VAULT

A battery-integrated system for fast
EV charging in grid constrained locations

POLITECNICO
MILANO 1863

01 Motivation

Collaboration
Starting point

This project originates from a collaboration with Energy Management Systems, specializing in EV charging solutions.

Motivation

Collaboration
Power Cube

Power Cube is a charging system with integrated energy storage, which enables fast charging from low-power grid connections.

Battery

Fully sourced from external suppliers

Power electronics

Enclosure sourced from external suppliers

My contribution

Satellite

Designed from the ground up

Rationale

Original project was limited by time, budget, and commercial constraints, leaving design potential unexplored.

Foundation

Practical experience

Technical knowledge

Engineering support

02 Research

Research

Key Insights
Infrastructure gap

By 2030, 50% of all new car sales will be electric if producers meet their announced targets

IEA Report (2024)

Infrastructure gap

In the years 2017-2023, sales of electric vehicles in EU grew at a rate three times faster than that of charging point installations

ACEA Report (2024)

Bridging the gap

ACEA estimates in order to fill the growing gap, there needs to be 8.8 million public chargers in Europe by 2030.

ACEA Report (2024)

Key Insights
Challenges

01

Power Grid

Power grid in many areas is not prepared to support the growing demand for fast EV charging

02

User Experience

Poor user experience deters people from using public charging infrastructure

03

CPO Profitability

Despite growing demand for charging, achieving profitability remains challenging for CPOs due to thin margins

Research

Challenges
Power Grid

Power grid limiations are cited as a barrier by 75% of charger developers/operators

Xendee Survey (2024)

Polish power grid challenges

Case study

Strategic locations

Energy infrastructure along the highways and express roads is not prepared to deliver the required connection power

AFIR regulation requires fast chargers to be installed every 60 km along the Trans-European Transport Network (TEN-T)

Costly upgrades

Costs of upgrading power grid can exceed the expenses of purchasing and installing the charger itself by several times

Approval delays

It can take even 3 years for grid operators to build sufficient connection power that will support ev chargers

Challenges
User experience

43% women feel unsafe when using EV chargers during night

Geotab (2024)

53% elders report to have problems handling heavy cables

RiDC Reserach (2022)

Common Painpoints

Author's survey (n=94)

No weather protection	90% of polish drivers found charging uncomfortable due to lack of cover	90%
Poor signage	70% of polish drivers had a trouble spotting charger due to its poor visibility	70%
Short cable	65% of global drivers reported difficulty plugging the cable into the car socket	65%
Poor interface usability	60% of global drivers struggled to use charger interface due to sun glare, rain, or snow	60%

Challenges
User experience

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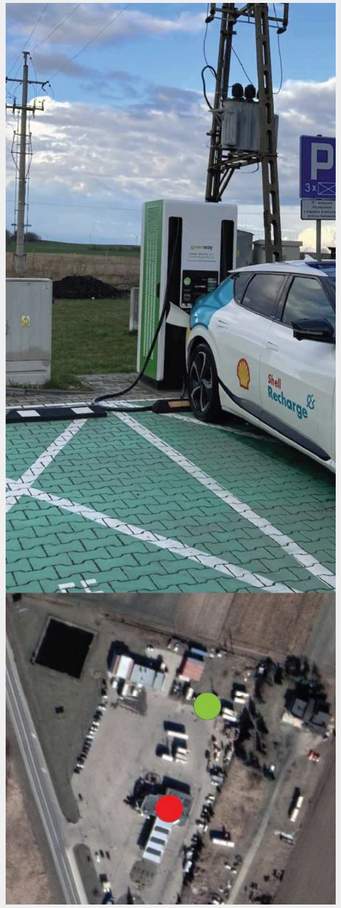

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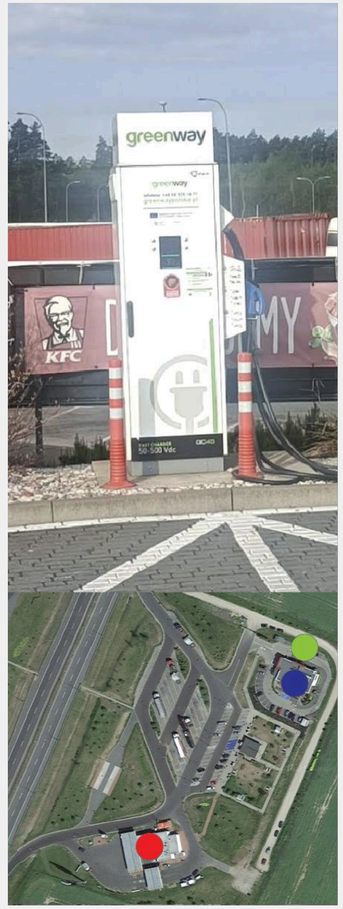

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charging station restaurant gas station

Site preparation

- Limited space
- Lack of dedicated lighting
- Lack of weather protection

Target locations

Strategic locations along highways and express roads that already installed charging stations

Part of the TEN-T network, mandated by AFIR

Challenges
CPO profitability

High upfront costs

Installing a single DC fast charger can exceed €100,000 and charging operators are often forced to cover additional grid upgrade costs

Allego charging operator

Case study

Diversified Revenue

To combat low margins, Allego generates 29% of its revenue from services like site management, billing, and consulting.

Interoperability

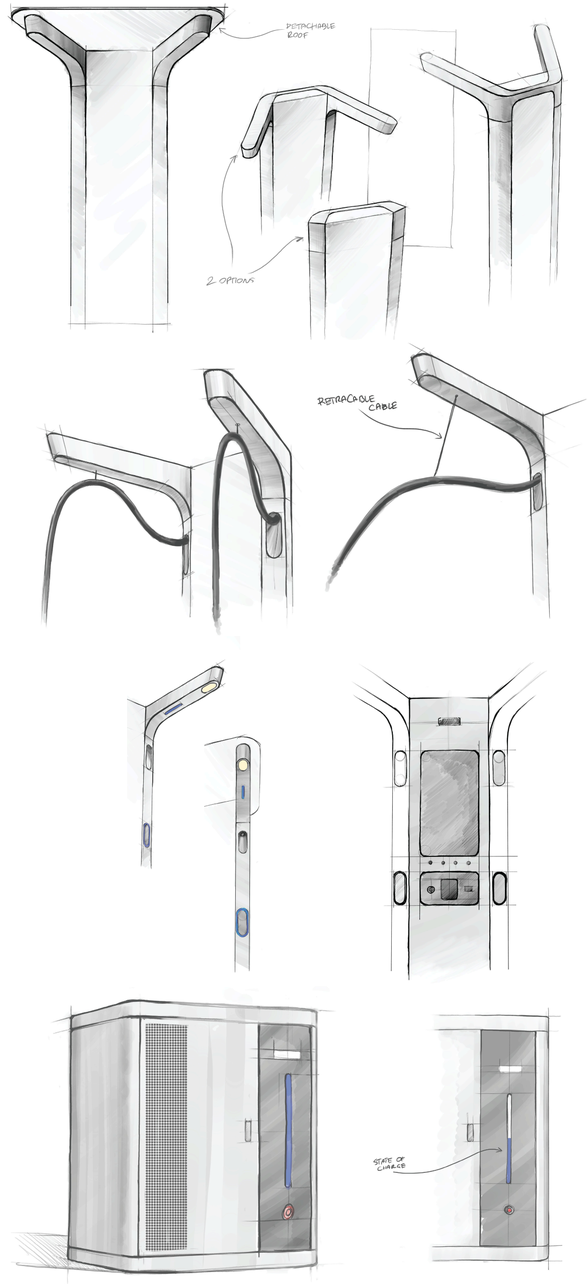
By connecting to 260 MSPs and supporting universal access Allego ensures compatibility with all EVs and users.

Transition to fast charging

Over the last years, Allego has seen dramatic increase in the utilization of their expanding fast charging network

03 Design

Design objectives



Objectives

Addressing challenges **Accessibile design** **Aesthetic goals**

The objective is to propose a design that realizes the potential of the technology developed by EMS without previous constraints.

Design

VAULT

Fast charging anywhere

Design

Vault Components

Cube

Powered by the grid. It houses both the energy storage system and the power electronics that support the whole systems

Satellite

Powered by the Cube. It serves as the only physical touchpoint between the system and the user, delivering the power directly to a vehicle

Design

Vault System

01 Charge

The Cube is gradually charged using a standard low-power grid connection

02 Store

The Cube stores energy that can be sold back to the grid during high-demand periods

03 Deliver

Through the Satellite, the Cube can release stored energy at high output to charge EVs

Design

Vault Specs

Grid input

+11 kW

Max output

150 kW

Cube capacity

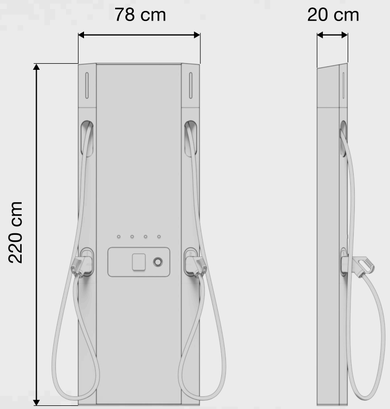
215 kWh

Cube charge time

3-12 hrs

Design

Satellite



Small footprint

The compact form factor of the satellite allows it to fit inside limited parking space

Design

Satellite Configurations

Core

The base version is intended for locations that already provide shelter and external lighting.

Plus

The enhanced version allows the integration of a roof, cable management system, and dedicated lighting.

Design

Satellite
Main pillars

Rigidity

Rigid aluminum extruded pillars provide a stable support for the whole structure

Modularity

Satellite can be upgraded to the enhanced version by replacing the upper extensions

Design

Satellite+
Lighting system

COB lights

Main lights illuminate the satellite and its surroundings, improving visibility and safety

Led indicators

Placed around the holsters and overhead, they show the current charge status

Design

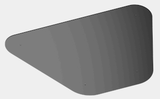
Satellite+

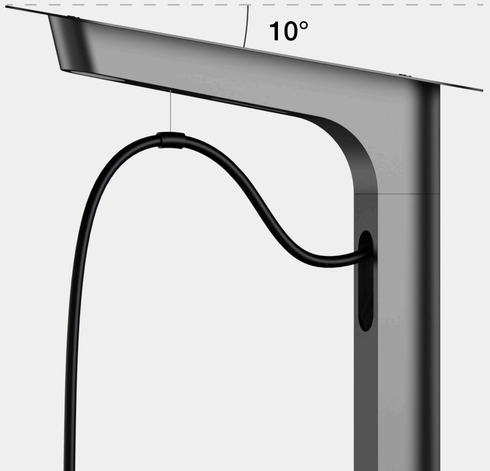
Protective canopy

Clear

Opal

Solid





Design

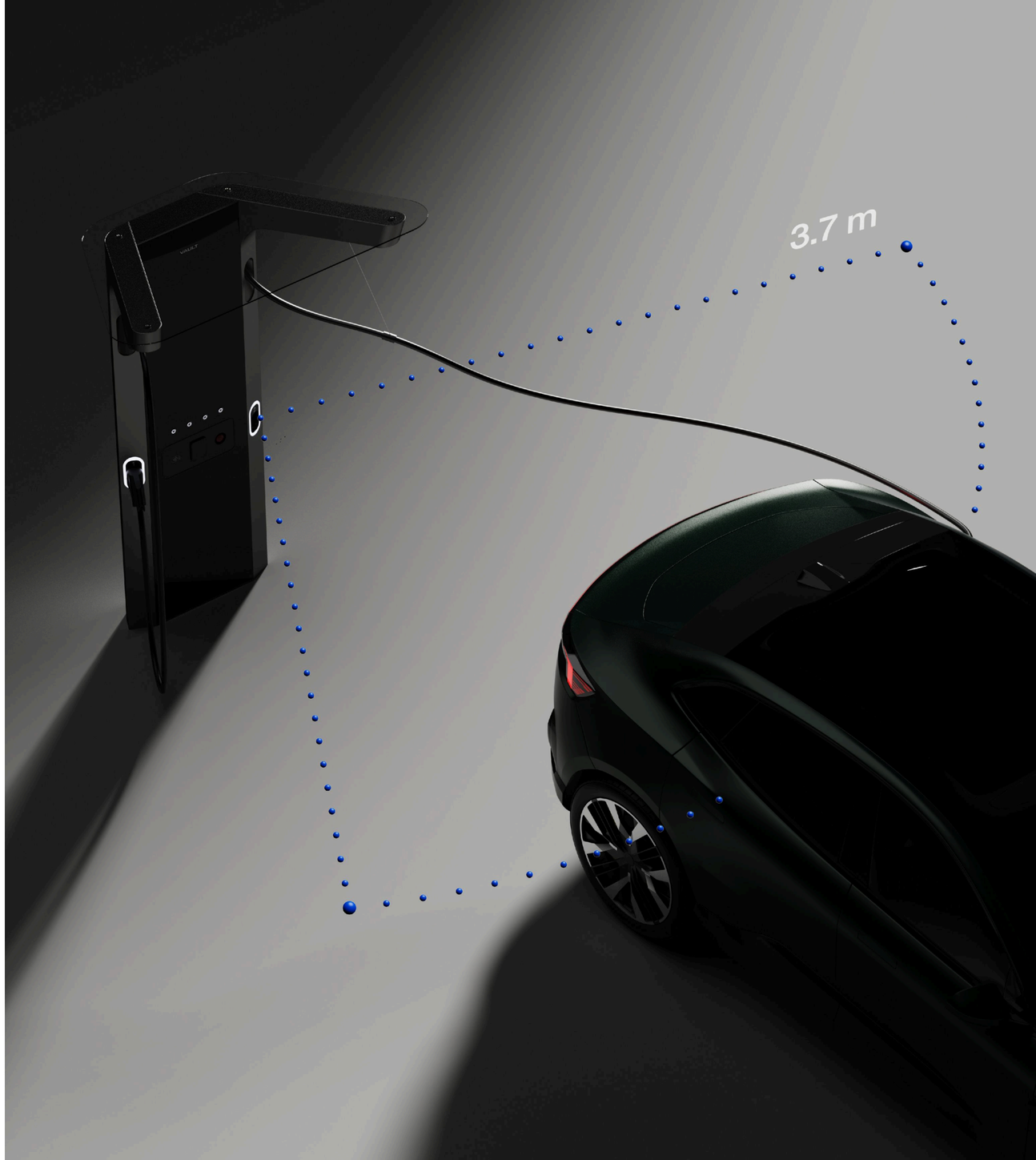
Satellite+
Cable management

Pulley system

Enables easy plug handling and extends the cable’s reach for easy connection to the vehicle

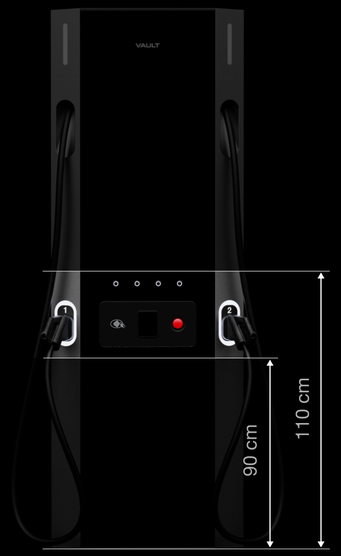
Max reach

3.7 m



Design

Satellite
User interface



Accessibility

All elements of user interface are easily accessible. Holsters are angled to leave more space in front of the satellite

Display

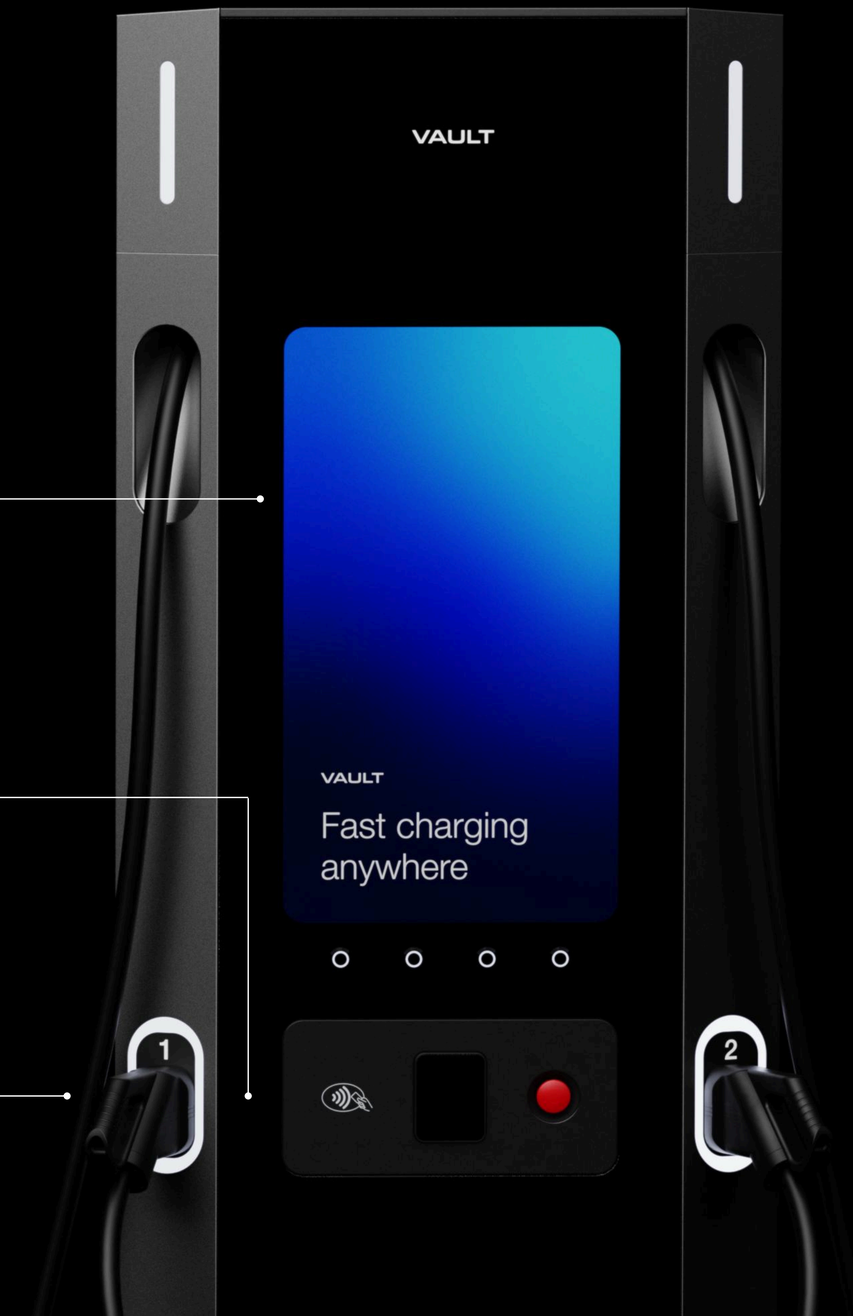
High contrast, 32 inch screen powered by 4 buttons

Customizable Panel

Houses RFID scanner, payment terminal and emergency button

Connectors

Connector holsters are angled and numbered for better recognition



Design

Interface flow
Arrival

Cube status

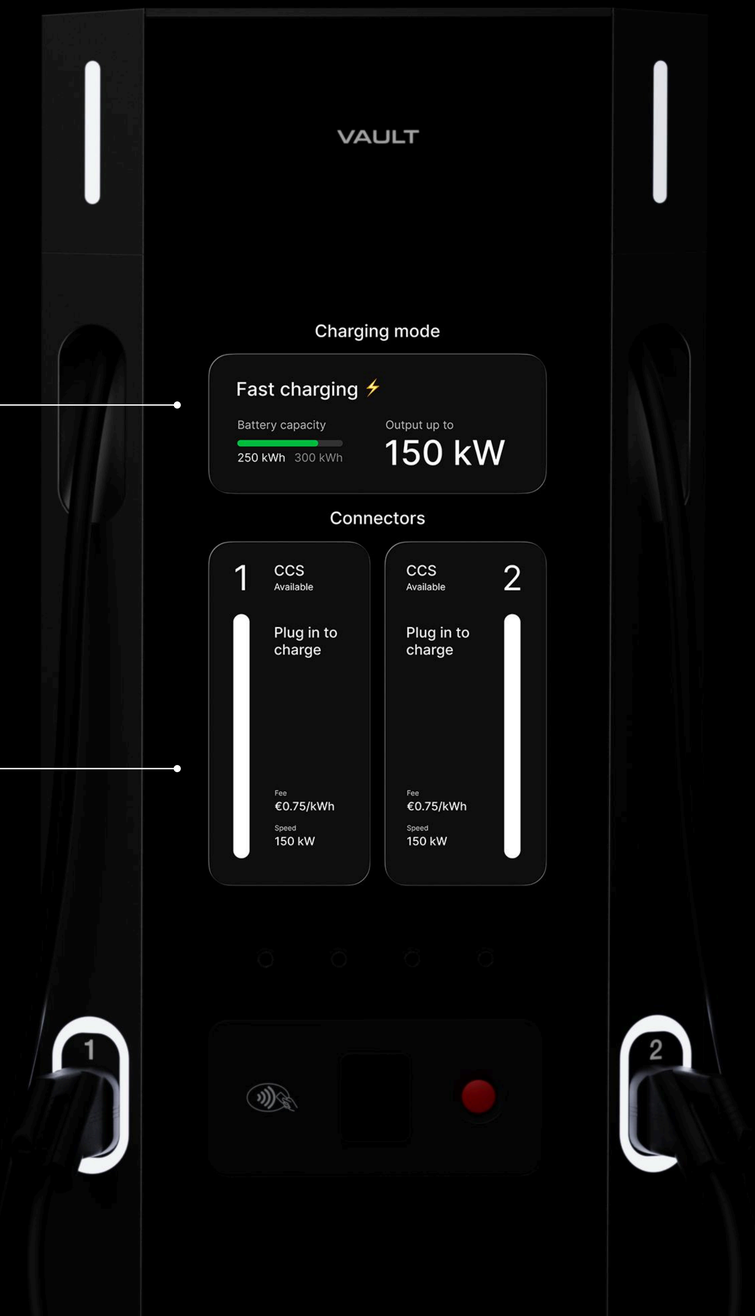
Information on the Cube battery capacity and its available output is displayed

Connector controls

All information for each connector is displayed in a separate modules

Charge indicators

When white, the charge indicators signal availability and readiness



Fee
€0.75/kWh

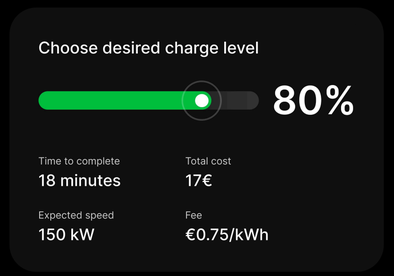
Speed
150 kW

Transparency

Clear communication on fees, available output and connector availability

Design

Interface flow
Connection



Full control

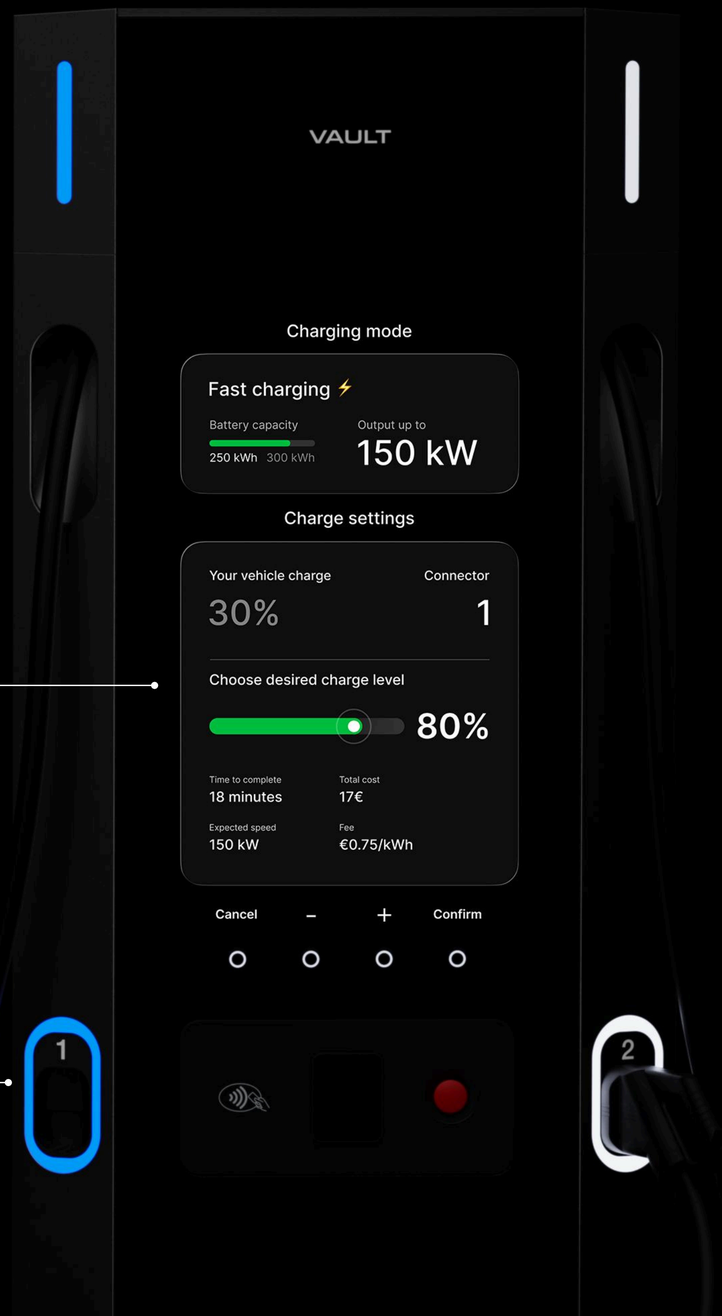
Users choose a desired charge level with clear price and duration info

Charge settings

After plugging in the available connector, the display centers on it’s settings.

Charge indicators

Indicators pulse blue when communication with vehicle starts.



Design

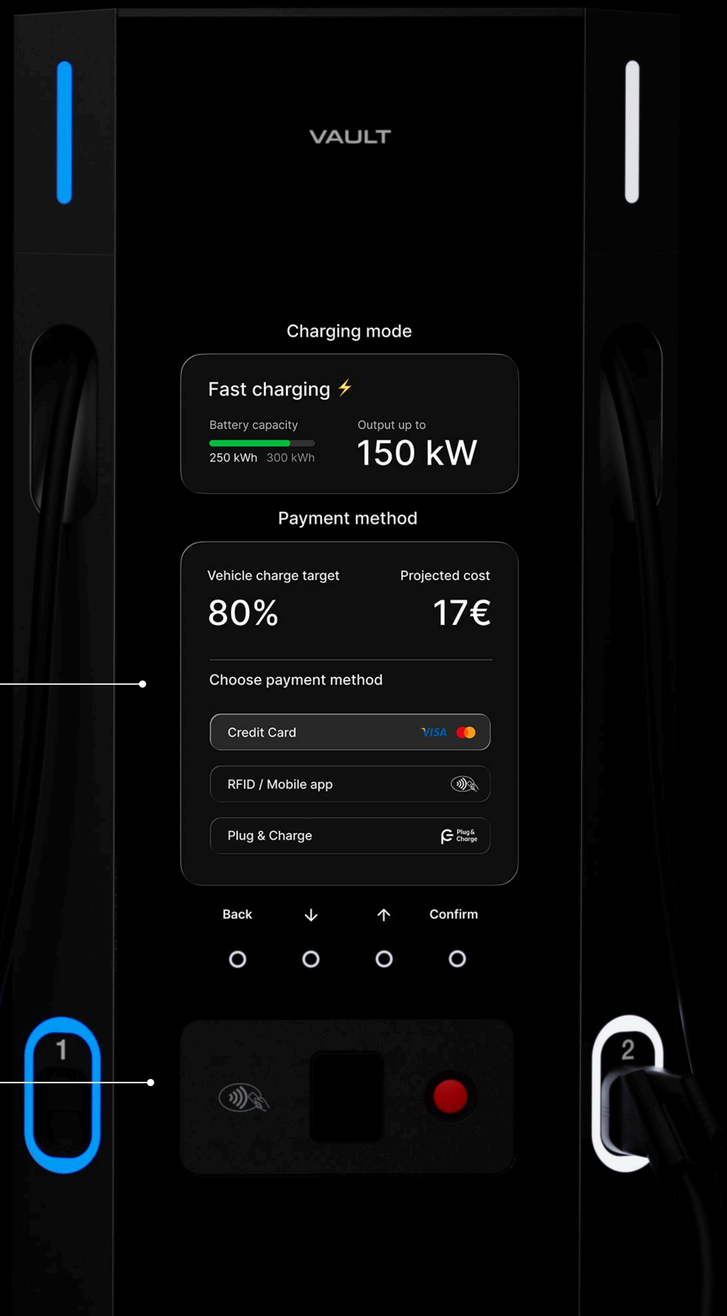
Interface flow
Authentication

Authentication methods

User can choose different payment and authentication methods

Panel elements

RFID scanner and terminal are used depending on the chosen method



Design

Interface flow
Charging

Monitor Remotely

Remote access

User can monitor the charge progress remotely by scanning QR code.

Connector controls

Charging has begun. The connector module and its bar communicate the progress

Charge indicators

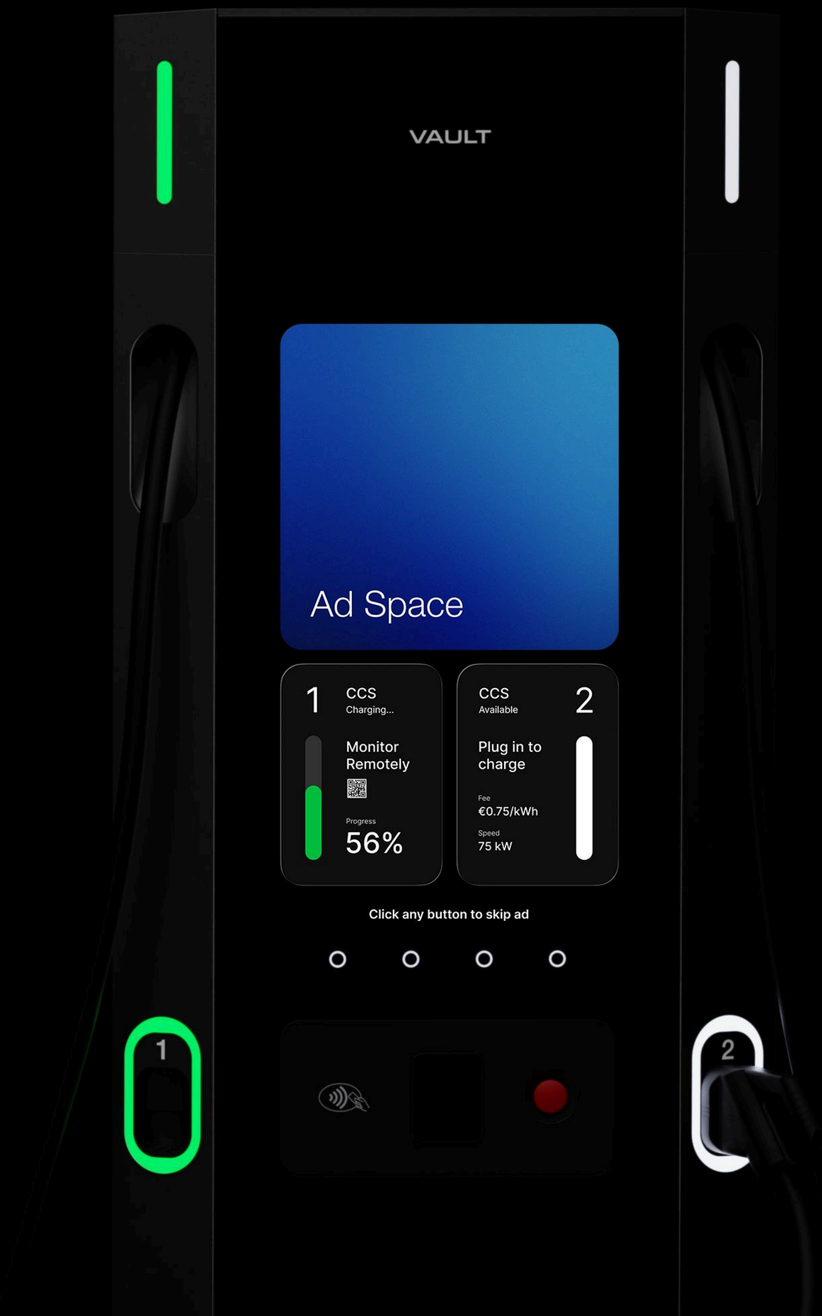
Once the charge starts, indicators pulsate with green color

Design

Interface flow
Standby

Unobtrusive ads

During inactivity, the screen displays ads while keeping the charging status visible.



Design

Interface flow
Completion

Convenience

The charging session is automatically finalized once the connector is returned

Charge indicators

Once charging finishes, the indicators stop pulsing and turn solid green.

Design

Satellite Components

1 **Canopy**
PC · 8 mm · clear

2 **Extension covers**
Steel · 1 mm· powder-coated

3 **Roof hood**
Steel · 1 mm · bent· powder-coated

4 **Extensions**
Aluminum · cast · powder-coated

5 **Mounting plate**
Steel · 2 mm

6 **Backside cover**
Steel · 2 mm · powder-coated

7 **Holsters**
ABS · injection-molded · matte

8 **Pillars**
Aluminum · extruded · powder-coated

9 **Panel**
PC · 8 mm · matte black · opaque

10 **Base profiles**
Aluminum · extruded

11 **Front panel**
PC · 8 mm · smoked black · clear

12 **Elevation spacer**
Steel · 1 mm · bent

13 **Base plate**
Steel · 10 mm

Fasteners

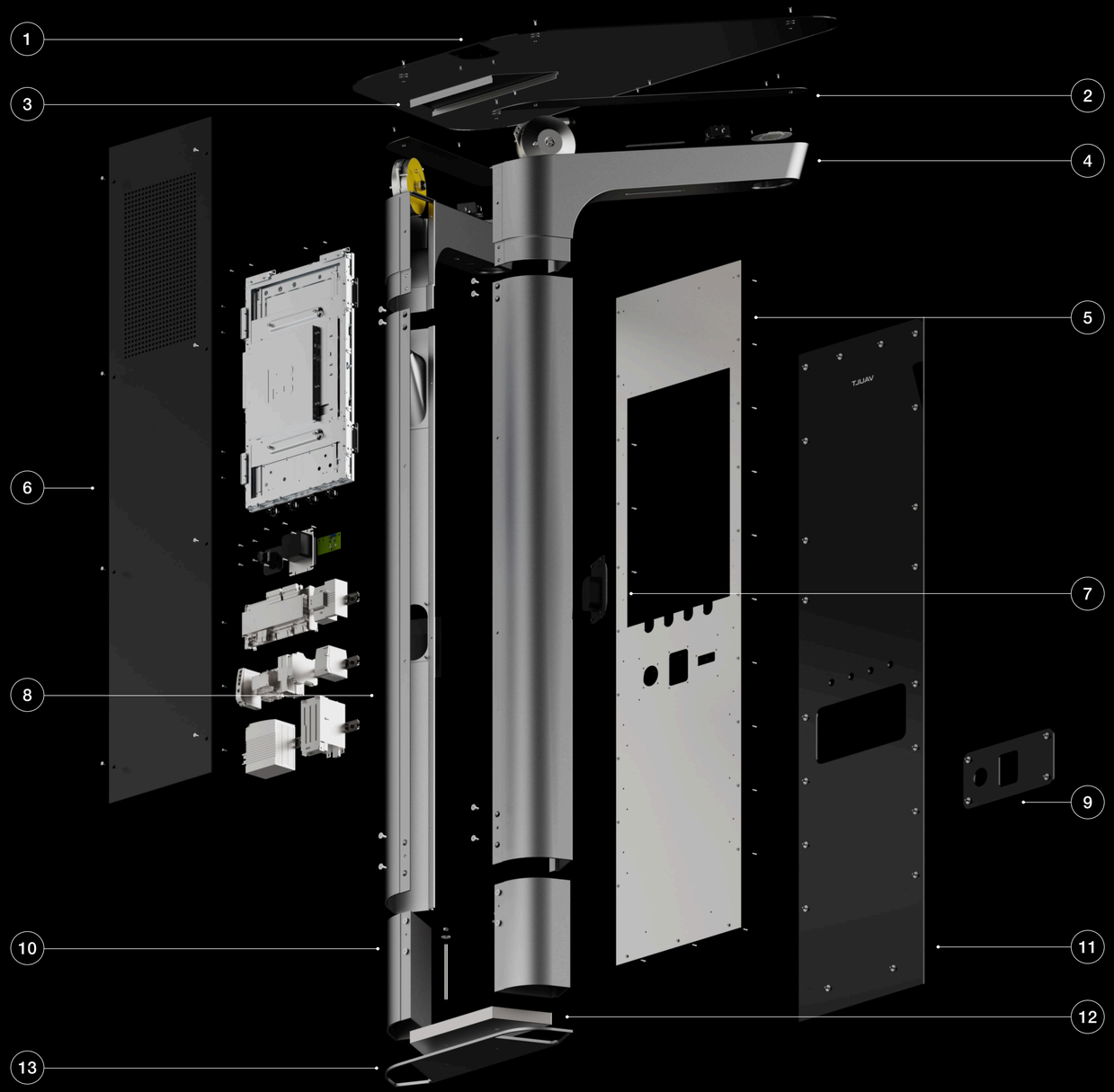
Structural
M10 CSK · ISO 10642

Panels/Canopy
M6 CSK · ISO 10642
Bonded M5 studs

Internal components
M5 BH · ISO 7380-1

Mounting plate
M5 SH · ISO 4762

Electronics
M5 SH · ISO 4762
M4 SH · ISO 4762



Production ready

The satellite integrates all components and mounting details, ensuring a design ready for production.

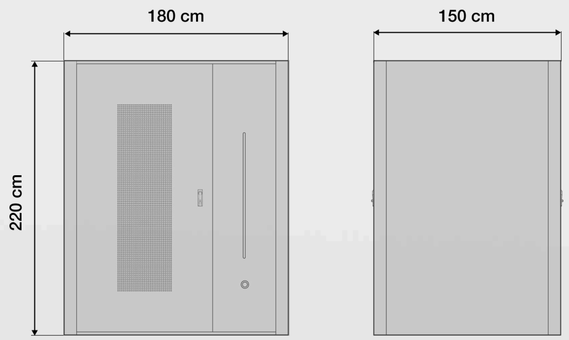
Design

Satellite
Assembly

Fundament

Design

Cube



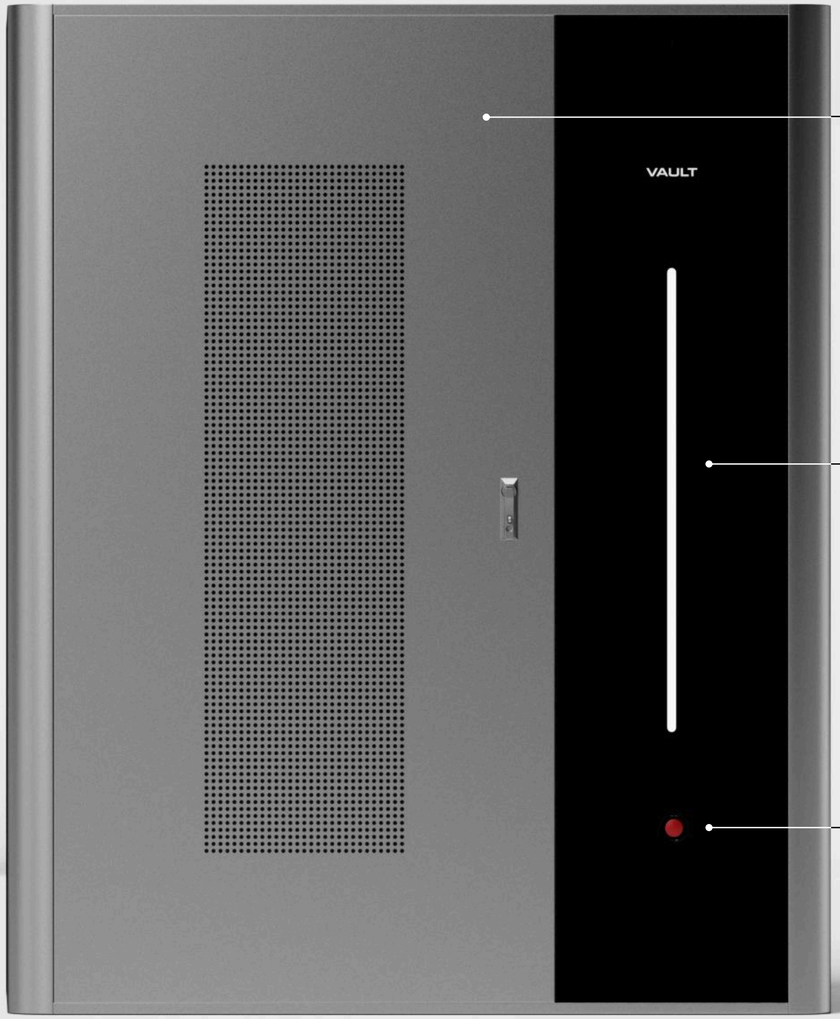
Off-site installation

The Cube’s larger form factor is designed for placement away from the parking area, as it is accessed only by maintenance staff.

Design

Cube

Rear side



Two-part doors

Enclosure fully opens at both the front and rear through a system of two-part doors

Led indicator

Displays the Cube’s operating status. White when functioning and red in case of fault.

Safety button

Provides immediate system shutdown in emergency situations.

Thank you