A Metamodel for Applying Green BPM Approaches with the EU Taxonomy

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Abstract. Increasingly, companies are obliged and incentivized to consider the impact of their business processes on the environment, to promote *sustainable* business practices. In particular, the *EU Taxonomy for Sustainable Activities* outlines criteria for when business practices contribute towards a sustainable future. However, it is unclear in how far existing methods for identifying, analysing, and improving business practices, in particular those of the disciplines of *Business Process Management* (BPM) and *Green BPM* (that is, a variant of BPM with a focus on environmental sustainability) can relate to those criteria and the concepts contained therein. Therefore, we develop and propose a metamodel that combines concepts of the EU taxonomy and Green BPM, and clarifies the relationship of the two frameworks. This metamodel increases conceptual clarity and allows practitioners to apply Green BPM approaches in light of the EU taxonomy, and researchers and tool providers to further explore technical solutions in light of the EU taxonomy. It provides a clear overview of how the gap between sustainability regulations and approaches for sustainable business practices can be bridged. We evaluate the semantics and pragmatics of our metamodel, and sketch potential applications with an illustrative example.

Keywords: Green BPM · EU Taxonomy · Metamodel · Sustainability.

1 Introduction

Organizations and businesses, particularly in industrial sectors, usually consume natural resources, leading to habitat destruction and resource scarcity, climate change and waste that pollutes ecosystems and harms communities. Global supply chains extend these environmental impacts between regions [3,14,18]. In response to these significant environmental challenges, the notion of *sustainability* outlines "adopting practices that meet present needs without compromising the ability of future generations to meet their own" as a solution [13]. Recognizing the importance of this, bodies such as the *European Union* (EU) have developed frameworks and incentives to help and to incentivize companies to integrate sustainability into their business practices and strategies. One of the frameworks is the EU's *taxonomy for sustainable activities*,

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subsequently referred to as *EU taxonomy* [7,26]. An overarching goal of the EU taxonomy lies in providing clear criteria for when business practices contribute to sustainability objectives, and when not [20].

As a relevant viewpoint for managing and improving business practices, and specifically business processes, *Business Process Management* (BPM) is a discipline commonly used within organizations. The underlying notion of BPM is that each product or service an organization offers results from various activities performed in a coordinated manner, i.e. a business process [39]. *Green BPM* extends this concept by integrating environmental sustainability into all phases of the process management lifecycle [5,17]. Given this, it therefore is prudent to examine in how far the EU taxonomy aligns with a Green BPM "perspective" — doing so will offer the potential for making business processes more sustainable by providing a structured methodology for analysing and improving them in light of the EU taxonomy.

However, integrating Green BPM with the EU taxonomy is challenging due to different points of view: BPM, the foundation upon which Green BPM is built, is concerned with managing activities and processes w.r.t. business goals [39], whereas the EU taxonomy formulates criteria for when business practices contribute towards specific sustainability goals [20]. Bridging this gap by conceptually linking Green BPM approaches to the EU taxonomy would help organizations in increasing regulatory compliance and meeting potential reporting obligations on the one hand, and in implementing sustainable business practices on the other [20]. Further, it would allow Green BPM practitioners, researchers, and vendors to orient Green BPM approaches towards the EU taxonomy. In this study, we therefore explore how, conceptually, Green BPM and the EU taxonomy could be aligned and jointly used to assess and improve business processes w.r.t. sustainability criteria. To achieve this, we here propose a *metamodel* that explicates the conceptual relationships between Green BPM and the EU taxonomy; in doing so, we aim to address the following research objective:

RO1: Constructing a metamodel that represents aligned concepts between Green BPM and the EU taxonomy.

The remainder of this work is organized as follows: In Sect. 2, we provide the necessary background and discuss related work. In Sect. 3, we describe the methodology used to develop the metamodel. Section 4 presents the main result of our study, which is evaluated and applied to an illustrative example in Sect. 5. Finally, we discuss our findings and conclude the article in Sect. 6, in addition to suggesting directions for future work.

2 Theoretical Background

In the following, we summarize the general concept and aims of the EU taxonomy, and provide an overview of existing Green BPM approaches; we also discuss existing work relating to our study.

EU Taxonomy. The EU taxonomy is a framework established to drive sustainable *economic activities* (i.e. families of *business processes* involving the production, distribution, or consumption of goods and services [10,20]) by offering a clear and standardized system for classifying environmentally sustainable practices. It aims to assist investors, businesses, and regulators in determining which economic activities contribute to environmental sustainability. The primary objective of the taxonomy is to aid the European Union in its goal of achieving climate neutrality by 2050 [9,36]. By establishing clear criteria for what constitutes a sustainable activity, the EU taxonomy contributes to 1) establishing clear indicators to differentiate between sustainable and non-sustainable business activities, thereby preventing greenwashing; 2) motivating businesses to prioritize sustainable practices; and 3) encouraging financial investments in companies that contribute to sustainability [7, 20].

To classify and identify sustainable activities, the EU taxonomy uses *Nomenclature of Economic Activities* (NACE) codes, a standard classification system for economic activities within the EU. Each economic activity is assigned one or more NACE codes, which provides a detailed categorization based on the type of activity being performed. These codes are essential in the context of the EU taxonomy because they allow businesses and regulators to identify which activities are subject to the sustainability criteria outlined by the EU taxonomy [15]. Further, the definition of NACE codes and economic activities (see [12]) is closely aligned with the definition of business processes (see [39]) — in line with Klessascheck et al. [20], we understand economic activities to provide "families" or "classes" of business processes and business practices.

For making a contribution towards sustainability goals, those economic activities that can theoretically do so (i.e. *taxonomy-eligible* economic activities) must meet four requirements [15]: First, *Substantial Contributions*: Economic activities must significantly contribute to environmental objectives, such as climate change mitigation, adaptation, water and marine resource protection, circular economy transition, pollution prevention, or biodiversity restoration [38]. Second, *Do No Significant Harm* (DNSH): Economic activities must not harm other environmental objectives [16, 38]. Third, *Minimum Safeguards*: Economic activities must adhere to social safeguards, including human rights and ethical practices [19, 29–31]. Fourth, *Technical Screening Criteria*: Economic activities must fulfil specific technical standards to ensure adherence to the requirements above. Notably, taxonomy-eligible economic activities identified as potentially contributing to environmental objectives become *taxonomy-aligned* only when all criteria are satisfied [6]. For another useful conceptual overview of the EU taxonomy, we refer to a previous study of ours [20].

Green BPM. An area of BPM that is well-situated to integrate concepts of the EU taxonomy is Green BPM: This field has emerged as a response to an increasing awareness of environmental concerns and a need to integrate a perspective on environmental sustainability into the management of business processes [33, 37]. To this end, Green BPM offers various techniques and approaches to model, deploy, manage, and improve business processes regarding their environmental performance [5]. These include: 1) *Modelling* approaches (e.g., modelling guidelines for modelling business processes that can be optimized for the environmental impact of corresponding process executions [25], or extended notions for representing environmental impact or resource consumption in process models) [5, 17]; 2) *Deployment* approaches (e.g., for measuring and controlling emissions) [5, 17]; 3) *Optimization* approaches (e.g., for benchmarking process redesigns for their environmental impact) [5, 17]; and 4) *Management* approaches (e.g., extensions of the business process lifecycle with concepts of sustainability) [17]. Further, in a previous study, we have proposed the applicability of *compliance monitoring*, in extension to existing deployment approaches, with which various constraints of the EU taxonomy might be monitored for violations during business process execution [20].

Related Work. In this paper, we investigate to what extent and where concretely the EU taxonomy aligns with Green BPM concepts, to outline fruitful avenues for operationalizing constraints from the taxonomy with Green BPM approaches. In that sense, our study is related to other contributions that deal with conceptual overviews of the (Green) BPM "perspective" on organizations and processes, or propose conceptual integrations of sustainability into BPM or organizational practice.

Several studies formally capture entities that make up business processes and organizations from the BPM discipline's standpoint. For example, Annane et al. [2] present a *BPMN-based ontology* (BBO) for business representation, aiming to provide a formal and structured representation of business processes using ontologies to improve the analysis, simulation, and automation of business processes. Vom Brocke et al. [4] emphasize the role of context in BPM initiatives, which influences through various factors the concrete application of BPM practices; they also propose a framework to systematically identify and analyse them. Andree and Pufahl [1] address the role of context in business process redesign by presenting a metamodel that captures relevant contextual information to assess change operations. Rosemann et al. [34] focus on addressing the flexibility of business process; they propose a framework and metamodel for identifying and integrating these contextual factors into business process modelling.

In addition, various studies have engaged with integrating sustainability concepts into business practice, particularly in the research stream of Green BPM [5,17]. However, only some studies, which we found via a literature search, provide conceptual models of the entities and relationships involved in this. For example, Medini et al. [27] provide a metamodel that combines components of enterprises and their processes with entities regarding sustainability. Reiter et al. [32] present a conceptual model for integrating IT components, applications, and business processes, for reducing the energy consumption of business processes. Further, [23] present a sequential approach for process analysis in Green BPM, and provide a metamodel that relates business processes with sustainability concepts. Finally, while not providing a conceptual model, Roohy Gohar and Indulska [33] describe concepts and indicators for incorporating environmental sustainability into BPM. In a previous study [22], we provide an approach for data-driven holistic assessments of the environmental impact of business processes; most relevant here being a metamodel that provides a conceptual overview of processes, activities, instances thereof, and instantiations of environmental impact.

In a similar vein as the previous group of related work, our study converses with contributions that conceptually address the complexities of multiple reporting standards and the ambiguity of informal textual descriptions of sustainability indicators. As a particular example, Zhou and Perzylo [40] propose the *OntoSustain* model and provide a conceptual overview of how small and medium-sized enterprises can benefit in navigating sustainability reporting challenges. While also providing a conceptual model, their contribution does not directly align with BPM practices, nor the EU taxonomy and the concept of EU taxonomy alignment.

Currently, there are only initial and exploratory approaches that investigate in how far companies can be supported in aligning Green BPM approaches and practices with sustainability regulations, without clear and generalized guidance [35]; only some attention has been paid to understand how business processes can be viewed from the EU taxonomy perspective: In a previous study [20], we investigated whether the constraints of the EU taxonomy could be used for regulatory compliance monitoring with process mining techniques. What is still missing, however, is a generalized notion of the conceptual alignment between Green BPM and the EU taxonomy. Although existing contributions and their conceptualizations of sustainability reporting or business processes (e.g., [2, 40]) can provide a point of departure, the specific alignment of Green BPM with the EU taxonomy remains unaddressed. We therefore see the need to provide a conceptual foundation for investigating and using this relation.

3 Research Method

So far, Green BPM and the EU taxonomy regulation have largely been treated separately. To bridge the gap between these domains and their concepts, we develop a metamodel in the following, thereby integrating both domains and identifying common concepts. In this, we follow the methodology for conceptual model development presented by Naeem et al. [28]; Figure 1 provides a graphical overview of our research method.

For developing the metamodel, we selected relevant statements from literature and abstracted and summarized them into keywords. We assigned these keywords to representative codes that better reflect the core entities of the EU taxonomy or the Green BPM domain, respectively, and organized them in meaningful themes that match our research objectives and embodied patterns of the regulations.

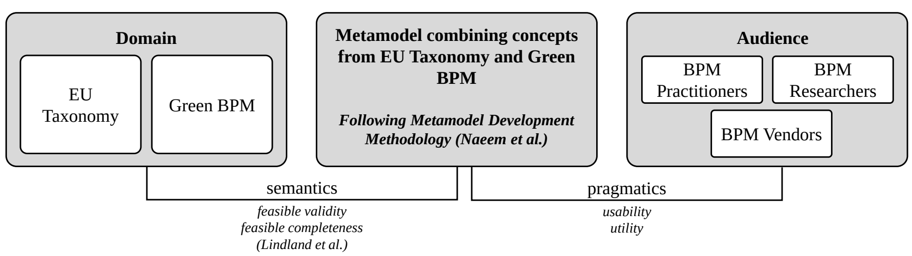

Fig. 1. Methodological overview, adapted from [24]

For conceptualizing the identified themes, we used *Unified Modeling Language* (UML) class diagrams, since it allows for detailed modelling of relationships between entities. Its widespread and standardized nature ensures clear communication and consistent modelling. In short, we create a metamodel for each domain to determine the relevant concepts. By comparing both models, we identify commonalities and differences, merging them into a unified metamodel.

For evaluation, we follow the methodology for conceptual modelling according to Lindland et al. [24]. As shown in Fig. 1, we focus on *semantics* to assess the feasible validity and completeness of the model and on *pragmatics* to evaluate usability and utility. The audience of the aligned metamodel includes BPM practitioners wanting to align business practices with the EU taxonomy, BPM researchers wanting to make sense of the EU taxonomy to research novel techniques and approaches in this field, and BPM vendors wanting to make use of concepts from the EU taxonomy in their tools. Correct syntax of the model is already given, since we strictly follow the UML standard for modelling. In the following, we provide an overview of the sources being used for statement selection for each model. Moreover, we explain how the aligned metamodel was derived.

EU Taxonomy Model Development. Following Naeem et al. [28], we manually extracted relevant statements from the EU taxonomy regulation [15] by thoroughly exploring the specific sustainability criteria and compliance requirements. For this extraction step, we used the *taxonomy navigator* [8] and the *official journal* [15], both providing identification and classification of economic activities aligned with sustainability objectives. In addition, the ontology presented in Zhou and Perzylo [40] was particularly useful for extracting sustainability entities. It captures key sustainability aspects and indicators relevant to corporate reporting, thus helping us in better conceptualizing the sustainability perspective for companies and how sustainability indicators relate to the business domain entities. However, due to the specific focus of the OntoSustain model on corporate sustainability reporting, it does not deal with all the elements covered by the EU taxonomy. Therefore, we added further statements directly from the EU taxonomy regulation [15]. We then abstracted and summarized the collected statements into keywords. We assigned these keywords to representative codes that better reflect the core entities of the EU taxonomy, and organized them into meaningful themes that match our research objectives and embody patterns of the regulations. We then arranged the extracted entities into a schematic model. This schematic model was iteratively improved with additional relationships between the entities.

Green BPM Model Development. Relevant statements within the BPM domain were selected by screening various related work, in line with Naeem et al. [28]. We incorporated the foundations of BPM presented in [22,39], in particular the BPM lifecycle, business-relevant works, such as [2,4,34] to bridge the gap between process and different business perspectives, and principles of the Green BPM field [5,17] to include environmental objectives, sustainability practices, and compliance requirements. Similarly to the metamodel derived from the EU taxonomy, we applied the methodological framework of Naeem et al. [28] to conceptualize the identified statements.

Aligned Metamodel Development. Having established the two metamodels for the EU taxonomy and the Green BPM domain, we analysed their similarities and differences to determine areas of alignment. Overlapping concepts were identified by comparing entities from both models. Common elements such as economic activities, compliance requirements, and sustainability indicators were assessed. Elements from BPM were mapped to corresponding regulatory components from the EU taxonomy, with economic activities in the taxonomy aligning with processes in BPM. Shared concepts, including environmental impact assessments, sustainability reporting, and regulatory compliance were also counted in the alignment. At the same time, certain elements remained unique to each framework, such as BPM's business goal structuring and the EU taxonomy's legal enforcement criteria. These differences were carefully considered to determine whether they should be incorporated or omitted in the final aligned metamodel. The decision-making process was guided by the principle of maintaining relevance to the core objective of our study (i.e. conceptually aligning business processes with sustainability regulations) and discussed between all authors. The final step involved synthesizing the identified overlaps into a single aligned metamodel. Redundant elements were removed, to present the model without sacrificing important details. This led to the synthesis of the two developed metamodels on Green BPM and the EU taxonomy into a third model that represents their conceptual alignments.

4 Results

In the following, we present the results of applying the metamodel development methodology on the EU taxonomy and Green BPM.[3]

EU Taxonomy Model. The EU taxonomy metamodel outlines the regulatory framework for sustainable economic activities. *Economic Activities or Business Practices* as the core entity of the EU taxonomy metamodel are classified according to the *NACE* code classification [26]. We differentiate between *transitional* and *enabling* economic activities, indicating whether they are moving towards sustainability or facilitating sustainable business practices directly.

Assessing whether an economic activity aligns with the EU taxonomy is represented via the *Taxonomy Alignment* entity. Relevant for this is whether activities meet *Technical Screening Criteria*, i.e. specific requirements they must satisfy to be considered sustainable. Additionally, activities are linked to *Environmental Objectives*, such as mitigation, adaptation, and biodiversity protection, complying with *DNSH* criteria. *Key Performance Indicators* such as turnover, *operational expenditure* (OpEx), and *capital expenditure* (CapEx) are used to measure the performance and financial implications of sustainability initiatives. These KPIs, along with other reporting values, feed into *Sustainability Reports*, which document the organization's efforts to align with the EU taxonomy.

To realize a *Product* or *Service*, *Resources* are required and, thus, considered as *Input*. Resources include humans, finances, materials, and data. They contribute to the *Environmental impact* of the organization's *Operations*, which can be tracked using the model. *Information and Traceability of Substances* maintain transparency and ensure compliance with sustainability standards, particularly in monitoring the environmental footprint of materials used within processes. Plants, vehicles, and machinery are listed as the organization's assets. They are managed via the *Equipment Restrictions*. *Environmental impact* is caused by *Outputs*, e.g., *Emissions* (such as Greenhouse Gas (GHG) and others) and *Waste*.

[3] Due to limitations in length, we provide the intermediate metamodels and further illustration of the conceptual model development via supplementary material available online at https://figshare.com/s/cd00a430235071e4d5e6

Green BPM Model. The developed Green BPM metamodel presents a conceptual view on Green BPM. A *Business Process* is a collection of related, structured activities that are performed in coordination to produce a service or product serving a particular business goal [39]. A *Process Instance* contains multiple *Activity Instances* representing the real-time execution of individual process activities. These instances are critical for generating operational data and *Key Performance Indicators* (KPIs) measuring efficiency, effectiveness, and alignment with business goals.

The extended Green BPM model incorporates a broader set of entities to represent the internal and external dynamics of an enterprise. *Resources*, e.g., *Data*, *Material*, *Software*, are the inputs necessary to execute *Activity Instances*. We differentiate between *Raw* materials, *Energy*, *Equipment*, and *Technology* [2, 27]. Furthermore, *Environmental Resources* include resources related to *Air*, *Water*, *Land*, and *Mined resources* [27]. *Enterprise Objects* are functional units or assets within the organization that interact with or are impacted by the *Process Model* [27]. The *Enterprise* entity represents the organization as a whole, incorporating all *Enterprise Objects*, *Business Processes*, and *Compliance Requirements*. *Compliance Requirements* ensure that business operations meet legal, environmental, and quality standards. *Business Goals* drive the design and execution of processes and are categorized into *Hard*, *Soft*, and *Environmental* goals, taken from [34]. *Market* represents the external environment composed of customers, governments, and local communities [27]. *Organization Policy* guides the strategic direction and operational standards within the organization. It includes policies that support environmental sustainability.

In the context of Green BPM, KPIs continue to play a central role in measuring the performance of activities and process instances. However, in an environmentally conscious approach, these KPIs are extended to include *Environmental Performance Indicators* (EPIs) and specifically measure environmental impacts such as emissions, waste, energy consumption, and water usage [33]. The more sustainably *Resources* are used, the better the environmental impact of business processes. *Resources* are linked to the execution of activities and are essential for achieving the desired outcomes of the processes. The concept of *Green Supplier Monitoring* emphasizes the importance of sustainable sourcing by ensuring suppliers meet environmental standards [5].

Green Behaviour captures environmentally conscious actions within the organization, such as recycling, energy conservation, and emission reductions. *Stakeholders*, which include customers, employees, and suppliers, play a significant role in influencing business goals and processes. In this, their *Green Behaviour* is important [5]. *Environmental* goals (i.e. goals stemming from the *environment* of a process) [34] are particularly relevant in the context of *EU taxonomy*, as they motivate adopting sustainable practices within business operations.

Aligned Metamodel. The aligned metamodel that is the result of synthesising the two previous models into one, shown in Fig. 2, integrates concepts from Green BPM and the EU taxonomy framework to create a unified ("*aligned*") model. The entities highlighted in purple represent aligned concepts that bridge the gap between Green BPM and the EU taxonomy. Green entities originate exclusively from the Green BPM discipline, while yellow entities are drawn exclusively from the EU taxonomy.

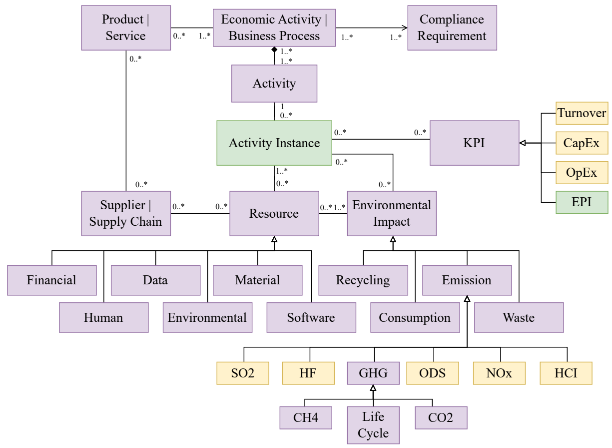

Fig. 2. Metamodel displaying concepts from Green BPM (in green), the EU taxonomy (in yellow), and their relationships; aligned concepts shown in purple

At the centre of the aligned metamodel is the *Economic Activity / Business Process* entity, which serves as the bridge between Green BPM and the EU taxonomy. A business process is subject to *Compliance Requirements*, which are concerned with regulatory, legal, and environmental constraints. The *Activity* entity represents the individual tasks or steps that comprise a business process or economic activity. Each activity contributes to the overall objective of the business process or economic activity, and is necessary for realizing a *Product* or *Service*. A specific execution of an *Activity* leads to an *Activity Instance*. *Activity Instance*s also interact with *Resource*s, drawing from financial, material, human, and other input forms (such as resources that can be "taken" directly from the environment, e.g. sunlight, or air) to execute specific tasks. External partners are represented by *Supplier / Supply Chain*. Suppliers provide the *Resources* necessary for processes to operate effectively. In this aligned view, the supply chain is important to achieve business goals and ensure that sustainability criteria are met through the inclusion of Green Supplier Monitoring [33].

In the aligned view, the sustainability of products ties directly to compliance with environmental regulations. The quality, lifecycle, and environmental footprints of products are influenced by the activities and resources used in their production. The impact of these business processes/economic activities on the environment is captured by *Environmental Impact*. An *Environmental Impact* can be divided into a range of subcategories, such as *Recycling*, *Emissions*, *Consumption*, and *Waste*. Although some of them align and are covered by both views, there are more specific types of *Emissions* and *Waste* from the EU taxonomy view, which is why purple highlighting was not used for them. Subcategories under *Resource* and *Environmental Impact* (e.g., emission types, material inputs) are included to reflect established sustainability standards and enable domain-specific granularity where needed. Another area of overlap is that both *Economic Activities* and *Business Processes* are evaluated using performance indicators. However, while the EU taxonomy prescribes financial metrics (shown in yellow) for reporting alignment, Green BPM introduces process-level and environmental indicators to support operational sustainability. Finally, the *Compliance Requirement* entity ensures that all economic activities or processes adhere to relevant legal, environmental, and regulatory standards.

5 Evaluation

In the following, we will evaluate the aligned metamodel. For this, we draw on the framework for systematically addressing different aspects of model quality provided by Lindland et al. [24]. Concretely, we will evaluate the metamodel for 1) *semantic* validity and completeness and 2) *pragmatic* usability and utility.

Semantics. For semantic evaluation, we examine the model's validity and completeness, considering feasibility [24].

Feasible Validity. A *valid* model only contains correct statements regarding its domain. Thus, we systematically assess each *relation* in the model and verify whether it accurately reflects the domain (i.e. EU Taxonomy Regulation (EU) 2020/852 [15], or Green BPM) to be considered correct. Table 1 presents all explicitly modelled relations included in the aligned metamodel model shown in Fig. 2 and their origin, proving its validity.

Table 1. Overview of relations included in the aligned metamodel and their origins (**EU T**axonomy, **G**reen **BPM**)

Relationship	EUT	G-BPM
KPI - Taxonomy Alignment Metrics	x	
Emissions - Types of Emissions	x	
Product | Service - Supply Chain and Environmental Management	x	
Business Process - Activity	x	[39]
Activity Instance - Activity		[39]
Activity Instance - KPI		[39]
Resource - Resource Types		[2, 27]
KPI - EPI		[33]
Resource - Green Supplier Monitoring		[5]
Resources - Activity Instance		[39]
Resources - Environmental Impact	x	[5]
Business Process - Product | Service		[39]
Supplier - Resource		[39]
Economic Activity - Compliance Requirement	x	[20]

For example, the relationship between *Economic Activity* and *Compliance Requirement* is directly validated by the EU taxonomy's regulatory requirements, while relationships such as those between *Activity Instances*, *Resources*, and *KPIs* are part of the Green BPM domain. The model is considered valid for both domains.

Feasible Completeness. A *complete* model contains all relevant statements defined by the domain. *Feasible* completeness ensures that the model accurately represents the domain while only focussing on significant statements. Thus, we review each statement defined by the domain and assess whether it is already included in the respective metamodel and whether it adds value to it. If not, it is excluded from the model to reduce complexity. This is done for each metamodel separately. If the two models of the individual domains (i.e. Green BPM and the EU taxonomy) are complete regarding their respective domains, the aligned metamodel representing the intersections of the two models is complete regarding the intersection of their domains.

Statements made by the EU taxonomy were derived from official sources and related work, including [11–13, 15, 20, 40]. In line with the methodology of Naeem et al. [28], only relevant concepts have been incorporated into the EU taxonomy metamodel, which is why we consider it to be feasible *complete*. Significant but missing statements would have been identified by the methodological process we followed. Thus, we conclude that there are no missing statements that would provide additional value to the metamodel. For including concepts of Green BPM, we also followed the predefined and systematic approach by Naeem at al. [28], thereby ensuring that all key components and key statements of Green BPM are included. Sect. 4 explains each concept included in the model in detail, and provides a rationale for why it is relevant to the metamodel. This shows the significance of the statements made by the Green BPM metamodel. Therefore, this metamodel is considered feasible *complete* regarding Green BPM.

Now we further consider the completeness of the aligned metamodel: The decision to include only the overlapping concepts from both metamodels was made to maintain focus on the main objective, i.e. aligning Green BPM with sustainability goals as outlined by the EU taxonomy, while ensuring feasible completeness. The majority of concepts that appeared in only one of the two metamodels was excluded intentionally, as they were not necessary for the primary goal of this alignment. Including additional concepts from only one domain would have introduced complexity without adding value to the model. Notably, some entities, while not mutual between both metamodels, were still considered in the aligned metamodel. These include *Activity Instance*, *Types of Emissions*, and *KPIs*. *Activity Instance* was added to represent the execution of a business process or economic activity. The different types of *KPI* represent how both Green BPM and the EU taxonomy measure business processes or economic activities. While both perspectives use KPIs, it is important to emphasize that the specific KPIs are not the same. *Types of Emissions* and *Waste* were also included. Although the EU taxonomy covers a broader range of emissions and waste types compared to Green BPM, which focuses on some overarching categories [17], both perspectives deal with these environmental outputs. Thus, including these entities reinforces the model's completeness because it covers both perspectives without introducing unnecessary or invalid elements.

The aligned metamodel is considered feasible *complete* because all relevant concepts from the EU taxonomy and the Green BPM metamodels that are necessary to address both the business process execution and the compliance with sustainability goals have been incorporated. Removing any of the existing elements would compromise the model's ability to address key questions of sustainability and Green BPM alignment, as already demonstrated above, where each concept is justified in detail.

Pragmatics. For evaluating the pragmatics of the aligned metamodel, we employ a business process for *battery manufacturing* as an illustrating example. The business process, shown in Fig. 3, consists of four sequential stages, being 1) electrode manufacturing, 2) cell assembly, 3) formation, and 4) pack production, with various subordinate activities, and results in a single battery pack. We iteratively developed the business process model (provided here as a BPMN diagram) based on a description of battery manufacturing of lithium-iron batteries provided by a large battery manufacturing company[4] and the description of the economic activity "Manufacture of batteries" (NACE code C27.2). Thereby, we ensure that the illustrating example corresponds to an economic activity covered by the EU taxonomy. A full-size version is provided in the supplementary material available online.

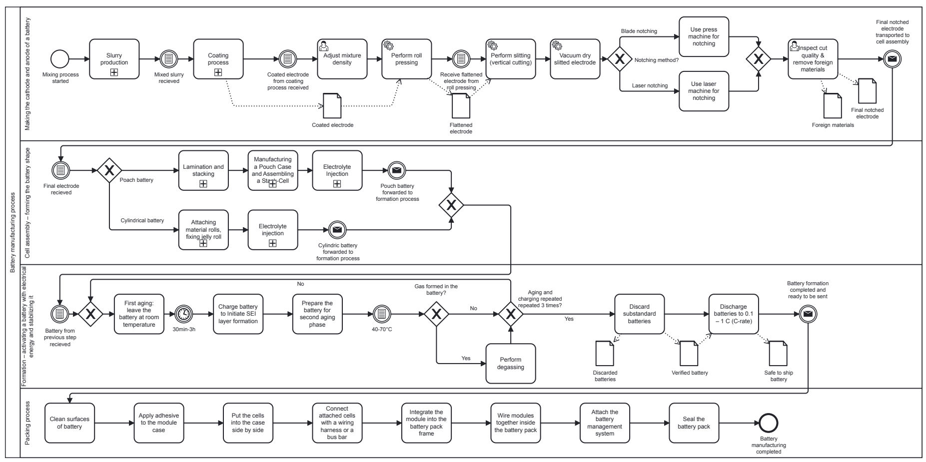

Fig. 3. A BPMN diagram of a battery manufacturing business process, covered by the EU taxonomy. A full-size version is available as supplementary material online.

For evaluating the aligned metamodel regarding its usability (i.e. can the model's audience apply it to real-world settings) and utility (i.e. does it help the model's audience to identify the conceptual alignment between Green BPM and the EU taxonomy), we *first* identify and summarize constraints formulated in the taxonomy [8] for the battery manufacturing process (i.e. the technical screening criteria), and identify entities of the aligned metamodel that relate to these constraints. *Second*, based on the constraints and their corresponding metamodel entities, we identify potential types of Green BPM approaches with which the constraints formulated for the metamodel entities can be assessed, improved, or made use of.

We find, as shown in the first two columns of Table 2, that all concepts of the aligned metamodel are covered by our illustrating business process. For example, the *Economic Activity* concept maps the entire business process of battery manufacturing. An obligation to report financial KPIs relates to the *KPI* concept. The requirement for the business process to produce rechargeable batteries is covered by the *Product* concept, as is the requirement for the product to be durable, recyclable, disassemblable, and adaptable. The requirement to recycle at least 70% of non-hazardous materials maps to the *Environmental Impact - Recycling* concept, whereas the requirement

[4] See https://inside.lgensol.com/en/2023/06/infographics-3-battery-making-at-a-glance/

to use software systems to aid in resource efficiency, emission management, and compliance aligns to the *Resource - Software* concept. Finally, the requirement to recycle end-of-life batteries maps to the *Activity* concept, as this requires that the process contains an activity in which the recycling is done (for which then also an *Activity Instance* must exist).

Based on the mapping of taxonomy constraints to the aligned metamodel, we can better reason about potential applications of Green BPM approaches to assess or improve taxonomy alignment of our illustrative process. Due to limitations in length, we can only provide an *intuition* of how such a mapping could work, and plan to further investigate the alignment between entities and techniques in the future. This intuition is illustrated in the third column of Table 2.

Table 2. Summarized constraints from the EU taxonomy for the example process, with relating concepts from the aligned metamodel (AM) and potential Green BPM approaches

EU Taxonomy Constraints	**AM** Concepts	**GBPM** Approaches
Battery Manufacturing	Economic Activity	Modelling
Report turnover, CapEx, and OpEx to show alignment with sustainable activities	KPIs	Compliance Monitoring
Rechargeable batteries, battery packs, accumulators	Product	Modelling, Management
Recycle end-of-life batteries	Activity	Modelling, Compliance Monitoring
Design products for high durability, recyclability, easy disassembly, and adaptability	Product	Modelling, Management
Materials must be sourced responsibly, incorporating secondary raw materials	Material, Supplier	Management, Compliance Monitoring
Substantial GHG emission reductions in transport	Environmental Impact - Emission - GHG	Deployment, Optimization
Recycling at least 70% of non-hazardous materials	Environmental Impact - Recycling	Optimization
Support GHG reduction, comply with EU waste laws, implement sorting systems, and ensure at least 70% recycling of non-hazardous construction waste	Environmental Impact - Waste	Deployment, Optimization
Information on and traceability of substances of concern throughout the lifecycle of manufactured products	Environmental Impact - Consumption	Deployment, Management
Minimize use of hazardous substances	Resource - Material	Modelling, Deployment
Environmental impact assessment has been conducted, and the necessary measures have been implemented	Resource - Environmental	Compliance Monitoring
Adherence to EU labour laws and standards	Resource - Human	Management, Compliance Monitoring
Software systems aid in resource efficiency, emissions management, and compliance	Resource - Software	Deployment, Optimization
Report on sust. metrics as part of disclosure obligations	Compliance Requirement	Compliance Monitoring

For example, we could use modelling approaches to make sure that recycling end of-life batteries is part of the business process (since so far, no such activity is part of Fig. 3), and use compliance monitoring approaches to ensure that recycling actually takes place. We can implement deployment and optimization approaches for addressing various constraints that require GHG emission reductions. With management approaches, we can make sure that information on the traceability of specific substances is collected, and use deployment approaches for collecting adequate data. While the implementation of all approaches requires further understanding of the constraints at hand, we can now nonetheless better understand how they relate to entities known from a Green BPM point-of-view and reason about the kinds of Green BPM approaches that might be relevant.

6 Discussion and Conclusion

In this work, we have designed and evaluated a metamodel that conceptualizes the alignment between concepts of the EU taxonomy and Green BPM, thereby having addressed RO1. Besides showing the semantic quality of the model, we have also shown its usability and utility via an exemplary case. By making the involved concepts and relations explicit, we have contributed towards 1) empowering practitioners to apply Green BPM approaches for assessing and improving taxonomy alignment of business practices, 2) enabling research to develop novel Green BPM approaches in light of the EU taxonomy, and 3) allowing Green BPM tool providers to align their systems with the EU taxonomy.

Threats to Validity. There are several limitations to the validity of our study that we need to acknowledge. Firstly, the way the intermediate and final models were developed and statements were selected was subjective in nature. However, we aimed to counter potential biases by continuously discussing among the author team each decision during model development and evaluation and resolving any arising conflict. Further, the EU taxonomy as a *political* project may be subject to change in its implementation. However, we have shown that this *type* of regulation, making requirements for economic activities and outlining criteria for when they contribute to certain environmental objectives can be integrated into, and used for, Green BPM. Finally, the evaluation was limited to semantics and pragmatics, and a real-world case study for usability regarding Green BPM practitioners and vendors is, so far, missing. Nonetheless, we show the feasibility and usability/utility of the developed metamodel with a real-world-*adjacent* scenario.

Potential *future work* may include empirical evaluations of our conceptual perspective on alignments between the EU taxonomy and Green BPM concepts — concrete applications of approaches after having identified them via the metamodel could strengthen the validity of our findings further. We also believe that it would be beneficial to provide more concrete guidance on how, based on identified entities of the aligned metamodel for a specific business process, concrete Green BPM approaches can be chosen and implemented. As diagnosed in a previous study [21], we see substantial potential for technical (in particular, automated or semi-automated) support for checking conformance of specific business processes regarding regulations; we believe that the metamodel developed herein can form the basis of such an approach, at least regarding the EU taxonomy.

Data Availability. Supplementary material, including all figures, is made available via an online repository at https://doi.org/10.6084/m9.figshare.28554260.

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