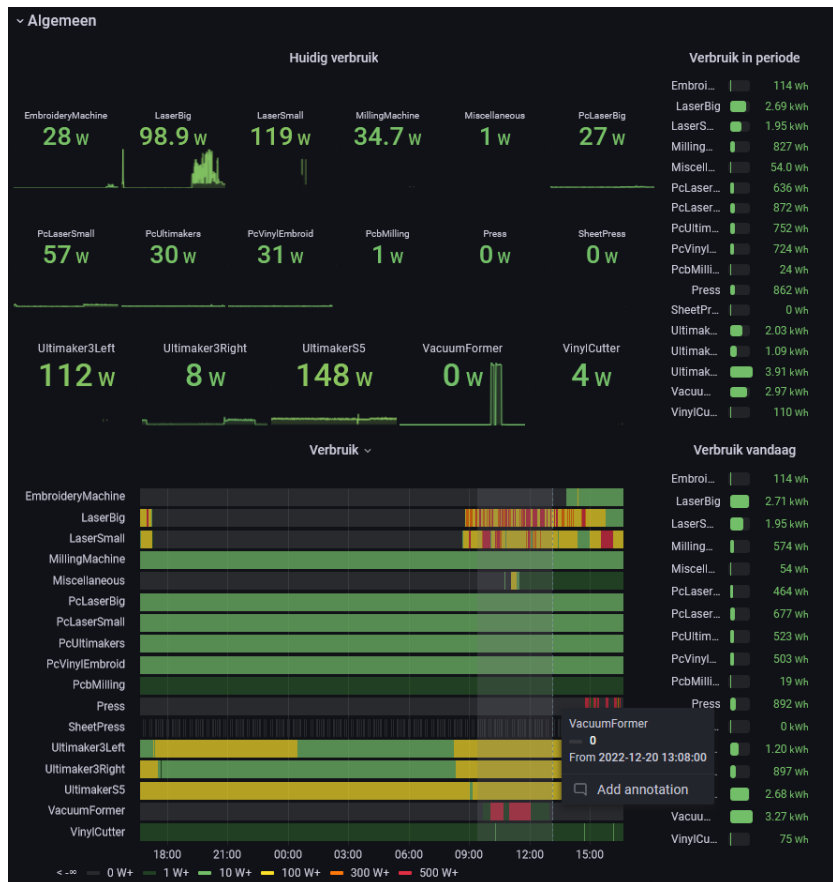

Figure 9 Grafana dashboard showing usage bars and last energy usage in given time
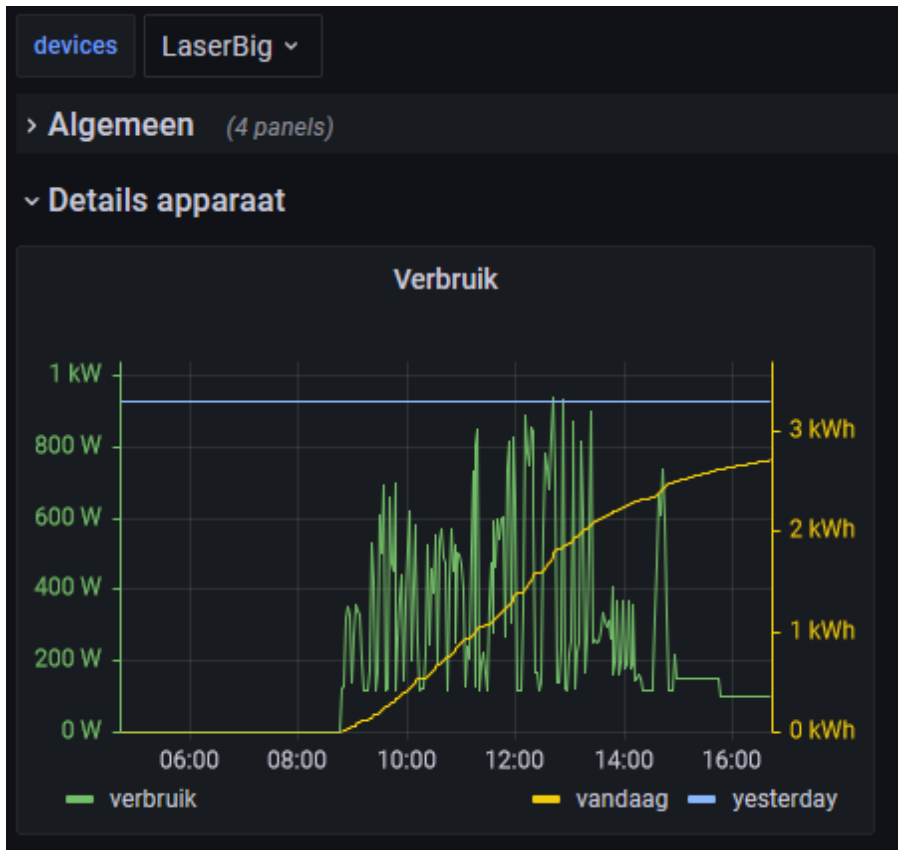
Figure 10 Grafana Graph which shows detailed data per machine in the makerspace

Conclusion and Future Work

We have created a **variety of visualisations** for most parts of the project, ranging from very high-level visualisations for laypeople to low-level visualisations for more technical users.

These dashboards can be used to monitor and investigate energy consumption per device and/or per chosen period as well as the energy production coming from different origins.

We see the following improvements for these visualisations:

Grafana Interface (FH Aachen)

The Grafana Dashboard from the FH Aachen allows to visually interact with the data which was made available. It allows to easily interact with different datasources from InfluxDB or TimescaleDB, which internally uses PostgreSQL – a mature SQL based RDBMS.
It allows to create different visually appealing realtime monitoring dashboards for all the created data in the project.

We can analyse data from the main distribution and analyse the actual energy usage on a very high resolution. Therefore, a lot of analysis still needs to be done on the data which was made available through this project.

By looking at the data from other campuses in Aachen, one can also compare the energy usage of other public buildings. This will be done as a next step.

Besides that, the resolution will be increased by wiring a few office rooms and laboratories so that the energy consumption of all actual devices can be measured individually and presented on a floormap like visualization.

Blockchain Explorer

The blockchain explorer is used to visualize the transactions on the blockchain. One can visualize the transaction and see that each new block is created and appended to the blockchain, even if there is not a single transaction on it.

This shows, that the blockchain technology itself provides a lot of overhead which exists independently from using it – in contrast to traditional solutions using a database cluster for example.

Still, the technology itself allows to make publicly verified transactions which can be seen and analysed by comparing the public keys with the wallet addresses. This option also exists for the usage of smart contracts, where the actual source code of it can be viewed in compiled form, the Application Binary Interface (ABI).
Here, one can verify if a given source code matches the ABI, yet it is quite impossible to read the actual behavior of the smart contract from the ABI, even after decompiling it.

Even though many nice tools exist to make interaction with the blockchain much easier, it is still not as easy to interact with in contrast to traditional databases, especially in comparison to the data aggregated and visualized through the Grafana interfaces.

The explorer is used to visualize all experiments and usages of the virtualized blockchain trading from the demonstrators in the Blockchain4Prosumer project, and it was tested in multiple scenarios by connecting the trading simulation to it.

Makerspace visualisation

Concrete next steps for the asset interface of the Makerspace is that the 3D Makerspace will be further expanded within the project for the pilot in Hasselt. This interface also requires an AR component, where we can see the same consumption data overlaid on the physical machines of the makerspace, with a smartphone camera. We can also expand the types of visualisations used in this interface, as they're currently quite limited. Which visualisations we need will be determined collaboratively.

Using the visualisations:

Furthermore, as far as energy consumption is concerned,

these kind of visualisations can be used to be more aware of energy consumption and in this way, lower the consumption taking into account the usage of a device. Also in places like Makerspace you can define a smarter pricing for your customers based on the usage of energy of a device. A possible use is also that you don't keep a fixed pricing during the whole day but that you take into account energy production and make the use cheaper when there is more (solar) energy production.

Students or customers in general can then also change their behavior in the use of devices taking into account the moments when it is cheaper to "consume".

Showing the evolution in energy production makes it possible to estimate when energy and energy consumption is cheap(er). Making prosumers more aware of the moments of high energy production, they can steer the use of energy and – in the context of blockchain and peer to peer energy trading – steer and stimulate the moments of energy trading.

Future work can consist of making visualisations suitable on other devices (tablets, apps on smartphones) or for other target groups. However one should take into account the cost for maintenance of these visualisations.

There might also be other parameters important to show for prosumers.

We will further explore possibilities and needs in the visualisations during the pilot projects (D.T4).

Glossary

RDBMS	Relational database management system
PostgreSQL	A mature open-source RDBMS which is used to store structured data
MQTT	Message Queuing Protocol which transports messages, based on a publish/subscribe mechanism (MQTT = Message Queuing Telemetry Transport)
FTP	File Transfer Protocol
InfluxDB	A time series database
Web crawling	Programming technique where you scrape data from websites where regular-format data can be extracted and processed
PV system	Photovoltaic system or solar energy system
Ethereum	A decentralized, open-source blockchain with smart contract functionality, chosen as underlying blockchain solution in this project.
Docker container	A container is a standard unit of software that packages up code and all its dependencies so the the application runs from one computer environment to another. A Docker container image is a lightweight, standalone, executable package of software that includes everyting to run an application.
ABI	Application Binary Interface, an interface between 2 program modules
SSI	Self-sovereign Identity, an approach to digital identity that gives individuals control over the information they use to prove who they are to websites, services and applications across the internet.
Unity3D	A game engine, especially for development of computergames
MetaMask	Software cryptocurrency wallet used to interact with the Ethereum blockchain.
kWh	Kilowatt hours, unit of an amount of energy
Gridsingularity Exchange	A simulation platform for novel types of energy markets respecting grid behavior https://gridsingularity.com/
Proof-of-authority	Proof of authority (PoA) is an algorithm used with blockchains that delivers comparatively fast transactions through a consensus mechanism based on identity as a stake
Telegraf	Open source server agent to help you collect metrics from you stacks, sensors and systems.
Tasmota	Tasmota is a free software / firmware that makes it possible to operate Smart Home devices and solutions without connecting them to a cloud.
SmartPi	It enables to control electricity production consumption and turns the Raspberry Pi into a full featured smart meter.
Grafana	Grafana is a multi-platform open source analytics and interactive visualisation web application tool. It provides charts and graphs for the web when you connect to data sources. It is extendable through a plug-in system. End users can create complex monitoring dashboards using interactive query builders.
InfluxDB	Open source Timeseries Database used to log data written from Telegraf
SQL	Structured Query Language – used to query relational database systems