White Paper

ZVEI-Show-Case PCF@Control Cabinet

Product Carbon Footprint Calculation of a Control Cabinet using the Asset Administration Shell

German Electro and Digital Industry Association

Content

Management Summary

Sustainability and the circular economy, including the associated decision-making criteria, are already a relevant topic today and are likely to become even more important soon. In this context, the topic of sustainability is fraught with great uncertainty, as the details and possible implementations in this area are not clear and can hardly be outlined. For example, the declaration of the product carbon footprint (PCF) will become one of many new regulatory requirements of the European Union under the Sustainable Products Initiative (SPI) as part of the Green Deal. Following on from this, industry in all sectors will probably be required to provide certain product information in the form of a Digital Product Passport (DPP).

To prepare the industry with a flexible, efficient, and future proven way to fulfil these requirements the ZVEI-Show-Case “PCF@Control Cabinet” will demonstrate the feasibility of ZVEI’s DPP4.0-concept for a Digital Product Passport.

ZVEI’s DPP4.0-concept is based on two main pillars, developed under the Industrie 4.0 (I4.0) initiative:

- the Digital Nameplate (DNP4.0) via IEC 61406 (Identification Link, under development)
- the Asset Administration Shell (AAS) according to IEC 63278 (under development)

The basic idea of I4.0 is to link the OT and IT levels (operational technology and information technology). Each asset of the OT level (hardware and software) becomes an I4.0 component by linking it to the so-called Asset Administration Shell (AAS), which creates a general interoperability between all I4.0 components and connects the I4.0 component with the IOT world in a plug-and-play manner.

The AAS represents a framework format for describing the assets in a standardised and semantically unambiguous form and thus functions as a digital twin of the asset. The described characteristics and properties of the respective asset are summarised in the AAS in submodels.

In the demonstrator of the ZVEI-Show-Case on display at Hannover Messe 2022, visitors can observe how the product carbon footprint (PCF) of a control cabinet consisting of many different products from the participating companies is calculated automatically.

The visitor learns how the submodels for the Digital Nameplate (DNP4.0) and the submodel for the PCF value of the individual components are realised and how the PCF calculation of the overall system “control cabinet” was implemented.

This concept can be easily extended in the future by adding additional submodels representing product information that needs to be documented under new and other regulatory requirements. It is a pattern that is easy to learn and therefore easy to repeat.

A remarkable team of ZVEI members has contributed to the project in order to show in an interdisciplinary and cross-company effort under the umbrella of ZVEI, how to prototypically combine different aspects that are important for the calculation of PCF values in order to meet regulatory, legal, economic and technical requirements.

Amongst others the following aspects are outlined in the upcoming chapters:

- What are the roles, their relations and deliverables (products and related information)?
- What are the different methods of PCF calculations and how to combine the values properly?
- What needs to become standardised and what is the current status of standardization?
- How to fulfil requirements of security and trustworthiness (e.g. to ensure that values authorized by the component provider remain unchanged)?
- How to apply the concepts of AAS and submodels to capture the lifecycle of the control cabinet?

The demonstrator at Hannover Messe 2022 is a first version in which not all concepts have been implemented to the possible depth. Some questions are still open but will be answered in the next steps. In particular, the stated values of the product carbon footprints are to be regarded merely as examples for the technical proof of concept and, where applicable, as rough estimates - there is no claim to accuracy / correctness. In particular, the comparability of the product-specific product carbon footprints with each other is not given at this point in time.

1 Introduction and Motivation

Climate change mitigation is one of the greatest challenges of our time. To overcome this challenge, a major goal of the European Union is to reduce greenhouse gas (GHG) emissions. In several stages, climate neutrality (no net emissions of GHG) is to be achieved by 2050.
As part of the European Green Deal and the building blocks contained therein, for example the Circular Economy Action Plan (CEAP) and the Sustainable Products Initiative (SPI), the introduction of a Digital Product Passport is also being discussed to achieve this goal, which provides documentation on various product information and in particular on sustainability indicators such as the product carbon footprint (PCF).
The technical implementation of such a Digital Product Passport has not yet been clarified. The approach to determining the PCF of a product also poses various challenges that are essential for a reliable calculation. In this regard, the need for action is not limited to the individual companies concerned, but also requires an overarching approach along the entire potentially global value chain.
The ZVEI has set itself the goal of illustrating this coordination along the value chain. Therefore, ZVEI is developing a show case in which the product carbon footprint of a control cabinet is calculated. Various companies are actively involved in this show case in different roles in the value-added network.
The show case also demonstrates a feasible concept for the Digital Product Passport. The concept is based on the ZVEI Digital Nameplate (via IEC 61406 “Identification Link”, under development) and the Asset Administration Shell (AAS). The link to the Digital Nameplate is obvious since it is also a compilation of production information. The AAS serves as a technical tool to allow the automated interpretation of the documented product information because of its standardised semantic descriptions. For the automated data exchange between stakeholders, different data providers, e.g., data bases and networks, can be contacted via data interfaces (connectors) to retrieve the needed information as shown in Figure 1.

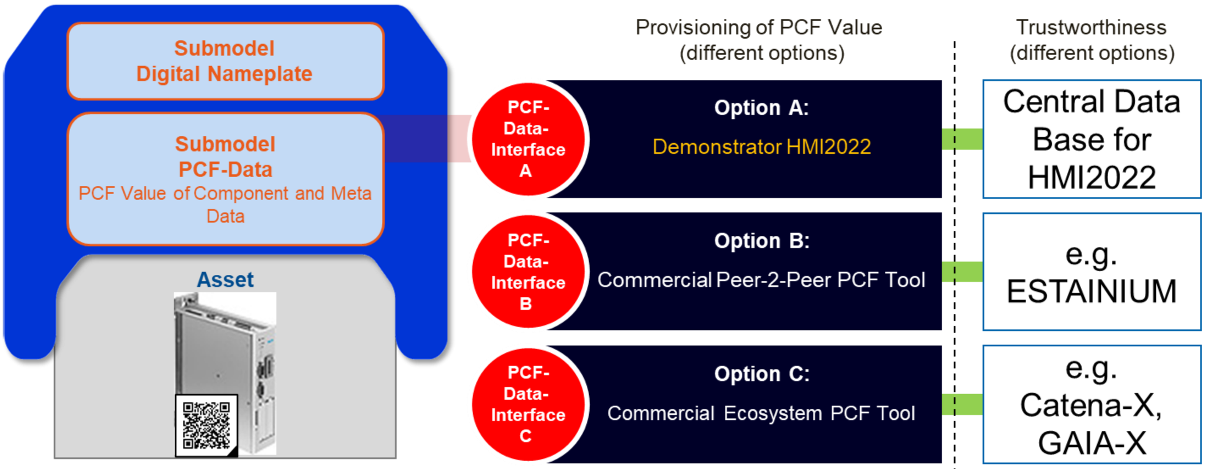

Figure 1: Different exemplary data providers that can be contacted via interfaces

Furthermore, the AAS is used for the conception and implementation because the AAS offers the possibility to address the regulations still to be expected in the future in a uniform manner within the framework of a Digital Product Passport.
The ZVEI-Show-Case PCF@Control Cabinet is organised in five working groups working on different items, as depicted in Figure 2.

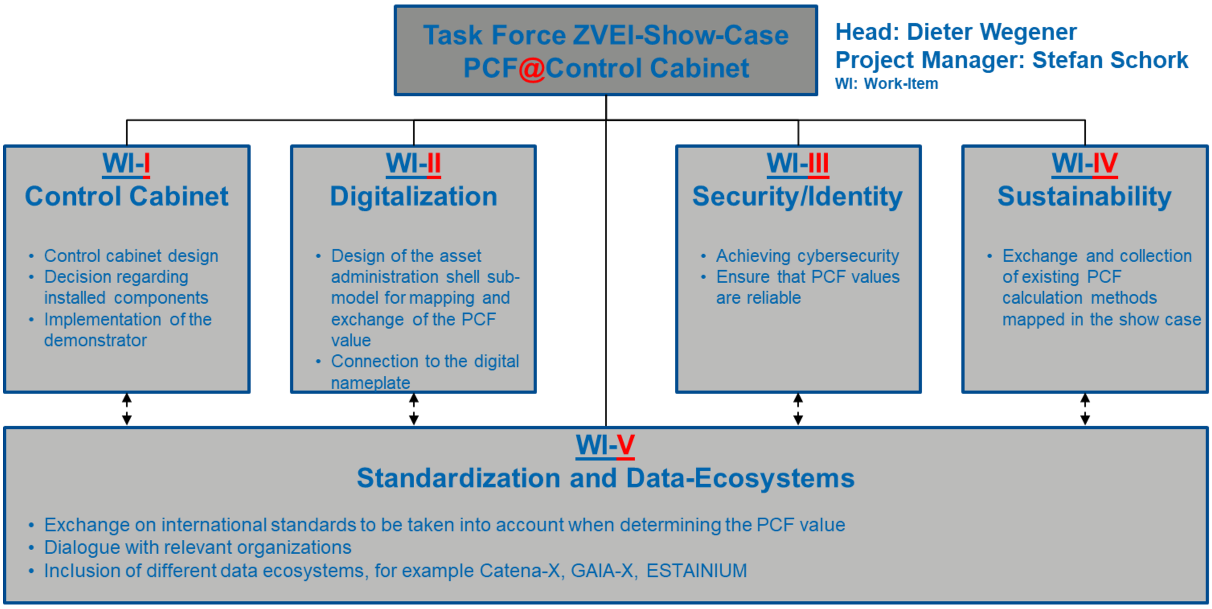

Figure 2: Organisational diagram of the five working groups in the ZVEI-Show-Case

2 The Example: Control Cabinet

To be able to proceed as practically as possible, a control cabinet was put together for the ZVEI-Show-Case from products and components of participating companies. For this purpose, the entire value chain was simulated, from which various user stories can be derived that are intended to make the Industrie 4.0 technologies around the Asset Administration Shell tangible. These practical examples are intended to illustrate the benefits of these technologies.
In this project, the control cabinet stands symbolically for every type of system integration for which an exchange of data between different companies and different engineering systems is necessary. This service, in which standard components are combined to form a functioning electrical system, with its very individual character, places very high demands on system interoperability and the associated almost data exchange. These requirements form the basis of the Industrie 4.0 idea of being able to manufacture extremely individual products with comparably low efforts.
System integration begins with the electrical design. In this phase, the components and the function of the system are defined. The documents are then handed over to the system integrator by a bill of materials (BOM) and a circuit diagram. Then the value add on the system begins with scheduling and handling of material and finally the assembly of the components and wires.
As to be seen in Figure 3, the process of building an electrical system consists of very many interfaces between the companies and IT systems involved. In addition to the fact that the engineering data must be transferred, the data of the individual components must also be transferred from the suppliers to the system integrators. In this simple example, there are already 15 companies involved, from which data on 56 different products and components, which finally lead to a system of 93 parts in total, are required to fulfil the value add.

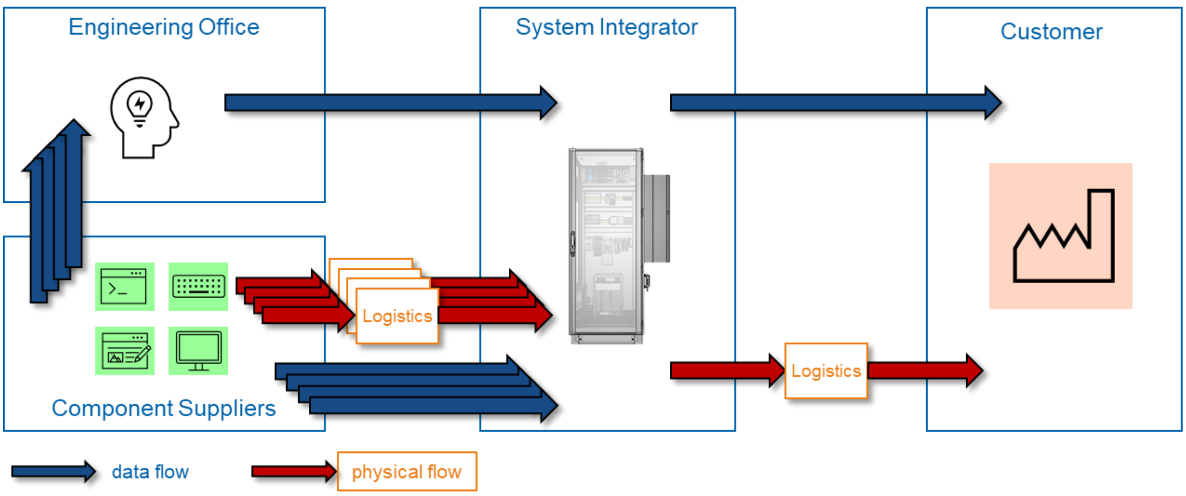

Figure 3: Data and physical flow in the system integration process

Currently, data collection is mostly done manually, as the existing technologies such as ECLASS for data exchange are not used by the masses or cannot be used due to a lack of software tools. The ZVEI-

Show-Case presents a way of overcoming the organizational and IT system boundaries using the example of the product carbon footprint to minimise the effort required to transfer product information from the manufacturer to the user. This is possible by using the existing technologies of the Asset Administration Shell and concept repositories (e.g. ECLASS, IEC CDD) that are applied within the framework of the Digital Product Passport.

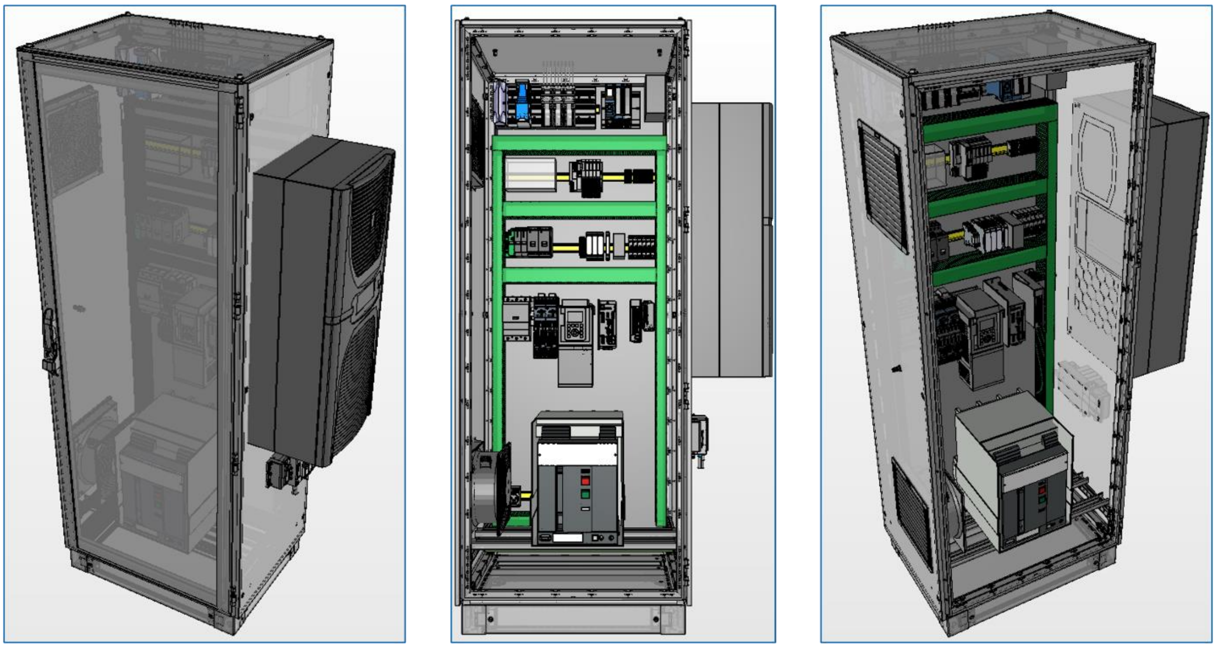

Figure 4: CAD-model of the control cabinet presented at the Hannover Fair 2022

At the Hanover Fair 2022, the control cabinet will for the time being only consist of the components of the participating companies, without any wiring to realise a function of the system, as shown in Figure 4.

3 CO_2-Footprint Calculation Method

CO_2 footprints are currently a much-discussed topic with far-reaching implications for individuals as well as companies. Companies can make a proactive contribution to transparency by reporting their corporate or product-related CO_2 footprint, so called PCF (product carbon footprint).
There is today a wide landscape of standards and guidelines when it comes to greenhouse gas (GHG) quantification. But not all GHG calculation methods are equivalent and comparable, a framework to establish a common understanding of considered life cycle aspects and boundaries is necessary, as much as a standardized way of communicating environmental disclosure to avoid greenwashing.
Among the ecosystem described in Figure 5, interests can be focused on the following aspects:

- the Quantification driven by IEC and ISO standards, regroups all standards related to calculation methods of CO2. These standards are mainly referenced and used in the showcase to define the product carbon footprint calculation method. Horizontal standards, e.g., IEC 63372, can highlight the electric and electronic equipment.
- the Life Cycle Assessment (LCA) is a key pillar for sustainability and for GHG impact calculations because it focuses on the full product and system life cycle from the design phase up to the recycling phase after the end-of-life, including all intermediate stages. It is clearly a big challenge for the CO2 footprint calculation but definitively key for a consistent calculation.

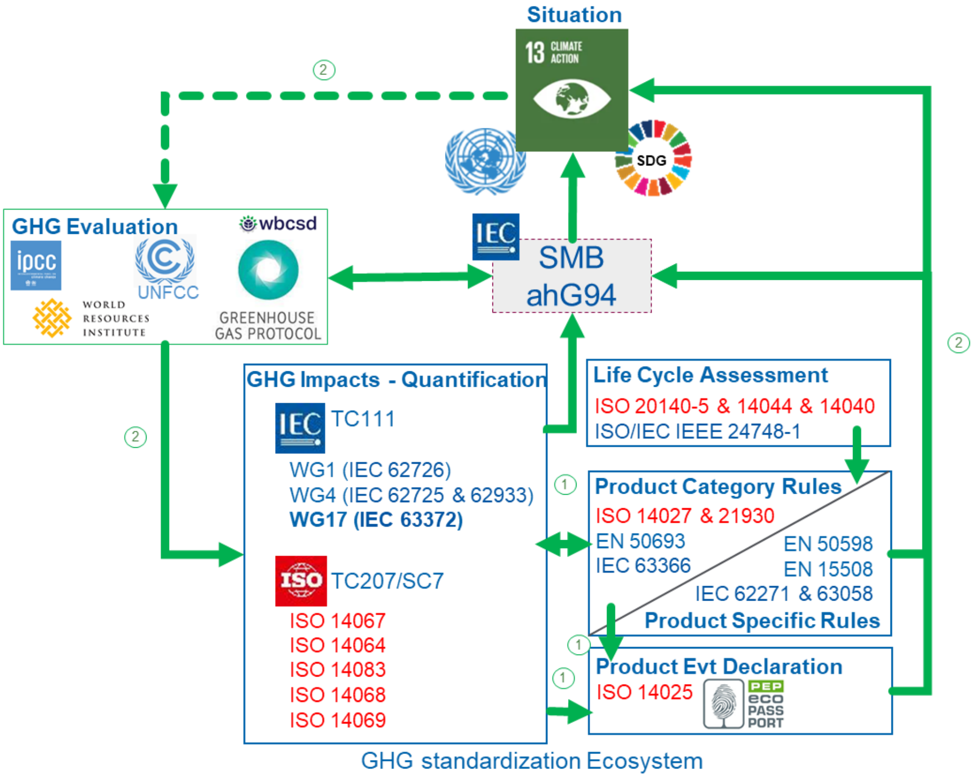

Figure 5: Overview of existing standards and guidelines regarding GHG quantification and calculation

As it can be understood through Figure 5, the ecosystem is structured around two main circles, the first between standardization bodies (1) (Quantification / Product Rules / Life Cycle Assessment) to improve continuously their standards by learning and sharing their respective knowledge and skills. And the second is around the situation, the assessment, and standards (2) to really track the production of standards and their implementation.
To reinforce and generalize this continuous evolution, and to manage all activities done around the GHG impacts, IEC, within the SMB, has completed its organization with an Ad-hoc Group (AhG94) started in April 2022 with the goal to accelerate the definition and the consistency of standards.
The calculation of PCF values for products along the life cycle consists of scope 1 and scope 2, from the usage of directly CO2-equivalent emitting energy sources (such as fossil fuels) and the used electric energy mix. Additionally, scope 3 includes the supply chain, upstream transport processes and manufacturing, but these values are mostly modelled and no primary data. To increase the reliability of scope 3 PCF values, an automated transfer of PCF values across the supply chain would be a conceivable approach. This ties in with the general idea of transferring data between stakeholders and the proposed concept of the DPP4.0, introduced in chapter 1.

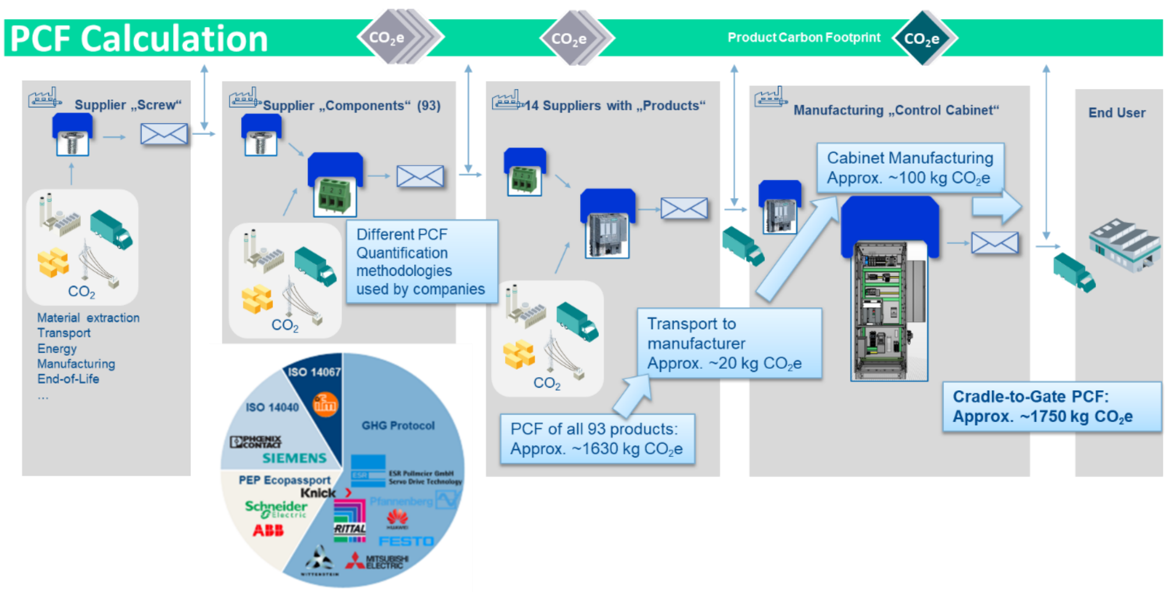

Figure 6: Exemplary supply chain of an integrated product

For the show case, the goal is to especially demonstrate the feasibility of using the DPP4.0 in order to calculate the PCF of an integrated product or system across the supply chain, as shown in Figure 6. For

the demonstrator on the Hannover Fair 2022, only the tier 1 relation between product manufacturer and system integrator is investigated.
In Figure 6 the PCF calculation methods used in the showcase and the respective approximate results are displayed. Every partner calculated the PCF values of their products and components according to a “cradle-to-gate” approach, which was decided among the participating companies as the best-practise approach. The approach included material acquisition, manufacturing, and transport to manufacturing site, while manufacturing involves assembly, components/parts manufacturing, end-of life treatment of generated waste and packaging. In total the PCF values of more than 93 components are collected to be approximately 1630 kg CO_2e. The manufacturing of the cabinet in Chemnitz resulted in approximately 100 kg CO_2e. For the transport from manufacturer to system integrator, a uniform CO_2e per kilometre and kilogram constant for transport by lorry was used[1], resulting in approximately 20 kg CO_2e.
The PCF calculations of the control cabinet are intended as examples for the technical proof of concept with no claim for accuracy / correctness since there is no comparability of the product-specific product carbon footprints now. As for now, the total PCF value is calculated by simply adding up PCF values calculated with different PCF calculation methods. Two companies are using ISO 14040, two companies PEP Ecopassport, one company using ISO 14067 and other partners using GHG Protocol quantification. It was agreed among the partners that this simple addition of PCF values is useful to achieve the required transparency for a system integrator.

4 Industrial Security

Security is required along the value chain to support regulation and as an enabler of features and value-added services.
The security aspects like authentication, access control, integrity and confidentiality need to be provided for the protection of the AAS and its functions:

- Authentication and access control: Access along the value chain shall only be granted to authorised and authenticated companies. Sensitive data about suppliers of subcomponents must not be generally open and accessible.
- Integrity: Data exchanged between partners in the value chain, such as PCF values and contents of bills of materials, must be protected against unauthorised modification and manipulation.
- Confidentiality: encryption shall be possible for any communication to prevent access to business-relevant data by uninvolved parties.

Security functions will also be provided to support trustworthiness of information along the value chain. This enables the reliable use of certified information, such as PCF values, even across different instances of the value chain that cannot independently determine/re-measure such values. Here, the efficient integration of independent certification bodies will be made possible through security infrastructures and mechanisms.
Protection of intellectual property and trade secrets along the value chain is also needed to be supported and preserved, making it more difficult to introduce counterfeit components along the supply chain.
In addition to the enablers of services through security, the protection of attacks against the system (in terms of availability and resilience) is also an important goal. Hackers must not be able to stop the value chain or obtain information on blackmail attempts through targeted attacks on digitised applications (Ransomware attacks).
All stakeholders along the value chain must also be able to operate the security. This requires user-friendly and standardised applications and the integration of interoperable security functions which are as transparent as possible. For this purpose, a security infrastructure for the use of cryptographic functions must be created using existing international standards from ISO, IEC, IETF or W3C.
The principle of “security-by-design” requires the consideration and integration of these aspects from the very beginning.

5 The Asset Administration Shell

Industrie 4.0 describes the increasing convergence of the real world in the operational technology level (OT) and the virtual world in the information technology level (IT), in which more and more assets, such as machines and field devices, have intelligent sensor and actuator technologies and are networked via the Internet of Things. To enable this networking in an effective and efficient way, the interoperability, based on regulatory frameworks and standards, must be ensured. This is achieved by linking the assets to the Asset Administration Shell (AAS), as shown in Figure 7. The AAS therefore is an interoperable implementation of a digital twin and contains a variety of information, for example about the physical

[1] In accordance with the DSLV guide on calculating GHG emissions for freight forwarding and logistics services (March 2013)

and functional properties of the respective asset. By linking assets with Asset Administration Shells, the assets become Industrie 4.0 components.

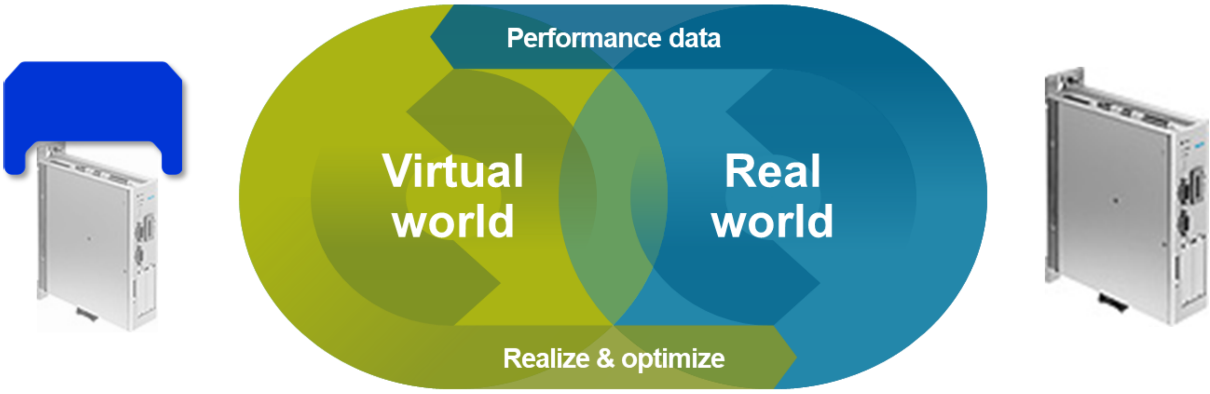

Figure 7: Convergence of OT and IT using the Asset Administration Shell (Source: Based on Siemens AG)

The AAS provides – among others – structured information (data and services) to describe assets along their life cycle. For high flexibility and adoption to all kind of products the AAS uses the concept of submodels. Submodels are structured information for a special purpose (e.g. Digital Nameplate, Product Carbon Footprint, Technical and Operational Data, Documents), which is depicted in Figure 8. AAS relates information to assets and harmonizes the access to it on its north bound interface. Submodels integrate different data sources on their southbound interfaces. This concept ensures the unified usability of information from different sources which itself remain unchanged.

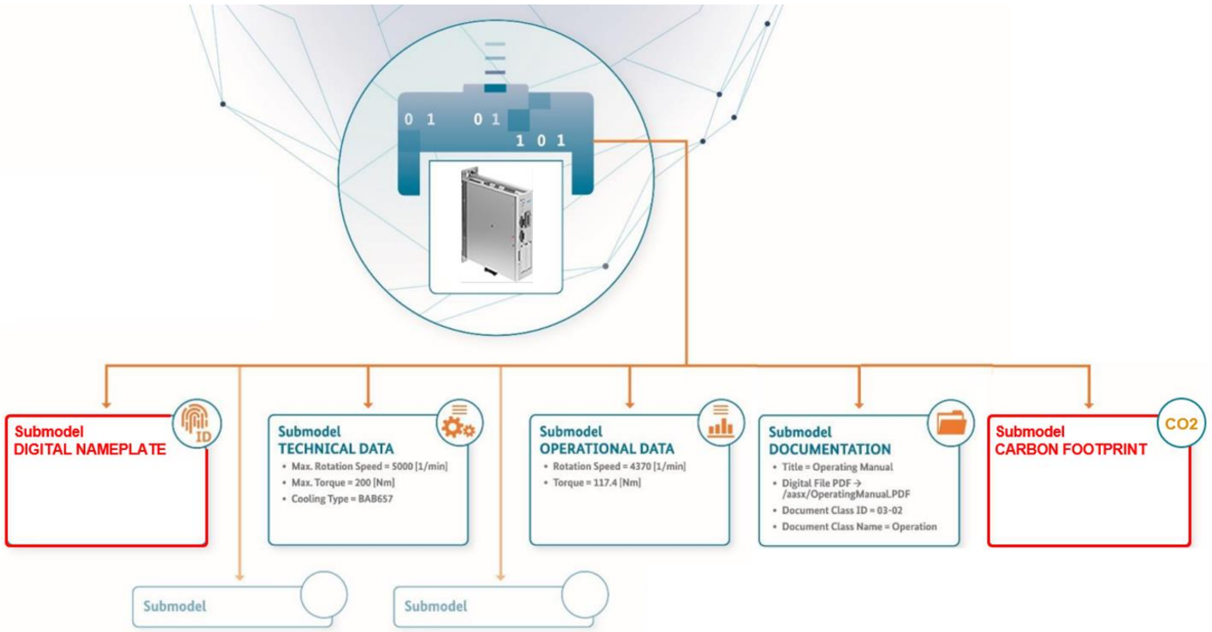

Figure 8: Submodels of the Asset Administration Shell (Source: Based on Plattform I4.0 - Details of the Asset Administration Shell)

To be able to exchange the concrete information, such as the PCF value and the underlying calculation method across companies, this information must be made available in a standardised way. For the Asset Administration Shell, the necessary standards are described in IEC 63278-series (under development):

- IEC 63278-1 "Asset Administration Shell for industrial applications – Part 1: Asset Administration Shell structure"
- IEC 63278-2 Asset Administration Shell for industrial applications – Part 2: Information meta model"
- IEC 63278-3 Asset Administration Shell for industrial applications – Part 3: Security provisions for Asset Administration Shells"

For the description of AAS-submodels (or AAS-submodel templates) references to a semantic dictionary is required. For AAS the dictionaries of IEC 61360 CDD (Common Data Dictionary) and ECLASS are used.

More detailed information regarding the Asset Administration Shell can be found in the publication series of the Plattform I4.0, "Details of the Asset Administration Shell"[2].

[2] Plattform Industrie 4.0 - Details of the Asset Administration Shell - Part 1 (plattform-i40.de)
Plattform Industrie 4.0 - Details of the Asset Administration Shell - Part 2 (plattform-i40.de)

5.1 Using the Asset Administration Shell for Regulatory Means

Due to new regulations, data on products must increasingly be made available and enriched during the lifecycle of the respective product.
The I4.0-component (consisting of an asset and a corresponding AAS) is a concept which is able to implement such regulatory requirements in a uniform and advantageous way. Therefore, the AAS can be used as a concept for an upcoming Digital Product Passport, the DPP4.0. For the ZVEI-Show-Case, the assumed regulatory requirement is the calculation and documentation of the product carbon footprint. As an example, the control cabinet is used as explained in chapter 1. Therefore, the control cabinet as well as all products and components inside the cabinet are provided with an Asset Administration Shell. All products and components including their Asset Administration Shells are delivered by the product manufacturers to the system integrator (manufacturer of the control cabinet) who is then able to use the included information to calculate the product carbon footprint of the completed system, as shown in Figure 9.

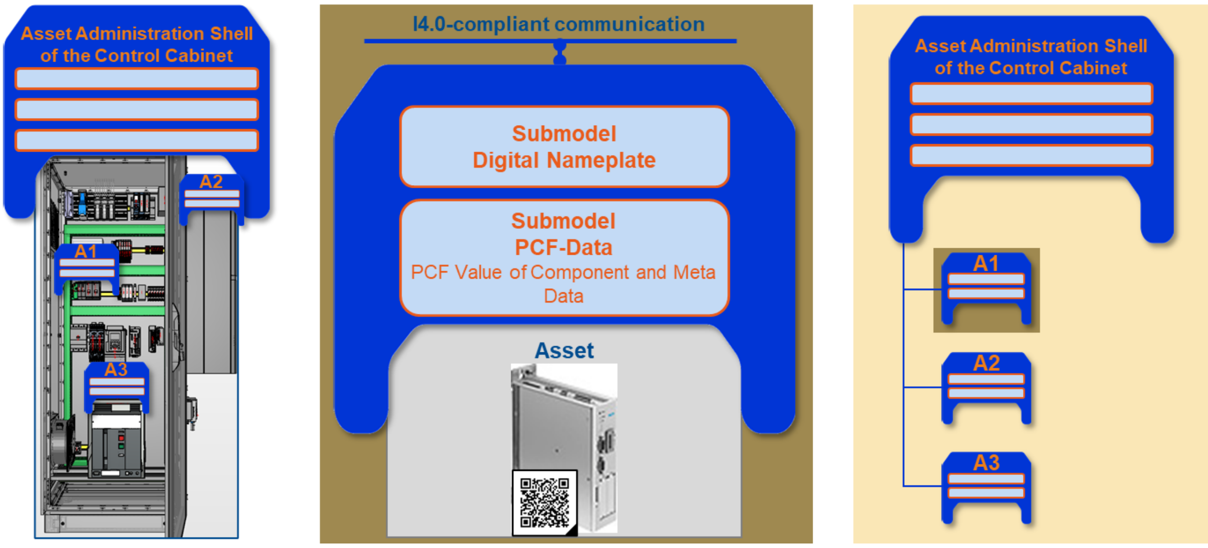

Figure 9: Asset Administration Shells of the control cabinet and the integrated products

This concept can be used to provide all sorts of information about the products, such as compliance with legislation and standards, technical specifications or safety instructions. Some of this information are already required on the (physical) name plate and can be provided in digital form using the Asset Administration Shell (DNP4.0). The link between an asset and its AAS is created via the Identification Link (IEC 61406, under development) that is applied on the asset.
The amount of information provided via the Asset Administration Shell is technically not limited and can be extended as desired. This leads to an optimal technical basis for a Digital Product Passport. It is also possible for companies to provide additional information voluntarily, e.g., to enable new digital services and business models, as shown in Figure 10.

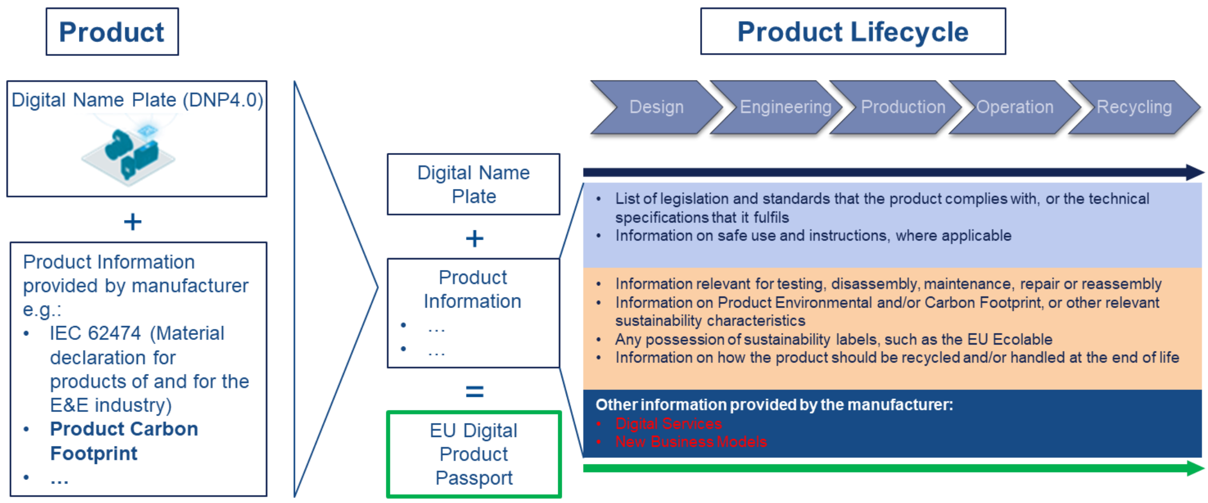

Figure 10: Possible product information that can be provided using the AAS

5.2 Submodels of the Asset Administration Shell

The AAS offers the possibility of structuring information (data and services) uniformly in the form of so-called submodels. Among other things, it provides the so-called AAS Interface for this purpose.
In the ZVEI Showcase, the submodels "Digital Nameplate for Industrial Equipment" (DNP)[3] and "Product Carbon Footprint" (PCF) are used as examples to provide a first version of the planned "Digital Product Passport" (DPP) of an asset. Additionally, a submodel for the bill of materials (BOM) is used for the control cabinet and some of the integrated products to provide the list of present parts.
The PCF submodel is in the early phase of development, its standardization is considered and shall include the experiences made in the show case. In the following we provide details on the preliminary state of the PCF submodel used in the showcase.
The submodel is modelled according to the I4.0 specification of the submodel metamodel according to the currently established modelling best practices from I4.0 community[4]. This enables a uniform structure (syntax) of the PCF submodel as well as uniform access in the application via the REST API of the submodel.[5]
The elements (properties) of the submodel, which are decisive for the unambiguous interoperability of the PCF values are expressed in conformity with the specifications of the information model (based on ISO 13584-42/IEC 61360-2). By referencing to concept repositories, such as IEC CDD or ECLASS, they receive unambiguous semantics. This is depicted in Figure 11.

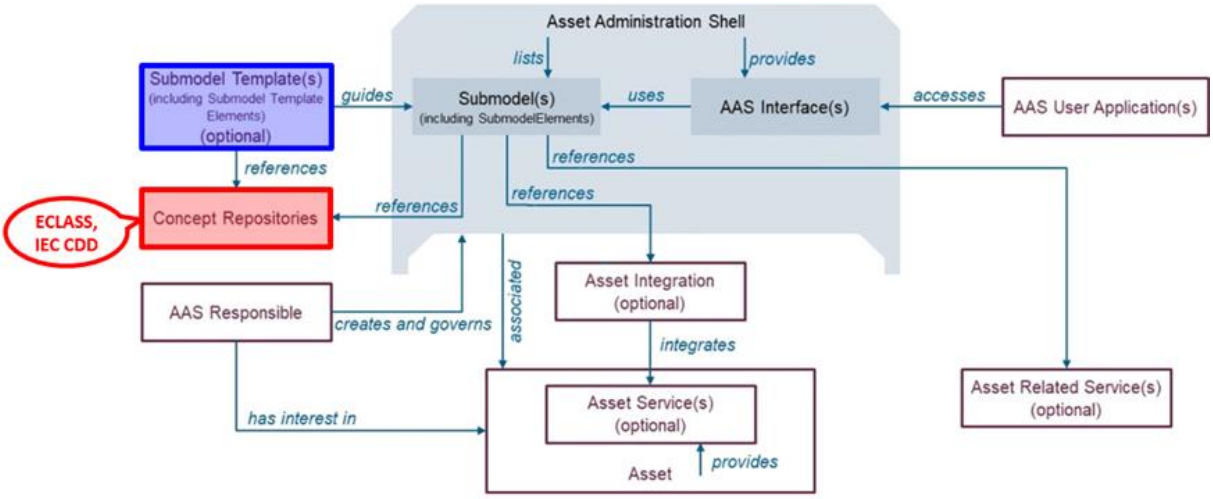

Figure 11: Relation between the AAS and external services and applications based on IEC 63278

In its current form for the ZVEI-Show-Case, the PCF submodel consists of the following properties to describe the PCF information:

- The PCF value in kg CO2-equivalent
- The calculation method used to calculate the given PCF value, e.g., ISO 14067 or the GHG protocol as shown in chapter 3
- The respective life cycle phase for which the given PCF value was calculated, e.g., cradle-to-gate, production or distribution
- References to describe the quantity of objects the PCF value was calculated across, e.g., when calculated for batches of smaller parts
- The location from which the asset is distributed to a customer

These properties are summarized in a "SubmodelElementCollection", which can be used multiple times, for example to include PCF values reflecting multiple life-cycle phases and to provide PCF values calculated with different calculation methods.
The list of included components within the control cabinet is maintained using a Bill of Material (BOM) submodel which is part of cabinet's AAS. The BOM submodel is furthermore present in further components having internal components (e.g., a PLC containing a memory card) to indicate their structure. For the show case, the PCF submodel of the control cabinet includes additional information modules called "FootprintInformationCombination" which are used to sum up the PCF values of the contained components. These information collections, and therefore the PCF value of the control cabinet, are generated recursively based on the contents of the BOM submodel and updated dynamically when BOMs are changed.

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[3] Submodel Templates of the Asset Administration Shell-ZVEI Digital Nameplate for industrial equipment (Version 1.0) - zvei.org
[4] https://admin-shell-io.github.io/questions-and-answers/
[5] Plattform Industrie 4.0 - Details of the Asset Administration Shell - Part 2 (plattform-i40.de)

The combination of unified syntax and semantics of elements of the submodel simplifies the calculation of the PCF value of the control cabinet. The REST APIs of the PCF submodels of the components are used to access the PCF information. The combination of DNP, BOM and PCF submodels allow comprehensive dashboards to be able to reflect the current configuration of the cabinet and the resulting PCF as shown in Figure 12.

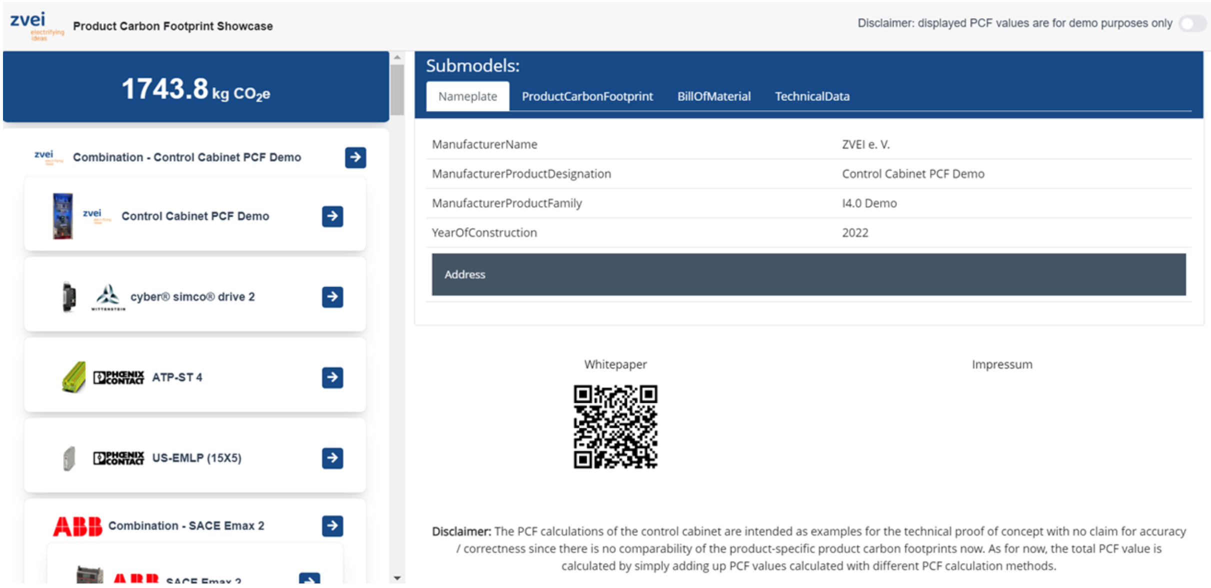

Figure 12: Dashboard for the ZVEI-Show-Case PCF@Control Cabinet

Potentially, the PCF submodels allow the integration of different PCF data sources as shown in Figure 1. This integration of different data sources is implemented by the AAS server serving the respective submodel in such a way that the integrated data source can be used unchanged. The only prerequisite for this is that all information is available at the interface of the data source that is needed to transform it syntactically and semantically correctly to the corresponding submodel elements that are accessible to North bound. In addition to the actual PCF values, this also includes the specification of the standards according to which they were determined.
This approach conceptually ensures maximum flexibility for the integration of existing, but also future sources of PCF data and thus forms, among other things, investment protection for the installed base. Furthermore, it lays the foundation for global suppliers to decide where and how they want to store PCF values of their components and make them available for use.

6 Outlook

The demonstrator at the Hannover Fair 2022 impressively shows how product information can be made available with the help of the Asset Administration Shell (AAS) in conjunction with the Digital Nameplate (DNP4.0) and can be used automatically in relevant processes. This was exemplified by the calculation of the product carbon footprint (PCF) of the control cabinet across the supply chain.
Through this applicable technical solution for the provision of product information, the solution shown also represents a concept for a Digital Product Passport (DPP4.0).
In the further course of the project, the concept is to be transferred to other processes in order to underline its feasibility and potential. The engineering process, for example, is to be given greater prominence. Furthermore, the inclusion of OPC UA is envisioned, e.g., with a use-case in the area of energy efficiency in an automobile factory in collaboration with the VDMA and in a chemical plant in collaboration with NAMUR.
In terms of sustainability and PCF calculation, the reliability of the PCF data is expected to be increased by bringing the results shown in Chapter 3 to standardisation organisations to work towards standardised PCF calculation methods, so that the results of different calculations are comparable and usable in subsequent calculations. This is also needed to create a basis for certification providers, to realise the meaningfulness of the PCF values by certifying them and the used calculation method. This leads directly to the question of how certificates are given. Furthermore, we will investigate possibilities to increase the scope to higher tier suppliers to cover a larger range of the supply chain in order to show feasibility and potentials of the automated PCF information provision.
One major topic will be the expansion of the showcase in terms of connecting the different PCF data sources as depicted in Figure 1. In this regard, questions in terms of how the data connectors will be realised arise and have to be discussed in the working groups and with the respective data and trustworthiness providers.
AAS aims to ease system integration and to lower engineering efforts. This will be supported by additional meta-information of AAS and SMs. Such meta-information belong to a well-defined set of

categories and will support intelligent search of AAS and SMs as well as access control to it. (For further information see also “Functional View of the Asset Administration Shell in an Industrie 4.0 System Environment"). This may lay the foundation to even deeper integrate with other networks like GAIA-X and Catena-X.
In this showcase meta-information assignment, intelligent search and access control will demonstrate the reduction of effort to determine the components which are currently part of the specific control cabinet.
This will support the ability to automatically re-calculate the PCF value of the control cabinet after replacing a component.
Work is continuing to incorporate the results and experiences gathered in this showcase into regulatory and standardisation processes, especially regarding the Digital Product Passport.

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