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Evaluation of publicly available heat pump specifications for digital planning and design tools

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Abstract

The quality of publicly available data for heat pumps and heating peripherals is crucial for developing innovative digital solutions that enhance the planning and installation of heat pumps. In Europe, the main data formats for design and connection information are VDI 3805/ISO 16757 and ETIM. However, the quality of the data in these formats is currently heterogeneous. This paper aims to describe this heterogeneity and identify gaps within these standards that impede comprehensive heat pump system planning in existing single-family homes.

To enable analysis, public data platforms for VDI 3805 data were evaluated regarding the completeness of the available data. Furthermore, a previously developed decision tree was used to visualize interactions between end customers and craftsmen, facilitating tailored solutions. Subsequently, 25 system components and 111 relevant attributes critical for planning and installation were identified and compared with the ETIM and VDI 3805 data models. The results indicate that while these models are useful, they do not cover all necessary components. Additionally, a trial was conducted to evaluate the data quality of geometric component information for 3D modelling based on the TGA diagrams of three heat pump manufacturers using only VDI 3805 connection information. This evaluation revealed gaps in the available data. However, visualization can enhance communication between planners and craftsmen and support prefabrication, leading to faster heat pump installations. Finally, eight expert-interviews with software providers of heat pump planning tools were conducted to evaluate current use and origin of heat pump data and challenges in using standardized product data formats.

The study recommends extending existing data models to address planning gaps and establishing regular data verification based on real projects.

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Keywords: Heat pump installation; data models; data quality; HVAC trades; VDI 3805; ETIM; Germany.

1. Introduction

Rapidly scaling heat pump adoption is essential for climate mitigation and for reducing dependence on imported fossil fuels. However, compared with fossil-based systems, heat pump projects entail higher planning and installation complexity, which drives up soft costs and inhibits market uptake. To achieve cost parity at the point of investment, these non-hardware costs must decline substantially, with digital solutions playing a central role in streamlining design, procurement, pre-configuration, and commissioning.

Manufacturers and wholesalers increasingly augment traditional installation with digital services such as system planning and pre-assembly. In parallel, new market entrants (e.g., autarc [1], lun [2], Heizreport [3]) are introducing innovative quotation services that further catalyze process automation and user-centric tools. Yet this innovation is frequently constrained by limited availability, quality, and standardization of publicly accessible product data for heat pump components. Fragmented formats, incomplete specifications, and inconsistent data models impede interoperability and hinder the development of scalable digital services.

In this study, we focus on the two most widely used product data standards in Germany: ETIM [4] and VDI 3805 [5]. The European Technical Information Model (ETIM) is a standardized classification system for technical products, originally primarily used in electrical engineering but increasingly applied in the HVAC sector. It allows for the classification of components at two levels: group and class. To each class a set of attributes (features) is assigned that enable a technical description of the component. The VDI 3805, developed by the Association of German Engineers (VDI), is a widely used data model for describing technical product data in the HVAC industry of Germany (the corresponding international guideline ISO 16757 is currently being developed). The highest classification level in the VDI 3805 is the product groups, whose attributes and dependencies are detailed in individual appendices known as "VDI 3805 Parts". The technical attributes, ranging from product type to geometric representation, provide a very detailed description of the product. ETIM is employed in the HVAC industry mostly for commercial processes, while VDI 3805, due to its high level of technical detail, is primarily used in design processes.

This paper evaluates the current landscape of the above-mentioned publicly available heat pump specifications to feed the next generation of digital solutions across the value chain. We examine the current state of data provision, assess their suitability for current digital workflows, identify gaps relative to prevailing data models, and propose minimum data requirements for today's services as well as priorities for future data publication. We address the following research questions:

- To what extent are public data already available to support digital services?
- Which manufacturer data for digital services are missing from existing data models?
- What minimum information must data contain to support current digital services?
- Which data for digital services should be urgently made publicly available?

By aligning service needs with data availability and highlighting actionable gaps, the study offers guidance for industry stakeholders and standardization initiatives aiming to lower soft costs and accelerate heat pump deployment through data-driven innovation.

2. Methods

To evaluate publicly available heat pump specifications for development of current and future digital solutions a mixed-methods approach was chosen. This approach includes the assessment of the current state of data provision via the public platforms QualityBIM [6] and BIM4HVAC [7], an analysis of the completeness of data models based on the example of a heat pump quote for single-family houses, the analysis of current data quality using a case study on semi-automated 3D modeling of a heat pump installation and the evaluation of semi-structured expert interviews regarding the current and future use of data and the resulting requirements.

2.1. Evaluation of the current state of data provision

The most widely used data platforms for VDI 3805 are QualityBIM and BIM4HVAC, which share the VDI 3805 database in the backend. Manufacturers can provide their product catalog files there. Either the catalog files in .vdi format can be downloaded directly, or the pre-processed product files in .xml format are provided by the platform operator. Additionally, a conversion program for VDI 3805 geometry data into common formats such as .obj or .step is available for download. Some manufacturers also provide catalog files directly on their websites. We have accessed catalog files from these sources, which will be analyzed below.

In the analysis, we primarily consider data from the main components of heat pump systems, specifically VDI 3805 Part 22 (heat pumps), VDI 3805 Part 20 (storage tanks and instantaneous water heaters), and VDI 3805 Part 03 (heat generators). For the analysis, we developed a pipeline that extracts individual product files from the catalog files and performs the following analyses:

- Publication date of the catalog file
- Presence of connection information (record type 970.01)
- Existence of performance data (only heat pumps) (record type 710.09 / 710.91)
- Number of data points specified in the performance characteristic curve (only heat pumps)

This information is relevant for typical use cases of VDI 3805. This is the case, on one hand, for the design of heat pump systems (see Section 2.2) and, on the other hand, for the 3D modeling of technical building equipment (HVAC) (see Section 2.3). The results of the evaluations are presented in Section 3.1. No evaluation of the current data provision in ETIM format was conducted, as there is no publicly accessible platform through

which manufacturers provide data in this format. The data is usually sent by manufacturers and wholesalers along with current price lists, e.g., in Datanorm format [8] or via Open Masterdata (OMD) from the Open Datacheck platform [9].

2.2. Evaluation of the completeness of data models – case study on heat pump quotations

Next, a detailed analysis was conducted to assess the completeness of the data models. It was analyzed whether the ETIM (Version 9.0) and/or VDI 3805 data models are sufficiently complete to create a quotation for the installation of an air-water heat pump (AWHP) in an existing single-family home based solely on publicly available data.

Methodologically, the state of the art for the rough design of air-water heat pumps and the main system components was reviewed according to relevant standards and guidelines. Acoustic requirements (TA Lärm/BImSchG [10]) and practical rules (e.g., surcharge for restricted times, storage sizing) were also considered. Sources included VDI 4645 [11], DIN EN 15450 [12], DIN/TS 12831-1 [13], as well as supplementary literature (Bonin [14,15], Glaesmann [16], Sobotta [17], Schenk [18]) and studies (e.g., Vering et al. [19]). Based on this, a sample quotation used by about five craft businesses was examined, and four standard hydraulic schemes were defined: (i) monoenergetic with freshwater station, (ii) monoenergetic with drinking water storage, (iii) gas-bivalent with freshwater station, and (iv) gas-bivalent with drinking water storage.

To systematically represent the quotation process, a decision tree was developed according to BPMN 2.0 Standard (created with Modelio 5), which translates the customer conversation into questions, decisions, and calculation steps (Data Input/Output, Description), thus enabling the stepwise sizing of the components. The documentation of this can be found in [20]. As an interim result, all components relevant for the quotation and their attributes were defined in such a way that the four scheme variants can be fully represented; materials that are typically billed according to consumption (e.g., pipes, fittings, cables, fasteners) were deliberately not considered. Finally, a systematic comparison of the identified components and attributes with ETIM (Class-Code / Feature-Code / Feature-Description) and VDI 3805 (Part / Record Type / Serial No. / Description) was conducted; all assignments and gaps were fully documented in [20]. As a summary the share of missing components and attributes for both data models can be found in a tabular evaluation in Section 3.2.

2.3. Analysis of current data quality - case study on 3D modeling

The background of this analysis is that geometry information can fundamentally be represented in the VDI 3805 format. In addition to pure 3D models of the components, additional information regarding the location of connections, their dimensions (e.g., ½” or ¾”), their intended function, such as inlet or outlet, and the medium, such as heating water, drinking water, or electrical connection, can be provided in record type 970.01. This information can significantly facilitate the virtual planning of heating installations. Such planning allows for more accurate effort and material estimates and improvements in the coordination of an installation. In the long term, this also enables prefabrication, which contributes to reducing installation times and thus lowering investment costs. However, it is crucial that this information is available not only for the heat pump to be installed but also for all components used in a heating system. As shown in Section 3.2, not all relevant components can currently be represented in VDI 3805. Additionally, there are components for which VDI 3805 parts exist, but no product data for these components is available on public platforms for VDI 3805 data. For this reason, the present analysis is limited to the following main product groups: Heat pumps, buffer tank, domestic hot water / multifunction storage tanks, hydraulic stations (of heat pumps), distribution manifolds, and hydronic control stations (for mixed heating circuit).

Eight hydraulic schemes issued by three different manufacturers are used as the analytical basis, as most installation companies rely on such manufacturer schemes when planning heat pump systems for single-family homes. The schemes typically list the manufacturers’ possible main products (see above) with which they can be implemented. In some cases, this is a single product per group; more often, several are offered (e.g., storage tanks with different capacities or storage volumes). For each of the eight schemes, we investigate whether records for the corresponding products exist on the public VDI data platforms and, if so, whether connection information is available in record type 970.01. The quality of the connection information is not further assessed. The ETIM data model was not assessed with this approach either, as it does not contain any geometry information.

2.4. Current and future data use and requirements—expert interviews

Finally, we analyze how existing data models should be further developed. For this purpose interviews are conducted with potential users and providers of these data. To select suitable interviewees, we leveraged findings from the WESPE research project [21]. As part of a panel survey in Q3 2024 by the German Central Association of HVAC craftsmen (ZVSHK) among more than 2,000 HVAC craft businesses, the following responses were obtained:

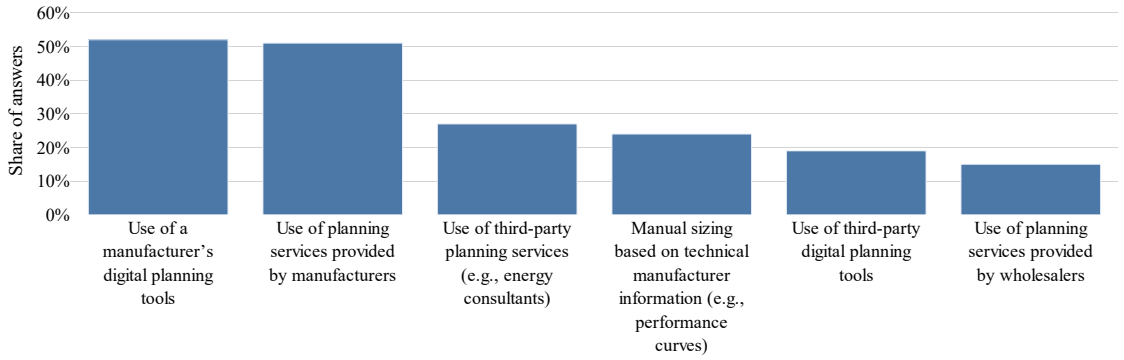

Figure 1. Results of the ZVSHK panel survey in Q3 2024 among more than 2,000 HVAC craft businesses for the question: "How do you perform the sizing calculation for heat pumps when preparing quotations? (Multiple selections possible)"

Participants who indicated they use manufacturer tools were additionally asked, as a free-text question, which manufacturers' tools they use. The responses are shown below:

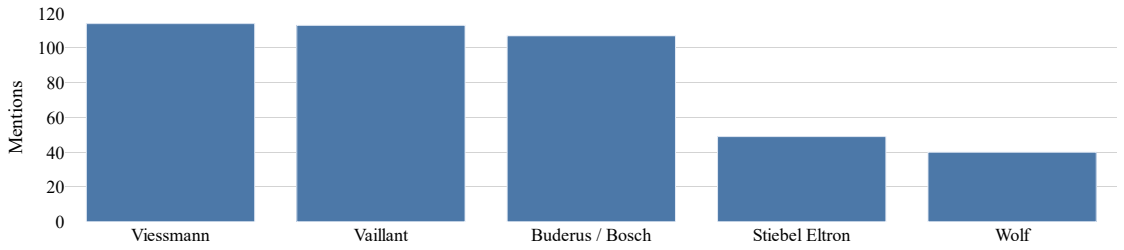

Figure 2. Results of the ZVSHK panel survey in Q3 2024 among more than 2,000 HVAC craft businesses for the question: "Which manufacturer-provided digital planning tools do you use?" (only five most frequently named shown)

The same question was posed to those who reported using third-party planning tools:

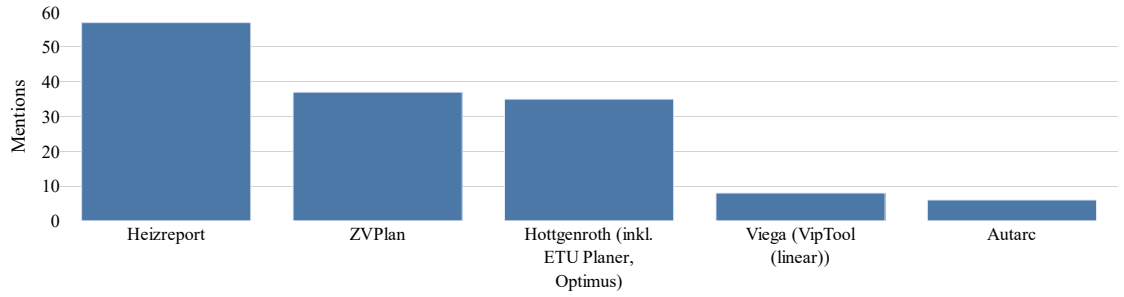

Figure 3. Results of the ZVSHK panel survey in Q3 2024 among more than 2,000 HVAC craft businesses for the question: "Which third-party-provided digital planning tools do you use?" (only five most frequently named shown)

All companies listed in the figures (the five most frequently named manufacturers and the five most frequently named third-party providers) were contacted for telephone interviews. In addition, the following wholesalers were approached: SISTEMS GmbH, Cordes & Graefe KG, Wiedemann GmbH & Co. KG. Of the 13 companies contacted, interviews were conducted with three third-party providers of software, three heat pump manufacturers, and two wholesalers.

The interviewees were interviewed based on a semi-structured survey containing the following questions:

1. What analyses, sizing, and calculations for heat pump systems does your software perform?
2. Which technical attributes for which products are used in your tool? What resolution is required in each case (e.g., number/resolution of data points for heating/cooling curves, part-load behavior)?
3. Does your tool use or import product information from standardized data models (such as VDI 3805, ETIM, …) for automated analyses, calculations, and sizing? If yes: Which ones? If no: Why not?
4. Where do you see the greatest hurdles in integrating standardized product data into your software?
5. From your perspective, are there missing product types (classes) or attributes in the product data standards that should be included in future extensions?
6. Would you use standardized product data if they were provided in higher quality?
7. Where do you source the manufacturer data?
8. Are there additional digital services you could envision offering if you had more or different data than you have today? Which services would these be?

Interviewees from manufacturers were only asked questions 1, 2, and 8.

3. Results and Discussion

3.1. Evaluation of the current state of data provision

The current state of data provision by manufacturers was investigated as described in Section 2.1. Manufacturer names were pseudonymized. The data are analyzed separately by VDI 3805 part.

3.1.1. VDI 3805 part 22: Heat pumps

In Figure 4, for each heat pump manufacturer we show the share of products for which connection information (blue) and performance map data (orange) are available, along with the date of the last catalog update. Five manufacturers last updated their data in 2025, four in 2024, one in 2023, and one in 2017. Seven of the eleven manufacturers provide both connection and performance information for at least 85% of their products.

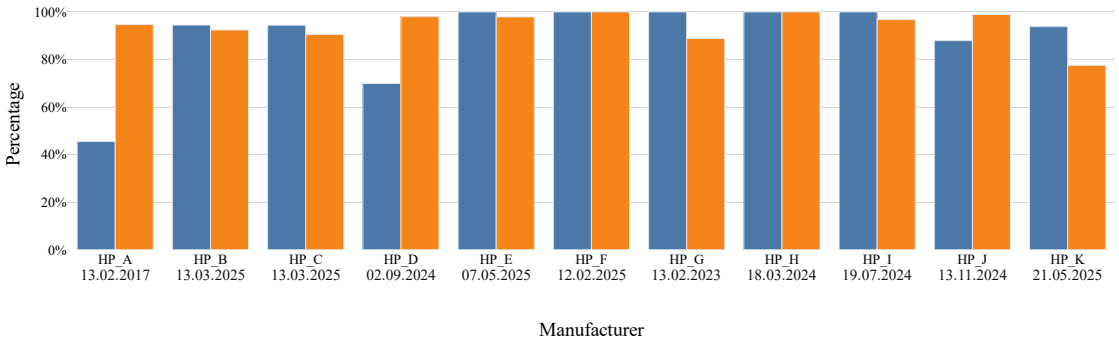

Figure 4. Share of products with connection information (record type 970.01, blue) and performance points (record type 710.09, orange) in VDI catalog files part 22 for manufacturers providing data on the QualityBIM portal (pseudonymized), with the date of the last update of the VDI catalog

Figure 5 shows, for the same manufacturers, the average number of data points in the performance map that are relevant for sizing heat pump systems. Clear differences are evident: while three manufacturers provide on average more than 100 data points, four provide fewer than 20. Comparing the two figures reveals manufacturers that offer performance data for all products but with very few points (e.g., manufacturer HP-F).

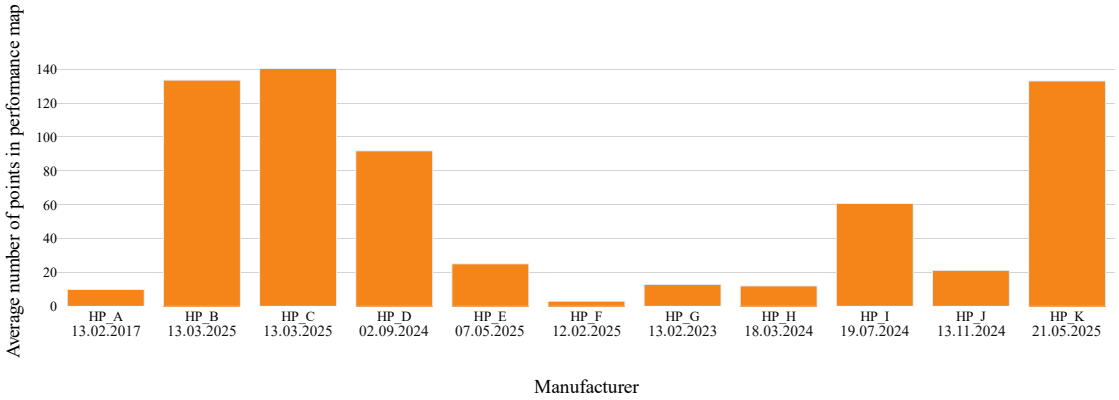

Figure 5. Average number of performance map data points (record type 710.09 / 710.91) per product in VDI catalog files part 22 for manufacturers providing data on the QualityBIM portal (pseudonymized), with the date of the last update of the VDI catalog

3.1.2. VDI 3805 part 20: Storage tanks and instantaneous water heater

Figure 6 reports for each manufacturer of storage tanks and instantaneous water heaters the share of products with available connection information, as well as the date of the last catalog update. Compared to heat pumps, the data are notably less current: only one manufacturer updated this catalog in 2025, one in 2024, one in 2023, two in 2022, three in 2021, and one in 2016. Fewer manufacturers provide connection information overall: while four manufacturers cover at least 95% of products, three cover less than 20%, and two provide 0%.

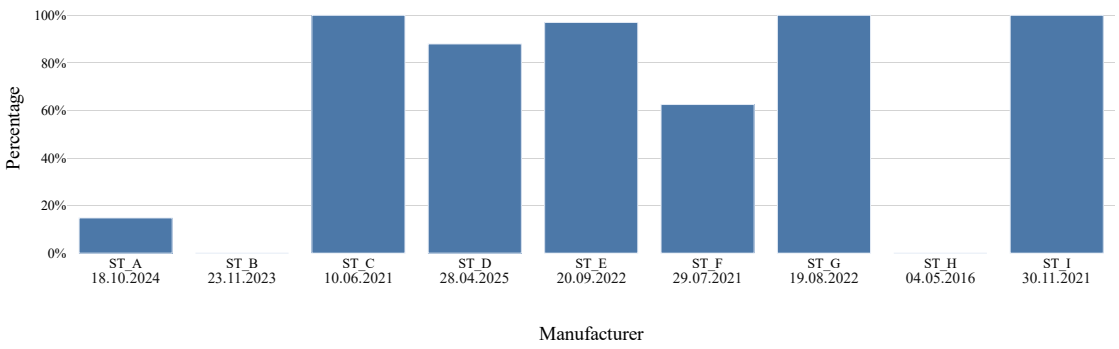

Figure 6. Share of products with connection information (record type 970.01) in VDI catalog files part 20 for manufacturers providing data on the QualityBIM portal (pseudonymized), with the date of the last update of the VDI catalog file

3.1.3. VDI 3805 part 03: Heat generators

Figure 7 presents, for each manufacturer of heat generators, the share of products with available connection information and the date of the last catalog update. Only three manufacturers provide connection information for more than 60 % of their products, while three manufacturers provide it for fewer than 20 %.

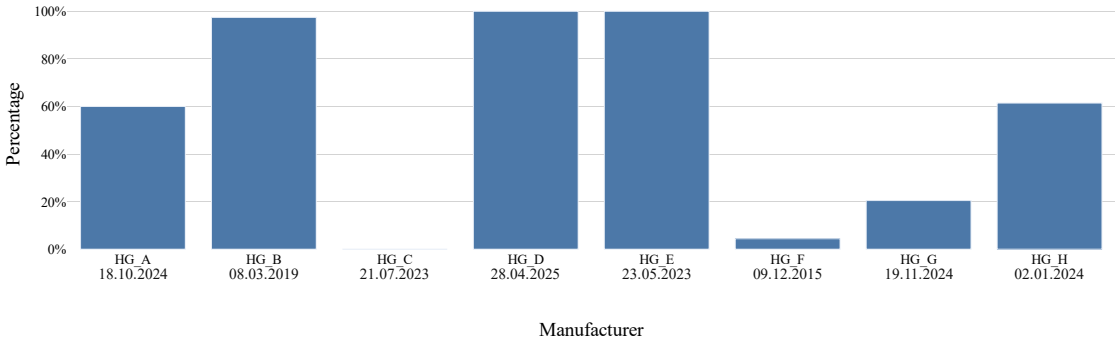

Figure 7. Share of products with connection information (record type 970.01) in VDI catalog files Part 03 for manufacturers providing data on the QualityBIM portal (pseudonymized), with the date of the last update of the VDI catalog file

3.1.4. Conclusion on the current state of data provisions

The evaluations for the three product groups show that data quality varies substantially by manufacturer and product group. Data quality is highest for heat pumps: catalogue data are generally kept up to date, and most manufacturers provide both performance data and connection information for the majority of their products. This indicates that manufacturers have recognized the importance of supplying data for heat pumps. However, when the level of detail of the provided performance data is considered, large differences become apparent, so the quality of a heat pump design may vary depending on the number of data points supplied. Data quality for storage tanks and heat generators is markedly poorer: catalogues are less frequently updated, and information is available for fewer products. This could be due to less innovation in these product groups or a lower prioritization of keeping data up to date for these the product groups by the manufacturers. Section 3.3 presents the implications for 3D modelling and also provides a hint toward the answer to this question.

3.2. Evaluation of the completeness of data models – case study on heat pump quotations

As described in Section 2.2 a decision tree for quotations of an air-to-water heat pump in a single-family house for four variants of hydraulic integration was developed based on literature reviews (mainly norms). The identified relevant components for these quotations are shown in Table 1.

Table 1. Representation of the main system components described for a quotation of an air-to-water heat pump in a single-family house

No.	System component	No.	System component
1	Air-to-water heat pump (split or mono block)	14	Diaphragm expansion vessel
2	Buffer tank	15	Air separator
3	Fresh-water station	16	Sludge and magnetic separator
4	Hot water heater	17	Radiator valve
5	Three-way valve	18	Radiator thermostat head
6	Gas storage boiler	19	Radiator return coupling
7	Gas wall-mounted boiler	20	Room thermostat for underfloor heating
8	Hydraulic separator	21	Actuator for underfloor heating
9	High-efficiency pump	22	Wastewater pipe
10	Pre-insulated district heating pipe	23	Compact sewage lifting station
11	Sealing insert for wall penetration	24	Metering device
12	Safety valve	25	Mixed heating-circuit station
13	Refill station		

Next, these components and their properties, which are required for creating the quotation, were compared with the classes and attributes of the VDI and ETIM (Version 9.0) data models. The comparison showed that of the 25 system components listed in Table 1, 23 have an assignable class code in the ETIM data model. This corresponds to a percentage of 92%. When compared with the feature codes, 111 attributes were queried, of which 100 are contained in the ETIM data model with a code (90.09%). In the available datasets, 97 of the queried 111 attributes were described by the feature descriptions (87.39%). In Table 2 the above results are presented.

Table 2. Result of existing attributes and information from the ETIM data.

ETIM 9.0	Number queried	Number contained	Result in %
Classcode	25	23	92.00
Feature-Code	111	100	90.09
Feature-Description	111	97	87.39

Of the 25 system components listed in Table 1, 19 could be assigned to a sheet of VDI 3805 (76.00%). Of 111 attributes, 93 could be described with a record type and the corresponding running number (83.78%). In Table 3 the above results are presented.

Table 3. Result of existing attributes and information from the VDI 3805 data.

VDI 3805	Number queried	Number contained	Result in %
Parts	25	19	76.00
Record types	111	93	83.78

VDI 3805 does not include components 8 (hydraulic separator), 11 (sealing inserts for wall penetration), 15 (air separator), 16 (sludge and magnetic separator), 20 (wireless room thermostat for underfloor heating), and 25 (mixed heating-circuit station). By combining ETIM and VDI 3805 for data mapping, up to 23 of 25 components (92%) can be described; components 8 and 11 remain undefined even when both models are used. Similarly, 107 of 111 attributes (96.4%) can be mapped using both models; the remaining attributes are listed in Table 4.

Table 4. Result of attributes not describable when using the VDI 3805 and ETIM data models simultaneously.

No.	Attribute	System component	ETIM	VDI 3805
20	Heat pump tonality	Air-to-water heat pump (mono block)	Not included	Not included
23	Heat pump tonality	Air-to-water heat pump (split)	Not included	Not included
55	Hydraulic separator	Hydraulic separator	Not included	Not included
73	Sealing inserts for district heating pipe / exterior wall	Sealing insert for wall penetration	Not included	Not included

3.3. Analysis of current data quality - Case study on 3D modeling

Eight manufacturers were examined to assess the availability of VDI 3805 datasets for their main components and the presence of inlet/outlet connection details in data record type 970.01. A summary of dataset availability follows:

Manufacturer	Schema	Heat pump(s)	Buffer tank	Domestic hot water / multifunction storage tank	Hydraulic station (of heat pump)	Distribution manifold	Hydronic control station (for mixed heating circuit)
A	A						
A	B						
A	C						
B	D						
B	E						
C	F						
C	G						
C	H						

Figure 8. Overview of the presence of VDI 3805 data sets for products from eight manufacturer schemes (green = available for all product variants, orange = available for some product variants, red = not available for any product variant, white = not present in the manufacturer scheme). Schema E uses an integrated buffer tank in the heat pump.

It is evident that data sets exist for all heat pumps in the schemes. In one scheme, data sets are missing for the employed domestic hot-water storage tank. In the same scheme, different variants of the buffer tank are present; only some of these variants have VDI 3805 data sets. Hydraulic stations occur in the schemes of only one manufacturer. For the other manufacturers, the hydraulic stations/control units (in all cases mono block devices) are included in the heat pump data sets. In one case, a buffer tank integrated into the heat pump is present. In no case, however, are hydronic control stations (for mixed heating circuits) available from the respective manufacturers. This is because these are not described in VDI 3805 but only in ETIM (see Section 3.2).

In the next step, it was examined whether the component data sets from the table above contain connection information for inlets and outlets in data record type 970.01 (see Figure 9). It turns out that only one

manufacturer provides connection information for all components except hydronic control stations. That means, automated 3D planning is possible if hydronic control stations are excluded and their installation location is decided on-site. In all other cases these connection data are missing for some or all of the storage components listed in the schemes. This means that 3D modelling of the systems from these manufacturers using public data would only be possible with considerable effort, since connections would have to be manually extracted from the 3D models of the storage tanks or selected in the respective modelling tools. Automated planning, e.g. by auto-routing algorithms, is therefore greatly impeded. It is important to emphasize that the positioning of storage tanks and their connections can have a significant influence on installation effort.

Manufacturer	Schema	Heat pump(s)	Buffer tank	Domestic hot water / multifunction storage tank	Hydraulic station (of heat pump)	Distribution manifold	Hydronic control station (for mixed heating circuit)
A	A						
A	B						
A	C						
B	D						
B	E						
C	F						
C	G						
C	H						

Figure 9. Overview of the presence of connection information of data record type 970.01 in the VDI 3805 data sets for products from eight manufacturer schemes (green = available for all product variants, orange = available for some product variants, red = not available for any product variant, white = not present in the manufacturer scheme). Schema E uses an integrated buffer tank in the heat pump.

3.4. Current and future data use and requirements – expert interviews

Of the eight interviewed companies, four offer manufacturer-independent (MI) and three offer manufacturer-specific (MS) configurators. The following distinction is used in the evaluation. The software provides, among other functions, the following:

- MI software features: Heating and cooling load calculations; hydraulic balancing; site/layout and acoustic analyses; design of heat pump systems, radiators, surface heating systems and distribution systems; pipe network calculations
- MS software features: Heating load calculation; design of heat pump systems; schematic generation; product recommendations; acoustic calculations

3.4.1. Product data attributes: use and origin

The interviewed manufacturers use data from their own product information management (PIM) systems to size their products. One manufacturer additionally obtains data from other manufacturers via direct exchange for products not in its portfolio. Among the manufacturer-independent software providers, one primarily uses ETIM data supplied via Open Datacheck, while the other three partly use VDI 3805 data sets that are enriched through manual post-processing steps or whose records are created manually. Some providers receive product data from manufacturers directly.

Heat pump system design is performed with performance map (characteristic curve) points. Of the six providers that offer such sizing, five provide sizing based on a detailed performance map and one uses a simplified sizing with performance points from DIN EN 14511 [22] (e.g. A-7/W35 or A-7/W55). The three manufacturers offering detailed sizing stated they use more detailed maps than those provided in their VDI 3805 catalog files. The one MI provider offering detailed evaluation either receives more detailed data from manufacturers than available in VDI 3805 or enriches these data manually. One MI software provider commented on the theoretically necessary minimum number of performance-map points for heat pump sizing: source temperatures should be given in 5 K steps between −15 °C and 15 °C and sink temperatures in 5 K steps between 30 °C and 65 °C for good interpolation quality. Values should be provided both for full load (100% modulation to determine the bivalence point) and for the minimum technically possible modulation range (to determine the dew point). This yields a minimum of 112 map points, which the software provider states are necessary for heat pump sizing. A comparison with Section 3.1.1 shows that datasets from only three of eleven manufacturers meet these requirements on average.

One MI software provider notes that the VDI 3805 data format only allows specifying the sound power level according to the ErP for indoor and outdoor units (record type 700). Important details required for TA-Lärm calculations are therefore missing, e.g. tonality of the sound and the maximum sound power level in noise-reduced operation (also called night mode).

3.4.2. Challenges in using standardized product data formats

When using the VDI 3805 data format the following problems were reported by the MI software providers:

- Integration of the format into processes requires high effort because the structure of the format is complex and no machine-readable documentation exists. Quote: "*If my best software developer has to work for half a year to make these data usable in our processes, and in the end much still cannot be automated, something is wrong. […] The VDI 3805 database urgently needs to provide a developer API.*"
- The data quality provided by manufacturers is partially poor and varies greatly by product group and by manufacturer. For some product groups VDI 3805 is established as the primary exchange format and data are delivered at high quality (e.g. radiators); for others this is not the case.
- For some product groups no corresponding VDI 3805 part exists (e.g. surface tempering systems).
- There is sometimes room for interpretation when using the data.

The MI software provider who uses ETIM data sets in their software named the following problems:

- There are inconsistent class assignments, which makes automated use of the information difficult. Quote: "*Classification is inconsistent: […] Some [manufacturers] treat the indoor unit of a heat pump as its own class, others assign it to the heat pump class.*"
- Detailed technical sizing requires additional ETIM attributes (e.g. extra performance points).
- The quality of the provided data, especially technical attributes, is poor.

While there are various optimization potentials, poor data quality was named as the primary problem. All MI software providers stated they would use standardized product data if it were provided in sufficient quality. Quote: "*We would even be willing to pay for better data.*"

Higher data quality can save time by eliminating or simplifying the laborious data-enrichment processes. In addition, some providers that currently do not enrich data could offer more detailed sizing in their tools. One software provider also described the use of AI models – especially large language models – as a future service. Better data quality is the prerequisite for using such models in future software workflows.

4. Conclusion

Using a mixed-methods approach, we examined the current state of data provision and the completeness of the main data models for heating components in Germany, VDI 3805 and ETIM. The results of the analysis from the previous chapters is summarized in Figure 10.

	Data model	
	VDI 3805	ETIM 9.0
Current state of data provision*		
Completeness of data model		
Current data quality of provided data*		
Current challenges in using standardized product data formats		

Figure 10. Overview of results of the analysis undertaken in the previous sections (green = good with minor room for improvement, orange = has significant room for improvement, red = major improvement necessary, white = not evaluated within the analysis, * = referring only to data from the public QualityBIM portal).

The analysis shows that data provision is highly heterogeneous and depends on the manufacturer. This heterogeneity exists not only between individual manufacturers but also between product groups within the same manufacturer. Overall, the quality and accuracy of datasets for heat pumps tend to be higher than for burners and storage tanks. As a result, innovative application scenarios for VDI 3805 data – such as semi-automated 3D planning and prefabrication – are hindered, because these use cases typically require not only planning data for the heat pumps themselves but also for peripheral components. Even for established use

cases, for example sizing a heat pump based on the bivalence point, only few manufacturers supply a sufficient number of data points. Consequently, manufacturer-independent (MI) software providers are forced to enrich these data manually and/or obtain them directly from the manufacturers.

Moreover, VDI 3805 data suffer from the problem that no machine-interpretable documentation of the VDI format exists and the domain knowledge required to correctly interpret the format is high, so a large personnel effort is needed to make the data usable. As a result, efforts – especially for manufacturer independent software providers – could be reduced by better data quality, more intuitive interpretability of the data, and readily accessible interfaces.

The assessment of model completeness shows, for the examined case of a heat pump quotation, that both models are already well suited but not fully complete. The scope of components that can be represented is larger in ETIM (92%) than in VDI 3805 (76%). However, interviewees reported that ETIM has issues with ambiguous class assignments in some cases. At the attribute level, the combination of ETIM (alone covering only 87%) and VDI (alone covering only 84%) substantially increases completeness for the use case to 96%. Thus, combining datasets from both formats would provide added value. Technically, linking the datasets via the article number would often be possible, since VDI 3805 includes an attribute for the article number and ETIM datasets are typically offered together with commercial data that contains the article number (e.g., via Open Datapool [23]). At the same time, the analysis shows that both data models must be continuously extended; established channels for this exist via working groups and technical committees.

The initial research question “What minimum information must data contain to support current digital services?” was only partially answered by the interviews. One aspect is acoustic information required for TA Lärm calculations. Another is a minimum resolution for data points in heat pump performance maps. The resolution demanded by one interviewee – approximately 112 data points – could likely be reduced substantially by limiting full-load data points to a typical bivalence-range (e.g., −15 °C to 5 °C) and the minimum-modulation data points to a typical dew-point-range (e.g., 0 °C to 15 °C). Further research is needed to determine whether this is sufficient for real use cases. Geometric connection information (as investigated in Section 3.3) appears, based on the interviews, to play a minor role in many current applications but could play a more important role in the future applications like prefabrication or other HVAC applications, that were not investigated, like ventilation.

Defining minimum requirements (for example via a data quality policy from the German Central Association of HVAC craftsmen (ZVSHK) [24] or the German Wholesale Association for Building Services (DGH) [25] for data quality combined with continuous monitoring of published datasets could improve data quality across the sector. This, however, requires joint efforts from both manufacturers and software providers. Manufacturers would benefit from correct product data in third-party software tools because planning and execution errors could be reduced; software providers would benefit from reduced manual adaptation effort. However, until data quality improves, software providers will likely continue to rely on direct exchanges with manufacturers in non-standardized data formats.

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