Reflow | Co-Creating Circular Resource Flows in Cities

constRuctive mEtabolic processes For materiaL flOWs in urban and peri-urban environments across Europe

Deliverable 2.4

Design and Development of REST API Application and Pub/Sub Interfaces

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DELIVERABLE

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1. Introduction

REFLOW is an EU Horizon 2020 research project running from 2019-2022, which aims to enable the transition of European cities towards circular and regenerative practices. More specifically, REFLOW uses Fab Labs and makerspaces as catalysers of a systemic change in urban and peri-urban environments, which enable, visualize and regulate "four freedoms": free movement of materials, people, (technological) knowledge and commons, in order to reduce materials consumption, maximize multifunctional use of (public) spaces and envisage regenerative practices. The project will provide best practices aligning market and government needs in order to create favourable conditions for the public and private sector to adopt circular economy (CE) practices. REFLOW is creating new CE business models within six pilot cities: Amsterdam, Berlin, Cluj-Napoca, Milan, Paris and Vejle and assess their social, environmental and economic impact, by enabling active citizen involvement and systemic change to re-think the current approach to material flows in cities. In the course of this project, Work Package 2 (WP2) develops a set of technologies and tools to aid cities to transform their economies. The developed tools are utilized and demonstrated in the project's pilot cities. City partners are implementing a variety of use cases with the provided tools. WP2's main contribution is the development of an Operating System (REFLOW OS). REFLOW OS seamlessly integrates the components developed by the different WP2 partners and ensures compatibility with existing infrastructures in the pilot cities, enterprises, community organizations, fablabs, and so on. REFLOW OS combines tools to aggregate data from existing platforms and marketplaces, connects to specifically installed infrastructures, such as sensors, tracking labels and allows for the integration of open data or data obtained during the pilot's work process. One objective of Task 2.4 in WP2 is to realize efficient points of access to the wealth of information which are gathered and circulated within the REFLOW OS. These points of access are developed to ensure the seamless usability of data by machines as well as human users. Machine-to-machine interactions are realized by means of APIs. Human interaction with the system is realized by a variety of user interfaces and data visualization mechanisms.

REFLOW OS contains three main components.

- ZenPub is the federated platform, which serves as the backend to record and persist the value flows in circular cities. ZenPub is developed by the project partner DYNE.
- WeLoop is an exemplary implementation of a user interface for ZenPub. It provides marketplace functionalities and enables users to share, reuse and recycle materials in a circular city. WeLoop is developed by the project partner IAAC.
- The Open Data Dashboard is a tool to provide insight into circular economies. The Open Data Dashboard offers means to visualize data generated in circular cities and inform citizens, stakeholders or municipalities about developments, potentials or possible hazards to the city environment or the circular economies value flows. The Open Data Dashboard is developed by the project partner FRAUNHOFER.

1.1 Purpose of this document

The purpose of the document's corresponding task T2.4 is to define the points of access for machines to insert or request data from REFLOW OS. This document's purpose therefore is to provide assistance in using the developed data endpoints and APIs. It serves as an accompanying document to the release of REFLOW OS's components. Further, this document gives an overview about how the three main components interact within REFLOW OS, which public interfaces they expose

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and what purpose those public interfaces serve. Alongside this document, the components are released or deployed. The public interfaces are available externally and are linked from the corresponding sections of this document.
This document delivers information about how the external resources are to be used and understood. Therefore, the intended audience for this document are technical staff in the pilot cities.

1.2 Structure of this document

Chapter 2 provides a broad overview about the components of REFLOW OS and how they are connected. In the chapter, data flow between the different components is described. Further connection points to external data suppliers will be depicted. Chapter 3 describes the ZenPub component in more detail. The chapter encompasses information about the software itself as well as how to read and use the external API descriptions provided for the component. In Chapter 4 the Open Data Dashboard is described. Analogues to the chapter about ZenPub, this chapter will provide information about the component itself and how to read and use the external API documentation.

2. REFLOW OS

REFLOW OS is an “operating system” for circular cities. As such, it is a set of tools which help cities to change from traditional economies to circular economies. At the core of REFLOW OS the ZenPub server serves as the central data storage unit. ZenPub however contains a wide variety of functionalities reaching far beyond a simple data store. The ZenPub server is accessed via a ZenPub client. The ZenPub client is an extensible concept and can be implemented and adjusted to the individual needs of a circular city. In the context of REFLOW project, one implementation of a ZenPub client is created. This implementation called WeLoop realizes the use case of a material marketplace including material passports, value flows and social interactions based on the circular exchange of materials. As a third component, REFLOW OS includes the Open Data Dashboard. The Open Data Dashboard’s purpose is to serve as a dissemination tool, to spread information about the current state, advances and general insides into the circular city. As such, it is able to ingest a variety of data sources, from static open data to data generated in the circular process of operating REFLOW OS.
Figure 1 depicts the components of REFLOW OS and how data is transported between the components. The ZenPub client WeLoop is operated by users within the circular city via its web-based user interface. It utilizes the ZenPub server’s API to display data for its users and inserts data supplied through its web forms. The Open Data Dashboard is accessed via web-based user interfaces as well. Users create or view dashboards created on a variety of datasets. In the process of creating data visualizations, the data stored in the ZenPub server is again accessed via its API.

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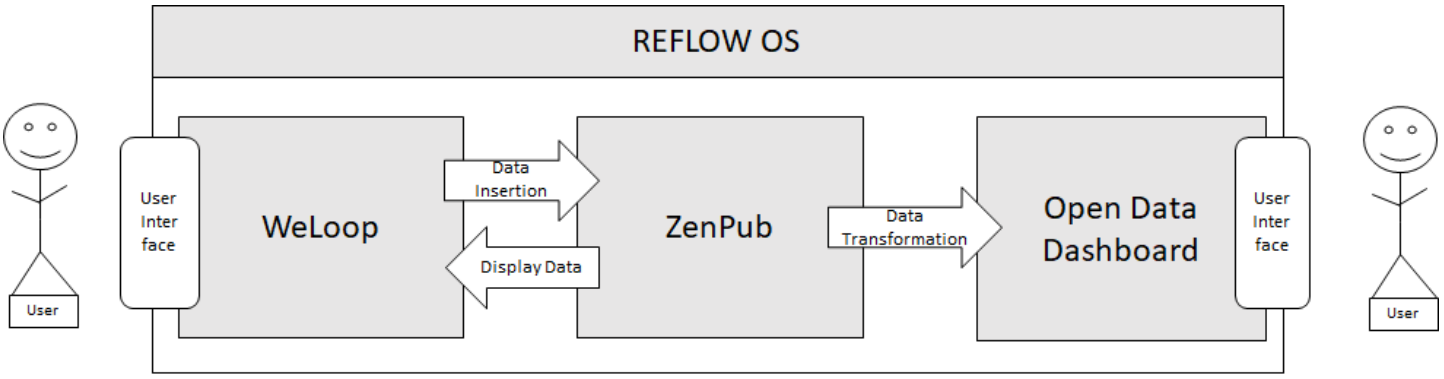

Figure 1 Components of REFLOW OS

As REFLOW OS consists of these three individual tools, a utilization of the whole tool suite is possible but may not be necessary for every usecase. WeLoop, as a ZenPub client, forms an exception as it does not provide the backend APIs by itself but utilizes the ZenPub servers infrastructure. Circular cities aiming to implement tracking of material flows and enabling local suppliers and consumers to trade and recycle good, are advised to utilize the potentials of WeLoop combined with ZenPub. Cities who strive to implement a different circular use case but are in need of a flexible, federated data management solution are advised to use the ZenPub component in combination with a custom build ZenPub client. As for cities, who do not aim to generate data based on value or material flows, but want to communicate insights, the Open Data Dashboard can be used. The Open Data Dashboard is able to process data from sources other than ZenPub, e.g. open data portals or pre-assembled collections of data. As such, ZenbPub is one of many potential data sources for the open data dashboard.
In the following chapters, the components of REFLOW OS are described in more detail, focusing on the interfaces and APIs, that ensure the insertion and querying of data.

3. ZenPub

The aim of ZenPub is to provide access to core REFLOW OS functionalities including decentralized federation networking, value flow ontology vocabularies, and local data transformations (including cryptographic transformations such as material passports) to participating ZenPub clients.

ZenPub has been developed building on CommonsPub[1], built itself on an implementation of the W3C ActivityPub[2] API standard for a decentralized social networking protocol. This protocol provides a client to server API for creating, updating and deleting content, as well as providing a federated server to server API for delivering notifications, subscriptions and content. ZenPub was built on the federated content exchange capabilities of ActivityPub standard together with required core components of REFLOW OS:

[1] https://bonfirenetworks.org/
[2] https://www.w3.org/TR/activitypub/

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- ActivityPub, which provides ActivityPub federated publish-subscribe (pub/sub) functionalities
- ValueFlows, which provides a set of common economic vocabularies to describe flows of economic resources within distributed ecosystems
- GraphQL, which provides data graph transformations, mutations, and update subscriptions via a pub/sub model
- Zenroom, which provides the cryptographic data transformations of Zenroom (e.g., to generate material passports)

The developers of CommonsPub have recently re-factored and renamed the project Bonfire and in order to benefit from long term support and compatibility, the ZenPub functionality required for the Reflow core technology is incorporated into core pluggable extensions, respectively:

- bonfire_federate_activitypub
- bonfire_valueflows
- bonfire_graphql
- bonfire_reflow

The move to Bonfire and its extensible architecture significantly eases not only further development, but also integration with the core extensions cleanly reflected in each subcomponent.

3.1 REFLOW OS Architecture and Manual

The Reflow deliverable D2.2 Architecture and Manual for Distributed Network Setup and Maintenance submitted in M18 outlined the dataflows of the ZenPub component.

Updated from that deliverable, the following data flows diagram incorporates the minor updates required with the ZenPub transition from CommonsPub to the Bonfire core.

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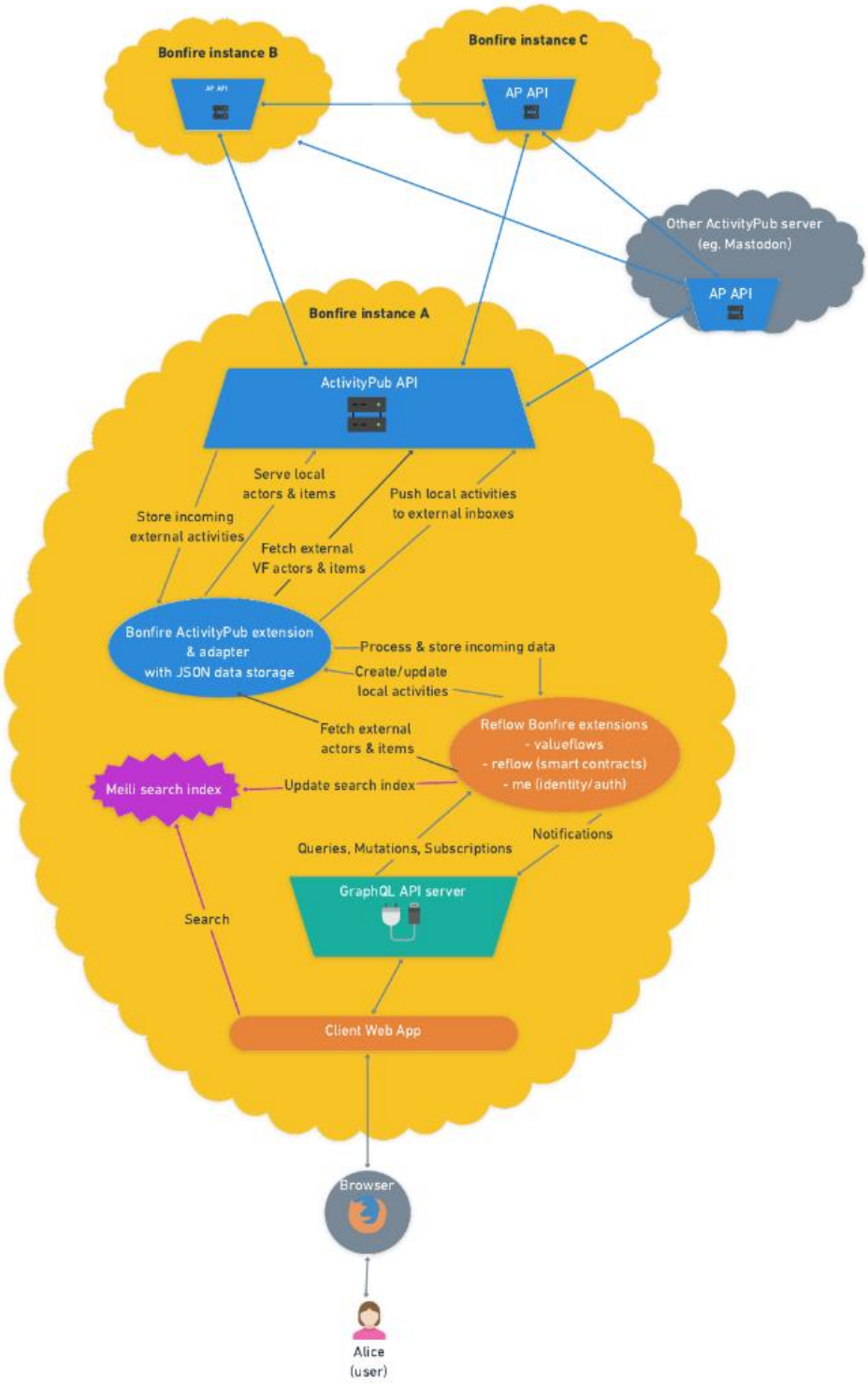

Figure 2 Data Flow Diagram of the ZenPub Component

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For the ease of dissemination of detailed architectural and operational updates during and beyond the life of the project, this deliverable is reflected as a living operational document available at https://reflowos.dyne.org

3.2 ZenPub and GraphQL

The ZenPub client API exposes a GraphQL API, which is flexible enough to satisfy a wide range of use cases and scenarios, according to the client requirements. For example, the GraphQL API fits the use case of the Open Data Dashboard component, due to its adaptable and dynamic data transformation capabilities required for the circularity of the Reflow project.

3.2.1 Introduction to GraphQL

GraphQL was developed to address some shortcomings of the OpenAPI-based approach. It has a leaner approach as it lets clients specify and ask for only what they need. In brief, it provides graph data transformation and *alias* capabilities, explicit capabilities to separate data *reads* from updates (or *mutations* in GraphQL terms) as well as pub/sub notifications when updates have occurred (through *subscriptions*).

The pub/sub subscription functionality is particularly well suited to REFLOW OS applications such as the Open Data Dashboard for data ingress, in terms of providing an API that not only suits consumption of one-shot data uploads but also provides close to real-time dynamic updates through subscribed client publication.

Detailed example use of GraphQL API within the REFLOW OS perspective is given in the API Tour section of the living documentation set of the REFLOW OS Architecture and Manual.

3.2.2 ZenPub client API flow example for ODD Data Updates

The ZenPub GraphQL API exposes not only data *read* functionality, but also allows for continuous dataset updates through a Publish/Subscribe push model (Pub/Sub). The diagram below gives an example of how the ZenPub GraphQL API can offer its clients, for example the Open Data Dashboard, continuous dataset updates as updates occur in pilot ZenPub client applications.

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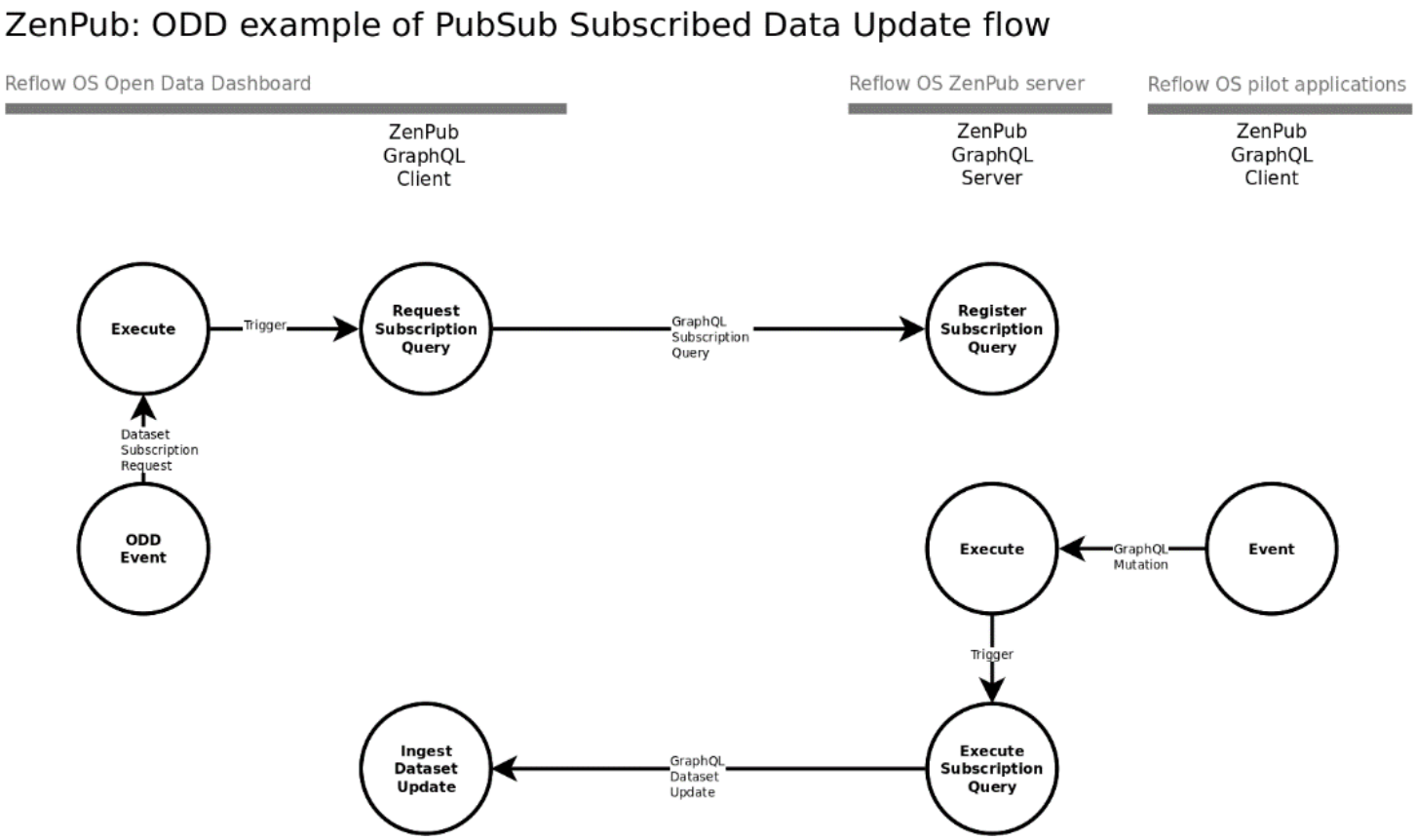

Figure 3 Pub/Sub Data Flow of the ZenPub GraphQL API

The ZenPub GraphQL API cannot only be used by a centralized Open Data Dashboard instance, but also by an on-premises instance (as part of a REFLOW OS instance).

3.2.3 Future Work

Within the context of a remote or centralized Open Data Dashboard, it may be useful to explore connecting an ODD instance to ZenPub via the pub/sub capabilities of the ActivityPub standard API, rather than via the GraphQL API as presently proposed. This would bring the potential to do data analysis of the activities of multiple users/organizations across several on-premises Reflow OS instances. Activities pushed from each Reflow OS instance to a remote ODD could then be utilized by its own local GraphQL server to query cached data from all those instances. This would require further evaluation as well as federation integration within the bonfire_valueflows extension.

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4. Open Data Dashboard

The Open Data Dashboard's aim is to provide access to the data generated, integrated and used in the context of the REFLOW project. Data collected by sensors or machines, generated by users of the WeLoop frontend or the ZenPub backend, or open data relevant to the REFLOW pilots's use cases, harvested and integrated from open data portals across Europe or worldwide is accessible and reusable using the Open Data Dashboard. Publishing (open) data under appropriate open licenses creates transparency and can serve as justification for the actions performed by the different REFLOW pilots. The component therefore serves as a tool to create awareness about REFLOW's case. Potential recipients for the information shared via the Open Data Dashboard are citizens, public administration or potential industry stakeholders.
In addition to accessing, searching and of course publishing the various raw datasets of the REFLOW context, the Open Data Dashboard provides pilots with the possibility to create graphs and other visualizations from the data. Visualizations can either be accessed by themselves or joined to create a data dashboard.

4.1 Architecture of the Open Data Dashboard

As described above, the Open Data Dashboard component of REFLOW OS consists of two main parts. The open data portal, used to publish metadata and make the available datasets searchable and more accessible, and the visualization part. The latter part can be used to create graphical representations of the collected data and arrange the created visualizations on dashboards. Two technical solutions are employed to achieve the described functionality. The data management ecosystem piveau[3] is used in implementing the metadata registry and the UI of the open data portal. Piveau follows a micro-service architecture and offers an easy-to-use portal UI, a linked data metadata registry, a search service, simple data upload and means to harvest metadata from a variety of sources. For the data dashboard component, Apache Superset[4] is used. Superset is a modern platform to explore and visualize data. It provides a wide range of visualization types available by default and offers customization capabilities to integrate further desired visualization types. The architecture of the Open Data Dashboard is depicted in figure 4. The figure shows the different parts of the component and the interactions between component and users, as well as API interactions between the parts and with external data sources.

[3] https://www.piveau.de/
[4] https://superset.apache.org/

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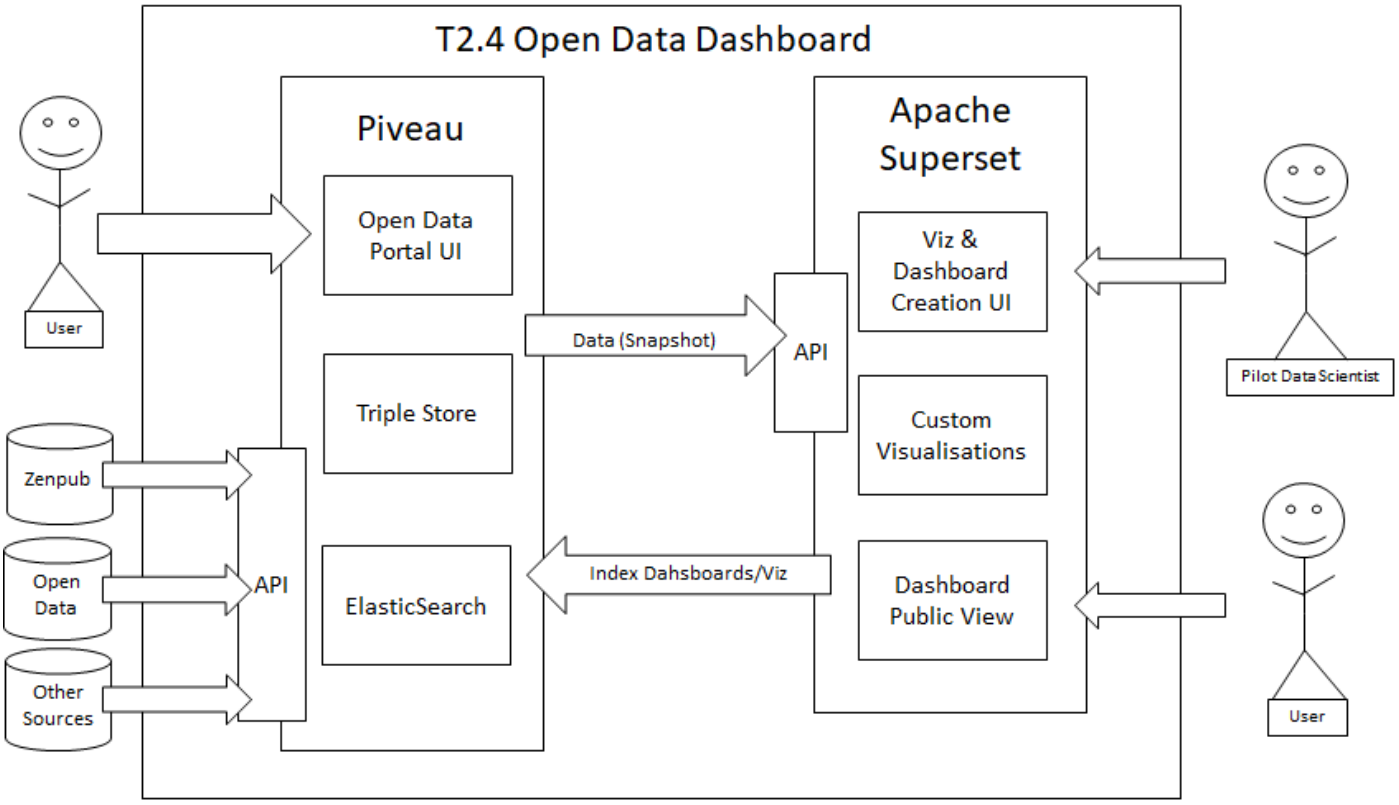

Figure 4 Open Data Dashboard Architecture

4.2 Component APIs

As depicted in figure 4 in the preceding section, the Open Data Dashboard offers only one main API, which is the piveau metadata registry API used to publish or query metadata to and from the open data portal. Via this API, datasets can be registered. In order to register a new dataset to the portal, an access url to the actual data need to be provisioned. Additionally various metadata can be provided. The transferred data should be in according to the DCAT[5] standard and in a linked data dialect of choice, i.e. Json-LD, N-Triples, Turtle or RDF-XML.

The API used to feed data into the Open Data Dashboard component is the piveau-hub API. The API can be accessed via https://reflow.fokus.fraunhofer.de/api/hub/

The API description follows the OpenAPI[6] specification can be visually explored at the given URL. Furthermore, the corresponding yaml file can be downloaded at the same place. With the provided yaml file, clients to communicate with the endpoints can be generated. Alternatively, requests to specific endpoints can be send via visual tools like Postman, command line tools like curl, or programmatically.

The open data portal part operates on metadata, while the visualization part utilizes the actual data. To ensure that the data is ready to be used in the visualization component, a micro-service is in place to import the actual data. This service is called during the process of registering datasets to the open data portal. It queries the provided access URL and

[5] https://www.w3.org/TR/vocab-dcat-2/
[6] https://www.openapis.org/

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transforms the data obtained from the given URL to the database format used by Apache Superset. In the version described in this document, the service is able to import data in CSV and Excel format into Superset. In order to connect to the graphQL endpoint of ZenPub and potential other sources, the importer will be adjusted and extended in cooperation with the pilots as a part of FRAUNHOFER's engagement in T5.4.
In addition to the metadata ingestion API, there exist several non-public APIs utilized in the micro-service architecture underlying the piveau ecosystem, as well as the API provided by Apache Superset.

Public API descriptions can be referred from the table below.

Component	API URL
Piveau-hub	https://reflow.fokus.fraunhofer.de/api/hub/
Apache Superset	https://superset.apache.org/docs/rest-api/
Piveau-hub-search	https://reflow.fokus.fraunhofer.de/api/hub/search/
Piveau-charts-importer	https://reflow.fokus.fraunhofer.de/api/charts/importer/

4.3 Future Work

At the time of delivery of this document, pilots are able to

- manually upload data to the open data portal
- use the portal's API to register external datasets to the open data portal
- create visualizations from the imported data
- create dashboards using the visualizations

With this, pilots are able to create dashboards and present information to a public audience. As a next step, the integration of data from ZenPub needs to be tackled. Since all pilots have different datasets and aim to publish different subsets of their generated data, individual connections between their ZenPub data and the Open Data Dashboard component need to be established.
Further visualizations and dashboards should be searchable and accessible at a central point in the REFLOW OS, giving interested parties the option to find and consume the information created in the REFLOW project. Therefore, the back channel metadata transfer from the visualization part to the open data portal needs to be established.
These remaining open points will be delivered after the release of this document.

5. Conclusion

In this document we described the backend components of REFLOW OS, their public endpoints, APIs and Pub/Sub interfaces. With this document, project pilot partners are enabled to understand how the parts of REFLOW OS fit together, how data is transferred between the components and which endpoints are used to ingest data. Furthermore, we depicted which functionality is available as of writing this document and the next steps in the work that has to be done in cooperation with pilot partners. This document, in connection with the

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Deliverable D2.2 and the deployed API documentations linked in the document, serves as a guide book to the architecture of REFLOW OS

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