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A Framework for Implementing the IEC CIM - Interoperability and Consent in the Energy Retail Market

Final Report

Master Design Project

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Abstract

Data sharing plays a crucial role in facilitating the energy transition, particularly by supporting the integration of distributed energy resources. The energy market comprises numerous participants who rely on data to operate efficiently. Following energy deregulation, diverse systems and processes have been developed to manage and transfer data across these participants. To improve interoperability between systems, the Common Information Model was developed to represent a common definition for power systems. This study explores the implementation of CIM in the energy retail market, focusing on its integration into a centralized data exchange platform and its extensibility to support new requirements, such as consent management for data exchange. A key contribution of this work is the development of an implementation framework for CIM, enabling a structured workflow for adopting the model in energy retail processes. The framework was extended to include a proposed consent business process, showcasing its adaptability to emerging requirements like compliance with the GDPR, as data exchange in the retail market contains personal data. The results indicate minimal impact on the centralized data exchange platform during CIM integration, demonstrating compatibility with the existing ebIX model. The study underscores the potential of CIM to enhance interoperability in the energy retail market but identifies significant challenges, including market readiness and business process alignment. Recommendations for future research include investigating CIM's role in TSO-DSO coordination, improving CIM alignment with business process modelling, and further refining the consent management proposal for integration into the CIM standard.

1 Introduction

Recent energy market deregulation and the global expansion of variable energy resources necessitate regular information exchange among power companies. Participants in the energy retail market employ various systems and processes to manage and transfer data across systems [1]. Traditionally, using proprietary data-sharing formats necessitated numerous translators importing and exporting data. This reliance on multiple translators significantly increased complexity as the number of data-exchanging applications grew. Consequently, reducing this integration complexity prompted the adoption of a model-based data exchange approach to achieve adequate interoperability. To achieve interoperability, it is essential to exchange semantic information across different domains [2]. Semantic understanding serves as a crucial bridge in closing the gap between the integration of two systems, as illustrated in Figure 1.

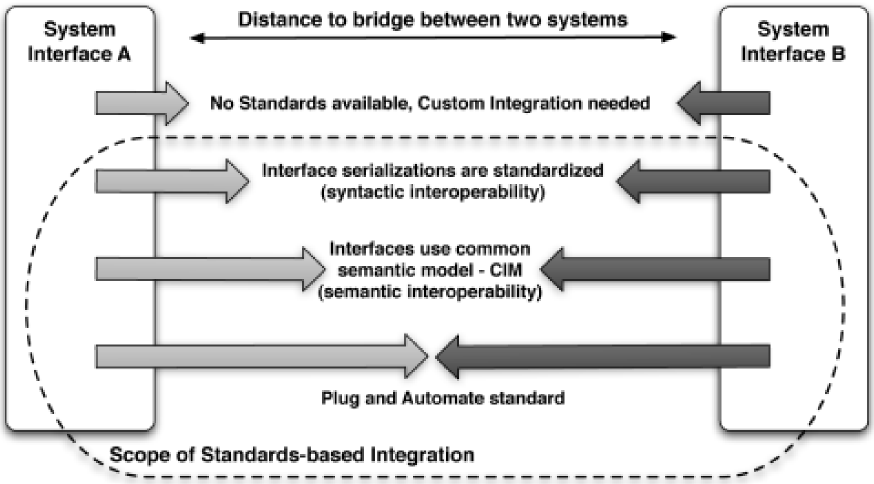

Figure 1: The distance to integrate two systems is reduced by using the Common Information Model (CIM), which functions as a semantic model to facilitate semantic interoperability [3].

The Common Information Model (CIM) was developed as an open standard to represent power system components and is currently maintained by the International Electrotechnical Commission (IEC) as a series of standards. The primary objective of CIM was to establish a common definition for power system components, enabling data exchange between their applications regardless of internal software architecture or operating platform [1]. Its widespread adoption and ongoing standardization efforts within the electric utilities sector position it as one of the leading global standards in the energy domain [4].

The adoption of CIM in the energy retail market is still in its early stages, primarily due to the highly diversified market operations across EU member states. Further research into the contribution of CIM in this domain holds significant potential, as sharing of energy data is a key enabler of the energy transition, formally directed by the EU [5]. Therefore, providing reliable and interoperable data is essential, in which CIM could play its role. Furthermore, information exchange in the energy retail sector also involves personal data, which is subject to the strict regulations of the General Data Protection Regulation (GDPR). A potential contribution to the CIM model could be the introduction of consent mechanisms for personal data exchange, a challenge many market participants currently face.

This study evaluates the potential extension of CIM to the energy retail market and proposes a consent management process that can be integrated into a CIM implementation framework. The research focuses on obtaining qualitative insights and assessing the practical applicability of CIM by examining its implementation within a centralized data exchange platform utilized by grid operators. The report begins with an overview of the problem context in Section 2, which examines the energy retail market and the system under study, emphasizing key challenges and complexities. Section 3 provides a problem analysis, identifying specific issues, conducting a stakeholder analysis, and defining the problem statement and research objective. Section 4 outlines the research methodology, describing the design science approach, research questions, and methods employed. Relevant literature and standards are reviewed in Section 5, where the research gap is also established. Section 6 introduces the CIM implementation framework alongside the proposed consent management process, while Section 7 evaluates the developed artefacts against the research objectives and requirements. Section 8 discusses the findings, interpreting the results and reflecting on their broader implications. The report concludes with Section 9, summarizing the key insights and contributions of the study.

2 Energy Retail: A Complex Market

This section describes the problem context, focusing on the European energy retail market. Given the complexity of the energy market, characterized by a wide range of diverse assets, the key challenges related to data exchange are examined. Additionally, the system under study is introduced, along with practical motivations for implementing CIM within this context.

2.1 The European energy retail market

The retail market represents the final stage in the energy sector, where energy is sold directly to end-users, including residential, commercial, and industrial customers. Typical data exchanged in this market are metering data, customer information, and market data. A key challenge in standardizing information exchange within the European energy retail market is the variation in market operations between countries. These differences result in diverse approaches to data management and information exchanges between market participants, complicating the implementation of a unified standard such as CIM. Furthermore, translating data from various sources into a mediated schema, such as CIM XSD, is a complex and demanding task. This process requires a deep understanding (domain knowledge) of the semantics underlying both the source data schemas and the mediated schema [6].

Grid operators are responsible for managing the electricity grid, where transmission system operators (TSOs) oversee the high-voltage grid that spans long distances from power generation facilities. This segment typically involves the energy wholesale market. In contrast, distribution system operators (DSOs) manage the medium- and low-voltage networks, ensuring the distribution of electricity from the transmission network to end consumers, and thereby being involved in the energy retail market.

CIM has not been applied within the European energy retail market, as it was originally developed for and predominantly used by TSOs, making its adoption largely confined to the energy wholesale market. This segment of the energy sector is characterized by a higher degree of harmonization across the European Union, driven by stricter legal regulations and the physical interconnection of member states' electricity grids, enabling the implementation of a standard model. This level of coordination is exemplified by the establishment of the European Network of Transmission System Operators for Electricity (ENTSO-E). In contrast, the coordination of DSOs within the retail market across the EU remains in its early stages of development [7].

2.2 CGI AgileDX

This study was conducted at CGI, a large IT and business consulting firm. CGI facilitates data exchange within the energy retail market at its Groningen location, offering various tailored solutions. One of CGI's solutions is AgileDX, a scalable cross-industry data exchange solution that integrates business data, business rules, and process models for seamless data sharing between stakeholders. The main purpose of AgileDX is to enable more efficient data exchange by facilitating centralized energy market data, see Section 2.2.1.

The information exchange within AgileDX is based on the ebIX framework, which was developed to standardize electronic information exchange in the European downstream energy market but never became a formally EU-acknowledged body. In addition, ebIX has decided to close by the end of 2023. As a result, CGI is interested in assessing the opportunities of replacing ebIX with CIM due to CIM's emergence as the new industry standard, with potential new customers expressing interest in adopting CIM. Furthermore, to accommodate future requirements in information exchange, adopting a standard model such as CIM is crucial to ensure continued relevance. Since ebIX is no longer supported, it cannot be extended to incorporate new requirements, underscoring the need for a more adaptable and future-proof standard.

2.2.1 System description

The high-level system under study is Finland's Datahub, maintained by the grid operator Fingrid. Built using CGI's AgileDX, the Datahub functions as a centralized data exchange system accessible to all participants in the retail market, as illustrated in Figure 2. In a centralized data exchange system, all information exchange and storage are managed through the Datahub. For example, when a Supplier requires a metering report, the DSO forwards the report to Datahub. The Supplier can then retrieve the metering report directly from the Datahub. Both the business processes and information exchange are based on the ebIX format.

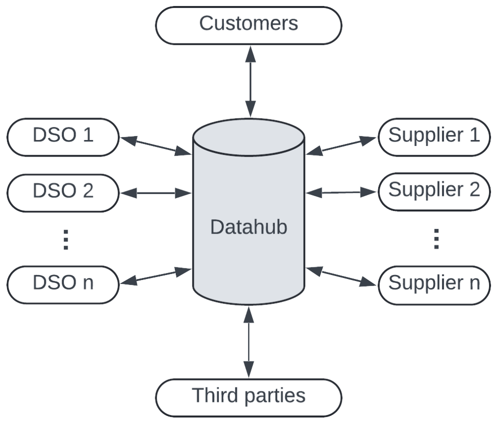

Figure 2: Information exchange model of Fingrid. Market participants can access the centralized data exchange system to exchange data.

2.2.2 Business process and data models

The Datahub's business processes and data models are comprehensively outlined in the events document provided by Fingrid [8]. Applying a model such as ebIX or CIM begins with identifying the relevant business process. This foundational step ensures that the meta-model aligns with the specific requirements and context of the process being modelled.

In this study, the DH-200 - Metering Data Maintenance Processes [9] are utilized as the predefined business processes, as metering is well covered by the existing CIM model [10]. The DH-211 process has been selected to specify this study's scope. This process represents a metering data request initiated by a party, such as a DSO, Supplier, or Third Party. In this process, the requesting party must possess the necessary authorization for the data before it can be retrieved from the Datahub.

2.3 Consent-based information exchange

One critical aspect of the retail market is the handling and processing of personal data. The introduction of the GDPR [11] has significantly tightened the requirements for managing personal data, presenting considerable challenges for organizations. A fundamental principle of the GDPR is informed consent. This ensures that the data subject—the individual to whom the data pertains—is explicitly informed about how their data will be processed. Furthermore, it requires that the data subject provides unambiguous agreement for the processing to take place. As a result, consent management is an important part of information exchange in the energy retail market. Given that the handling of this process is still evolving within the market, future requirements and methods must be incorporated into the data exchange model to ensure compliance. This highlights the importance of transitioning from the ebIX standard, as it no longer allows for the official inclusion of new additions, such as consent management, which are essential for aligning with regulatory and operational needs.

3 Problem Analysis

The problem analysis section outlines the primary issues derived from the problem context. The main problem of this study is qualitative in nature, focusing on assessing the impact of CIM on AgileDX. Additionally, a stakeholder analysis will identify the key stakeholders involved and their respective requirements. These insights, alongside the problem statement, will ultimately shape the research objective, guiding the direction of the study.

3.1 Problem diagnosis

With the energy retail market as the problem context, several key challenges emerge. The CIM model, already comprehensive and extensive, is inherently an information model rather than an implementation model. This distinction creates a significant barrier to entry for market participants transitioning to CIM, requiring substantial expertise and adaptation efforts. Additionally, the comparison between CIM and older standards like ebIX remains largely unexplored, further complicating the decision-making process for stakeholders. The European retail market's high diversity adds another layer of complexity, making the implementation of a uniform model like CIM challenging. However, this diversity also presents an opportunity for CIM to serve as a unifying framework. By leveraging CIM effectively, it could guide the market towards greater harmonization, offering a standardized approach that fosters interoperability and efficiency across the sector.

For CGI, a pressing issue is the future support of the ebIX standard, which is being deprecated. This poses challenges for AgileDX, especially if new requirements, such as consent management, need to be implemented. Additionally, potential customers may increasingly demand the adoption of the CIM format for information exchange, given its growing acceptance as an industry standard. This shift could necessitate AgileDX's alignment with CIM to remain competitive and meet evolving market expectations.

3.2 Stakeholder analysis

A stakeholder analysis for this project has been conducted, and the main stakeholders involved are summarized in Table 1. The stakeholders are classified based on their interest and influence in the project, which helps in understanding their role and the level of engagement required throughout the research process.

Stakeholder	**Interest**	**Influence**	**Engagement Strategy**
Product owner of AgileDX	High	High	Actively involve in the project
Developers (CGI)	Medium	Medium	Regularly inform and consult about the project
Market parties	Low	Low	Consult when implementing CIM
IEC	Low	Low	Consult when implementing CIM
User of AgileDX (e.g. Fingrid)	Medium	Low	Consult when implementing CIM

Table 1: The identified stakeholders for this project.

The product owner of AgileDX serves as the problem owner and is the primary stakeholder most interested in the outcome of the project, as it is important to maintain the functionality of AgileDX. The product owner is responsible for allocating resources and possesses the most relevant expertise.

The intended users of the project's outcome are the developers, who, while having less influence on the overall project, play a crucial role in its success. Regular communication with the developers is beneficial, as they hold much of the technical expertise, specifically regarding ebIX. Other stakeholders have minimal interest and influence at this stage, but their engagement and influence are expected to grow once CIM is implemented. However, the implementation is outside the scope of this project.

The key stakeholders for this project are the product owners of AgileDX and the developers involved in its implementation. For the product owners, the primary requirements include evaluating the impact of CIM on AgileDX and facilitating a more efficient approach for assessing the implementation of various business processes in CIM in the future. For the developers, the project necessitates the provision of a user-friendly workflow for CIM implementation, along with tools to effectively assess the impact of CIM during the implementation process. Furthermore, it is desired that an extension of the consent management proposal be included in CIM.

3.3 Problem statement

The initial problem is that CGI lacks an approach to evaluate CIM and its impact on AgileDX. Underlying issues can be identified by broadening the scope of the problem definition to include the extension of CIM to the energy retail market. In addition, a generalized process for handling data consent in the energy retail sector is unavailable. This can be formulated into the following statement:

> *CGI currently lacks a clear approach for evaluating the impact of CIM on AgileDX and identifying how CIM can be extended to the energy retail market to improve interoperability. Furthermore, there is no standardized process to facilitate consent management in the data exchange in the energy retail market.*

3.4 Research objective

The research objective is divided into key goals: an artefact design goal and a knowledge goal. The artefact design goal focuses on developing a framework for integrating CIM into AgileDX. The knowledge goal, on the other hand, extends the artefact by exploring new components, specifically consent-based data exchange, and its integration within the existing CIM context. Both goals are formulated into a SMART goal [12]. The goal statement is:

> *The goal is to identify the impact of CIM on AgileDX based on the DH-211 business process. Furthermore, a proposal for a generalized business process for handling consent in data exchange in the energy retail market and its relation to a CIM data model is included. The results will be integrated into a generalized framework to enable a more efficient assessment of different business processes in the energy retail market.*

To limit the scope of this study, the impact of CIM on AgileDX will be evaluated using a predefined business process from the Datahub: DH-211 [8]. This message is created in the CIM format and assessed within AgileDX to determine its compatibility in comparison to the ebIX standard. Additionally, to propose a generalized process for managing consent, a similar message format will be used. The primary objective is to demonstrate how a new consent process can be extended into CIM, thereby assessing its extensibility. However, developing a comprehensive model for fully integrating consent management into AgileDX is beyond the scope of this study.

4 Research methodology

4.1 Methodology

The research methodology is based on the concepts of Wieringa's design science methodology [13], to improve the relevance of the artefact by ensuring that the research is tightly linked to the application domain, which in this case is the energy retail market. This domain's specific requirements drive the research objectives and shape the framework developed. The study aims to create an artefact, in the form of a framework, that interacts with and improves the problem context.

The design science process follows Wieringa's design cycle, which emphasizes problem investigation and the design and validation of an artefact. To effectively visualize the design cycle and guide the research through its various stages, the design science research process (DSRP) proposed by Peffers et al. [14] will be utilized as the research methodology. This process enhances the understanding of artefact validation by incorporating distinct demonstration and evaluation steps within the design framework.

The problem identification and objectives have been outlined in the previous sections. To clarify the design, demonstration, and evaluation phases, elements from systems engineering, as described by Buede [15], are applied to support the design science process. During the design phase, the framework's functionality and architecture are defined based on the requirements gathered from stakeholders. The design is then validated by demonstrating it within a suitable context, allowing for the evaluation of whether the requirements established in the design phase have been successfully met.

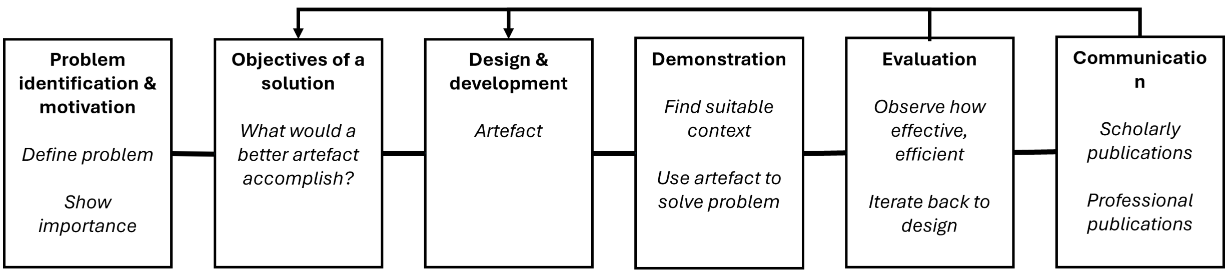

Figure 3: The design science research process (DSRP) model [14], which can be iterated multiple times during the research.

4.2 Research questions

The research questions (RQs) are structured around two main goals: the artefact design and knowledge goals. RQ1-RQ3 are centred on the artefact's design, focusing on evaluating the implementation of CIM in AgileDX. RQ4 addresses the knowledge goal, which explores consent management for data exchange within the CIM framework. This question is further divided into three sub-questions that provide a deeper understanding of the consent-based information exchange.

- **RQ1:** How can CIM be integrated into AgileDX to improve interoperability in the energy retail market?
- **RQ2:** What are the key differences in compatibility between ebIX and CIM?

- **RQ3:** What is the general architecture of a framework for assessing the impact of CIM on AgileDX?
- **RQ4:** How can CIM be extended to support a consent-based data exchange model in the energy retail market?
  - **SQ4.1:** What are the requirements for a generalized consent-based information exchange business process in the energy retail market?
  - **SQ4.2:** What are the existing methods or processes to facilitate consent-based information exchange?
  - **SQ4.3:** What is the data model of consent?

4.3 Operationalization

This section outlines the methods necessary to address the research questions. To begin with, **RQ1** and **RQ2** can be answered by recognizing that both ebIX and CIM are implemented in AgileDX as XML Schema Definitions (XSD). Therefore, a single-case mechanism experiment will be conducted. In this experiment, the architecture of the object of study is a controlled test environment in AgileDX, where the message is based on the DH-211 business process. The instance that is changed is a DH-211 message in CIM format, which is compared to the standard ebIX format.

The general architecture for addressing **RQ3** will be shaped, in part, by the requirements of the stakeholders, who are the intended users of the artefact. These goals will be identified through surveys conducted with the stakeholders. Furthermore, the operationalization of **RQ1** and **RQ2** will dictate the architecture of the framework.

The answer to **RQ4** will be derived from the development of a generalized consent-based business process. This process will be proposed based on a literature review of existing methods for handling consent and an analysis of the current consent-handling approach employed in the Datahub. Additionally, the process will be informed by the findings of the subquestions under **RQ4**. To address **SQ4.1**, the requirements will be gathered through a combination of stakeholder surveys and a literature review. The remaining subquestions will primarily rely on insights obtained from the literature review. For **SQ4.2**, the Datahub model will also be analyzed to gain a deeper understanding of its data consent management practices. Once the consent-based business process has been developed, it will be mapped to the CIM framework, thereby creating a data model of consent that serves as the foundation for answering **SQ4.3**.

5 Background

5.1 The IEC CIM standard

A comprehensive explanation of the development of the CIM model is available in the EPRI primer [1], as EPRI originally developed the CIM. Below is a brief overview of the CIM's development as described in the primer. CIM emerged from the needs of modern utilities' IT infrastructures, where large-scale applications such as Energy Management Systems (EMS) and asset management systems needed to communicate with one another. Initially, this communication was facilitated through customized formats, often based on the internal database schema. However, as the power industry moved toward deregulation, utilities began shifting away from custom-built software solutions. This transition resulted in utilities running software from various vendors, creating a need to exchange large datasets efficiently. The reliance on proprietary, custom formats complicated this data exchange, as it required complex translations between multiple formats. The solution lies in adopting a highly detailed and standardized format capable of interfacing with various applications.

The CIM addresses this by providing a highly detailed model that accounts for global design and operational differences. An information model, as defined by Lee [16], is "*a representation of concepts, relationships, constraints, rules, and operations to specify data semantics for a chosen domain of discourse*". CIM leverages Unified Modeling Language (UML) to express its structure, which is a widely accepted standard in software development. UML enables CIM to visually represent the model's components, relationships, and data structures, facilitating clarity and consistency in its application.

Defining an information model for a system separates the data structure from its serialization format, enabling the data to be treated as abstract entities rather than as specific components tied to files or databases. This separation allows the same data to be serialized into various formats without changing its underlying structure. An information model can also automate the generation of database schemas, file formats, user interfaces, and documentation. In the case of the CIM, this model functions as a semantic model or ontology, which precisely defines utility business objects and processes, along with associated rules. As a Canonical Data Model (CDM), CIM provides a scalable and maintainable framework for integrating enterprise data and mapping distinct sources to a unified model.

The IEC CIM is described in three parts:

- **IEC 61970:** "Energy Management System Application Program Interfaces (EMS-API)"
- **IEC 61968:** "Application Integration at Electric Utilities - System Interfaces for Distribution Management"
- **IEC 62325:** "Framework for energy market communications"

For a detailed explanation of all parts of the IEC CIM standard, the reader is referred to the book of Uslar et al. [3]. The CDM itself is covered in IEC 61970-301, IEC 61968-11 and IEC 62325-301, which are maintained in SPARX Enterprise Architect in UML format.

Only the aspects relevant to market operations must be addressed in this study. To this end, the modelling framework described in IEC 62325-450 is employed, as depicted in Figure 4. The regional contextual model utilized is the European-style market profile [17]. The document contextual model will be based on the business specifications of the Datahub [8]. The output of the modelling framework will be message schemas derived from the CIM information model.

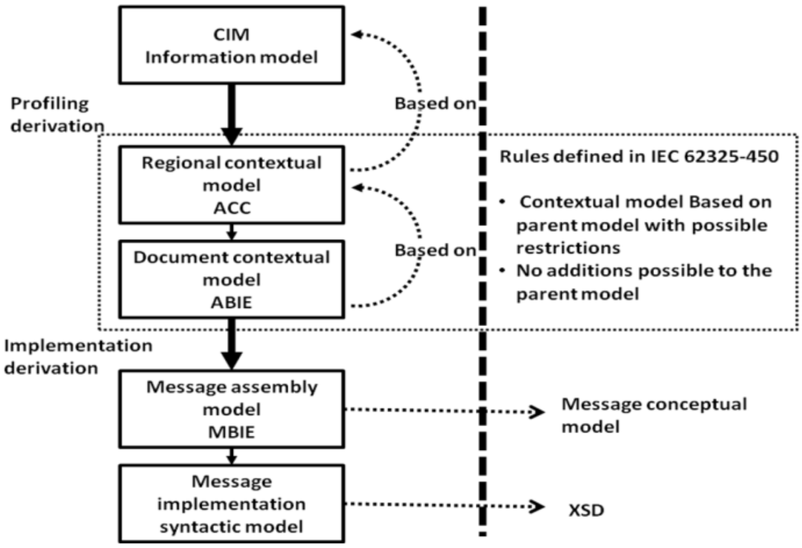

Figure 4: The IEC 62325-450 modelling framework [17].

Kim et al. [2] provide a comprehensive review of the practical issues and challenges associated with utilizing CIM for data exchange. The study identifies three primary areas of concern: CIM extension, harmonization with other standards such as IEC 61850, and the validation of model instances. Extending CIM is essential to address a wide range of business requirements, while harmonization with other standards is critical for achieving interoperability within smart grid environments. The authors also highlight various approaches to addressing these challenges. Further gaps in CIM are discussed by Uslar et al. [18], who outline several shortcomings within the model. The effectiveness of a domain data model like CIM relies heavily on the quality of input from domain experts. Furthermore, its application is often hindered by improper use of IT techniques.

Bytyqi et al. [19] provide a comprehensive review of TSO-DSO data exchange, highlighting the critical role of standardized interactions for the efficient operation of future power systems. The study underscores the potential of CIM and its Common Grid Model Exchange Standard (CGMES) for enabling robust TSO-DSO coordination. However, the authors also recognize the limitations of CIM and propose potential enhancements to CGMES profiles to address evolving requirements. The growing significance of ICT in TSO-DSO coordination frameworks is further emphasized by Rodrigues et al. [20]. Their work highlights the widespread adoption of CIM as the foundational information model while calling attention to the need for CIM extensions to tackle emerging challenges. Specific areas identified for improvement include data hubs, data portability, sub-meter data handling, and interoperability with other standards, such as IEC 61850. Both studies underline the key challenges in TSO-DSO cooperation, which include the development of a conceptual European data exchange model, ensuring interoperability across platforms, and addressing data handling complexities. These challenges point to the need for continuous evolution of CIM to meet the demands of modern and future power systems.

Shahid et al. [4] propose a novel smart grid framework, EMBARK, which leverages CIM as its central data model. The framework aims to enhance interoperability between smart grid applications provided by different vendors, enabling modular and scalable deployment. By integrating CIM as a foundational component, EMBARK addresses the complexities of multi-vendor environments and supports efficient system integration. The challenges faced by DSOs in managing and exchanging data within their system landscapes are explored by Ascher and Kondzialka [21]. Their research introduces a middleware platform based on CIM to improve interoperability among diverse DSO systems and applications. This solution is demonstrated through a practical scenario, showcasing its ability to streamline data exchange and integration across complex system architectures.

A review of the literature reveals that CIM is widely recognized as a foundational element in enabling smart grids. Its application is particularly promising in the context of TSO-DSO coordination, where it offers significant opportunities for facilitating standardized data exchange and improving interoperability. However, to the best of my knowledge, there is no documented implementation of the IEC 62325 standard within the energy retail market available in the existing literature.

5.2 Business process modelling

A key aspect of the IEC 62325-450 modelling framework is its foundation in business processes. The document contextual model from Figure 4 is directly derived from the business requirements specifications. Given the complexity of the energy market, which encompasses numerous interconnected aspects, accurately modelling business processes is essential for their proper description and understanding. Business process modelling (BPM) involves the representation of these processes through a business process model, typically created using a process modelling language (e.g. UML). This approach facilitates the identification and specification of the business processes in question, ensuring clarity and precision in their characterization [22].

Alotaibi [23] provides a comprehensive review of the challenges and solutions in BPM, identifying three primary challenges: misalignment between business and IT, security concerns, and the complexities of managing customer power. A major cause of the misalignment is the differing perspectives and priorities held by BPM and IT managers, who often approach objectives with contrasting viewpoints. Additionally, effective collaboration requires individuals from diverse backgrounds to work together, yet it is rare to find someone with a comprehensive understanding of all system processes. Typically, individuals are only familiar with specific areas of the overall system, as noted by Luftman [24]. Combined with the inherent complexity of business processes, this fragmented knowledge makes it challenging for individuals to fully comprehend every aspect of the system. This lack of a shared understanding is a significant contributor to the misalignment between business and IT.

This importance of aligning business processes with data models to enable the effective use of CIM within a specific context is highlighted by Chandramohan et al. [25]. Their research presents a case study illustrating the application of the Business Process Model and Notation (BPMN) to model the processes involved in defining a CIM profile. This approach, according to the authors, facilitates CIM implementation by providing a clear understanding of data requirements and flows within utility operations, thereby bridging the gap between business processes and data modelling.

5.3 Consent management

Consent management in the context of data exchange is the lawful handling of personal data, which is any information relating to an identified or identifiable natural person (i.e. data subject). Consent of the data subject defined by the GDPR [11] means that the data subject gives clear and voluntary permission for their data to be processed. The consent must be freely given, specific, informed and unambiguous.

Politou et al. [26] review the challenges associated with the GDPR, highlighting its significant impact on organizations. One of the GDPR's most notable contributions is its legal form as a regulation rather than a directive. This distinction means that organizations are required to comply strictly with its provisions, a requirement that many find challenging. A key difficulty lies in achieving a balance between data utility and privacy, as organizations must ensure that data remains useful while adhering to stringent privacy standards. Additionally, implementing the "right to be forgotten" and the "right to withdraw consent" poses substantial challenges due to their technical and operational complexity. These provisions require organizations to adopt data management practices, which can be difficult to execute effectively.

An existing approach, similar to CIM, is through the lens of semantics. Kurteva et al. [27] present a state-of-the-art survey on the use of semantic technologies for implementing consent. Their research provides guidelines for developing a semantic model to manage consent, including graphical visualization techniques to enhance understanding for individuals. Additionally, they demonstrate how ontologies can effectively represent the entire lifecycle of consent, encompassing key processes such as the withdrawal of consent. Among the ontologies reviewed, GConsent is identified as particularly well-suited for alignment with the GDPR. GConsent, as outlined by Pandit et al. [28], provides a generic framework for modelling consent. This approach would be well-suited for integration into extensions of the CIM data model. Its flexibility allows for the representation of consent in a standardized and interoperable manner, making it a valuable addition to CIM, particularly in addressing regulatory requirements such as those outlined in the GDPR. In addition to ontologies, Fatema et al. [29] propose a reference architecture for the Consent and Data Management Model (CDMM). The CDMM encompasses a range of design decisions that extend beyond the use of ontologies, integrating context changes within the data processing model. This framework supports data controllers by enabling them to assess and demonstrate compliance with regulatory requirements.

In the healthcare sector, consent plays a critical role in enabling the secure and ethical sharing of data. One of the emerging technologies gaining traction in this domain is blockchain technology. Kararlapudi and Mahmoud [30] provide a comprehensive review of blockchain's application for consent management. Additionally, various studies [31] [32] [33] have explored blockchain-based solutions for consent management. While these solutions address specific aspects of consent management, there remains a significant gap, as a generalized process for handling consent in information exchange is currently unavailable. Such a process is crucial for translating theoretical models into practical implementations and mapping consent workflows to standardized data exchange formats, such as CIM. This highlights the need for a unified framework to bridge the gap between consent management practices and data exchange technologies.

6 Design

This section outlines the design and development of the artefacts in this study, which is the heart of the DSRP model. The structure of the design subsections is based on the design requirements, design process and design description. The research objective focuses on two primary goals: developing a framework for integrating CIM into AgileDX and proposing a generalized process for managing consent in data exchange. The primary aim is the creation of the framework, with the design process addressing some research questions. A key issue identified is the inability of the ebIX standard to accommodate new requirements. Consequently, the consent proposal contributes to the body of knowledge within the framework, while the consent process itself serves as a means to validate the framework. To conclude, the critical aspects of the framework design are assessed.

6.1 Artefact 1: CIM Implementation Framework

Design Requirements

The framework is necessary to guide the implementation of CIM in AgileDX. Given that CIM is a comprehensive and extensive information model rather than an implementation model, it presents a significant challenge for users to understand how to apply it effectively. Additionally, the framework is intended to evaluate the impact of CIM implementation on AgileDX. The design requirements for the framework are derived from the Problem Analysis and the identified stakeholder needs. These requirements must be translated into clear framework requirements to ensure the framework is designed effectively. The main requirement, as defined by the research goal, is that the framework should support a more efficient assessment of various business processes within the energy retail market. The framework requirements are:

- The framework shall provide a structured workflow to guide users in implementing CIM within AgileDX.
- The framework shall enable a more efficient assessment of implementing various business processes in the energy retail market to CIM.
- The framework shall assess the impact of CIM implementation on AgileDX.
- The framework shall provide methods to extend CIM.
- The framework shall make the CIM methodology more user-friendly.

Design Process

The framework development is based on the IEC CIM 62325 modelling framework, as outlined in Section 5.1. To demonstrate the applicability of the modelling framework, the predefined business process DH-211, based on ebIX, is used as the reference process. The data model of DH-211 is detailed in the Datahub events document [8]. The primary goal is to translate the DH-211 data model into a CIM XSD format. This mapping process has been completed, and the resulting contextual model, which represents the DH-211 data model in CIM format, can be found in Appendix A. The next step is to organize this contextual model into an assembly model, which is also included in Appendix A. This model outlines the structure of the message in a serialization format and is used to generate the XSD. With the completion of the modelling phase, the newly created CIM XSD is now undergoing verification in a real test environment within AgileDX to ensure its compatibility.

The verification process, depicted in Figure 5, consists of three key steps. Robot Framework, an open-source automation tool, generates real message fields, such as accounting points, IDs, and data points for time series, which AgileDX will recognize. The steps are:

1. **Step 1: XML generation with Robot Framework** - Robot Framework generates an XML message based on the DH-211 requirements, initiating the process.
2. **Step 2: CIM-based XSD verification** - The CIM model is utilized to generate an XSD derived from the DH-211 process. The XML is then verified against this XSD to ensure that the XML message generated by Robot Framework conforms to CIM standards.
3. **Step 3: Transformation to JSON** - The verified XML message is transformed (using an XSLT) into JSON which is the format used by AgileDX.

If all steps are executed successfully, AgileDX will accept the JSON message, enabling the requested time series to be retrieved from the portal. This verification process demonstrates that CIM is compatible with AgileDX, and it also provides insights that may help refine the framework further.

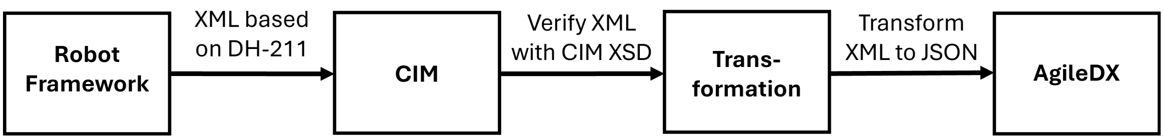

Figure 5: Verification process of the CIM-based DH-211 message in AgileDX.

Applying the CIM modelling framework followed by the verification process revealed the required information needed for designing the implementation framework. These results provide a systematic approach for integrating CIM into AgileDX and assessing the compatibility with ebIX. This systematic approach can transformed into a structured workflow that will outline the key steps necessary for modelling business processes using CIM.

Artefact Description

The key components of the framework are presented in Figure 6. The workflow is divided into three main partitions: *Business Requirements Specification*, *Requirements Mapping*, and the *IEC CIM 62325 Modeling Framework*. The workflow starts with the definition of the business process, which is typically predefined by market participants. This process is subsequently translated into a set of requirements, which are used to develop a corresponding data model. The final step in this partition involves selecting the appropriate version of the CIM standard to ensure alignment with the latest developments, as the CIM framework is subject to continuous evolution.

The subsequent partition represents the most challenging phase of the workflow, as it necessitates a certain level of domain expertise from the user. Specifically, the user must possess a solid understanding of both the business process model and the CIM standard to effectively map the requirements from the data model to CIM. The primary objective of this phase is to maximize the alignment of requirements with CIM, thereby ensuring the interoperability of the resulting model.

In cases where a required class is absent in the CIM model, the workflow initially encourages users to adjust the requirements rather than extend the CIM standard, as extending CIM is generally discouraged. However, if the missing class is critical for operational purposes, the CIM model can be extended. This is facilitated through the *Extend CIM* action, which is detailed in Figure 7. Within this process, user-defined elements such as classes, attributes, or associations can be extended into the CIM model.

The final partition is the IEC CIM 62325 modelling framework, identical to Figure 4. A detailed instruction guide on how to conduct this partition can be found in Appendix D. The output of the workflow is the CIM XSD based on the business process, which serves as the input.

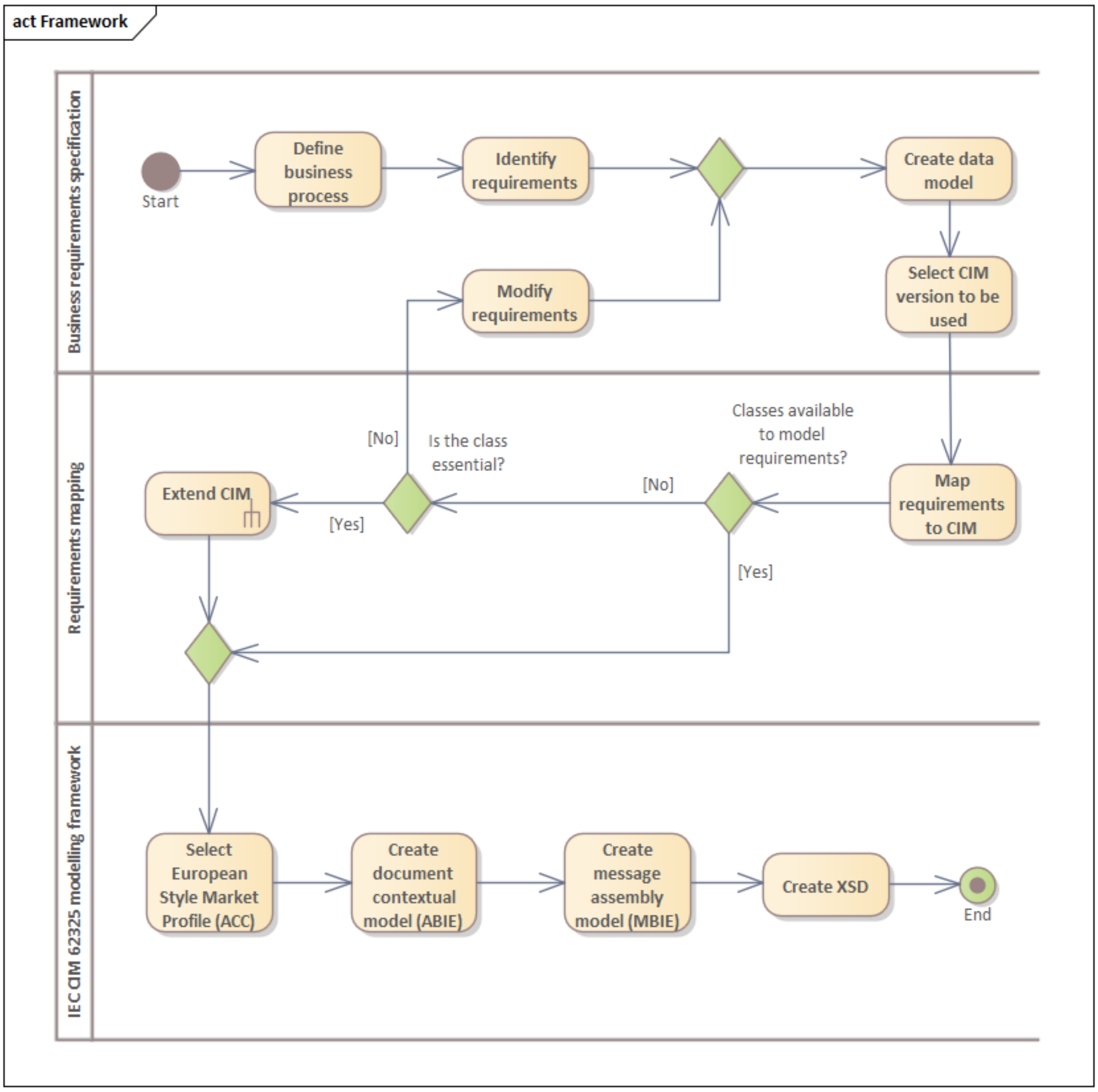

Figure 6: Activity diagram which describes the workflow of the CIM implementation framework.

6.2 Artefact 2: Consent Business Process

Design Requirements

The literature review identified a gap in existing methodologies, as discussed in Section 5.3. On one hand, a wide range of ontologies are available that address the handling of consent. Additionally,

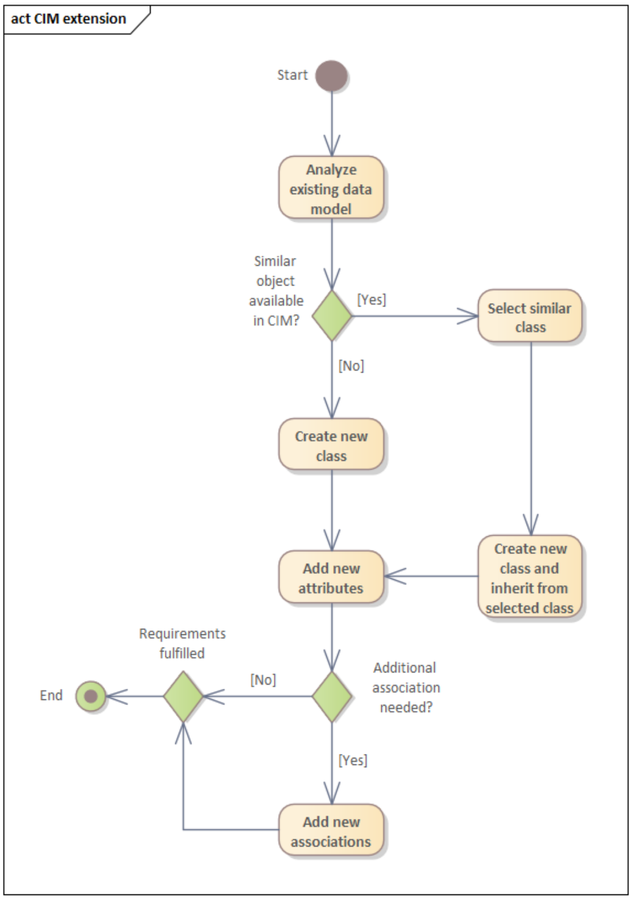

Figure 7: Acitvity diagram which describes the workflow of extending CIM. This activity is a child diagram of the *Extend CIM* action of the main CIM implementation framework. This workflow is based on the extension process described by Uslar et al. [3]

numerous studies focus on technologies such as blockchain. However, a generalized business process for managing consent remains absent. This process is essential for modelling the integration of consent management into CIM, which is also a key activity of the CIM implementation framework previously outlined. Therefore, the primary requirement is that the consent process must be mappable to CIM. The following requirements have been identified:

- The proposal shall support a generalized consent management process applicable to various industries beyond the energy retail market.
- The proposal shall ensure that consent management activities comply with GDPR.
- The proposal shall support the translation of consent management data into CIM-based data models.

Design Process

The design process begins with identifying the primary requirements and various roles derived from the GDPR [11]. Five distinct roles have been identified: Third Party, Data Controller, Data Subject, Data Processor, and Recipient. A potential scenario of a data request is provided in a sequence diagram, found in Appendix B. This diagram demonstrates how a data request in the energy retail market could be managed and is used to design the consent-based process. The sequence starts with the Third Party requesting data from the Data Controller, who holds full responsibility for handling consent. The Data Controller then either grants or denies authorization. If the consent of the Data Subject is required, the person must be informed. If consent is not required or is granted by the Data Subject, the Data Controller proceeds to forward the request to the Data Processor. Once the request is processed, it is sent to the Recipient. It should be noted that the Third Party and Recipient can be the same entity.

The next step involves utilizing the existing GConsent ontology [28]. Key elements from this ontology are applied to model the business process. First, the Third Party must be identified. Following this, the Third Party must provide a valid justification for requesting access to the data. According to the GDPR, this justification includes specifying the purpose of the data request, the type of personal data required, and the type of processing that will be performed on the data. To automate the authorization process and narrow the possibilities for a request, a policy can be applied [34]. This policy is associated with the Data Subject, allowing them to set their consent preferences. The policy can categorize fields such as the purpose of the data request and the type of processing involved [35]. Additionally, if informed consent is required, the Data Subject must be contacted to obtain the necessary consent.

Artefact Description

The design process has guided the development of the artefact, which is presented in Appendix C. The resulting artefact is an activity diagram that illustrates the process of handling a data request from a Third Party. The process begins by identifying the Third Party and conducting an initial check to determine whether the Third Party already possesses the necessary authorization for the request. If authorization is confirmed, the request is approved immediately. If not, the policy of the Data Subject must be retrieved. If no policy exists, the process is terminated. If a policy is available, essential fields such as recipient, personal data, purpose, and processing are matched. As an example categories for the purpose of data use, which the Data Subject may consent to, are detailed in Figure 8. This matching process is envisioned to be automated. However, even when policies are matched, explicit consent from the Data Subject is required. The policy matching serves as a preliminary screening, ensuring that only valid requests proceed to the consent stage. If the Data Subject provides consent, the data request is completed as specified. All requests, whether authorized or denied, are logged to ensure compliance.

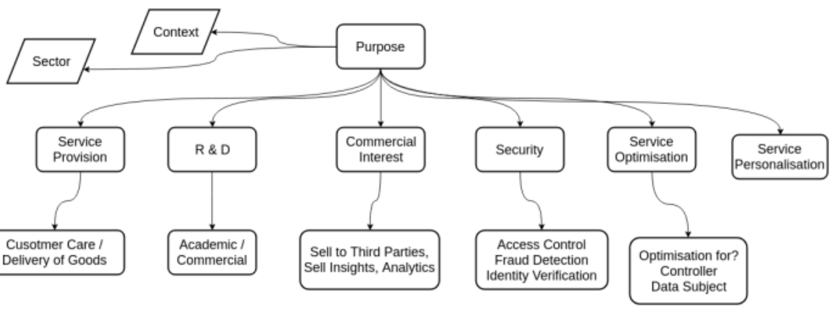

Figure 8: Example of purpose categories for the matching process [35].

6.3 Integration of the Artefacts

The two designed artefacts are closely connected and complement each other. In practice, it is desirable for a CIM message to include consent information within the message itself. For instance, when a party requests a metering report, any necessary consent should already be embedded in the message to streamline the process. As a result, these two artefacts will be merged in the validation section, where the CIM model will be extended with the proposed consent process by applying the framework, meaning the consent process effectively becomes a part of the framework itself. This approach ensures that both the CIM model and the consent business process are aligned and integrated.

6.4 Critical aspects of the design

With the preliminary design of the implementation framework now complete, it is important to analyze it to reveal design-related knowledge. One effective method of analysis involves identifying four critical aspects (CAs) of the system [36]. The System's Design Critical Aspects are illustrated in Figure 9.

Context-related CAs are external dependencies that the system relies on to function, such as regulations, subsidies, societal acceptance, or market conditions. Function-related CAs encompass the core functions vital to the system's purpose, such as safety, security, or training, depending on the specific domain. Technology-related CAs are tied to particular technologies, skills, or resources, including emerging technologies or specialized human expertise. System-wide CAs refer to overarching qualities that impact the system's overall performance and success. These characteristics are not specific to any individual function or component but are essential for ensuring the system's reliability, efficiency, and adaptability [15].

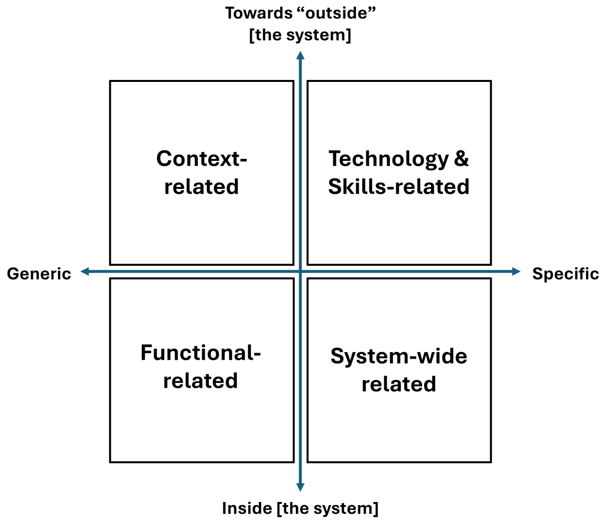

Figure 9: The System's Design Critical Aspects quadrant classifies four key aspects of the system's design. On the left side, it represents generic and abstract components, while on the right side, it includes specific physical components. The top half section highlights external components that exert influence on the system, whereas the bottom section focuses on internal components that are inherent to the system itself [37].

The CAs are identified and presented in Table 2, which outlines the CAs relevant to the framework for implementing CIM within the existing energy retail market. The CAs of the framework have been ranked to prioritize their consideration in later implementation phases. An abstract analysis of these CAs reveals several important design considerations. The context, as outlined in Section 2, focuses on the European energy retail market. This context is reflected in the identified CAs, where factors such as market readiness, harmonization, and regulatory compliance are crucial for the successful implementation of CIM. While the framework can adapt to these contextual changes, it currently lacks a mechanism to align stakeholders. If the retail market is not prepared to adopt CIM—for instance, by harmonizing and standardizing business processes—the framework faces challenges in adapting to such conditions.

Category	Critical Aspect	Rank	Description
Context	Market readiness	1	The adoption of CIM in the retail market relies on the readiness of the market to adopt such a standard.
	Regulation	13	Regulations such as the EU directive are important to standardize a diversified market. It can also be a limitation.
	EU harmonization	7	Because the EU market is diversified, harmonization at the EU level is critical for ensuring interoperability.
	Stakeholder alignment	9	The various market parties involved need to align with the CIM standard.
Technology & Skill	CIM standard	6	As the CIM is a standard, customizability is limited. The system must adapt to the standard to a certain degree.
	CIM Tools	14	Availability of mature CIM tools to support the framework, as well as skilled personnel.
	Skilled personnel	3	Domain knowledge is essential to correctly implement CIM by applying the framework.
	The legacy system	16	For example, AgileDX has to be able to adapt to a new standard for information exchange.
Functional	Process integration	4	Integration of CIM-based processes within the existing data exchange system. A key challenge is to align the business process with CIM.
	CIM message validation	12	Ensuring that messages conform to CIM standards, to prevent errors and ensure framework reliability.
	Business requirements mapping	11	A high coverage of mapping requirements to CIM format to ensure interoperability.
	Stakeholder communication	10	Facilitating communication is critical in ensuring CIM implementation aligns with the requirements.
System-wide	Interoperability	5	The high-level goal of CIM is to improve interoperability.
	Compatibility	15	CIM should coexist with ebIX during the transitional phase.
	Reliability	8	The framework must ensure that the implementation process delivers accurate and error-free CIM-based messages.
	Integrability	2	The framework must accommodate the integration of new requirements.

Table 2: Critical aspects of the framework design. The rank signifies the importance of the aspect with 1 being the most critical aspect of the framework.

The functional aspects are covered within the framework well. Successful integration of CIM into existing processes, however, requires alignment of business processes with CIM. Although the framework provides feedback mechanisms to modify requirements, it does not offer a clear approach to modelling business processes for CIM integration. Effective stakeholder communication would play a vital role in addressing this gap.

The primary technological aspect of the framework is the CIM standard itself. While CIM is a mature standard, its adoption in the retail market is still in its early stages, which may present challenges during implementation. Furthermore, the framework's effective application and the successful implementation of CIM rely heavily on the user's skills and domain knowledge.

The system-wide critical aspects relate to the high-level goals of CIM. The framework should achieve interoperability mainly. Furthermore, the framework's degree of compatibility, reliability and integrability are essential for its success.

7 Validation

Validation ensures that the design process produces the "right system" — one that accurately addresses the stakeholders' needs [15]. The validation process aligns with the DSRP model, which divides validation into two steps: demonstration and evaluation. During the demonstration phase, a suitable context is identified, and the artefact is used to solve the problem. A key limitation of the current ebIX model is its inability to accommodate new requirements. Consequently, the designed consent business process was selected as a suitable context for demonstrating and evaluating the design. The primary objective is to assess how effectively the framework facilitates the implementation of a newly designed process, such as the consent example. This evaluation is then validated against the design requirements and the needs of stakeholders.

7.1 CIM verification process

Verification is the process of ensuring that the system is "built right" [15]. In this context, verification focuses on assessing the technical compatibility between CIM and AgileDX. This process mirrors the design procedure described in Section 6.1, where the objective was to send a metering report based on DH-211 to AgileDX. This type of message in AgileDX is described as an external to internal message. During verification, the message was successfully sent and received by AgileDX, and the metering report was accessible through the portal, demonstrating the CIM's technical compatibility and proper functionality.

While some effort was required to configure the message for functionality within AgileDX, the CIM model demonstrated a high degree of compatibility with the current ebIX implementation. CIM successfully covered almost all aspects of DH-211, with only a few optional fields missing. However, this did not impede the CIM-based modelling process. Thus, it is verified that CIM is compatible with AgileDX for DH-211. Additional Datahub business processes were also assessed, revealing similar levels of compatibility with CIM. However, to draw definitive conclusions, these processes must undergo a formal translation into CIM and be subjected to a comparable verification process.

7.2 Framework design validation

With the verification of CIM complete, the designed framework must now be validated to finalize the design process. A demonstration of applying the framework to integrate the consent business process is conducted. This requires the creation of a scenario that represents the designed consent business process. Following the workflow outlined in Figure 6, the business process and corresponding requirements must first be identified.

From the process depicted in Figure 14, which is based on the GConsent ontology [28], the following requirements are identified: Third Party ID, Personal Data, Purpose, Processing, Timestamp, Data Subject ID and Recipient ID. These requirements are then integrated with those of DH-221 [8] to create a complete message, which represents a Third Party's request for a metering report. By merging these requirements, a data model for the consent process is constructed, completing the *Business Requirements Specification* phase of the framework.

The next phase, *Requirements Mapping*, is initiated. Similar to DH-211, the requirements derived from DH-221 are readily mapped to CIM due to their shared characteristics. However, a significant challenge emerges as consent is not part of the existing CIM model. Since consent is a critical element

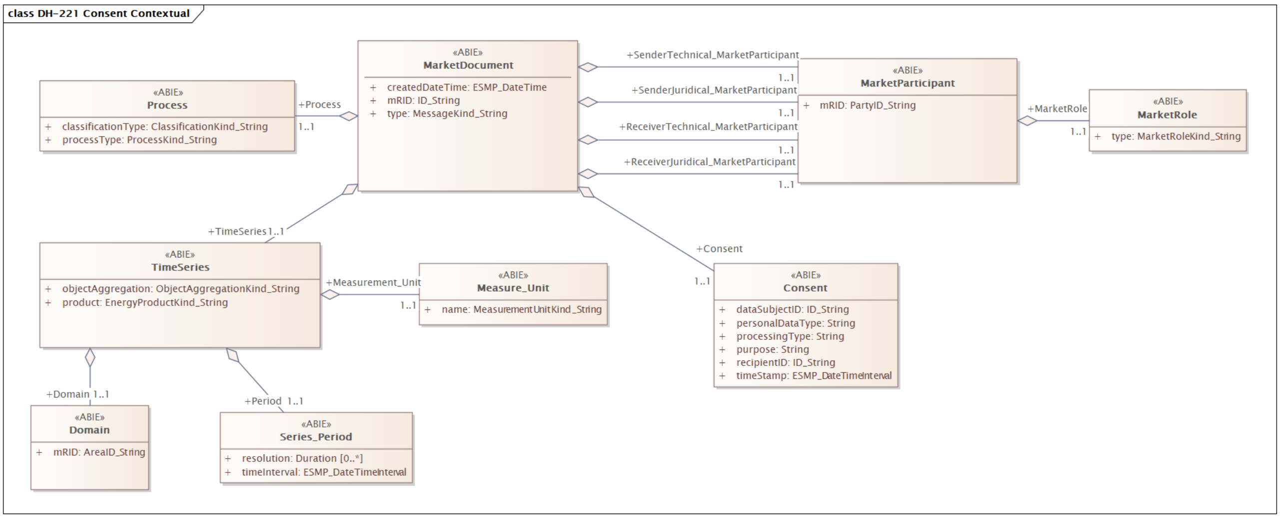

Figure 10: Class diagram of the document contextual model of DH-221 with the consent class included. The model has been developed by applying the designed framework.

for the business process, the model must be extended to include it. To address this, the activity diagram outlined in Figure 7 is applied. As no similar class exists within CIM, a new class—along with its attributes and associations—must be created and incorporated into the model. Once the consent class is successfully integrated into CIM, the final phase of the framework, the *IEC CIM 62325 Modelling Framework*, can commence.

The IEC CIM 62325 Modelling Framework becomes relatively straightforward once the requirements are derived and mapped to CIM. The process begins with selecting the European Style Market Profile and following the guidelines outlined in Appendix D. The document contextual model of DH-221, now extended with the consent class, is illustrated in Figure 10. This figure demonstrates that the business process for handling consent has been successfully integrated into the CIM standard. As a result, it is now possible to generate an XSD from this contextual model.

With the demonstration of the framework complete, the evaluation stage must be conducted. This demonstration was shown to experts and evaluated against the stakeholder's needs. The framework was validated by the expert opinion, where it was noticed that the framework has a similar work procedure as the ebIX approach. From the outset, the primary requirements for the framework were to assess the impact of CIM on AgileDX based on a predefined business process or a specific part of the CIM model. Additionally, the framework aimed to facilitate a more efficient evaluation of other business processes in the energy retail market.

Following the demonstration, both requirements have been successfully addressed. By applying the framework's structured workflow, other processes can be implemented more efficiently, as the users have an implementation guide. Furthermore, the CIM model is compatible with ebIX with similar characteristics and therefore has minimal impact on AgileDX when implemented. Moreover, the demonstration highlighted the framework's ability to extend CIM by incorporating a new consent business process, further validating its effectiveness. However, experts also identified that the framework is still susceptible to the misalignment of business processes, as some implementations other than the Datahub were assessed. This is identified as a limitation of the framework.

7.3 Consent validation

The primary function of the consent business process was to demonstrate the capabilities of CIM and the framework while also contributing to the broader body of knowledge, which was successfully achieved. However, it remains crucial to validate both the designed business process, as detailed in Appendix C, and its implementation. A suitable method for evaluating the representation of consent information is outlined by Kurteva et al. [27], who proposed using a set of competency questions, as provided in Table 3. These questions are directly based on the GDPR's requirements for informed consent.

No.	Question	Relevant Concept(s)	Relevant GDPR Clause(s)
Questions about consent			
1	Who collects the data?	Data Controller, Data Processor	Art. 4 (7), Art. 6, Art. 28
2	For what purpose?	Purpose	Art. 4 (4), Art. 6 (1a, 1f, 4), Art. 7 (32)
3	How to withdraw consent?	Consent Withdrawal	Art. 7, Rec. 63, Rec. 66
4	How long does consent last?	Consent Duration/Validity/Expiry	Rec. 32, Rec. 42
5	When was consent given/revoked?	Consent Duration/Revocation	Art. 17, Art 19
Questions about personal data			
6	What personal data is collected?	Personal Data Categories	Art. 4 (1), Art. 9
7	How is the personal data being used?	Processing	Art. 4 (2)
8	How is personal data collected?	Data Collection	Art. 12, Art. 13, Art. 14, Rec. 39, Rec. 58, Rec. 62, Rec. 73
9	With whom is personal data shared?	Recipient, Data Sharing	Art. 4 (7), Art. 6, Art. 28
10	Who is responsible for the personal data?	Data Controller	Art. 24, Rec. 74, Rec. 79
11	Where is personal data stored?	Data Storage	Art. 5
Questions about the data controller			
12	Who is the Data Controller?	Data Controller	Art. 4 (7), Art. 28
13	How to contact the Data Controller?	Data Controller, Contact Information	Art. 4 (7), Art. 14, Art. 28
14	What are the responsibilities of the Data Controller?	Data Controller, Responsibilities, Obligations	Art. 4 (7), Art. 14, Art. 28, Art. 37
Questions about the data subject			
15	Who is the Data Subject?	Data Subject	Art. 4 (1)
Question about third party			
16	Whom to contact?	Contact Information, Third Party	Art. 12, Art. 13, Art. 14

Table 3: Competency questions consent as provided by Kurteva et al. [27].

The comparison between the designed business process and its implementation, as discussed earlier, indicates that many of the consent-related competency questions are addressed. However, certain aspects of the GDPR remain inadequately covered. A significant exclusion is the right of withdrawal, represented by question 3. This limitation arises because the current business process focuses solely on data requests, whereas withdrawal of consent composes a distinct process requiring its design and implementation. Additionally, questions 8, 10-14, and 16 are not directly addressed by this study's business process. Nevertheless, these questions are inherently resolved within the context of the Datahub, where the process is demonstrated. The Datahub's existing mechanisms ensure compliance with these requirements. For future iterations, these fields must be explicitly integrated into the process model to align with the requirements of the GDPR.

Additionally, the proposed consent business process was validated through demonstration and expert opinions and by comparing it to the consent model currently employed in the Datahub. This comparison revealed a shared approach to structuring the data model, reinforcing the alignment of the designed process with existing industry practices. The validation confirmed that the core elements of consent, particularly those relevant to the scope of the designed process, are accurately represented. One of the recommendations of the experts was to subject the process to various practical scenarios, such as a decentralized market with unknown market parties involved. This should be supported by a validation workshop from different parties involved in the energy data exchange. Furthermore, the process supports processes outside the energy retail market and was translated into a CIM message. However, for any future expansions of the process, it is crucial to address the competency questions that are not currently covered. Incorporating these aspects will ensure a more comprehensive and adaptable consent management framework, fully aligned with GDPR requirements and capable of addressing a broader range of scenarios.

8 Discussion

In this section, the CIM, consent management and the framework will be discussed. By applying a design science methodology an important aspect is to contribute to the existing body of knowledge. Here the findings of the study are discussed.

8.1 CIM in the energy retail market

This research aimed to evaluate the impact of CIM on AgileDX and to explore the broader applicability of CIM within the energy retail market. Throughout this discussion, references to CIM specifically pertain to IEC 62325, focusing on the European Style Market Profile. The findings indicate that CIM is compatible with AgileDX and has a minimal impact on the system. A key factor contributing to this strong compatibility is the liaison between the IEC and ebIX, which ensures practical alignment between the respective models. However, the study also revealed that the high diversity in market operations severely limits CIM's interoperability capabilities. This diversity poses a significant challenge to standardization across the energy retail market.

It can be concluded that CIM is a mature and detailed model, with an implementation procedure similar to that of ebIX. However, it is important to note that the system under study, the Datahub, is based on ebIX. As a result, the coverage of CIM to other models within the European retail market remains uncertain. Furthermore, while a single process related to metering data was fully implemented in CIM during this study, other processes were only evaluated and would require full implementation to enable more definitive conclusions. The significant diversity across market operations poses a substantial challenge to standardization efforts using CIM, suggesting that harmonization must primarily occur at an organizational level. Therefore, the overall position of CIM in the energy retail market remains questionable. For instance, the role of CIM in TSO-DSO coordination has yet to be fully explored as this coordination is an area of ongoing research. Successful implementations in this coordination could significantly enhance the value of CIM in the energy retail market, particularly as CIM has already been adopted as a standard by TSOs. This alignment could serve as a foundation for expanding CIM's applicability and interoperability across the energy sector.

One of the most significant limitations of CIM is its generally poor documentation, which complicates its adoption. The lack of a clear, standardized procedure for extending the CIM model leaves much of the interpretation to the user, potentially resulting in inconsistent implementations. Additionally, while CIM is often presented as an open standard, the IEC CIM is not fully open, as neither the UML model nor its accompanying documentation are readily accessible for research purposes.

A practical implementation of CIM in the energy retail market now exists, serving both as a demonstration of its feasibility and as motivation for practitioners to adopt the standard. CIM can function as a tool to help market participants align their business processes with a unified information model. However, this study concludes that the energy retail market as a whole is not yet ready for a comprehensive standard like CIM. Harmonization at the organizational level remains a prerequisite, and close attention to developments from the EU DSO Entity is recommended. This organization, formally mandated by the EU Directive [5], is actively working on harmonizing master data across DSOs. Additionally, further research into CIM's role in TSO-DSO coordination could uncover new opportunities for its application and enhance its overall value in the energy sector.

8.2 Consent management in data exchange

For the practical demonstration of CIM's extensibility, a business process for handling consent was developed. The literature revealed a gap regarding a general process for managing consent and data exchange. Existing frameworks and ontologies may prove too complex for practitioners to implement easily. To define a CIM profile for consent, a business process is necessary to identify the requirements for the data model itself.

In this study, a proposal for such a process was developed, representing a data request from a third party. However, the entire life cycle of consent was not covered within the scope, as GDPR requirements such as the withdrawal of consent were excluded. Addressing these requirements in future extensions will be essential. Despite its limited scope, the process effectively demonstrated CIM's extensibility by accommodating new requirements, such as consent.

This proposal serves as a foundational step for further development of consent management within data exchange. The structure of the market, whether centralized or decentralized, significantly influences the handling of consent. Examining the proposed process across various scenarios, such as the inclusion of unknown parties or decentralized markets, could yield valuable insights for practical implementation. Additionally, functional elements of the process, such as identification mechanisms and policy matching, were not explored in detail. As these steps are crucial for effective consent management, future research must focus on addressing and implementing these aspects.

Recommendations for future work include conducting an empirical study within a real-world environment, with the energy retail market serving as an ideal context for this investigation. Such a study would provide valuable insights into the practical applicability and challenges of implementing the proposed process. Following refinement based on empirical findings, the model could be proposed to the IEC for consideration as an official profile within the CIM framework. To maximize its utility, the process itself should remain as general as possible, enabling its broader applicability across various fields of data exchange. This generalization ensures that the process can serve as a foundational approach, adaptable to different sectors and contexts. Given the strong desire from the industry for a process to address GDPR requirements, the proposed model offers a starting point on which organizations can build and align their data exchange practices with regulatory compliance.

8.3 CIM implementation framework

The extension of CIM in the energy retail market has now been thoroughly discussed, with the final step focusing on evaluating the designed framework. The primary goal of this framework was to streamline the implementation of processes beyond DH-211 by offering a structured workflow revealed through this study. Due to the similarities between CIM and ebIX, the workflow closely mirrors existing ebIX processes. This resemblance facilitates the understanding and adoption of the framework, particularly for users already experienced with ebIX.

The study demonstrated the framework's utility through the efficient implementation of an extended consent process. Notably, no prior research has implemented CIM in the energy retail market, with existing guidance primarily focusing on the IEC 61970 part. Consequently, the proposed framework provides much-needed support for practitioners navigating CIM implementation in the retail market.

However, the framework has several limitations. A critical requirement when working with standards is demonstrating compliance through conformity and interoperability testing. This aspect was not addressed within the current framework. To ensure practical viability, such testing must be conducted when implementing the CIM model in an environment like AgileDX, in consultation with the IEC. Additionally, the process for extending the CIM model, as outlined in the framework, relies on interpretations of recommendations from guide documents. The absence of a formal, standardized method for CIM extensions means the correctness of the approach cannot be definitively validated. While the technical feasibility of extending the CIM model using this framework is clear, it remains uncertain whether this method aligns with IEC's desired practices. To enhance CIM's applicability in real-world scenarios, the IEC should provide a formalized procedure for extending the model. Lastly, the framework does not address the alignment of business processes with the CIM information model, which could present challenges for markets not based on ebIX. In such markets, a significant gap may exist between business processes and the information model, highlighting an area that requires further exploration and refinement.

The CAs of the framework have been assessed and the top four CAs will be discussed here. The most critical aspect is market readiness; if the energy retail market is not prepared to adopt CIM as a standard, due to a lack of harmonization, regulatory frameworks, or stakeholder willingness, the framework risks becoming obsolete. As previously mentioned, the retail market appears not to be ready as a whole. However, a framework as proposed here can be an important first step to improve market readiness. The second-ranked aspect is integrability, emphasizing the importance of incorporating new systems into CIM implementations or accommodating new requirements, both of which are essential for the framework's success. Skilled personnel ranks third, as effective CIM modelling processes demand a certain level of domain expertise. Finally, process integration is highlighted as the fourth critical aspect, reflecting the challenge of aligning CIM with legacy systems and ensuring compatibility with existing business processes. A limitation of the ranked CAs is the lack of proper validation by experts. A validation method proposed by Merhi [38] has been identified but remains as future work for this study.

9 Conclusion

This study proposed an implementation framework for CIM in the energy retail market and demonstrated its extensibility by integrating a consent management business process. The findings showed that the CIM standard can be implemented in AgileDX with minimal impact, as it proved compatible with the existing ebIX model. Moreover, CIM supports the inclusion of new requirements, such as consent management, demonstrating its adaptability. The framework enables more efficient implementation of various business processes in the retail market, ensuring AgileDX's compatibility with future requirements. On a broader scale, CIM adoption in the European energy retail market has the potential to enhance interoperability across market participants. However, the current market lacks the readiness to adopt a standardized approach to data exchange due to limited harmonization.

The implementation framework can serve as a demonstration tool to showcase CIM's functionality and encourage market participants to align on a standardized approach for information exchange. These demonstrations could play a small but meaningful role in advancing the harmonization of the European energy market. However, market readiness depends significantly on the incentives for market participants to adopt a standard like CIM, a factor that remains underexplored. This study identified a potential application of CIM in TSO-DSO coordination, a topic gaining attention in the energy sector with the establishment of the EU DSO Entity. Future research could explore CIM's role in facilitating TSO-DSO coordination, particularly in the context of smart grids. Additionally, further investigation into aligning business process modelling with the CIM information model could be instrumental in improving CIM adoption. Expanding and refining the proposed consent management process could also serve as a valuable enhancement to the CIM standard.

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Appendices

A Contextual and assembly model of DH-211

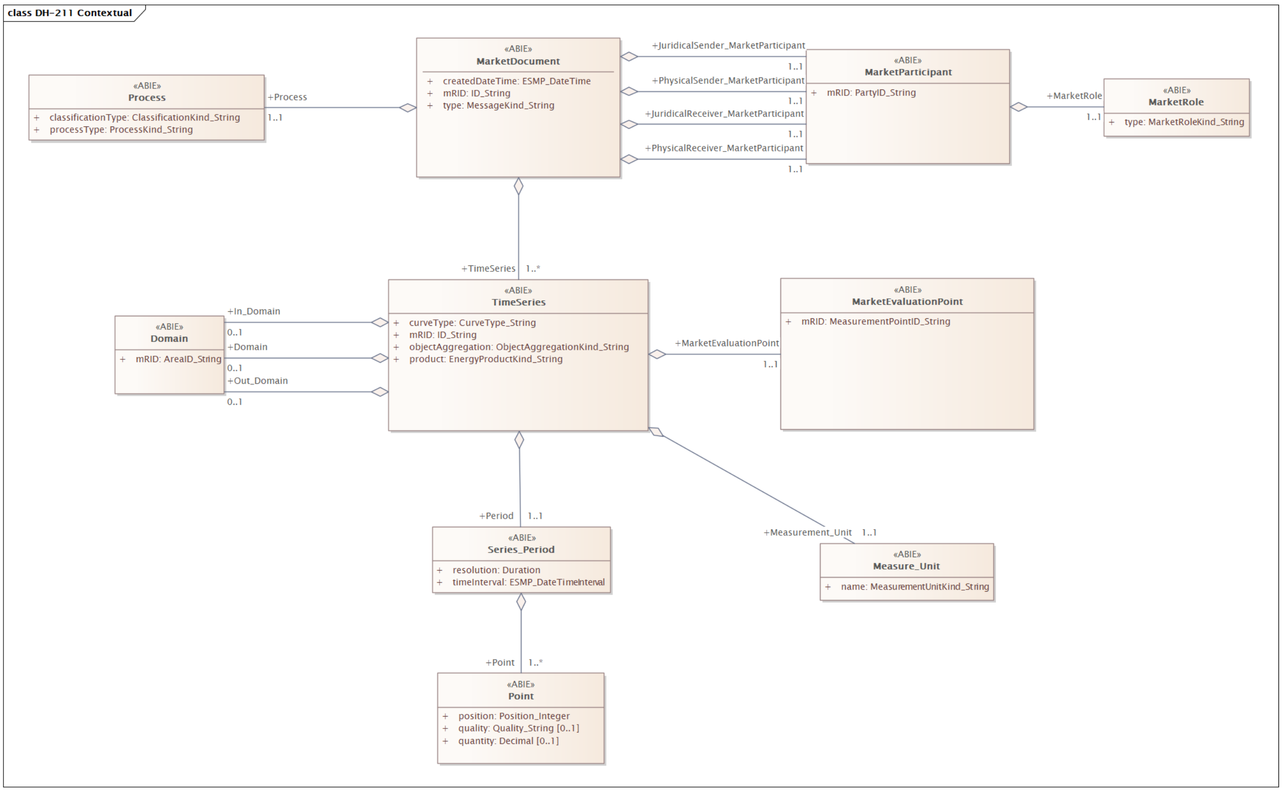


Figure 11: Class diagram of the DH-211 document contextual model.

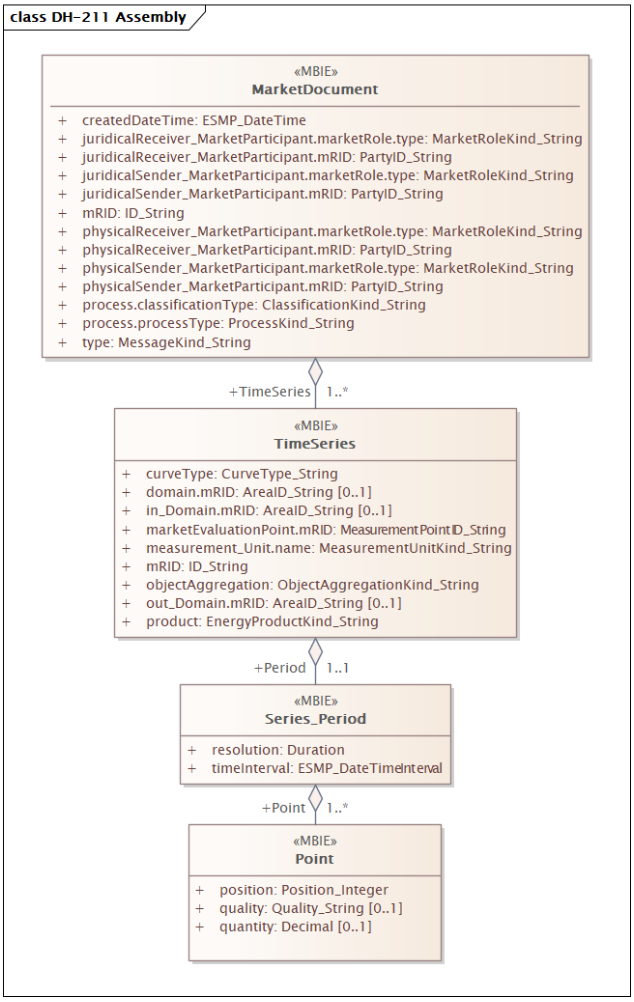


Figure 12: Class diagram of the DH-211 message assembly model.

B Sequence diagram

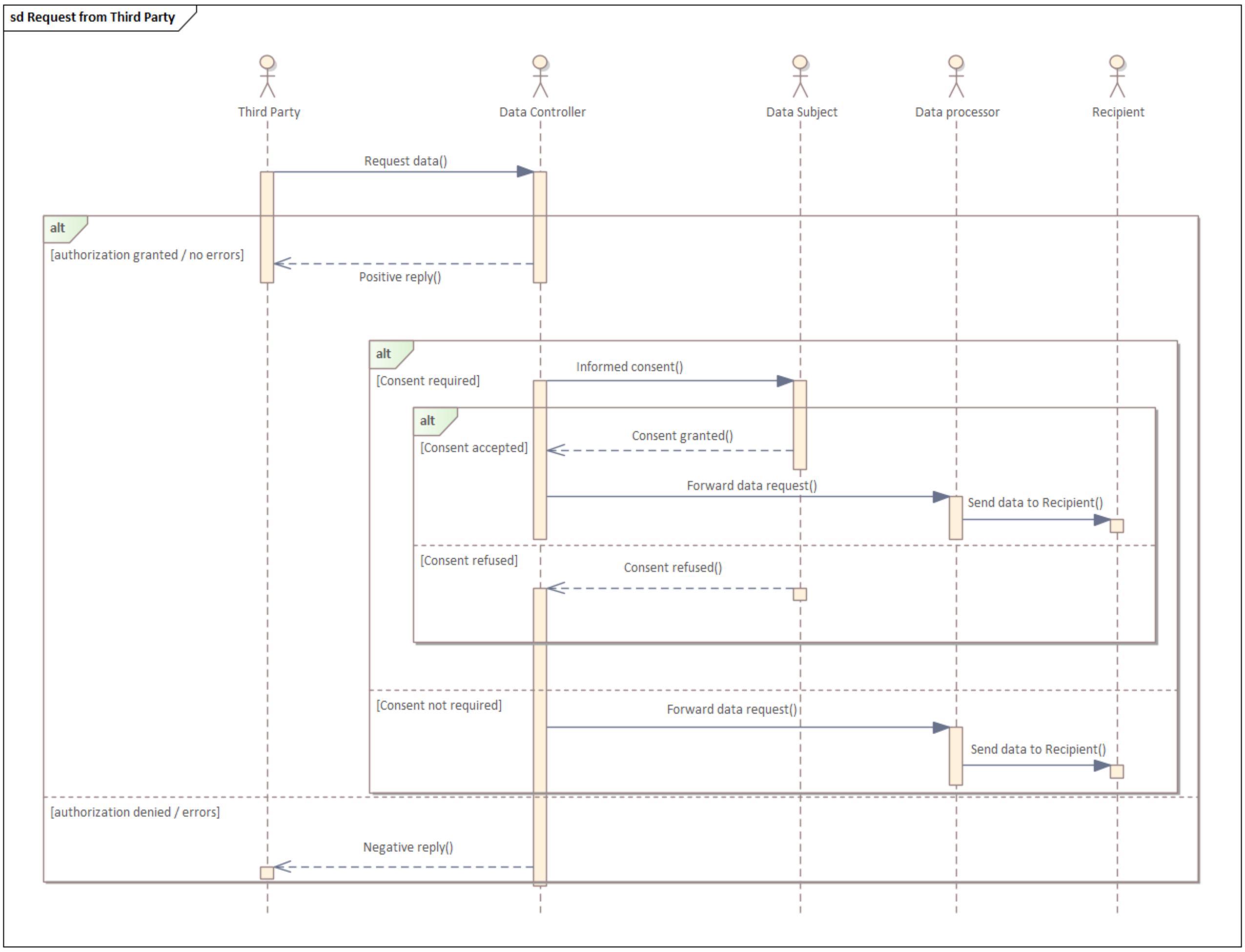


Figure 13: Sequence diagram of a data request from a (un)known Third Party.

C Consent-based business process

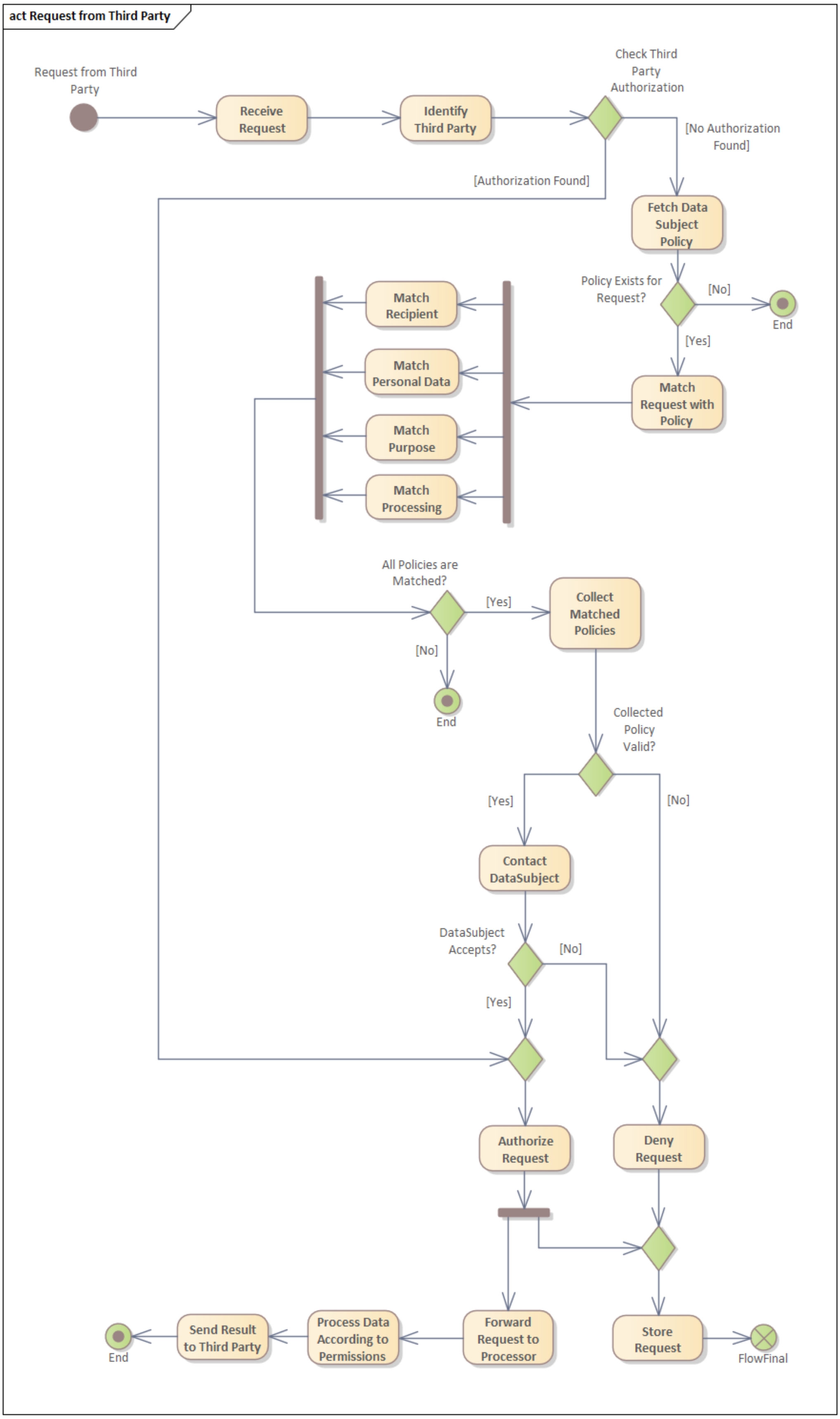


Figure 14: Activity diagram of a data request from a (un)known Third Party.

D CIM Profile Creation Instruction Guide

Introduction

This instruction guide provides an example of how to create a CIM profile in Enterprise Architect using CimConteXtor and CimSyntaxGen. The example provided was based on the DH-211 process.

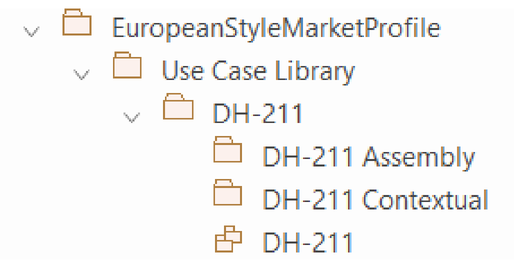
Tools Required

- Sparx Enterprise Architect
- CimConteXtor and CimSyntaxGen add-ins by Zamiren
- ENTSO-E CIM European Style Market Profile

Step-by-Step Instructions

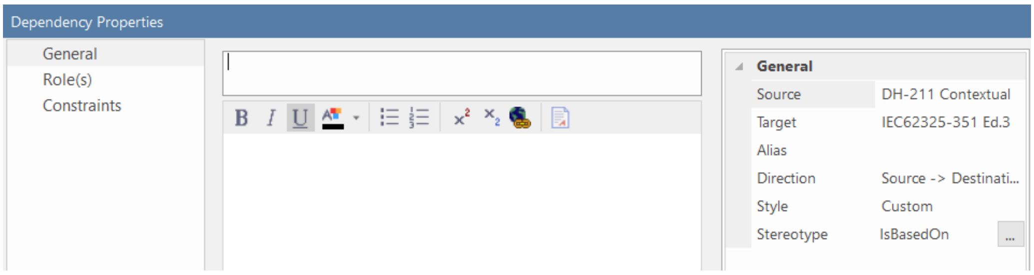
Follow the detailed steps below to complete the task.

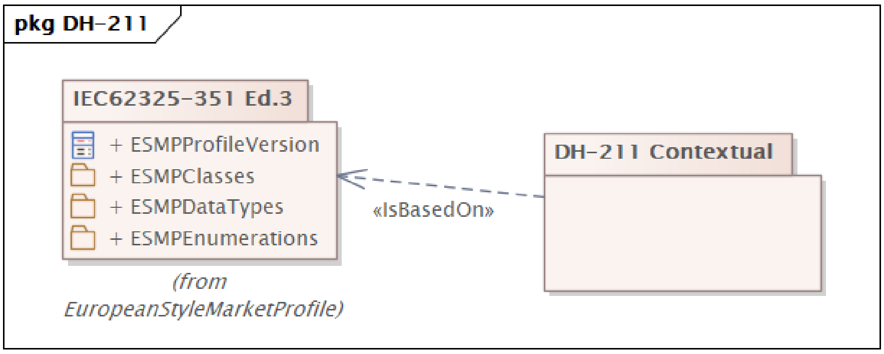
1. Open the project file in Enterprise Architect (EA) that contains the relevant model (e.g., `20230517_ESMPv4_iec6197017v34_iec61968cim13v12_iec6232504v09`).
2. In the Project Browser, navigate to the package `EuropeanStyleMarketProfile` → `Use Case Library`. This is where the new profile will be created.
3. Create a new package. Within this package, create two additional sub-packages named `<profile name> Contextual` and `<profile name> Assembly`, along with a package diagram.



4. Reorganize the package hierarchy by placing the `Contextual` package above the `Assembly` package using the arrows in the Project Browser.
5. Open the newly created package diagram by double-clicking on it.
6. In the Project Browser, locate the package that serves as the base for the new profile (e.g., `ESMP IEC62325-351 Ed.3`) and drag it to the package diagram. In the dialogue box, select ”Package Element.”
7. Drag and drop the `<profile name> Contextual` package into the package diagram. In the dialogue box, select ”Package Element.”
8. Establish a relationship between the `Contextual` package and the base package by selecting the `Contextual` package in the diagram, clicking the small arrow, and dragging it to the base package. In the dialogue box, select ”Dependency.”

9. Double-click on the dependency arrow to open its properties. In the new window, assign the stereotype `IsBasedOn` to the dependency.





10. Right-click the `Contextual` package in the Project Browser and select `Add Diagram`. Choose the `Class Diagram` type.

11. In the contextual model diagram, drag and drop a required class from the profile upon which the new profile is based (e.g., `<<ACC>> MarketDocument` from `ESMP`). When prompted by CimConteXtor, confirm the `IsBasedOn` relationship.

12. In the subsequent dialogue, deselect all unnecessary attributes for the profile and edit the cardinalities for each attribute as needed by selecting the attribute and choosing `Edit Cardinality`.

13. Deselect `Copy Parent's Stereotype` and assign the stereotype `ABIE` to the class.

14. If the class is a first-level class (often `MarketDocument`), mark it as `Root (Active)`.

15. Execute the `IsBasedOn` function.

16. Repeat steps 11 to 13 and 15 for all other required classes in the profile.

17. To create associations between classes, right-click a class and select `Specialize → CimConteXtor → Edit Hierarchical Connectors`.

18. In the new window, select the required association and choose `Modify Selected Association`.

19. Edit the cardinality and, if necessary, add a qualifier to the association. Save the changes. Add additional associations between the classes as required, and save the updated associations.

20. Repeat steps 17 to 19 for all associations needed for the profile. If two associations are created between the same classes, they will initially overlap in the diagram but can be repositioned manually.

21. For each class in the profile, right-click and select `Specialize` → `CimConteXtor` → `AttributeOrder`. Reorder the attributes so that `1..1` attributes are at the top, followed by `0..1`, and finally `1..*`. This step must be completed for all classes, even if a class contains only a single attribute.

22. In the Profile Browser, select the `Assembly` package, right-click, and choose `Specialize` → `CimConteXtor` → `PropertyGrouping`. In the new window, select the `Contextual` package. Confirm the action when prompted.

23. Arrange the classes appropriately within the Assembly model diagram.

24. Ensure that the `Contextual` package remains above the `Assembly` package in the Project Browser.

25. To generate the XSD file, right-click the `Assembly` package and select `Specialize` → `CimSyntaxGen` → `XSD` → `XSD WG16`.

26. Assign a name to the file, specify any additional parameters as required, and click `OK` to generate the XSD file.

E Evaluation of the MDP

Evaluation of working within the company environment

Working within CGI has been a great learning opportunity. Because I had no prior background on the MDP topic it was challenging sometimes. Furthermore, it takes some time to understand the different aspects of the energy market. However, there was enough expert knowledge within the company to support the successful completion of the MDP. Because the company had the resources available, the MDP was not only theoretical based but an actual test implementation of CIM in AgileDX was successfully conducted. It is a great experience to see the artefact that you have designed actually working within a real environment. Sometimes navigating yourself in a large organisation can be challenging. Because I had prior experiences in this, I did not encounter any issues with this during the MDP. Often you need the consult some people within the company who are very occupied, making it challenging to get a fast solution to your problem. This requires careful planning of the project, which sometimes is difficult to manage.

Short analysis of this MDP

Here the pros and cons of the MDP are described. The pros of the MDP are:

- Successful completion of the objective set from the start of the MDP. To this additional work was included in the MDP.
- A CIM-based message was successfully implemented in AgileDX. There now exists a real working example of CIM in AgileDX. This serves as a very strong validation of the MDP itself.
- The framework developed is something that CGI can actually use in the near future as more clients are willing to adopt the CIM. It is not only a theoretical body of knowledge but a practical tool.

The cons of the MDP (i.e. what must be improved) are:

- A challenge identified from the start was the high diversity of the retail market. This made motivating the outcome of the MDP sometimes challenging.
- Stakeholders outside CGI were not included that much in this project. This could reveal useful insights. Furthermore, validation with those stakeholders is not included in this project.
- Some process challenges during this MDP were identified. Because of the lack of background information, it took some time to understand the topic. While the assignment itself was completed successfully, there were time constraints on deeper delving into the issues from the problem context. This is something interesting for future work.