IDTA 02080

Material Data for the Characterization of Plastic Waste Feedstocks and Recycled Plastics

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Chapter 1. General

1.1. About this document

This document is a part of a specification series. Each part specifies the contents of a Submodel template for the Asset Administration Shell (AAS). The AAS is described in [1], [2], [3] and [6]. First exemplary Submodel contents were described in [4], while the actual format of this document was derived by the "Administration Shell in Practice" [5]. The format aims to be very concise, giving only minimal necessary information for applying a Submodel template, while leaving deeper descriptions and specification of concepts, structures and mapping to the respective documents [1] to [6]. Common terms and abbreviations can be found in [7].

The target audience of the specification are developers and editors of technical documentation and manufacturer information who describe assets in smart manufacturing by means of the Asset Administration Shell (AAS) and therefore need to create Submodel instances with a hierarchy of SubmodelElements. This document specifies which SubmodelElements, with which semantic identification, shall be used for this purpose.

1.2. Scope of the Submodel template

The Submodel template "Material Data for the Characterization of Plastic Waste Feedstocks and Recycled Plastics" aims at the interoperable provision of information describing prioritized physical and chemical characteristics of plastics materials. At its core, this Submodel is modelled after EN 18065 [8], and in particular with the intent to provide all necessary data elements and a template structure to support automated designation of data sets (in individual Submodel instances) as specified therein. This document makes the necessary specifications of elements such that stakeholders along the value chain and life cycle of plastics materials can aggregate and exchange data about such materials.

Anticipated use cases have an asset view on such materials and and associate them with one or more AASs comprised of instances of this and other Submodels. Sharing (access) to these AAS can facilitate

- market- and match-making for digital trading of materials;
- integration of electronic, machine-readable, batch-specific product data sheets into business software and manufacturing processes;
- implementations of 'digital product passport'-like ('DPP'-like) data sets as specified in EN 18065, supporting, for example, automated greenhouse gas asset accounting and reporting, automated verification and audits, end-to-end traceability of materials, and AI-powered data analytics.

The current version of this Submodel makes provisions for all 'Required' characteristics in EN 18065; 'Optional' characteristics in EN 18065 are currently out of scope. (See §1.4.) Likewise, this Submodel alone does not make provisions for a full implementation of a plastics 'DPP' conformant with EN 18065. (See, however, §2.1 and Annex B.)

1.3. Relevant standards for the Submodel template

EN 18065 [8] is a European standard for a harmonized description of characteristics of plastics, from virgin materials to waste, waste feedstocks, and compounds with recycled components. It defines a scheme to assign Data Quality Levels (DQLs) to a plastics material based on the depth of the available material data. Furthermore, it provides guidelines for labelling and designating recycled content in compounds. Due to its importance for this Submodel, EN 18065 is discussed in greater relevant detail in §1.4.

EN 18065 makes reference to a list of relevant other standards; that list is not repeated here.

This document makes reference to QUDT.org [9], an open semantic specification for units of measure,

quantity kind, dimensions and data types.

Furthermore, reference is made to other AAS Submodel templates standardized by IDTA:

- IDTA 02029-1 - "Sensor 4.0 Part 1: Measurement Value";
- IDTA 02006-3 - "Digital Nameplate for Industrial Equipment";
- IDTA 02004-2 - "Handover Documentation";
- IDTA 02023-1 - "Carbon Footprint".

In particular, SMT "Sensor 4.0 Part 1: Measurement Value" is used as a SMC drop-in to describe measurement values under the Property Characteristics category as described in §3.4.

1.4. DIN EN 18065

EN 18065 [8] provides a classification and designation system for plastics materials across polymer types, use cases, and industries. It was drafted as an 'umbrella standard' for a series of standards pursuant to the Standardization Request M/584 of the European Commission, in the context of the Commission Implementing Decision C(2022) 5372 regarding plastics recycling and recycled plastics in support of the European Strategy for Plastics in a Circular Economy. The norm defines a scheme to assign Data Quality Levels (DQLs) based on the depth of data - quantity and quality of physical and chemical characteristics -reported for a given material, thereby offering a clear, standardized benchmark for data quality for (recycled) plastics. Importantly, EN 18065 outlines the concept of a 'digital product passport' (DPP) for plastics materials. Its view is that such a DPP is critical for cross-stakeholder exchange of data as materials pass through value chains and, therefore, an enabler of a more circular economy of plastics.

EN 18065 specifies 'Required' (as well as 'Optional') material Characteristics to be reported against criteria assessing the available data depth. Characteristics are either Information (I) or Property (P) Characteristics: - Information is inferred from the documentation of collection, handling, and/ or recycling process; - a Property is obtained by laboratory test (i.e., measurements) conformant to suitable public or enterprise-internal standards or procedures. For a given material, and assuming that specific requirements regarding sampling and homogenization are satisfied, the available Information and Property Characteristics determine the DQL assigned to (or "reached by") the material.

Table 1. Quantities of Required Characteristics to reach a DQL. The identities of the Characteristics derive from Tab.s A.1 and A.2 in [8] and can be inferred from §3 of this document. (Optional Characteristics do not contribute to DQLs.)

Required Characteristics	DQL 1	DQL 2	DQL 3	DQL 4
Information	6	12	15	18
Property	1	4	5	8

If a given material additionally meets application-specification standards, a prefix "A" may be appended to its DQL (if it reaches any). Information on these additional application-specific standards is then to be included alongside the technical documentation of the material.

EN 18065 also defines a digital document referred to as a 'digital product passport' for a material. It is noted that, at the time of writing of this document, no European legislation on ecodesign requirements on chemicals and polymers in particular exists - for example, under the "Ecodesign for Sustainable Products Regulation (ESPR) (EU) 2024/1781. Therefore, a EN 18065 DPP is not to be mistaken with 'the' prospective ESPR DPP for polymers. Nevertheless, a (EN 18065) digital product passport for plastics is a well-defined, highly visible use case for EN 18065 and lends itself to an implementation in AAS in advance of future European legislation. §1.4.3 outlines such an implementation as a use case for the Submodel described in this document.

1.4.1. Textile-to-textile recycling of polyamide-6

Textile¬to¬textile recycling of polyamide¬6 depends on the seamless exchange of standardized, machine¬readable material data that persists beyond end¬of¬life. Textile feedstock items are identified and their polymers are described according to established nomenclature (e.g., ISO 1043, "PA 6") alongside composition and chemical identifiers such as CAS numbers for additives. These records are shared between manufacturers, collectors, sorters, and recyclers while laboratory results - e.g., ¬¬caprolactam purity, relative viscosity - are generated and exchanged from Laboratory Information Management Systems (LIMS) in machine¬readable formats. At take¬back and sorting, IDs are scanned and polymer type is verified with near-infrared spectroscopy. Here, standardized, machine¬readable material data lets stakeholders route items to the correct PA6 stream, confirm composition, and maintain an auditable chain of custody.

### 1.4.2. Enabling liquid, cross¬border markets for recycled plastics

Harmonized, machine¬readable material data and transparent classification of materials by Data Quality Level (DQL) per EN 18065 lay the foundation for liquid markets for recycled plastics. With standardized semantics and units for the Required Information and Property Characteristics, buyers can compare like¬for¬like across suppliers and jurisdictions, and sellers can signal quality and provenance - enabling quality¬differentiated pricing, automated tendering, and reliable supply scheduling across the EU and internationally. Cross¬border online trading, dynamic matchmaking of feedstocks to applications, and new service models become feasible when datasets can be queried, validated, and aggregated programmatically. Implementing these EN 18065 characteristics and DQLs as AAS Submodel instances provides the API¬level interoperability needed to operationalize such markets at scale.

1.4.3. A 'digital product passport' for plastics

Beyond just standardizing material data and enabling a classification of materials in terms of DQLs, EN 18065 defines a 'digital product passport' for a material. This is a digital document characterized in terms of aggregated data elements, requirements on validation, issuance, and supersedence, as well as general principles of data transfer and traceability. The standard assumes the view that this DPP is the critical enabler of a more circular economy for plastics; only by means of a DPP can material data be exchanged effectively and economically. As the de-facto standard for digital twins, the AAS provides a powerful framework for implementation and is projected to drive DPP adoption and proliferation.

In an AAS implementation of a DPP according to §7 of EN 18065, the AAS is foremost a data carrier (incl. a specified API) that aggregates information on producers and/ or suppliers; material identifiers, characteristics, and documentation; as well as (some) DPP metadata. Much of this information can be wrapped up in existing Submodel templates already established by IDTA, namely: Digital Nameplate and Handover Documentation.

However, a Submodel template to model relevant material characteristics is only provided here. In fact, the specification of the Submodel template "Material Data for the Characterization of Plastic Waste Feedstocks and Recycled Plastics" described in this document was both motivated and guided by the idea to implement EN 18065 DPPs in AAS.
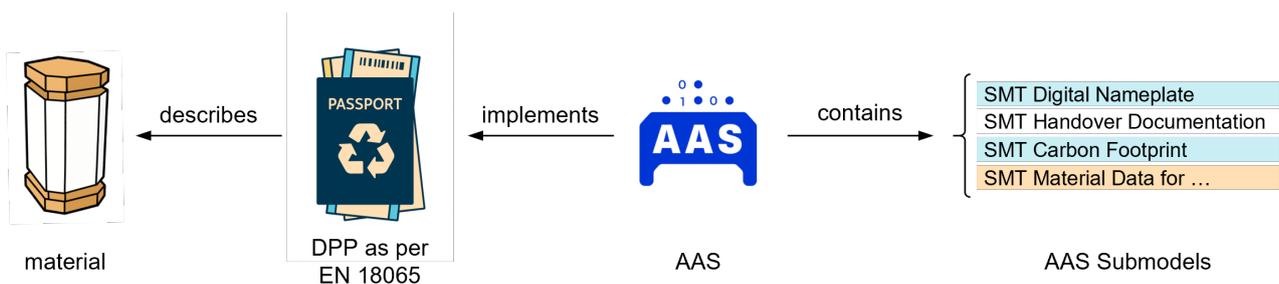
Chapter 2. Approach

2.1. About this document

2.1.1. Design principles

The Submodel template "Material Data for the Characterization of Plastic Waste Feedstocks and Recycled Plastics" enables AAS implementations of 'digital product passports' according to §7 of EN 18065 (cf. §1.4.3 of this document). The design of the Submodel follows these core principles:

- Reuse existing standards: Leverage standardized AAS Submodel templates wherever possible.
- Stay faithful to the source: Model only data structures explicitly specified in EN 18065.
- Keep it minimal but viable: Include only necessary components that still enable full DQL classifications and DPP functionalities.
- Ensure semantic clarity: Provide self-contained semantic descriptions with references to open dictionaries.

2.1.2. Scope limitations

This Submodel template addresses only those aspects of the EN 18065 DPP specification that are not covered by existing Submodel templates:

- IDTA 02006-3 - "Digital Nameplate for Industrial Equipment";
- IDTA 02004-2 - "Handover Documentation";
- IDTA 02023-1 - "Carbon Footprint".

In its current version, the Submodel template includes only 'Required' Information and Property Characteristics specified in EN 18065. (For a commentary on 'Optional' Characteristics and future Submodel versions, cf. Annex B of this document.)

For Property Characteristics involving physical measurements, the template uses SMT 'Measurement Value' from the 'Sensor 4.0' Submodel family as a SMT drop-in component.

2.1.3. Notes on qualifiers for Data Quality Level (DQL) implementation

All Submodel elements for Required Information and Property Characteristics include "RequiredAtDQL" concept qualifiers: These qualifiers denote the minimum Data Quality Level at which each element becomes mandatory according to EN 18065.

As an example, an element with "RequiredAtDQL" value of "2" means: Not required for DQL 1, required for DQL 2, 3, and 4.

All elements use ZeroToOne cardinality, enabling the template to describe also materials that do not reach any DQL classification. For such materials, the DataQualityLevel Property shall be removed from the DataQuality SMC in the Submodel instance.

2.1.4. Semantic enrichment and interoperability

This Submodel template maximizes interoperability through controlled vocabularies: - Enumerations: IEC 61360 value lists are provided wherever feasible to limit free-text fields and enhance semantic clarity - Semantic identifiers**: All semantic IDs use: - URIs under the admin-shell.io domain, or - open specifications from QUDT.org [9] for units of measurement and related concepts

2.2. Overview and UML diagram

The Submodel elements described in Section 3 are structured as shown in the following UML diagram.
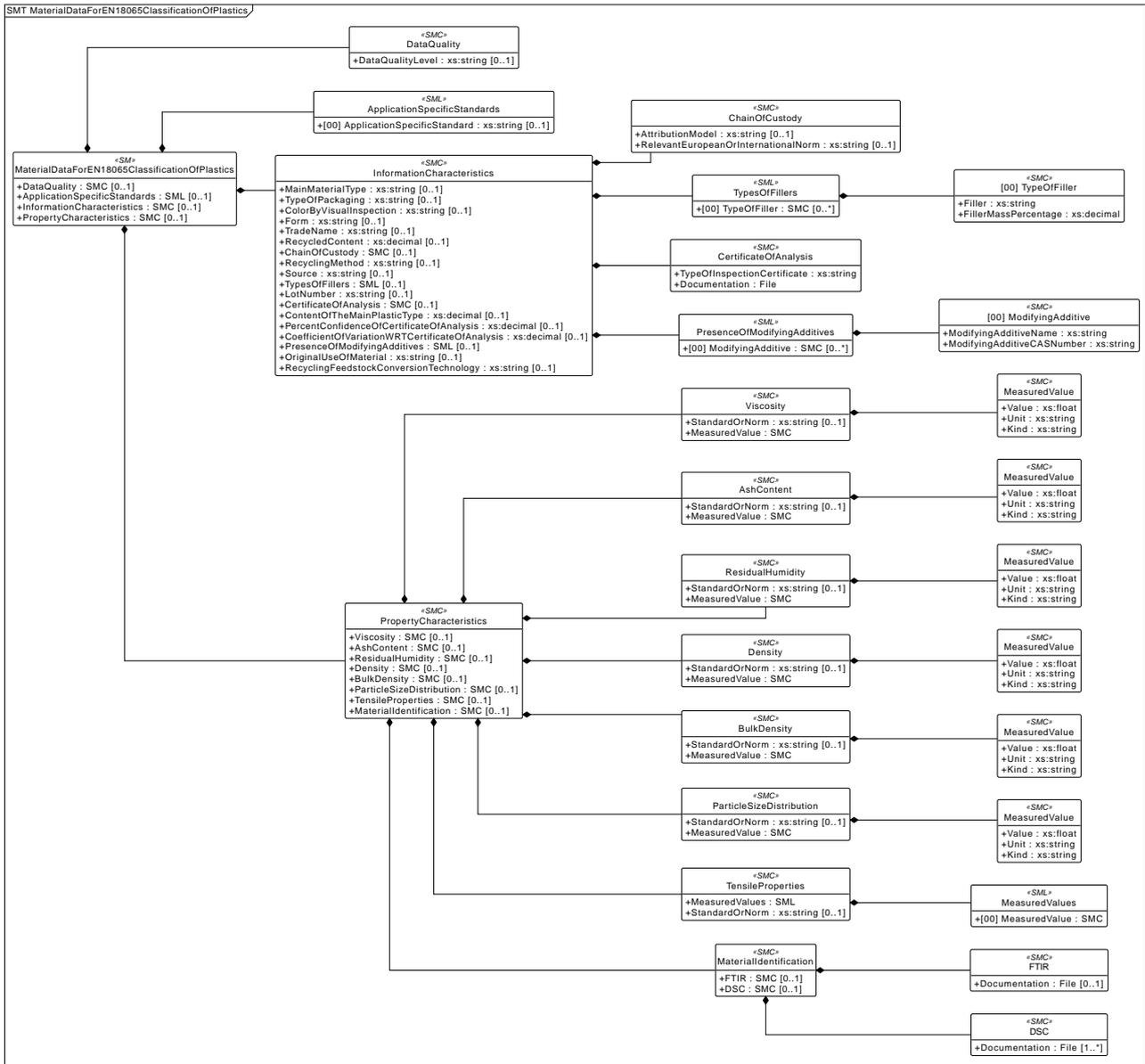
Figure 1. UML diagram for Submodel "Material Data for the Characterization of Plastic Waste Feedstocks and Recycled Plastics"

Chapter 3. Submodel elements and collections

3.1. Attributes of the Submodel template

Table 2. Attributes of the Submodel instance

idShort:	MaterialDataForEN18065ClassificationOfPlastics		
Class:	Submodel		
semanticId:	https://admin-shell.io/idta/SubmodelTemplate/en18065materialdata/en18065MaterialData/1/0		
Parent:	-		
Explanation:	Submodel template for material data enabling classification of plastics according to EN 18065		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[SMC] DataQuality	https://admin-shell.io/idta/en18065materialdata/DataQuality/1/0 Data Quality Level (DQL) as per EN 18065	[] 1 elements	0..1
[SML] ApplicationSpecificStandards	https://admin-shell.io/idta/en18065materialdata/ApplicationSpecificStandards/1/0 Relevant application-specific standards other than EN 18065	[] 1 elements	0..1
[SMC] InformationCharacteristics	https://admin-shell.io/idta/en18065materialdata/InformationCharacteristics/1/0	[] 18 elements	0..1
[SMC] PropertyCharacteristics	https://admin-shell.io/idta/en18065materialdata/PropertyCharacteristics/1/0	[] 8 elements	0..1

3.2. Attributes of SMC DataQuality

Table 3. Attributes of SMC DataQuality

idShort:	DataQuality
Class:	SubmodelElementCollection

semanticId:	https://admin-shell.io/idta/en18065materialdata/DataQuality/1/0		
Parent:	MaterialDataForEN18065ClassificationOfPlastics		
Explanation:	Data Quality Level (DQL) as per EN 18065		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[Prop] DataQualityLevel	https://admin-shell.io/idta/en18065materialdata/DataQualityLevel/1/0 DataQualityLevel (DQL) as per DIN EN 18065, Section 4 and elsewhere	[String]	0..1

3.3. Attributes of SML ApplicationSpecificStandards

Table 4. Attributes of SML ApplicationSpecificStandards

idShort:	ApplicationSpecificStandards		
Class:	SubmodelElementList		
semanticId:	https://admin-shell.io/idta/en18065materialdata/ApplicationSpecificStandards/1/0		
Parent:	MaterialDataForEN18065ClassificationOfPlastics		
Explanation:	Relevant application-specific standards other than EN 18065		
Element details:	orderRelevant=No, semanticIdListElement=[GlobalReference, https://admin-shell.io/idta/en18065materialdata/StandardOrNorm/1/0], typeValueListElement=Property, valueTypeListElement=xs:string		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[Prop] ApplicationSpecificStandard	https://admin-shell.io/idta/en18065materialdata/StandardOrNorm/1/0 Standard or norm	[String]	0..1

3.4. Attributes of SMC InformationCharacteristics

Table 5. Attributes of SMC InformationCharacteristics

idShort:	InformationCharacteristics
Class:	SubmodelElementCollection
semanticId:	https://admin-shell.io/idta/en18065materialdata/InformationCharacteristics/1/0
Parent:	MaterialDataForEN18065ClassificationOfPlastics

[SME type] idShort	semanticId Description@en	[valueType] example	card.
[Prop] MainMaterialType	https://admin-shell.io/idta/en18065materialdata/MainMaterialType/1/0 Main polymer type according to EN ISO 1043-1 (e.g., PE, PP, PET, …)	[String]	0..1
[Prop] TypeOfPackaging	https://admin-shell.io/idta/en18065materialdata/TypeOfPackaging/1/0 Packaging of the material (e.g., octabins, bagged goods, bale goods, silo, …)	[String]	0..1
[Prop] ColorByVisualInspection	https://admin-shell.io/idta/en18065materialdata/ColorByVisualInspection/1/0 Color of the material determined by visual inspection (e.g., black, natural, white, …)	[String]	0..1
[Prop] Form	https://admin-shell.io/idta/en18065materialdata/Form/1/0 Physical form of the recyclate (e.g., agglomerate, flake, regrind, regenerate, regranulate, …)	[String]	0..1
[Prop] TradeName	https://admin-shell.io/idta/en18065materialdata/TradeName/1/0 Commercial trade name of the recyclate	[String]	0..1
[Prop] RecycledContent	https://admin-shell.io/idta/en18065materialdata/RecycledContent/1/0 Percentage by weight of recycled plastic in the material as calculated according to Section 5.1 of EN 18065	[Decimal]	0..1
[SMC] ChainOfCustody	https://admin-shell.io/idta/en18065materialdata/ChainOfCustody/1/0 Physical segregation, controlled blending, mass balance etc. (with indication, which attribution model has been used pursuant to European or international standard)	[] 2 elements	0..1

[Prop] RecyclingMethod	https://admin-shell.io/idta/en18065materialdata/RecyclingMethod/1/0 Information about a mechanical recycling process, solvent-based process, etc.	[String]	0..1
[Prop] Source	https://admin-shell.io/idta/en18065materialdata/Source/1/0 Source of the material (e.g., post-consumer, post-industrial/ pre-consumer, …)	[String]	0..1
[SML] TypesOfFillers	https://admin-shell.io/idta/en18065materialdata/TypesOfFillers/1/0 Types of fillers	[] 1 elements	0..1
[Prop] LotNumber	https://admin-shell.io/idta/en18065materialdata/LotNumber/1/0 Batch or lot number for the material	[String]	0..1
[SMC] CertificateOfAnalysis	https://admin-shell.io/idta/en18065materialdata/CertificateOfAnalysis/1/0 Reference to certificate of analysis according to EN 10204:2005, clause 3.1	[] 2 elements	0..1
[Prop] ContentOfTheMainPlasticType	https://admin-shell.io/idta/en18065materialdata/ContentOfTheMainPlasticType/1/0 Content (mass percentage) of the main plastic type in the material	[Decimal]	0..1
[Prop] PercentConfidenceOfCertificateOfAnalysis	https://admin-shell.io/idta/en18065materialdata/PercentConfidenceOfCertificateOfAnalysis/1/0 Percentage confidence level of the certificate of analysis (CEN/TS 16010, CEN/TS 16011 - as explained in sec. 4.5.3 of EN 18065)	[Decimal]	0..1
[Prop] CoefficientOfVariationWRTCertificateOfAnalysis	https://admin-shell.io/idta/en18065materialdata/CoefficientOfVariationWRTCertificateOfAnalysis/1/0 Coefficient of variation with respect to the certificate of analysis (CEN/TS 16010, CEN/TS 16011 - as explained in sec. 4.5.3 of EN 18065)	[Decimal]	0..1

[SML] PresenceOfModifyingAdditives	https://admin-shell.io/idta/en18065materialdata/PresenceOfModifyingAdditives/1/0 Stabilizers, plasticizers, flame retardants, etc.	[] 1 elements	0..1
[Prop] OriginalUseOfMaterial	https://admin-shell.io/idta/en18065materialdata/OriginalUseOfMaterial/1/0 Original use of the material: what is it derived from, how has it been processed, and what was it in contact with?	[String]	0..1
[Prop] RecyclingFeedstockConversionTechnology	https://admin-shell.io/idta/en18065materialdata/OriginalUseOfMaterial/RecyclingFeedstockConversionTechnology/1/0 Technology for the conversion of waste-derived feedstock for recycling	[String]	0..1

Table 6. Attributes of SMC InformationCharacteristics

idShort:	ChainOfCustody		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/en18065materialdata/ChainOfCustody/1/0		
Parent:	InformationCharacteristics		
Explanation:	Physical segregation, controlled blending, mass balance etc. (with indication, which attribution model has been used pursuant to European or international standard)		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[Prop] AttributionModel	https://admin-shell.io/idta/en18065materialdata/ChainOfCustody/AttributionModel/1/0 Attribution model	[String]	0..1
[Prop] RelevantEuropeanOrInternationalNorm	https://admin-shell.io/idta/en18065materialdata/ChainOfCustody/RelevantEuropeanOrInternationalNorm/1/0 Relevant European or international norm	[String]	0..1

Table 7. Attributes of SMC InformationCharacteristics

idShort:	TypesOfFillers

Class:	SubmodelElementList		
semanticId:	https://admin-shell.io/idta/en18065materialdata/TypesOfFillers/1/0		
Parent:	InformationCharacteristics		
Explanation:	Types of fillers		
Element details:	orderRelevant=Yes, semanticIdListElement=[GlobalReference, https://admin-shell.io/idta/en18065materialdata/TypeOfFiller/1/0], typeValueListElement=SubmodelElementCollection		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[SMC] TypeOfFiller	https://admin-shell.io/idta/en18065materialdata/TypeOfFiller/1/0 Types of fillers and mass percentages	[] 2 elements	0..*

Table 8. Attributes of SMC InformationCharacteristics

idShort:	**TypeOfFiller**		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/en18065materialdata/TypeOfFiller/1/0		
Parent:	TypesOfFillers		
Explanation:	Types of fillers and mass percentages		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[Prop] Filler	https://admin-shell.io/idta/en18065materialdata/TypesOfFillers/Filler/1/0 Filler type	[String]	1
[Prop] FillerMassPercentage	https://admin-shell.io/idta/en18065materialdata/TypesOfFillers/FillerMassPercentage/1/0 Mass percentage of the filler	[Decimal]	1

Table 9. Attributes of SMC InformationCharacteristics

idShort:	**CertificateOfAnalysis**
Class:	SubmodelElementCollection
semanticId:	https://admin-shell.io/idta/en18065materialdata/CertificateOfAnalysis/1/0
Parent:	InformationCharacteristics

Explanation:	Reference to certificate of analysis according to EN 10204:2005, clause 3.1		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[Prop] TypeOfInspectionCertificate	https://admin-shell.io/idta/en18065materialdata/CertificateOfAnalysis/TypeOfInspectionCertificate/1/0 Type of inspection certificate according to EN 10204 (2.1, 2.2, 3.1, or 3.2), or none	[String]	1
[File] Documentation	https://admin-shell.io/idta/en18065materialdata/CertificateOfAnalysis/Documentation/1/0 Documentation for the certificate of analysis	[]	1

Table 10. Attributes of SMC InformationCharacteristics

idShort:	**PresenceOfModifyingAdditives**
Class:	SubmodelElementList
semanticId:	https://admin-shell.io/idta/en18065materialdata/PresenceOfModifyingAdditives/1/0
Parent:	InformationCharacteristics
Explanation:	Stabilizers, plasticizers, flame retardants, etc.
Element details:	orderRelevant=No, semanticIdListElement=[GlobalReference, https://admin-shell.io/idta/en18065materialdata/PresenceOfModifyingAdditives/ModifyingAdditive/1/0], typeValueListElement=SubmodelElementCollection

[SME type] idShort	semanticId Description@en	[valueType] example	card.
[SMC] ModifyingAdditive	https://admin-shell.io/idta/en18065materialdata/PresenceOfModifyingAdditives/ModifyingAdditive/1/0 Modifying additive	[] 2 elements	0..*

Table 11. Attributes of SMC InformationCharacteristics

idShort:	**ModifyingAdditive**
Class:	SubmodelElementCollection
semanticId:	https://admin-shell.io/idta/en18065materialdata/PresenceOfModifyingAdditives/ModifyingAdditive/1/0
Parent:	PresenceOfModifyingAdditives

[SME type] idShort	semanticId Description@en	[valueType] example	card.
Explanation:	Modifying additive		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[Prop] ModifyingAdditiveName	https://admin-shell.io/idta/en18065materialdata/PresenceOfModifyingAdditives/ModifyingAdditive/ModifyingAdditiveName/1/0 Name of the modifying additive	[String]	1
[Prop] ModifyingAdditiveCASNumber	https://admin-shell.io/idta/en18065materialdata/PresenceOfModifyingAdditives/ModifyingAdditive/ModifyingAdditiveCASNumber/1/0 CAS number of the modifying additive	[String]	1

3.5. Attributes of SMC PropertyCharacteristics

Table 12. Attributes of SMC PropertyCharacteristics

idShort:	**PropertyCharacteristics**		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/en18065materialdata/PropertyCharacteristics/1/0		
Parent:	MaterialDataForEN18065ClassificationOfPlastics		
Explanation:			
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[SMC] Viscosity	https://admin-shell.io/idta/en18065materialdata/Viscosity/1/0 Measurements of viscosity (MVR/ MFR, IV, VN) - according to EN ISO 1133 series, EN ISO 307, or EN ISO 1628 series	[] 2 elements	0..1
[SMC] AshContent	https://admin-shell.io/idta/en18065materialdata/AshContent/1/0 Measurements of ash content - according to EN ISO 3451 series, or EN ISO 1172	[] 2 elements	0..1

[SMC] ResidualHumidity	https://admin-shell.io/idta/en18065materialdata/ResidualHumidity/1/0 Measurements of residual moisture content - according to EN ISO 15512, ASTM D6980-17, EN 12099, or EN 15348, Annex B	[] 2 elements	0..1
[SMC] Density	https://admin-shell.io/idta/en18065materialdata/Density/1/0 Measurements of density - according to EN ISO 1183 series	[] 2 elements	0..1
[SMC] BulkDensity	https://admin-shell.io/idta/en18065materialdata/BulkDensity/1/0 Measurements of bulk density - according to EN ISO 60 or ASTM D1895, Method C, EN 15345, Annex A, or EN 15342, Annex A	[] 2 elements	0..1
[SMC] ParticleSizeDistribution	https://admin-shell.io/idta/en18065materialdata/ParticleSizeDistribution/1/0 Measurements of particle size distribution - according to EN 15346 Annex D, EN 15348 Annex A, ISO 22498, or ASTM D 1921	[] 2 elements	0..1
[SMC] TensileProperties	https://admin-shell.io/idta/en18065materialdata/TensileProperties/1/0 Measurements of tensile properties - according to EN ISO 527-1, EN ISO 527-2, EN ISO 527-3, or EN ISO 527-4	[] 2 elements	0..1
[SMC] MaterialIdentification	https://admin-shell.io/idta/en18065materialdata/MaterialIdentification/1/0 Material identification (FTIR or DSC) - using IR (database comparison) or DSC according to EN ISO 11357-1, EN ISO 11357-2, EN ISO 11357-3	[] 2 elements	0..1

Table 13. Attributes of SMC PropertyCharacteristics

idShort:	Viscosity
Class:	SubmodelElementCollection
semanticId:	https://admin-shell.io/idta/en18065materialdata/Viscosity/1/0
Parent:	PropertyCharacteristics
Explanation:	Measurements of viscosity (MVR/ MFR, IV, VN) - according to EN ISO 1133 series, EN ISO 307, or EN ISO 1628 series

Element details:	-			
[SME type] **idShort**	**semanticId** **Description@en**		**[valueType]** **example**	**card.**
[Prop] StandardOrNorm	https://admin-shell.io/idta/en18065materialdata/StandardOrNorm/1/0 Standard or norm		[String]	0..1
[SMC] MeasuredValue	https://admin-shell.io/idta/measurementvalue/measuredvalue/1/0 This is the measured value of the sensor output		[] 3 elements	1

Table 14. Attributes of SMC PropertyCharacteristics

idShort:	MeasuredValue			
Class:	SubmodelElementCollection			
semanticId:	https://admin-shell.io/idta/measurementvalue/measuredvalue/1/0			
Parent:	Viscosity			
Explanation:	This is the measured value of the sensor output			
Element details:	-			
[SME type] **idShort**	**semanticId** **Description@en**		**[valueType]** **example**	**card.**
[Prop] Value	https://admin-shell.io/idta/measurementvalue/value/1/0 The value of the of measured sensor output		[Float] 17.356	1
[Prop] Unit	0112/2///62720#UBA000 The unit of the measured value		[String] m	1
[Prop] Kind	0112/2///62683#ACI144 supplementalSemanticId: 0112/2///62683#ACI144 Kind of measured value		[String] Distance	1

Table 15. Attributes of SMC PropertyCharacteristics

idShort:	AshContent
Class:	SubmodelElementCollection
semanticId:	https://admin-shell.io/idta/en18065materialdata/AshContent/1/0

Parent:	PropertyCharacteristics		
Explanation:	Measurements of ash content - according to EN ISO 3451 series, or EN ISO 1172		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[Prop] StandardOrNorm	https://admin-shell.io/idta/en18065materialdata/StandardOrNorm/1/0 Standard or norm	[String]	0..1
[SMC] MeasuredValue	https://admin-shell.io/idta/measurementvalue/measuredvalue/1/0 This is the measured value of the sensor output	[] 3 elements	1

Table 16. Attributes of SMC PropertyCharacteristics

idShort:	**MeasuredValue**		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/measurementvalue/measuredvalue/1/0		
Parent:	AshContent		
Explanation:	This is the measured value of the sensor output		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[Prop] Value	https://admin-shell.io/idta/measurementvalue/value/1/0 The value of the of measured sensor output	[Float] 17.356	1
[Prop] Unit	0112/2///62720#UBA000 The unit of the measured value	[String] m	1
[Prop] Kind	0112/2///62683#ACI144 supplementalSemanticId: 0112/2///62683#ACI144 Kind of measured value	[String] Distance	1

Table 17. Attributes of SMC PropertyCharacteristics

idShort:	**ResidualHumidity**

Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/en18065materialdata/ResidualHumidity/1/0		
Parent:	PropertyCharacteristics		
Explanation:	Measurements of residual moisture content - according to EN ISO 15512, ASTM D6980-17, EN 12099, or EN 15348, Annex B		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[Prop] StandardOrNorm	https://admin-shell.io/idta/en18065materialdata/StandardOrNorm/1/0 Standard or norm	[String]	0..1
[SMC] MeasuredValue	https://admin-shell.io/idta/measurementvalue/measuredvalue/1/0 This is the measured value of the sensor output	[] 3 elements	1

Table 18. Attributes of SMC PropertyCharacteristics

idShort:	**MeasuredValue**		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/measurementvalue/measuredvalue/1/0		
Parent:	ResidualHumidity		
Explanation:	This is the measured value of the sensor output		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[Prop] Value	https://admin-shell.io/idta/measurementvalue/value/1/0 The value of the of measured sensor output	[Float] 17.356	1
[Prop] Unit	0112/2///62720#UBA000 The unit of the measured value	[String] m	1

[Prop]	0112/2///62683#ACI144	[String]	1
Kind	supplementalSemanticId: 0112/2///62683#ACI144	Distance	
	Kind of measured value		

Table 19. Attributes of SMC PropertyCharacteristics

idShort:	Density		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/en18065materialdata/Density/1/0		
Parent:	PropertyCharacteristics		
Explanation:	Measurements of density - according to EN ISO 1183 series		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[Prop] StandardOrNorm	https://admin-shell.io/idta/en18065materialdata/StandardOrNorm/1/0 Standard or norm	[String]	0..1
[SMC] MeasuredValue	https://admin-shell.io/idta/measurementvalue/measuredvalue/1/0 This is the measured value of the sensor output	[] 3 elements	1

Table 20. Attributes of SMC PropertyCharacteristics

idShort:	MeasuredValue		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/measurementvalue/measuredvalue/1/0		
Parent:	Density		
Explanation:	This is the measured value of the sensor output		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[Prop] Value	https://admin-shell.io/idta/measurementvalue/value/1/0 The value of the of measured sensor output	[Float] 17.356	1

[Prop]	0112/2///62720#UBA000	[String]	1
Unit		m	
	The unit of the measured value		
[Prop]	0112/2///62683#ACI144	[String]	1
Kind	supplementalSemanticId: 0112/2///62683#ACI144	Distance	
	Kind of measured value		

Table 21. Attributes of SMC PropertyCharacteristics

idShort:	**BulkDensity**		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/en18065materialdata/BulkDensity/1/0		
Parent:	PropertyCharacteristics		
Explanation:	Measurements of bulk density - according to EN ISO 60 or ASTM D1895, Method C, EN 15345, Annex A, or EN 15342, Annex A		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[Prop] StandardOrNorm	https://admin-shell.io/idta/en18065materialdata/StandardOrNorm/1/0 Standard or norm	[String]	0..1
[SMC] MeasuredValue	https://admin-shell.io/idta/measurementvalue/measuredvalue/1/0 This is the measured value of the sensor output	[] 3 elements	1

Table 22. Attributes of SMC PropertyCharacteristics

idShort:	**MeasuredValue**		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/measurementvalue/measuredvalue/1/0		
Parent:	BulkDensity		
Explanation:	This is the measured value of the sensor output		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.

[Prop] Value	https://admin-shell.io/idta/measurementvalue/value/1/0 The value of the of measured sensor output	[Float] 17.356	1
[Prop] Unit	0112/2///62720#UBA000 The unit of the measured value	[String] m	1
[Prop] Kind	0112/2///62683#ACI144 supplementalSemanticId: 0112/2///62683#ACI144 Kind of measured value	[String] Distance	1

Table 23. Attributes of SMC PropertyCharacteristics

idShort:	ParticleSizeDistribution		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/en18065materialdata/ParticleSizeDistribution/1/0		
Parent:	PropertyCharacteristics		
Explanation:	Measurements of particle size distribution - according to EN 15346 Annex D, EN 15348 Annex A, ISO 22498, or ASTM D 1921		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[Prop] StandardOrNorm	https://admin-shell.io/idta/en18065materialdata/StandardOrNorm/1/0 Standard or norm	[String]	0..1
[SMC] MeasuredValue	https://admin-shell.io/idta/measurementvalue/measuredvalue/1/0 This is the measured value of the sensor output	[] 3 elements	1

Table 24. Attributes of SMC PropertyCharacteristics

idShort:	MeasuredValue
Class:	SubmodelElementCollection
semanticId:	https://admin-shell.io/idta/measurementvalue/measuredvalue/1/0
Parent:	ParticleSizeDistribution
Explanation:	This is the measured value of the sensor output

[SME type] idShort	semanticId Description@en	[valueType] example	card.
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[Prop] Value	https://admin-shell.io/idta/measurementvalue/value/1/0 The value of the of measured sensor output	[Float] 17.356	1
[Prop] Unit	0112/2///62720#UBA000 The unit of the measured value	[String] m	1
[Prop] Kind	0112/2///62683#ACI144 supplementalSemanticId: 0112/2///62683#ACI144 Kind of measured value	[String] Distance	1

Table 25. Attributes of SMC PropertyCharacteristics

idShort:	TensileProperties		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/en18065materialdata/TensileProperties/1/0		
Parent:	PropertyCharacteristics		
Explanation:	Measurements of tensile properties - according to EN ISO 527-1, EN ISO 527-2, EN ISO 527-3, or EN ISO 527-4		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[SML] MeasuredValues	https://admin-shell.io/idta/en18065materialdata/MeasuredValues/1/0 Template collection to capture a list of measurement values	[] 1 elements	1
[Prop] StandardOrNorm	https://admin-shell.io/idta/en18065materialdata/StandardOrNorm/1/0 Standard or norm	[String]	0..1

Table 26. Attributes of SMC PropertyCharacteristics

idShort:	MeasuredValues
Class:	SubmodelElementList

[SME type]	semanticId	[valueType]	card.
idShort	Description@en	example	
[SMC] MeasuredValue	https://admin-shell.io/idta/measurementvalue/measuredvalue/1/0 This is the measured value of the sensor output	[] 3 elements	1

Table 27. Attributes of SMC PropertyCharacteristics

idShort:	**MaterialIdentification**		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/en18065materialdata/MaterialIdentification/1/0		
Parent:	PropertyCharacteristics		
Explanation:	Material identification (FTIR or DSC) - using IR (database comparison) or DSC according to EN ISO 11357-1, EN ISO 11357-2, EN ISO 11357-3		
Element details:	-		
[SME type]	semanticId	[valueType]	card.
idShort	Description@en	example	
[SMC] FTIR	https://admin-shell.io/idta/en18065materialdata/MaterialIdentification/FTIR/1/0 Material identification - using IR (database comparison)	[] 1 elements	0..1
[SMC] DSC	https://admin-shell.io/idta/en18065materialdata/MaterialIdentification/DSC/1/0 Material identification - using DSC according to EN ISO 11357-1, EN ISO 11357-2, EN ISO 11357-3	[] 1 elements	0..1

Table 28. Attributes of SMC PropertyCharacteristics

idShort:	**FTIR**
Class:	SubmodelElementCollection
semanticId:	https://admin-shell.io/idta/en18065materialdata/MaterialIdentification/FTIR/1/0

Parent:	MaterialIdentification		
Explanation:	Material identification - using IR (database comparison)		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[File] Documentation	https://admin-shell.io/idta/en18065materialdata/MaterialIdentification/FTIR/Documentation/1/0	[]	0..1

Table 29. Attributes of SMC PropertyCharacteristics

idShort:	**DSC**		
Class:	SubmodelElementCollection		
semanticId:	https://admin-shell.io/idta/en18065materialdata/MaterialIdentification/DSC/1/0		
Parent:	MaterialIdentification		
Explanation:	Material identification - using DSC according to EN ISO 11357-1, EN ISO 11357-2, EN ISO 11357-3		
Element details:	-		
[SME type] idShort	semanticId Description@en	[valueType] example	card.
[File] Documentation	https://admin-shell.io/idta/en18065materialdata/MaterialIdentification/DSC/Documentation/1/0	[]	1..*

Annex A. Explanations on used table formats

1. General

The used tables in this document try to outline information as concise as possible. They do not convey all information on Submodels and SubmodelElements. For this purpose, the definitive definitions are given by a separate file in form of an AASX file of the Submodel template and its elements.

2. Tables on Submodels and SubmodelElements

For clarity and brevity, a set of rules is used for the tables for describing Submodels and SubmodelElements.

- The tables follow in principle the same conventions as in [5].
- The table heads abbreviate 'cardinality' with 'card'.
- The tables often place two informations in different rows of the same table cell. In this case, the first information is marked out by sharp brackets [] form the second information. A special case are the semanticIds, which are marked out by the format: (type)(local)[idType]value.
- The types of SubmodelElements are abbreviated (see Table 30):

Table 30. Abbreviations for SubmodelElements

SME type	SubmodelElement type
Blob	Blob
Cap	Capability
Ent	Entity
Evt	Event
File	File
MLP	MultiLanguageProperty
Opr	Operation
Prop	Property
Range	Range
Ref	ReferenceElement
Rel	RelationshipElement
RelA	AnnotatedRelationshipElement
SMC	SubmodelElementCollection
SME	SubmodelElement type
SML	SubmodelElementList

- If an idShort ends with '__00__', this indicates a suffix of the respective length (here: 2) of decimal digits, in order to make the idShort unique. A different idShort might be choosen, as long as it is unique in the parent's context.
- The Keys of semanticId in the main section feature only idType and value, such as: https://admin-shell.io/vdi/2770/1/0/DocumentId/Id. The attribute "type" (typically "ConceptDescription" and "(local)" or

"GlobalReference") need to be set accordingly; see [6].

- If a table does not contain a column with "parent" heading, all represented attributes share the same parent. This parent is denoted in the head of the table.

- Multi-language strings are represented by the text value, followed by '@'-character and the ISO 639 language code: example@EN.

- The [valueType] is only given for Properties.

Annex B. Current limitations

AAs outlined in §2.1, this version of the Submodel "Material Data for the Characterization of Plastic Waste Feedstocks and Recycled Plastics" deliberately focuses on a core subset of capabilities. This restricted scope reflects two strategic considerations.

B.1 Leveraging emerging AAS SMTs

The AAS ecosystem continues to evolve with new standardized Submodel templates. Rather than duplicate these efforts, we have positioned this Submodel to benefit from upcoming standards.

While SMT "Sensor 4.0 Part I: Measurement Values" currently provides robust modeling for Property Characteristic measurements, the emerging SMT "Digital Quality Document (Digital Calibration Certificate)" will offer complementary or superior capabilities.

SMT "Digital Standards Datasheet" will provide comprehensive structures for describing: - standards and norms relevant to individual Property Characteristics; - application-specific standards that materials fulfill for DQL suffix -A classifications (as described in §1.4 of this document).

B.2 Managing complexity of Optional Characteristics

EN 18065 specifies numerous Optional Characteristics beyond the Required category covered in this current version of this Submodel. Most of these Characteristics are highly complex to model and have relevance beyond this Submodel's immediate scope. However, adequate modeling requires: - deep specialist domain expertise; - coordination with parallel standardization efforts; and - careful semantic alignment across use cases

Future versions will likely incorporate Optional Characteristics through SMT drop-ins from specialized Submodel templates developed in separate workstreams. This approach ensures that domain experts can properly address the nuances of these characteristics while maintaining consistency with broader AAS ecosystem developments. :sectnums!:

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