WOOD2WOOD

A Wood-to-Wood Cascade Upcycling Valorisation Approach

» Deliverable 13.2

Material Volume Estimation Tool (version 1)

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Version	Date	Author	Description of changes
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0.2	19/05/2025	Kostas Naskou	First draft
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Dissemination Level		
PU	Public	X
RE	Restricted to a group specified by the consortium	
CO	Confidential, only for members of the consortium (including the European Commission Services)	

Legal Disclaimer

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GLOSSARY OF ACRONYMS

Acronym	Extended Definition
CDW	Construction and Demolition Waste
IP	Intellectual Property
ML	Machine Learning
MVS	Multi-View Stereo
MVG	Multi-View Geometry
W2W	Wood2Wood

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EXECUTIVE SUMMARY

This deliverable report documents the progress of the development of the Material Volume Estimation Tool that allows the monitoring of wood waste material that is generated in construction sites and ends up to sorting facilities. Building a smart skip or upgrading an ordinary one requires an array of cameras that collect images of its interior at intervals and transmit them to a remote server which runs an image-based 3D reconstruction pipeline to model the top surface of the material. Comparing the last two surfaces allows the estimation of the material volume added at each interval. The type of material and their distribution within each layer can be estimated based on the distribution of the material detected at the top, assuming that this distribution is representative for the entire depth of each layer. The more frequent the image acquisitions the more this assumption holds. However, there needs to be a balance between the acquisition frequency and power management of this setup as the skips remain at a site for several days or weeks. This first version provides an overview of the frontend and the backend of the Material Volume Estimation Tool. The document also serves as the foundation and stepping stone for the development of the final version within the next 18 months of the project. The details of the integration to the project platform along with the other tools are provided in deliverable D9.5.

1. INTRODUCTION

1.1. PROJECT INTRO

The W2W project develops a comprehensive framework for multi-dimensional cascade valorisation of wood waste from construction, demolition and furniture manufacturing, consisting of four core components: i) advanced separation and sorting technologies; ii) upcycling processes and technologies to recover wood or resources from waste; iii) digital tools to improve circular flows of secondary materials; iv) a supportive framework in policy, market, and skills.

W2W will demonstrate efficient and sustainable value chains in three use cases for the production of wood without pollutants, biocomposite building materials, biopolymers, polyols, chemical detergents, and the recovery of nutrients using technologies and tools that allow the selection of optimal cascade valorisation paths. The project's holistic approach aims to reduce the demand for virgin materials, reduce the amount of waste that ends up in landfills or incineration facilities, allow for the creation of new value-added products from waste materials, and support the transition towards a circular economy by promoting closed-loop systems where materials are continually repurposed and reused, thus extending their useful life.

1.2. PURPOSE OF THE DELIVERABLE

The purpose of this deliverable is to document the progress of the development of the Material Volume Estimation Tool that allow the monitoring of wood waste material that is generated in construction sites and ends up to sorting facilities. This first version provides an overview of the frontend and the backend of the wood waste monitor. The document also serves as the foundation and stepping stone for the development of the final version within the next 18 months of the project. The details of the integration to the project platform along with the other tools are provided in deliverable D9.5.

1.3. INTENDED AUDIENCE

The primary audience of this report is the wider public and any third parties, researchers and practitioners who are interested in the concept of monitoring the generated construction and demolition waste in order to refine their logistics strategies. It is also addressed to the European Health and Digital Executive Agency services so as to assess the status of the W2W-task T13.2 in the context of the project's continuous reporting obligations. Lastly, it serves as the documentation of the state and intent for the development to the consortium party members so that they can coordinate their efforts accordingly, where necessary.

1.4. STRUCTURE OF THE DELIVERABLE

Section 2 provides an overview of the concept and the scope of the work. Section 3 presents the user interface of the Material Volume Estimation Tool that shows the volume of the collected material at each site and the reconstruction pipeline that estimates the quantities. Section 4 gives an outline of the next steps in this work until the next reporting period.

2. CONCEPT AND SCOPE

A widely used solution for managing construction, renovation and demolition waste is the deployment of skips—large, open-top containers that streamline the collection and transportation of debris from construction sites to recycling or disposal facilities. By enabling efficient waste segregation and handling, skips play a key role in reducing landfill reliance, minimising environmental impact, and supporting the circular economy through the recovery of valuable materials for further processing. At larger construction sites it is also common to have a dedicated yard space to stockpile material for reuse such as wood.

Analysing mixed construction and demolition waste for material recovery has gained interest lately but the variability of the materials that can be found at any given site means that there is no dataset or classification model that is widely applicable (Langley et al., 2025). One study utilises a static camera over a skip to monitor the type of material that are discarded at a construction site (Davis et al., 2021). Another study uses a static camera at the site entrance to monitor full tracks as they exit and infer the type and volume of the waste they carry (Chen et al., 2022).

The users whose needs are addressed in this work are employed by construction companies or companies that hire skips and manage construction and demolition waste logistics. Their needs are expressed in the following user story: *As a waste logistics manager at a construction or skip-hiring company, I want to be able to monitor the volume of the wood waste material that is available at all sites so that I can effectively arrange transportation and manage reception and the workload at the sorting facilities*.

2.1. CONCEPT

Building a smart skip or upgrading an ordinary one requires an array of cameras that collect images of its interior at intervals and transmit them to a server which runs an image-based 3D reconstruction pipeline to model the top surface of the material. Comparing the last two surfaces allows the estimation of the material volume added at each interval. The type of material and their distribution within each layer can be estimated based on the distribution of the material detected at the top, assuming that this distribution is representative for the entire depth of each layer. The more frequent the image acquisitions the more this assumption holds. However, there needs to be a balance between the acquisition frequency and power management of this setup as the skips remain at a site for several days or weeks.

As illustrated on Figure 1, skips and/or wood stockpiles at several sites can be monitored. Images from the former are automatically transmitted by the smart skips. Point clouds for the latter are manually uploaded by the site surveyor who frequently produces site surveys, as part of their usual duties. All datasets are tagged with a timestamp and an identifier related to the site.

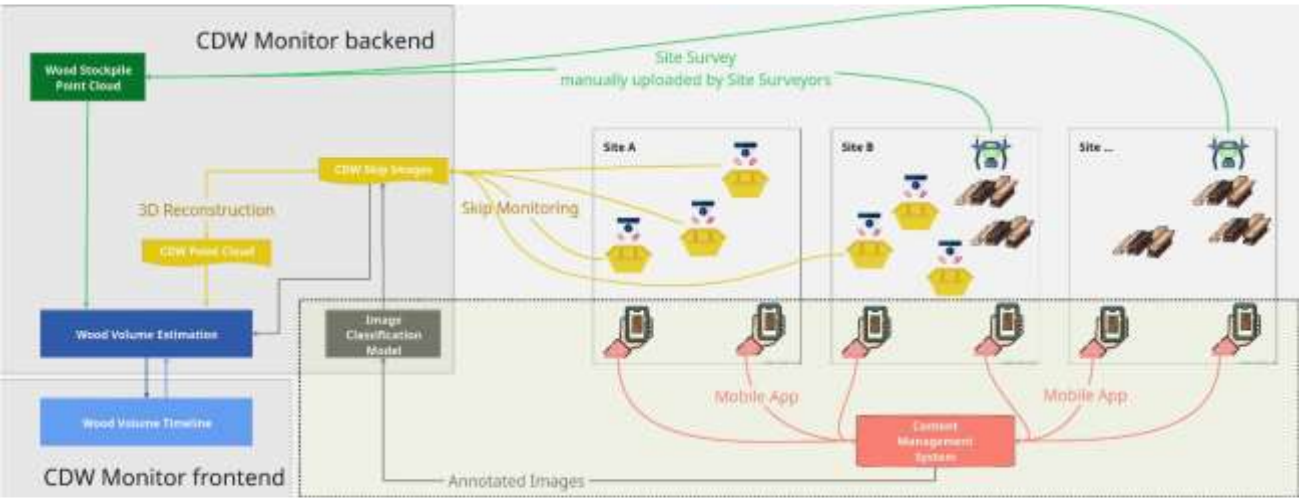

Figure 1. An illustration of the construction and demolition waste monitor.

2.2. SCOPE

In this project, a proof-of-concept prototype for skip monitoring is developed based on low-cost edge devices in order to investigate the practical feasibility of the approach. The tools that will be developed in the context of Tasks T13.2 and T14.2 will be demonstrated at the ICCS premises in the context of WP15. This first phase included the development of the frontend comprising a web interface showing the material volume timeline, which also allows the uploading of wood stockpile point clouds. The backend development for the image-based 3D reconstruction pipeline is also included in this phase as the software tools are the core outcomes of this task.

In the second phase, an ordinary skip will be hired and used in a small-scale pilot to test the smart skip monitor prototype with real data. Several low-cost and low-consumption cameras will be assessed for the design of the sensing array that will be attached to the demo skip to test the prototype. Point cloud data coming from aerial drone site surveys will be simulated. A custom-made mobile application for crowd-sourced classified image data will be developed based on ICCS's background IP of CirculAR (Katika et al., 2022) to collect data in order to be able to train a wood waste classification machine learning model specific to each construction site.

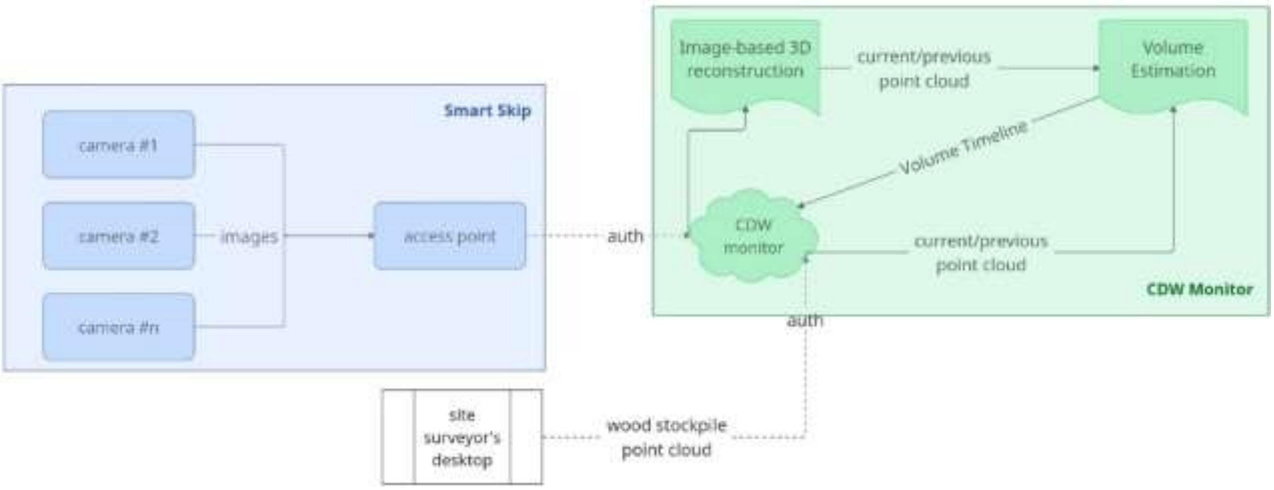

Figure 2. Data flow between the different modules of the wood waste monitor.

3. MATERIAL VOLUME ESTIMATION

This section describes the initial prototype of the construction and demolition Material Volume Estimation Tool. Two of the main components have been implemented so far. The frontend which visualises the CDW volume timeline at each site and the backend that runs the image-based 3D reconstruction and volume estimation pipeline.

3.1. CDW MONITOR

The web tool that allows a user to monitor the volume of wood material at all the sites they manage or at a particular skip or stockpile was developed based on Python and Flask, and is using Tailwind CSS for visual coherence with the other tools of the platform (Task 13.5). The user interface comprises three sections: an OpenStreetMap at the top left, a bar chart with the cumulative volume timeline of the selected area at the top right, and, at the bottom, UI elements to upload point clouds (Figure 3). A site surveyor with access to the web tool can regularly upload point clouds of the yard where the wood stockpile is kept. Along with the point cloud in PLY format, they need to provide an API key so that the file is accepted, as well as the identifier and coordinates of the stockpile and site, which can be populated through selecting an existing site or a new location on the map.

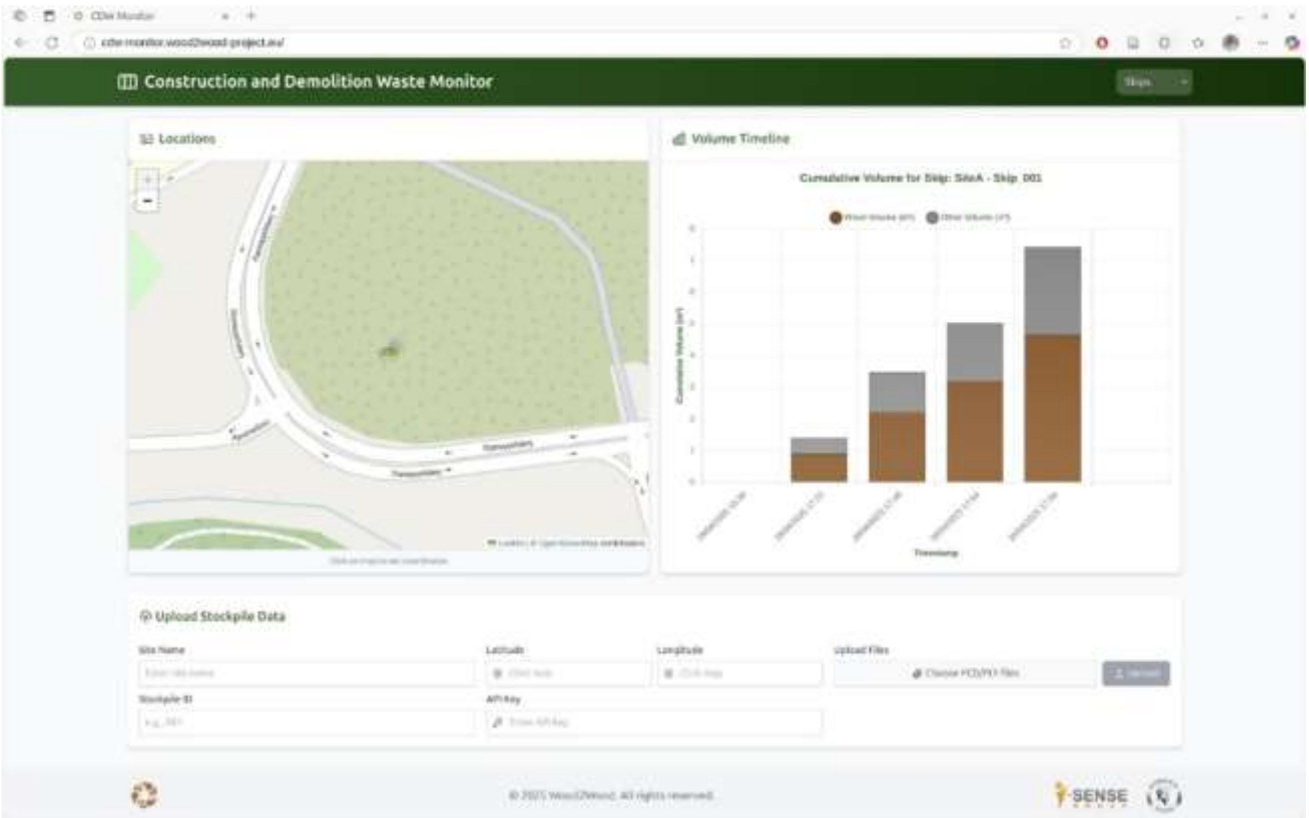

Figure 3. A screenshot of the Construction and Demolition Waste Monitor prototype.

3.2. Reconstruction and Volume Estimation

Turning a skip to a self-monitored piece of infrastructure is based on its ability to track its content and communicate that information to the interested parties. The approach used in this case is based on 3D computer vision. An array of cameras at the top edge of the skip looking into it, concurrently sends images at regular intervals to an access point, also attached to the skip, which in turn transmits them to the application's server for further processing to estimate the volume of the material layer that has been added to the skip since the last transmission.

During the period up to this first version, the development of the 3D reconstruction and volume estimation pipeline was done using the Python programming language and based on simulated data generated in Blender[1] (Figure 4, left). The scene includes a skip, at different fill states, and 12 virtual cameras (3 on each side) from which frames were rendered at each fill state (Figure 4, right). For the 3D reconstruction pipeline the OpenMVG library is used, with known camera intrinsics and extrinsics, (Moulon et al., 2017) and the output is fed to the OpenMVS multi-view stereo reconstruction library (Cernea, 2025) for dense image matching and point cloud generation of the top surface of the material in the skip. For the volume estimation between the top-material-surfaces acquired at each time interval, the CloudCompare ("CloudCompare," 2025) point cloud processing engine is used to rasterise each point cloud and calculate the volume between the latest two 2.5D surfaces.

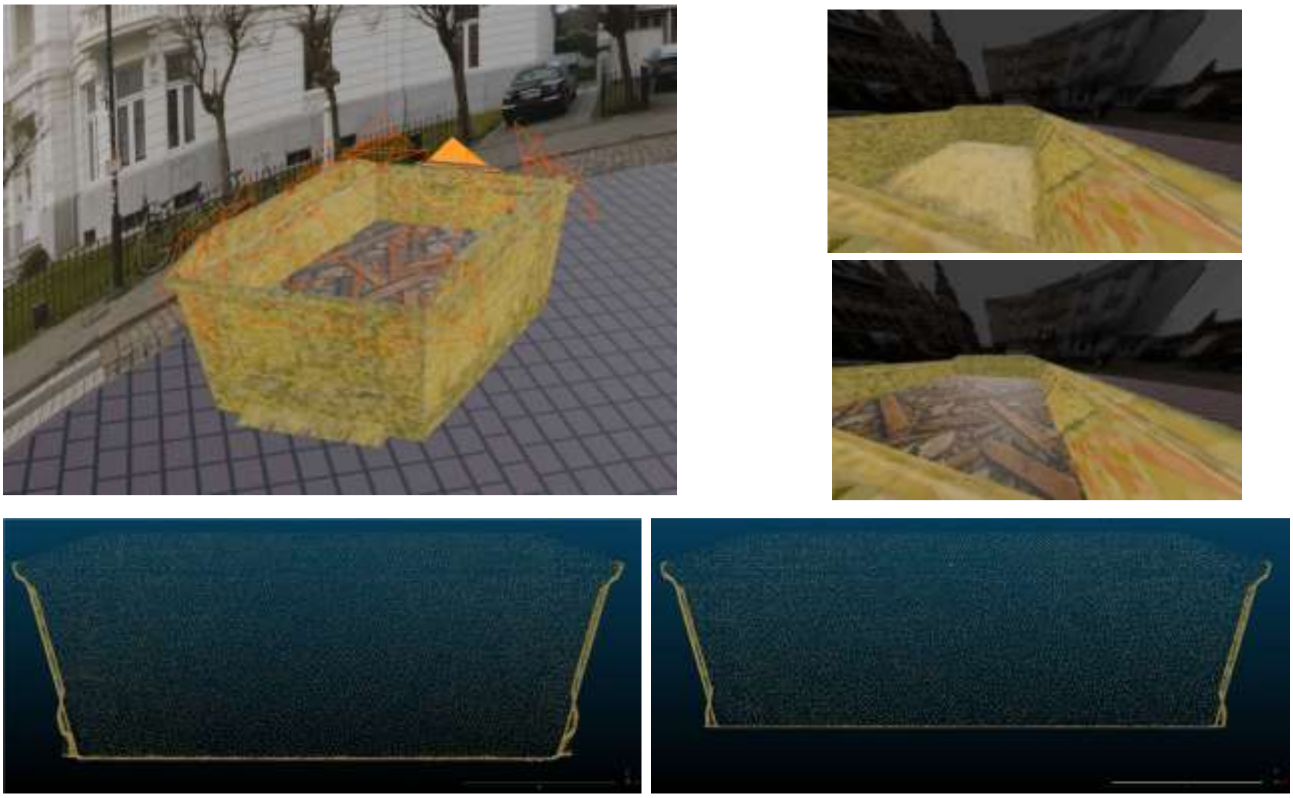

Figure 4. The virtual scene used to generate simulated data for the development of the reconstruction and volume estimation pipeline (top left). Two examples of rendered images (top right). Two reconstructed point clouds (trimmed at the horizontal footprint of the skip's top rim, as defined by the camera locations): empty skip (bottom left), and skip filled with a 0.25m-deep layer of waste (bottom right).

[1] 3D computer graphics software by https://www.blender.org/

4. NEXT STEPS

This work will continue with the assessment of microcontrollers and low-cost cameras with small form-factor and low power usage in order to build the prototype of a monitoring array that can be attached to a skip for the trials. The total number of cameras that is necessary to keep track of the material volume as the skip gets filled up will be chosen based on tests with simulated data. To verify these choices, cameras will be attached to a skip in order to run trials while adding construction waste to it. The volume for each type of material will be estimated and compared against ground truth data.

4.1. Material Recognition

Readily available CDW datasets will be assessed for their suitability to train a ML model to differentiate between wood material in the skip, e.g. the CODD dataset (Demetriou et al., 2024). This will be compared against models trained incrementally with a small number of images collected at the specific site where a skip is installed. The ML model developed in the scope of WP5, for the classification of wood pieces moving on the conveyor belt will also be considered for assessment.

4.1.1. Mobile Application for Training Data Collection

The source of the images that will be used to train the custom-made site-specific models is the workforce of each site. The implication of this is that this will not be a highly and accurately curated dataset collected under predefined circumstances. The question is to what extend can this dataset be used to train a CDW classification model without carefully managing it after it is collected and directly feeding it to train the ML model. This offsets the challenge to the UI used to guide a user to provide the data via the mobile application.

5. CONCLUSION

The implementation of the CDW monitor during the first period of the project has established the framework for the volume estimation based image-based 3D reconstruction. The initial experiments have showcased that the premise of this work is valid and remains to be verified in practice with real-world data as its development will be continued in the scope of task T10.3 and demonstrated within work package WP15. From a technical and practical perspective, efficient management of the power consumption of the edge devices will be pursued. Also, treating the skip surface as a 2.5D (a single elevation at each horizontal position) may not work for skips with vertical side walls; this will be addressed by alternative volume estimation strategies or specifying the fitting of the system to skips of appropriate geometry. The stakeholder involvement will continue in order to define in more detail all the user interface features and interactions that the CDW logistics managers require from the CDW monitor.

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