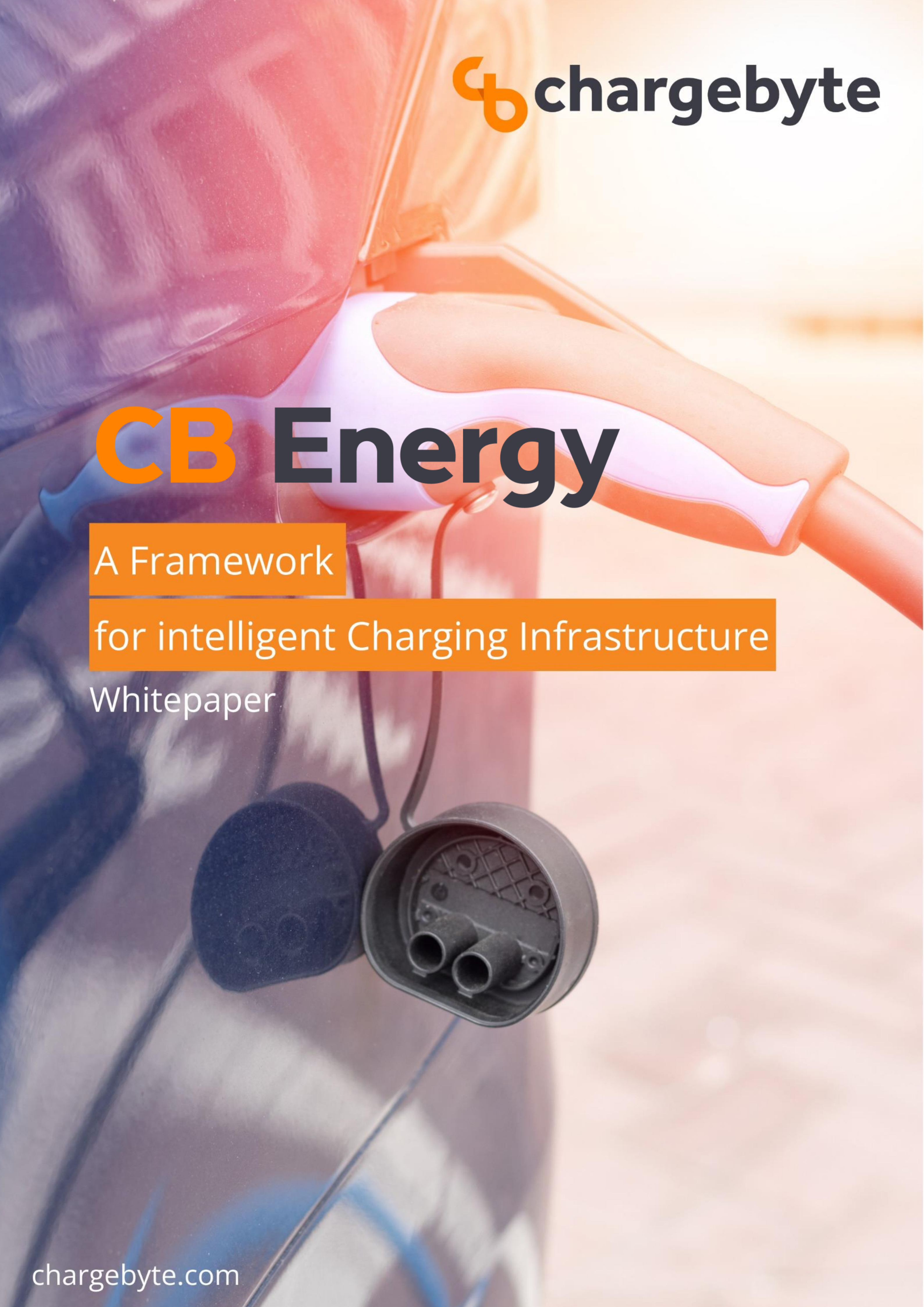

chargebyte

CB Energy

A Framework for intelligent Charging Infrastructure

Whitepaper

chargebyte.com

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1. Introduction

As the market for electric vehicles grows, so does the charging infrastructure for private use – over 80% of electric vehicles are charged at home or at work. Home charging stations – hereinafter referred to as "wallboxes" – serve as the electrical interface between the vehicle and the grid, making them a crucial component in the low-voltage network. It's no surprise that grid operators are seeking digital interfaces to manage charging processes.

Following a period of high subsidies, the market has entered a phase of consolidation. However, this challenging market phase presents an opportunity to expand market share. Today, significant differentiation can only be achieved through digital innovation.

The typical digital applications with increasing demand are:

- Integrated PV surplus charging through native compatibility with PV systems,
- Charging based on dynamic electricity tariffs (spot market rates),
- Active/dynamic load management,
- High-level charging with ISO15118,
- Bidirectional charging,
- User management via RFID/App,
- Charging transaction billing with the employer,
- Smartphone apps and/or dashboards,
- Open APIs for communication with higher-level EMS systems, grid operators, or billing platforms.

Figure 1: Upgrading to a smart wallbox is achieved quickly and with high quality through the use of the CB energy framework.

2. Definitions of V2X and HEMS

List of Abbreviations

EVSE	Electric Vehicle Supply Equipment
ESS	Energy Storage System
HEMS	(Home) Energy Management System
API	Application Programming Interfaces or Programming Interfaces
SoM	System on Module (a computer in module format)
SBC	Single Board Computer (a single-board computer)
HAL	Hardware Abstraction Layer
OTA	Over-the-Air Updates

Communication with the Electric Vehicle

Two types are commonly used (simplified):

- "Basic Charging" according to IEC 62196 and 61851 through simple PWM control
- "High-Level-Charging" according to DIN 70121 or its successor ISO 15118

Communication with a Backend

The OCPP (Open Charge Point Protocol) has become the standard for this purpose. A backend is used for the central management and billing of charging points. The protocol is continuously evolving and now supports additional use cases.

Communication with local Energy Systems

Standardization

This area is still underdeveloped in terms of protocols, and there are no industry-standard protocols or norms like those found in other communication channels.

Two projects are noteworthy:

- *EEBus* - an open standard. A few manufacturers of charging stations, heat pumps, and PV inverters use this protocol, but it has not achieved widespread market penetration. Additionally, this initiative is focused on Germany and the Central European market; for manufacturers from other continents with a global presence, the standard is considered insignificant due to its limited global adoption.
- On a global scale, the Smart Home standard *Matter* is gaining traction. The technology's adoption is significantly broader, as all major digital players are involved. However, it is not yet sufficiently advanced for professional energy management. Currently, the standard is limited to relatively simple smart home interactions. Nonetheless, energy information is already defined within the standard, and there is a clear trend toward expanding functionality in this area. Although it

is still early to fully engage with this standard, it is evident that Matter will play a role in both residential and commercial sectors in the future.

Middleware

The issue of lacking standards inevitably leads to the creation of many isolated solutions in the field of EMS (Energy Management Systems). Almost every manufacturer of PV inverters develops a proprietary EMS, covering only the ecosystem of its own products. To establish cross-manufacturer energy management, middleware is required. Middleware integrates the protocols (APIs) of various manufacturers and products. Middleware is akin to an operating system, on which various programs can be installed depending on the application. In our case, these are not programs operated by users through a graphical interface but rather small driver modules that interact with the API of a product, such as a PV inverter. Middleware processes the data to enable manufacturer-independent control ultimately.

Figure 2: Excerpt of Supported Products

At its core, CB energy is a middleware that integrates various components to ultimately optimize energy management. The system is visualized using the CB App.

Figure 3: CB App

3. The Market Potential of integrated HEMS

An increasing portion of the population is engaging with energy-related topics. Photovoltaic systems, balcony power plants, and battery storage are becoming more mainstream commodities. With the continuous growth in renewable energy and electromobility, many charging points will be installed in private, semi-public, and public parking areas over the next decade and integrated with energy systems.
A wallbox is thus a suitable "carrier medium" for introducing digital energy innovations to end customers. One of the most significant criteria for purchasing decisions today is already the intelligence and digital functionality of a charging station.

We assert:

A wallbox is the gateway to an intelligent energy system.

With CB energy software, a smart wallbox can be enhanced with the functionalities of a Home Energy Management System (HEMS). The wallbox transcends its role as a mere 'socket' and becomes a platform for energy-related services. Traditional, complex, and costly energy managers are rendered obsolete by this integrated solution. A HEMS software add-on simplifies the user's entry into the realm of energy optimization and also offers attractive upselling potential.

4. Possible Combinations

The core of CB energy is, as described earlier, middleware. This middleware can be installed as a simple Linux application in addition to other firmware components on a physical device. Operating and communicating over the local network offers a range of advantages, which will be discussed in section 6.1.

The following product variants are possible:

CB energy installed on an external device

CB energy on an EVSE charging controller

CB energy as an application in the firmware

The first variant - using an external device - is excluded from this white paper. We focus on the variants that are integrated into a wallbox, thus enhancing the wallbox as a product.

5. The Foundation of a Future-Proof Wallbox

It is evident that a wallbox sold in 2024 should fundamentally be a software-defined product. The lifecycle of a wallbox is likely to span 10 years or more. During this period, electromobility will experience a digital transformation akin to the changes seen in phones since the first iPhone.

5.1 Hardware

Many manufacturers have chosen to optimize their margins by cutting costs on hardware. Many wallboxes can be controlled via ModBUS or a simple IP protocol, but this limits their digital functionality in terms of energy management. While the wallbox can be integrated into higher-level HEMS systems through these interfaces, it cannot act as a higher-level system itself.
Newer devices are already using more powerful Linux-based CPUs as digital requirements continue to rise. Although high-performance hardware comes at a slightly higher price, these devices can be continuously supported with software upgrades for many years, significantly increasing the value of the wallbox.
Most buyers, provided they are aware that they are purchasing a future-proof product, are willing to accept the small additional cost.

5.2 Software

Once the decision for future-proof hardware has been made, it is also important to choose a software platform that is as future-proof as possible. Software development involves significant time and cost, and there are many technological risks that are often difficult to assess. CB energy offers absolute future-proofing and comes with a wealth of core functionalities. It saves thousands of developer hours and, in any case, provides a very high level of maturity, allowing it to be deployed directly in the field. The majority of technical risks are mitigated, as the solution has been in use across a variety of products for years. The time-to-market for CB energy-based products typically takes less than a quarter—sometimes even just a few weeks.

Open Source

CB energy is based on the open IoT platform nymea.io, which is already used in many modern IoT products. The software can control dozens of devices regardless of their interfaces, APIs, and protocols and comes with all the tools, libraries, and services necessary for a modern IoT product. Additionally, it includes a framework for user interfaces, enabling the rapid creation of attractive and high-performance end-user apps. The freely available CB energy App serves as a reference.

chargebyte is fundamentally committed to a strong focus on open source and also relies on the open-source charging stack 'EVerest' for other communication channels. CB energy and EVerest can, of course, be operated in parallel, creating a symbiotic relationship that represents one of the most advanced firmware stacks for charging stations globally.

6. Prerequisites

The Wallbox must have

- A Linux-capable charging controller, such as CCC or Charge SOM,
- a Linux module (SoM)[1] as a base, or
- a SBC[2] integrated into the wallbox enclosure.

[1] System on Module

[2] Single Board Computer

6.1 Installation

ⓘ This step is not required if a chargebyte controller is used.

CB energy is installed as an application within the Linux system. The software has low resource requirements. The storage needs vary depending on the number of installed interfaces/features:

- 50 MB RAM ±30%
- 100 MB Flash ±50%
- 15 to n MB Flash memory for storing log data

Common embedded Linux platforms are entirely sufficient. The CB energy stack can be built for all major Linux operating systems (Yocto, Debian, etc.).

Once the software is installed and properly configured, it can be controlled via the CB App. The app can be customized as a white-label solution to match the corporate identity of a B2B client, if desired.

6.2 Integration of Wallbox Functions

ⓘ This step is not required if a chargebyte controller is used.

To enable CB energy to control the internal functions of the charging station, an integration plugin needs to be developed. This plugin communicates either through the firmware's programming interface (HAL) or via ModBus with the charging controller.
This integration is typically created by a chargebyte expert within a few working days but can also be done by third parties.

6.3 Rebranding

Upon request, the entire CB energy App can be customized to meet individual design specifications or completely adjusted in terms of structure and feature set. The team at chargebyte GmbH is happy to provide advice on the available options.

7. Topology

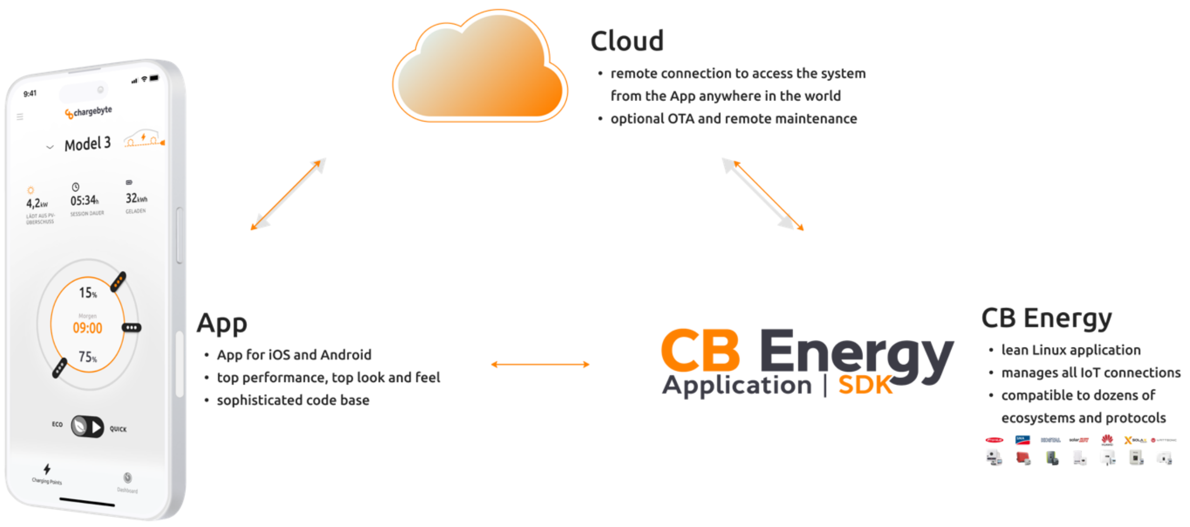

Figure 4: Topology of the Framework

7.1 nymea:core

As previously mentioned, CB energy is based on the IoT platform "nymea". This server application handles the communication and regulation of all connected participants.

nymea:core is a highly mature communication stack that has been under development since 2013 and has been commercially successful since 2016.

- Used thousands of times
- Proven and reliable
- Subject to continuous development
- Streamlined framework, highly extensible
- Open Source
- Growing platform

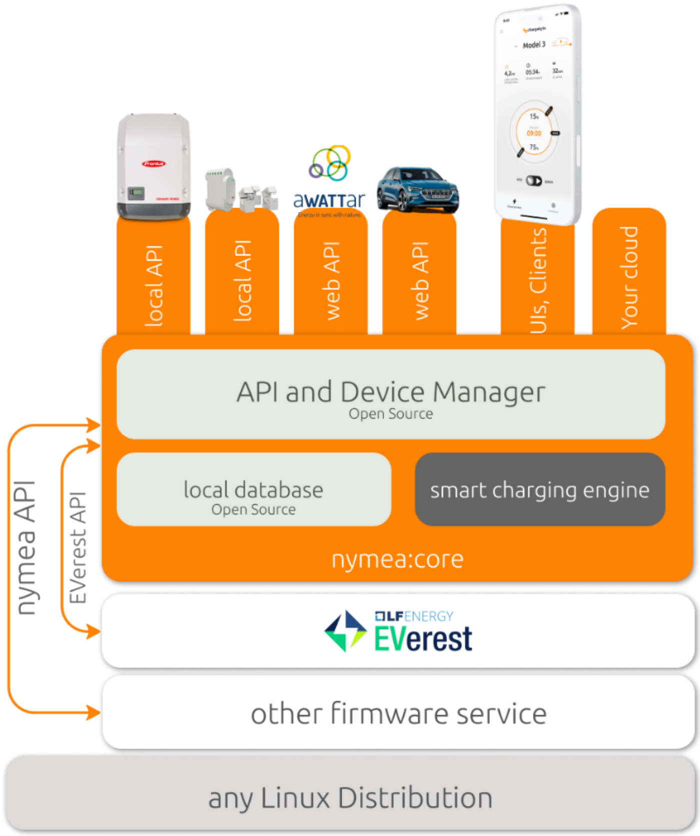

Figure 5: Linux application at the "Edge"

Local operation at the “Edge” offers the following advantages compared to cloud solutions

- Complete sector coupling is only possible locally. Field buses and protocols such as ModBus TCP/RTU, UDP, MQTT, etc., can only be accessed freely within the local network. Most of the devices available on the market can only be controlled locally.
- No cloud connection is required for functional operation
- No cloud infrastructure costs are incurred
- No costs for API/data access (some manufacturers charge fees)
- Fast response times
- More reliable than the cloud
- Privacy-by-design, as all data is stored locally

7.2 App

The CB energy app is a derivative of the nymea:app, which can be ported to all common platforms. The frontend is based on the cross-platform Qt framework, meaning it is executed as native code on the end device and therefore runs very smoothly. The quick connection setup and the refined code greatly enhance the user experience. The app can be easily customized as a white-label solution to meet various needs and can be launched as an independent product app in the app-stores. A white-label version can be submitted to the app stores in record time.

Figure 6: Symbolic representation of the CB energy white-label app

7.3 Cloud

Although the functional part is independent, a minimalist cloud application serves two important functions:

- Remote connection
- Optional OTA and remote maintenance

8. CB energy from the User's Perspective

8.1 Setup

The setup process is outlined at www.nymea.energy/b2b:

- The network is configured. Depending on availability, you can choose between
  - Wifi and
  - Ethernet.
- If a PV inverter is present, the setup of the PV system will begin.
- If a smart meter tariff is applicable, its configuration will be initiated.
- If no meter is integrated with the PV system yet, an external meter will be set up.
- Key details about the electric vehicle will be provided.

8.3 Operation

The user story defines a process that is initiated every time the user connects the car to the charging station:

- The user receives a notification. By clicking on this notification, the home screen of the app opens.
- This screen is used to enter the following information:
- Current battery level (in %) (if the So Cis not read via the Car-API).
- Desired charge level percentage by a specific time.
- Desired charge level at the target time.

The user can switch between two modes at any time:

- **Quick**: Charge as quickly as possible, considering load limits.
- **Eco** (with PV Surplus): charge up to 30% immediately. Afterwards, charge as much as possible with PV surplus. Depending on the desired target, the system will determine an optimal charging plan.

9. Features

9.1 Integration of existing measurement Devices

The information underlying PV surplus charging is the measurement of the electricity flow at the grid connection point. A meter measures the electricity flow at the source and is therefore also known as a source meter. Most PV surplus charging solutions come with a meter. Here is an example video showing how an external meter – costing a few hundred euros – needs to be installed and configured in combination with a wallbox.

In many cases, however, a meter is already installed with the PV system, making it redundant to install an additional meter. CB Energy, as one of the few providers, supports the majority of PV inverters available on the market and can read data from already installed measurement meters (e.g., Fronius Smart Meter, Kostal Smart Meter, etc.). The list of integrations is available at https://www.nymea.energy/integrations.

This not only saves the cost of an additional meter but also the installation in the control cabinet, resulting in further significant cost reduction. If no meter is available, we recommend the Shelly 3EM, as it can be relatively easily installed and transmits data via WiFi over the local network, eliminating the need for wiring.

or

Figure 7: Symbol images of PV inverters

9.2 Eco Modus (PV Surplus and/or Spotmarket)

The Eco Mode is the intelligent mode offered by CB Energy. Using machine learning, weather forecasts, and historical charging data, a charging plan is created for each charging point. The Eco Mode has the following advantages and considerations:

- A minimal charge ensures the vehicle's availability for emergencies.
- A dedicated dashboard in the app displays the amount of "cheap" PV electricity used.
- In practice, charging is rarely done exclusively with PV electricity, as 6 amps per phase is often the minimum charging power. Instead, the system charges the vehicle with as much PV electricity as possible in the energy mix. The amount of grid electricity used can be chosen by the user.
- All calculations and sensitive data are NOT stored in the cloud but are processed LOCALLY. This guarantees 100% privacy. While the system does retrieve data from the network, no data is sent to the network.

9.3 Why is PV surplus charging becoming increasingly interesting?

- Feed-in-tariffs are unattractive in most countries, as all subsidies have expired.
- The economic efficiency of a PV system increases with self-consumption. For “self-produced” electricity, grid fees, taxes and other charges are avoided.

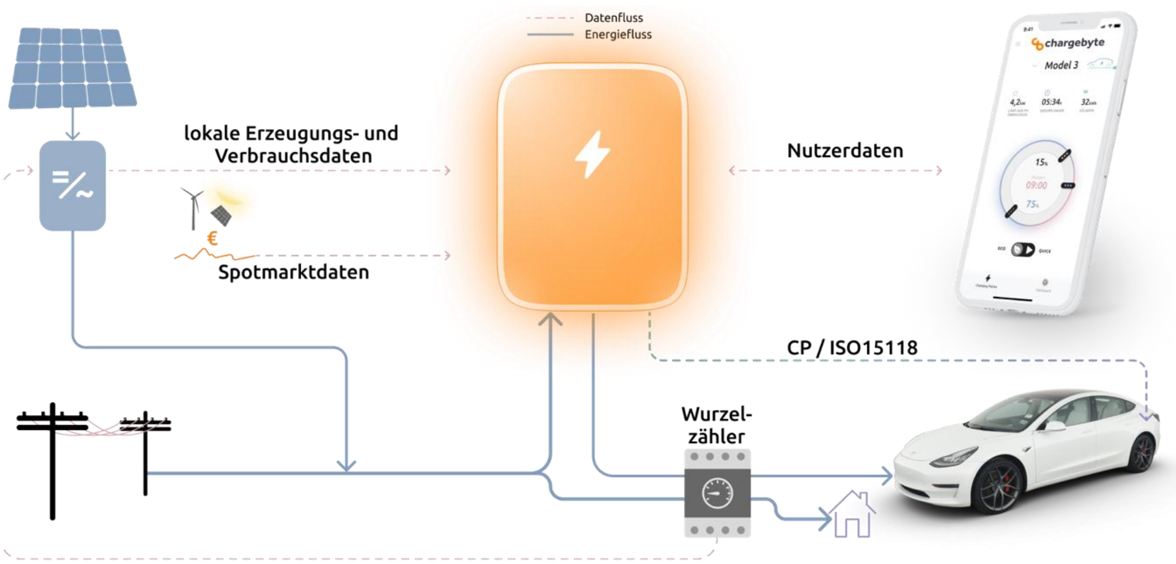

Figure 8: Communication and Energy Flow in Charging with Dynamic Power Sources

9.4 Why is Spot Market Charging becoming increasingly interesting?

Those who do not have their own PV system can still benefit from fluctuating, inexpensive, renewable energy through so-called spot market tariffs. Spot market tariffs, also known as "smart meter tariffs," require a smart meter so that the grid operator can measure and allocate electricity consumption in small time intervals. The spot market is an electricity exchange where electricity tariffs are calculated and settled very short-term (24 hours). The prices of the EPEX Spot electricity exchange underpin all dynamic electricity prices.
When charging with dynamic electricity tariffs, network fees and taxes must be paid as usual.
A few years ago, fluctuations in EPEX Spot prices were minimal, making dynamic tariffs largely unattractive. Today, the electricity market experiences significant fluctuations, making hourly billing very attractive.
The example of "aWATTar hourly" shown below demonstrates that gross prices can vary by up to 40 cents. With a full charge of an electric vehicle, this can result in savings of around 30 euros in optimal cases.
In Eco Mode, CB Energy shifts charging to a more favorable time period.

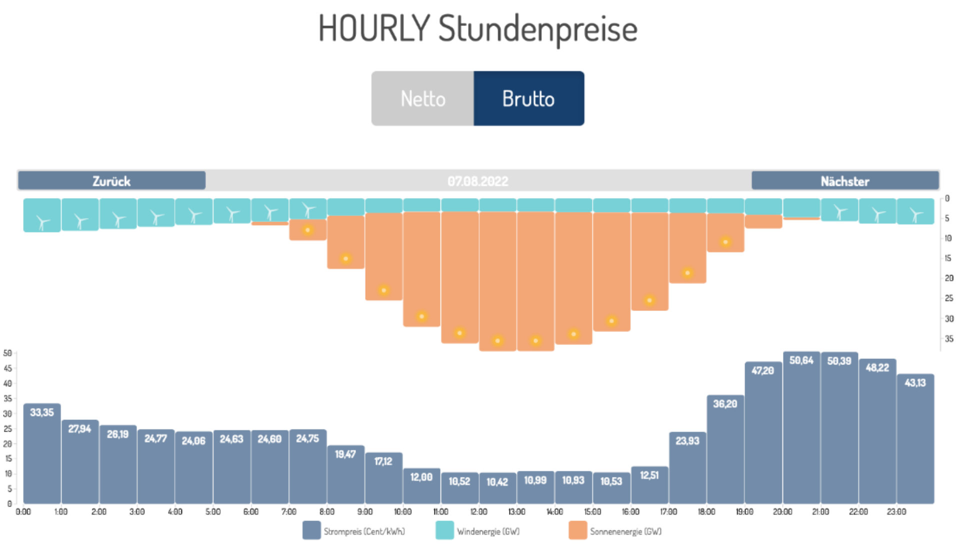

Figure 9: The electricity prices for the aWATTar Hourly Tariff as of August 7, 2022

The large fluctuations arise due to the significant share of inexpensive, renewable energy and the prevailing issues in the energy market, which are due to dependencies on foreign energy suppliers. Charging with spot market tariffs not only has a positive impact on the economic balance of the vehicle owner but also serves as an incentive for the use and expansion of renewable energy sources at all levels. Additionally, consuming renewable energy at the time of its generation has a very positive effect on grid stability across Europe.

9.5 Load Management (Blackout Protection)

The grid connection can become overloaded when multiple charging stations or other large consumers operate simultaneously. Therefore, load management is mandatory.
At CB Energy, the load is automatically regulated and limited. Load management is active in both Comfort and Eco modes.

If no meter is available to measure the total current at the connection, the system will always limit the load during two or more active charging sessions:

- For one active charging session → full power.
- For two or more active charging sessions → Equal distribution.
- The connection maximum is configured during setup.

If a meter is present, all electrical loads can be operated up to just below the load limit. If the load at the household connection suddenly increases—such as when a household appliance is turned on—the charging currents are immediately reduced by the necessary amount.

Many PV systems have an integrated meter, but any other external meters can also be connected.
There is generally no limit to the number of wallboxes that can be integrated, as long as there are no network-related limitations (such as IP subnet, ModBus RTU, etc.).
Each user can set a charging target for each wallbox. The distribution of charging currents is therefore primarily based on these charging targets.

9.6 Dynamic Load Management

CB Energy not only supports PV surplus charging but can also be used for dynamic charging and load management in semi-public areas (e.g., office parking lots). Each user of the charging park can configure the charging point, vehicle, and charging target using the CB Energy app, ensuring seamless use of the charging infrastructure.

Energy allocation is based on the set charging target at each charging point. CB Energy automatically calculates the individual charging profiles for each charging point. In addition to the maximum total power, factors such as PV surplus, spot market tariffs, power limits of vehicles/wallboxes/charging cables, and other variables are considered.
A PV system or spot market tariff is not a prerequisite. CB Energy is a leader in terms of price-performance ratio in modern, dynamic charging solutions. Any charging station connected to CB Energy can be used.

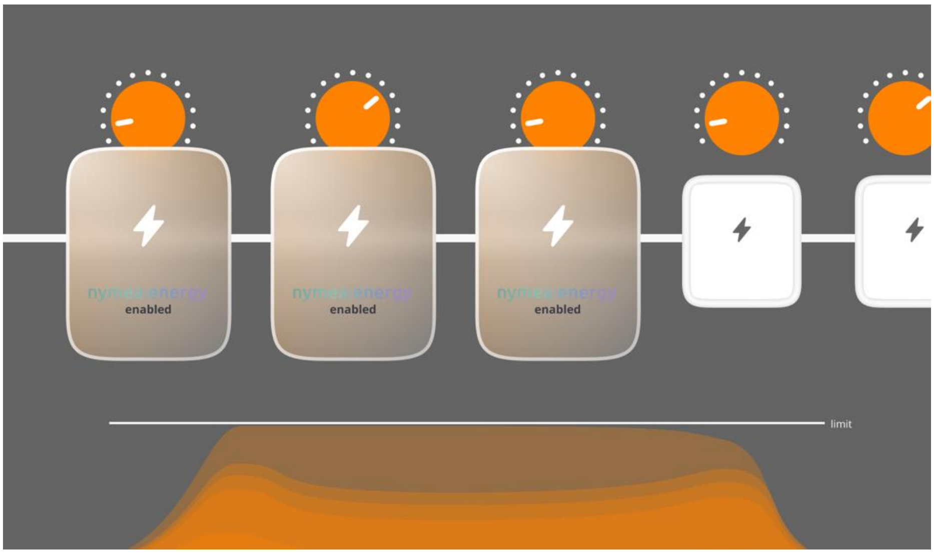

Figure 10: Load Balancing

10. Integrations

10.1 Available Integrations

The integrations listed here are an excerpt. A continuously updated list, including documentation, can be found at: https://www.nymea.energy/integrations

Photovoltaic Inverter

- Fronius
- SMA
- Kostal
- SolarEdge
- Huawei
- Sungrow
- Sunspec (almost all PV inverters, as well as some meters and batteries)

Charging Stations

- KEBA
- Webasto
- go-eCharger
- Schrack i-Charge
- Pantabox
- PCE

Meters

- All Smart Meters coupled with the PV inverter
- Sunspec-compatible meters
- Shelly EM3 (WiFi-based for retrofitting)
- B+G SDM 630 and other ModBus or ModBus TCP-based meters

Household Appliances

- Miele
- Bosch Siemens Household Appliences (B/S/H)

Other Systems

- Shelly
- myPV
- KNX (über IP Gateway)
- Loxone (über virtuelle I/Os)
- Solar-Log

Cloud-based APIs

- aWATTar
- OpenWeatherMap (Weather Forecasts)

11. New Integrations

Integrations („nymea Integration Plugins“) can be quickly and easily created by chargebyte GmbH, external service provider, or in-house. All documentation is quickly accessible at: https://nymea.io/documentation/developers/write-plugins.

The fastest and thus likely most cost-effective option is to assign this task to the experts at chargebyte GmbH.

12. Roadmap

As of: **10.09.2024**

The order of implementation depends on the requirements of the B2B partners:

- Charging session export for company car billing
- Dynamic load management
- RFID / User Management
- Charging schedule Display

13. Vision

In just a few years, with several million BEVs connected to the grid, a new class of energy storage in the terawatt range will emerge. However, standards are still lacking to digitally and reliably manage this collective energy storage. Currently, only a very small portion of home charging stations are accessible via OCPP or centrally from a cloud. CB Energy's software is a cutting-edge IoT stack that can quickly adapt to new standards or platforms.
With each CB Energy-based product, a new, controllable "cell" in the collective storage is created. We anticipate that CB Energy will capture a significant market share of the collective energy storage in a few years and thus will be beneficial to the grid (operator) on a global scale.

14. Competition

The market for intelligent charging solutions is rapidly gaining momentum. Here, we list some example products that are in direct or indirect competition with CB Energy.

14.1 Smart Wallboxes

- Zappi https://myenergi.de/produkte/zappi-wallbox/
- Wallbox.com www.wallbox.com
- Smappee https://www.smappee.com/ev-wall/
- SMARTFOX Pro https://youtu.be/rwAMYXt8X4o
- openWB https://openwb.de/main/

14.2 External Solutions

Open Source bzw. Software-only

- evcc.io www.evcc.io
- openEMS www.openems.io

Ecosystem Solutions

- Huawei Emma

Cross-Manufacturer System Solutions

- GridX www.gridx.ai
- Smartfox https://www.smartfox.at
- Solar Manager https://www.solarmanager.ch
- Enpal https://www.enpal.de/enpal-one
- 1Komma5° https://1komma5grad.com/heartbeat

Cloud Solutions

- Clever-PV https://clever-pv.com
- EV-Autocharge https://www.ev-autocharge.com/

15. Reputation

The team at chargebyte (formerly nymea GmbH) has been working on the nymea framework since 2013. The software has already been deployed in several tens of thousands of devices
The team possesses extensive expertise in the areas of interoperability (buses, protocols, APIs), embedded systems, and user experience. Since the nymea platform represents several man-years of effort and has been continuously perfected, there are very few comparable platforms that are so well-suited for intelligent embedded energy management systems.
Nymea is also based on Qt/C++ and, due to its small footprint, is ideally suited for embedded Linux systems. Comparable platforms, such as openEMS, require dozens or even hundreds of MB of RAM, which is rarely used for cost reasons.
Beyond the technical platform, there is considerable practical experience with digital business models based on IoT products. The managers at nymea GmbH bring a wealth of validated knowledge to product management in a strategic context.
Excluding purely open-source projects, no other company offers such a mature overall package for a state-of-the-art IoT product.

16. Window of Opportunity

Those providers who strengthen their position as digitalization leaders with CB energy today will enjoy comparatively high sales figures in the coming years.

We look forward to an informal and pleasant initial conversation. Of course, we are happy to showcase our technologies as well. Feel free to contact us at info@chargebyte.com!

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18. Version

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Version: **3.0**
As of: **10.09.2024**