



**Circular economy ecosystem to Recover, Recycle and
Re-use F-gases contributing to the depletion of
greenhouse gases - LIFE Retradeables**

Deliverable: Database structure

Action C1

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Abstract

This deliverable focuses on the back-end database of 3R ECOSYSTEM, which currently receives a continuous flow of many different pieces of information from the marketplace platform. Since the development of the prototype unit is still in progress, the Self-certification platform was initially chosen not to operate as a separate entity but within the Retradeables platform. This means that, apart from providing information on F-gas trading, further functionalities are available, thus enabling all eligible stakeholders (mainly installers) to enter pre-required and optional additional data per recovered/analysed/classified batch of F-gas quantity. Each category of information is assigned to a unique table within the database. Therefore, a dedicated set of tables hosts all critical data related to the activities of the installation and distribution companies within the platform. The individual tables consist of fields briefly defined in this report, too. Finally, it is clarified that the evaluation of refrigerant quality, in the present phase of the project, is carried out through self-declaration/self-assessment schemes by sellers and self-certification schemes by buyers, respectively. The ultimate objective is the full implementation of self-certification schemes that will contribute to the establishment of an accurate database on the quality of refrigerants. In any case, the existing structure and design of the database should not be regarded as final, as various improvements and adjustments are to be made until the end of the project in conjunction with the development of the IoT device to be attached on the prototype unit. Furthermore, there is currently no data on F-gas recycling/reclamation processes even though this will be an integral part of the database in the future.



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1 Database design – Current state

In the current phase of the project, the main source of information on the different stages of the used F-gas (from recovery to reuse) is the Retradeables Marketplace. Therefore, a back-end database has already been developed to store all the information recorded through the platform. Then, only some very basic information related to the F-gas recovery requires direct-manual input by the user (i.e., mainly technicians of installation companies) such as location, quantity and quality of the extracted refrigerant. At later stages of the recovery process, the traceability of the refrigerant is achieved by recording all user activities on the marketplace platform, including all relevant information derived from them. This information does not require direct data input by the user, but is mainly based on the user's interaction with the platform.

The database consists of a collection of tables that store the information about all the activities that take place through the Retradeables marketplace. The different stages related to refrigerant recovery and traceability for which information is collected and stored in the database are as follows:

1. Extraction of the refrigerant.
2. Initial quality assessment through a self-declaration scheme (on the seller's side).
3. Transfer of the refrigerant from the technician stock to the installation company's stock.
4. Offer for a refrigerant on the marketplace.
5. Start of the transaction (with the acceptance of a bid).
6. Collection of the refrigerant from the distributor (buyer).
7. Composition analysis (optional) and final quality assessment (on the buyers' side).
8. Completion of the transaction.

Step 1 relies on the direct input of information from the technician while on Step 2 the information about the quality of the refrigerant can be registered via a self-declaration/self-assessment scheme. The technician using the equipment on site (if available) can assess the quality of the refrigerant and declare its grade. Steps 1-3 are performed in the "Clients" and "Stock" sections of the Retradeables Marketplace, temporarily serving the purposes of an internal self-declaration platform ⁽¹⁾. The remaining steps (4-8) are closely linked to the trading activities within the marketplace platform and are automatically recorded in the "Sales Center" section.

Moreover, users, either sellers or buyers, may access the Retradeables Marketplace for the purpose of entering information linked to their activities. The input is possible through the User Interface (UI) of the platform. Users can also view information related to their activities through the dedicated sections of the platform.

(1). The internal self-declaration platform is actually considered as a preview of the fully-featured Self-certification platform that will be developed by the end of LIFE Retradeables project.



Finally, all the fields that require data entry by the technician through the sections dedicated to the internal self-declaration platform are listed below. Likewise, the outline of the information recorded by the sections dedicated to the Marketplace platform as well as the structure of the relevant database tables are both provided.

1.1 Database structure (Internal self-declaration platform) – User Input

In this sub-section, the information entered as **direct user input** to the internal self-declaration platform is briefly described. Definitions of the fields that constitute the corresponding database tables are also available.

1.1.1 Registration of the client and the HVAC-R unit

Before the recovery of the refrigerant, the user needs to register the client and the HVAC-R unit. This kind of information is collected through the "Clients" section of the Retradeables marketplace platform (**Figure 1**).

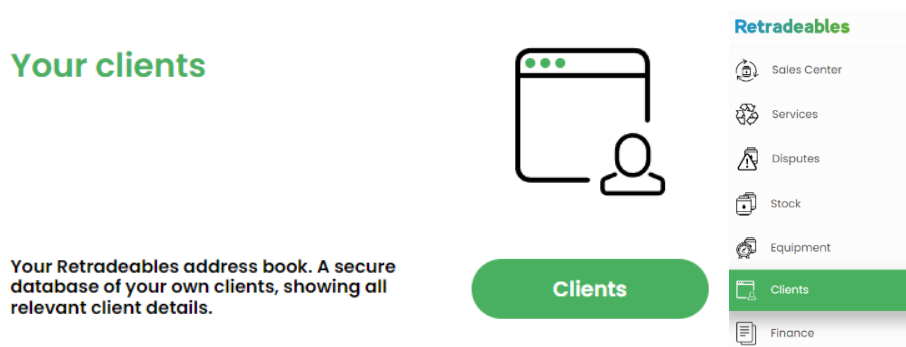


Figure 1: Section of the Retradeables marketplace platform/Internal self-declaration platform ready to receive information about the client.

When registering a new client, the user needs to provide the following information:

- Client's name;
- Client location(s);
- Client contact information.

Furthermore, each client can have more than one location registered. The technicians can use any of these locations as "Extraction Sites" where they recover refrigerant. The choice of the country is restricted to the 3 demo countries that are currently using the platform (Slovakia, Czech Republic, and Hungary).



Table 1 shows the complete list of data fields in which user inputs about the client are stored. For each of the fields (column "Characteristics"), it is further indicated whether it is optional or not, its data type and its length (number of digits or number of characters or date precision). However, the combination of information reported is only for the purpose of simplifying the structure of the dataset. In practice, the information in the database is stored in three different tables linked to each other, namely "Clients", "Locations" and "Countries", respectively.

Table 1: Structure of the table on Client information.

Characteristics	Required	Data type	Length
<i>Id</i>	<i>YES</i>	<i>Unique Identifier</i>	
<i>Client Name</i>	<i>YES</i>	<i>Character</i>	<i>50</i>
<i>VAT Number</i>	<i>NO</i>	<i>Character</i>	<i>50</i>
<i>IBAN</i>	<i>NO</i>	<i>Character</i>	<i>32</i>
<i>Location Name</i>	<i>NO</i>	<i>Character</i>	<i>50</i>
<i>Address</i>	<i>YES</i>	<i>Character</i>	<i>100</i>
<i>Postal Code</i>	<i>YES</i>	<i>Character</i>	<i>15</i>
<i>City</i>	<i>YES</i>	<i>Character</i>	<i>50</i>
<i>Region</i>	<i>NO</i>	<i>Character</i>	<i>50</i>
<i>Country</i>	<i>YES</i>	<i>Character</i>	<i>200</i>
<i>Email</i>	<i>NO</i>	<i>Character</i>	<i>200</i>
<i>Contact Person First Name</i>	<i>NO</i>	<i>Character</i>	<i>50</i>
<i>Contact Person Last Name</i>	<i>NO</i>	<i>Character</i>	<i>50</i>
<i>Phone Number</i>	<i>NO</i>	<i>Character</i>	<i>30</i>



After registering the client, the user should add an HVAC-R unit installed in one of the extraction sites. Unit registration by a user includes:

- The scanning of the QR code that labels the unit ⁽²⁾. A unique identifier is assigned to the unit.
- The selection from drop-down menus of the manufacturer, the type of application (commercial, domestic, industrial, supermarket) and the type of refrigerant. The capacity of the unit can also be entered.
- The addition of notes (optional) and
- The attachment of a picture of the HVAC-R unit.

Table 2 shows the complete list of data fields in which user inputs about the HVAC-R unit are stored. In practice, the information in the database is recorded in different tables linked with each other, namely "Units", "Manufacturers", "Refrigerants" and "Tags" (i.e., the combination of information reported is only for simplifying the structure of the dataset). It is noted that the column "Scale" gives the length of the decimal part of a decimal number.

Table 2: Structure of the table on HVAC-R unit information.

<i>Characteristics</i>	<i>Required</i>	<i>Data type</i>	<i>Length</i>	<i>Scale</i>
<i>Id</i>	<i>YES</i>	<i>Unique Identifier</i>		
<i>Manufacturer Name</i>	<i>YES</i>	<i>Character</i>	<i>100</i>	
<i>Application Type</i>	<i>YES</i>	<i>Integer</i>	<i>10</i>	
<i>Refrigerant Code</i>	<i>YES</i>	<i>Character</i>	<i>10</i>	
<i>Description</i>	<i>NO</i>	<i>Character</i>	<i>1000</i>	
<i>Capacity</i>	<i>NO</i>	<i>Decimal</i>	<i>16</i>	<i>2</i>
<i>Image URL</i>	<i>NO</i>	<i>Character</i>	<i>300</i>	
<i>Tag Id</i>	<i>NO</i>	<i>Unique Identifier</i>		

(2). A QR code scanner application for mobile phones has already been developed. Some extra information on this can be found in the C3's deliverable "Marketplace platform" (screenshots are also included).



1.1.2 Recovery of the refrigerant and initial quality assessment

After the registration of the HVAC-R unit, the user can perform an extraction. As shown in **Figure 2**, this can be initiated from the "Technician Stock" sub-section under the "Stock" tab. From there, the technicians can select a Click-to-Action (CTA) option available to perform a new extraction.

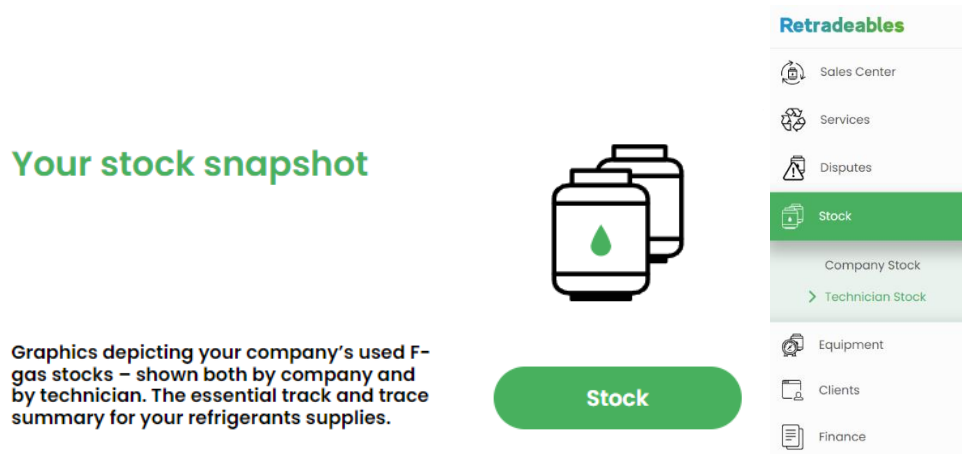


Figure 2: Section of the Retradeables marketplace platform/Internal self-declaration platform ready to receive information on the recovery of refrigerant.

Overall, the users provide the following input during the recovery of the refrigerant:

- The QR code of the unit (via scanning).
- The QR code of the cylinder used in the extraction (via scanning). It is possible to perform extractions from more than one unit if the cylinder is not full. However, the use of the same cylinder by the technician for F-gas recovery is not applicable in the case of units having different refrigerant type.
- The quantity of the recovered refrigerant and the date of recovery.
- The quality of the recovered refrigerant among three available options (Grade A, B and C – **Figure 3**). The default choice is Grade A.



- Extracted F-Gas is contaminated by oil, moisture or solid particles i.e. metal spans - Grade A
- Extracted F gas is a mix of different HFCs or component ratio (i.e. R410a, R32, R125) should be adjusted – Grade B
- Extracted F gas is a mix of HFC with HCFCs (i.e. R22) or a mix with HCs (i.e. R600a, R290) – Grade C

Assessed Quality Grade: A

Figure 3: F-Gas quality assessment and definitions of the Grades A, B and C.

Table 3 shows the complete list of data fields in which user inputs about the recovery of the refrigerant are stored. It is noted that the platform automatically records the value of the field "Extraction Datetime".

Table 3: Structure of the table on recovery information.

<i>Characteristics</i>	<i>Required</i>	<i>Data type</i>	<i>Length/Precision</i>	<i>Scale</i>
<i>Id</i>	YES	<i>Unique Identifier</i>		
<i>Unit Id</i>	YES	<i>Unique Identifier</i>		
<i>Cylinder Id</i>	YES	<i>Unique Identifier</i>		
<i>Extracted Quantity</i>	YES	<i>Decimal</i>	16	2
<i>Extraction Datetime</i>	YES	<i>Datetime</i>	3	
<i>Presumed Grade</i>	YES	<i>Integer</i>	10	0



1.2 Database structure – Refrigerant traceability

In this sub-section, the information stored in the database as a result of the **user's interaction with the Retradeables platform** is defined, including the dedicated sections of the Marketplace. Definitions of the fields that constitute the corresponding database tables are also available.

1.2.1 Transfer of the refrigerant from the technician stock to the installation company stock

Once the extraction of the refrigerant is finished, the cylinder with the recovered refrigerant is identified as a single stock item, which the user can move from "Technician stock" to "Company stock". The "Technician stock" is the area where the technician temporarily stores the cylinder during the recovery process. In the "Company stock", the user has the option to sell the refrigerant in the marketplace platform. It is also possible to move a cylinder from the "Company stock" back to the "Technician stock" and if the cylinder is not full, use it to perform a new extraction, since the type of refrigerant to be recovered is the same as previously. All of this information relating to operations occurring on a single stock item is recorded in the "SKUs" (Stock - Keeping Unit) table in the database.

Table 4 lists the corresponding fields stored in the database. The "Location Status" field tracks whether the cylinder with the recovered refrigerant is in technician or company stock. The field "Marketplace Status" tracks whether the stock item is available in the Retradeables platform and when the sale of the item is complete. The "Company Id" is the identifier of the company that is the owner of the stock item at each stage of the process. This means that when the "Marketplace Status" indicates that the item has been sold, the company-owner status changes and the name of the company that held the refrigerant until recently is overwritten by the name of the company that purchased it.

Table 4: Structure of the "SKUs" table.

<i>Characteristics</i>	<i>Required</i>	<i>Data type</i>	<i>Length</i>
<i>Id</i>	YES	<i>Unique Identifier</i>	
<i>Refrigerant Id</i>	YES	<i>Unique Identifier</i>	
<i>Company Id</i>	YES	<i>Unique Identifier</i>	
<i>Location Status</i>	YES	<i>Integer</i>	10
<i>Marketplace Status</i>	YES	<i>Integer</i>	10
<i>Cylinder Id</i>	YES	<i>Unique Identifier</i>	



1.2.2 The offer of the refrigerant in the Marketplace and the sales process

Once the recovered refrigerant is published on the Marketplace, its status is recorded in the "Offers" table, the structure of which is shown in **Table 5**. The "Offer Date Time" field captures the first time when the refrigerant becomes available on the Marketplace. The fields "Status" and "Last Change Date Time" record whether & when the buyer has collected the refrigerant and whether the sales process is complete, respectively. The field "Is Disposal" records whether the seller is seeking to pay a company to dispose the refrigerant when the refrigerant is of Grade C. The "Company Id" can be used to retrieve details about the company which performed the recovery.

Table 5: Structure of the "Offers" table.

<i>Characteristics</i>	<i>Required</i>	<i>Data type</i>	<i>Length/Precision</i>
<i>Id</i>	<i>YES</i>	<i>Unique Identifier</i>	
<i>Company Id</i>	<i>YES</i>	<i>Unique Identifier</i>	
<i>Offer Date Time</i>	<i>YES</i>	<i>Datetime</i>	<i>3</i>
<i>Last Change Date Time</i>	<i>NO</i>	<i>Datetime</i>	<i>3</i>
<i>Status</i>	<i>YES</i>	<i>Integer</i>	<i>10</i>
<i>Is Disposal</i>	<i>YES</i>	<i>Integer</i>	

In addition, **Table 6** shows the fields of the "Bids" table. With the "Bid Status" and "Bid Date Time" fields, it is possible to track when an offer receives a bid and when the bid got accepted and therefore the transaction process has started. Also, the fields "Offered Price Grade A/B/C" register the information about the price proposed by the potential buyer. The "Company Id" records the identifier of the company placing the bid.



Table 6: Structure of the "Bids" table.

<i>Characteristics</i>	<i>Required</i>	<i>Data type</i>	<i>Length/Precision</i>	<i>Scale</i>
<i>Id</i>	YES	<i>Unique Identifier</i>		
<i>Offer Id</i>	YES	<i>Unique Identifier</i>		
<i>Bid Status</i>	YES	<i>Integer</i>	10	
<i>Bid Date Time</i>	YES	<i>Datetime</i>	3	
<i>Company Id</i>	YES	<i>Unique Identifier</i>		
<i>Last Change Date Time</i>	NO	<i>Datetime</i>	3	
<i>Offered Price Grade A</i>	YES	<i>Decimal</i>	16	2
<i>Offered Price Grade B</i>	YES	<i>Decimal</i>	16	2
<i>Offered Price Grade C</i>	YES	<i>Decimal</i>	16	2

1.2.3 Composition analysis and final quality certification (buyer's side)

After collecting the recovered refrigerant, the buyer can perform a final analysis of the quality and then assign the final grade. The "Analysis" table stores all critical composition analysis information. **Table 7** lists the corresponding fields that include data on the company, date of analysis, quantity, final grade as well as an image of the analysis.



Table 7: Structure of the "Analysis" table.

<i>Characteristics</i>	<i>Required</i>	<i>Data type</i>	<i>Length/Precision</i>	<i>Scale</i>
<i>Analysis Id</i>	YES	<i>Unique Identifier</i>		
<i>SKU Id</i>	YES	<i>Unique Identifier</i>		
<i>Company Id</i>	YES	<i>Unique Identifier</i>		
<i>Analysis Date</i>	YES	<i>Datetime</i>	3	
<i>Quantity</i>	YES	<i>Decimal</i>	16	2
<i>Grade</i>	YES	<i>Integer</i>	10	
<i>Analysis Image File</i>	NO	<i>Character</i>	300	

1.3 Calculation of the installer's index

The relevant information stored in the database can be appropriately used to calculate an index value for installation companies based on the original assessment of the F-gas quality registered by their technicians during self-declaration. For each quantity of recovered refrigerant, the self-declared quality is compared with the final results of the composition analysis that can be officially performed by the buyer side (mainly distributors). Initially, when a company has no trading history it starts with an index value equal to 0. After completing its first transaction, the index is assigned a new value depending on the quality/accuracy of the first self-assessment (seller's side). Thus, the final grade may differ from the first grade by 0 (correct assessment), 1 (incorrect assessment by one grade) or 2 (incorrect assessment by two grades) points. Based on these differences, the index of an installation company is evaluated by calculating how much of the quantity extracted so far by the technicians corresponds to a correct assessment. For this purpose, a factor is defined which multiplies the quantity. **Table 8** shows the values of the quality assessment factor in relation to the quality of the first assessment. If the assessment is wrong by one degree, then only half of the quantity of the export in question will contribute to the index.



Table 8: Correlation of Quality Difference between self-declaration (seller's side) & composition analysis (buyer's side) and Quality Assessment Factor.

Difference between the first and the final assessment (in absolute value)	Quality assessment factor (F_{QA})
0	1
1	0.5
2	0

The calculation of the index is summarized in the following formula:

$$I = 100 \times \frac{\sum_i F_{QAi} \times Q_i [kg]}{\sum_i Q_i [kg]},$$

where the Q_i is the quantity of recovered refrigerant in kg corresponding to a single stock item (cylinder with recovered refrigerant). The index takes values in the interval [0,100]. An index value which is lower than 100, means that not all of the quantity recovered so far has received a correct quality assessment.

2 Database design – Future developments

2.1 Key development

The **upgrade of prototype units with IoT functionalities** is regarded as the cornerstone of future developments with a direct impact on the database design. This is reasonable since the use of IoT devices is intended to automate and expand the collection of data on the recovery process to be sent to the existing database.

Overall, the uploaded IoT data is expected to include:

- A 1st unique identifier: this has been extracted during the scanning process of the QR code pre-printed and placed by the technician on the installed HVAC-R unit.
- A 2nd unique identifier: this has been extracted during the scanning process of the QR code pre-printed and placed by the technician on the recovery bottle(s)/cylinder(s).
- The collection date: this is the date that the extraction takes place.
- The Global Position system coordinates: these are the coordinates (Longitude and Latitude) of the location of the IoT device. A precision of eight numbers is used with a scale of six where:



- ✓ Precision is the number of digits in a number.
- ✓ Scale is the number of digits to the right of the decimal point in a number.

For example, the number 123.45 has a precision of 5 and a scale of 2.

- The temperature: This is the temperature of the F-gas as it is extracted from the unit using either infrared or Bluetooth technology.

Table 9 shows the full list of data fields in which IoT-based inputs will be stored:

Table 9: Structure of the "IoT data" table.

Characteristics		Required	Data type	Precision	Scale
<i>Installed HVAC-R unit</i>	<i>Id</i>	YES	<i>Unique Identifier</i>		
	<i>QR code id</i>	YES	<i>Character</i>	100	
<i>Recovery bottle(s)</i>	<i>Id</i>	YES	<i>Unique Identifier</i>		
	<i>QR code id</i>	YES	<i>Character</i>	100	
<i>Collection Date</i>		YES	<i>Date Time</i>	3	
<i>GPS Location (Longitude)</i>		YES	<i>Decimal</i>	10	8
<i>GPS Location (Latitude)</i>		YES	<i>Decimal</i>	10	8
<i>Temperature</i>		YES	<i>Decimal</i>	5	2

2.2 Other potential developments

The parts of the database that will undergo further developments can be listed as follows:

Currently, the database can store information of the available F-gas identification equipment, such as serial number and manufacturer. Considering the final implementation of the prototype unit, it is envisaged to **further develop the registration of the equipment to be used** not only for the F-gas composition analysis at the distributor site but also for the self-certification of the refrigerant quality at the export site (only self-declaration/self-assessment schemes are now applied). Therefore, the registration of information on the equipment will



be upgraded and the details of the analysis outcome from both the installer's and the distributor's side will be recorded. At the same time, it is also intended that the database will include information on all possible recycling processes.

Regarding the index of the installation company, **future developments include taking into account the company's experience in refrigerant recovery**. Another parameter to be evaluated is the **duration of the recovery process**. This could be calculated as the time between the first extraction of the refrigerant by the technician and the time it becomes available for sale on the Retradeables Marketplace.

Furthermore, **the calculation of the index value for more user categories is also under consideration**. This means that a separate index could be assigned to companies dealing with the recovery of refrigerants used in automotive air conditioning, since they would have access to the platform as sellers of mainly R134a. The same applies to distribution companies now acting as buyers of recovered/recycled F-gases from installers. For example, one of the parameters that could be related to the index value is the time interval between the collection of the refrigerant from the installer's site and the recording of the quality test results, which optionally can be performed at the distributor's site. After that, a fixed deal expiration date is automatically generated by the platform to define the maximum allowable time limit for the completion of any procedures after the acceptance of an offer (bid) by the seller.

Finally, it is planned to **make the database accessible to users from installation and distribution companies, as well as local administrations**. This will be done in an indirect way through reports and dashboards of users' activities within the platform. Specific users from local administrations can be authorised to extract information on the purpose of the integration into local databases.

3 Conclusions

In conclusion, a well-structured database is already in use, covering all 3 demo countries (SK, HU, CZ) of the project and storing all the necessary information derived either from the direct input of local users or from their interaction with the marketplace platform. However, the Self-certification platform does not act as a standalone tool, but is actually integrated into the Retradeables marketplace. It is the final implementation of F-gas identification and recycling IOT equipment that will practically determine whether a possible functional separation of the Self-certification platform from the marketplace platform, under an overlapping scheme of one with the other, will further improve the usability levels of the 3R ECOSYSTEM.

Depending on whether and what kind of adaptations will be realized by the project partners, this deliverable will be updated accordingly, if necessary. What can be taken for granted is that the database will be upgraded in the future with tables that will record more accurate and complete information on all the self-certification and recycling/reclamation processes



taking place, thus enhancing the traceability of all quantities at all stages from recovery to reuse of the used refrigerant. Meanwhile, the IOT equipment is expected to contribute to the automatic uploading of data on the F-gas recovery process, including location, date, installed HVAC-R unit and recovery bottle(s), as well as recording the measured temperature of the extracted refrigerant.