Project acronym:	**GeoSmart**		
Project title:	Technologies for geothermal to enhance competitiveness in smart and flexible operation		
Activity:	LC-SC3-RES-12-2018		
Call:	H2020-LC-SC3-2018-RES-SingleStage		
Funding Scheme:	IA	**Grant Agreement No:**	818576
WP 5	**GeoSmart Simulator and Decision Support System**		

D5.5 – Development of Knowledge-Based System (KBS) database.

Due date:	M40	
Actual Submission Date:	29/03/2024 (M58)	
Lead Beneficiary:	TVS	
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Dissemination Level[1]:	PU	
Nature:	REPORT	
Status of this version:		**Draft under Development**
		For Review by Coordinator
	X	**Submitted**
Version:	1.0	
Abstract	This report describes how the knowledge base system (KBS) database is built and populated to represent, store, and manage all the experimental and research data generated in WP2, WP3, and WP4.	

REVISION HISTORY

Version	Date	Main Authors/Contributors	Description of changes

[1] Dissemination level security:

PU – Public (e.g. on website, for publication etc.) / **PP** – Restricted to other programme participants (incl. Commission services) / **RE** – Restricted to a group specified by the consortium (incl. Commission services) / **CO** – confidential, only for members of the consortium (incl. Commission services)

This project has received funding from the European Union's Horizon 2020 program Grant Agreement No 818576. This publication reflects the views only of the author(s), and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Executive Summary

This report describes how the knowledge base system (KBS) database is built and populated to represent, store, and manage all the experimental and research data generated in WP2, WP3, and WP4. First, the KBS database design process identified all possible entities relevant to experiments and analysis performed in the GeoSmart project and extracted properties of and relationships between these entities. Next, the entities, properties, and relationships are converted to database tables, attributes, and relational tables. State-of-the-art open-source database technologies such as Postgres [1] and Parse Platform [2] are used to develop the KBS database. Following the execution of the development process, data and experimental results received from project partners are populated into the database. The report also describes the web-based data management panel, class documentation, and application programming interface (API). In Task 5.7, the knowledge-based system (KBS) and decision support system (DSS) with graphical user interfaces (GUI) will use this KBS database as a knowledge base.

Objectives Met

Develop the GeoSmart system simulator suite which combines flow assurance simulator, knowledge based engineering, and decision support systems, to provide robust options for future design capability across diverse European geothermal sites, investment decision making and policy analysis.

CONTENTS

1. INTRODUCTION

In task 5.5, a relational database is designed, developed, and deployed on the web. The database is populated with experimental and research data generated in WP2, WP3, and WP4.

Concrete details about the database components and tables relevant for representing data and establishing relationships between data elements are extracted by analysing the following reports from WP2, WP3, and WP4:

D2.1 Correct material choices documented for Demo sites (submitted)
D2.2 Energy storage system design schematics (submitted)
D2.3 Heat exchanger design trial report (submitted)
D2.5 Insheim system designed (submitted)
D2.6 Zorlu system designed (submitted)
D2.7 Final material choices documented for demo sites (submitted)
D3.1 ORC Model ready for off-design performance estimation with constraints (submitted)
D3.2 Control system software built (submitted)
D3.3 Groundwater system installed and tested (submitted)
D3.7 ORC Model ready for off-design performance estimation with constraints 2 (submitted)
D4.1 Modelling of silica scaling potential (submitted)
D4.2 Report on the formulation of inhibitor against silica scaling (submitted)
D4.3 Report on the preliminary design of HX, including materials compatibility investigation (submitted)
D4.4 Report on optimisation of the design of HX (submitted)
D4.5 Report on design and building of retention tank (submitted)
D4.6 Heat-exchanger produced (submitted)
D4.7 Retention Tank Produced (submitted)

These reports described the design specifications of three types of thermal energy storage (TES) systems: a scaling reduction system comprising a scaling heat exchanger, a scaling reactor and retention tank, and an adiabatic cooling system.

The experimental results' design specifications, parameters, and relationships between thermal energy storage (TES) systems, the scaling reduction system, and the adiabatic cooling system have been identified, analysed, and extracted for designing the database tables and properties. Also, primary cost data and life cycle assessment (LCA) models are identified, analysed, and extracted to create the database for GeoSmart components. Finally, the database is populated with data published in the reports through a data management tool developed as part of the database design. The rest of this report is structured as follows:

- Section 2 overviews the database design process and its outcome as the entity relationship diagram.
- Section 3 describes the database development process using the Postgres [1] and Parse Server [2] technologies.
- Section 4 shows the database population techniques using data management tools and RESTful application programming interfaces (APIs) [3].
- Section 5 provides the overall conclusions.

2. KBS DATABASE DESIGN

2.1 Overview

The Knowledge Base System (KBS) database is a relational database designed to extract all the entities and their properties and relations. The extracted entities are:

- Thermal Energy Storage (TES) Systems
  - PCM (brine) storage system
  - Steam accumulator
  - Water thermocline
- Separator
  - New IP separator
- Scaling reduction system
  - Scaling Heat Exchanger
  - Scaling reactor
  - Retention tank
- Adiabatic Cooling System
- Basic cost data and parameters
- Life Cycle Inventory (LCI) data and parameters

2.2 Entity Relationship Diagram

The entity-relationship (ER) diagram is a high-level visual representation of a database system. It is often an initial step to model a particular database. ER diagrams help to define entities, attributes, and relationships. ER diagrams have been modelled for each extracted entity mentioned in section 2.1.

An example of an ER diagram of the PCM storage system table is depicted in the Figure 0.1. The PCM storage system table represents, stores, and manages data and metadata about the PCM storage system used in the GeoSmart project. The PCM storage system table has many properties reflected in the ER diagram used in the GeoSmart project. ER diagrams of other entities or tables are provided in Appendix A.

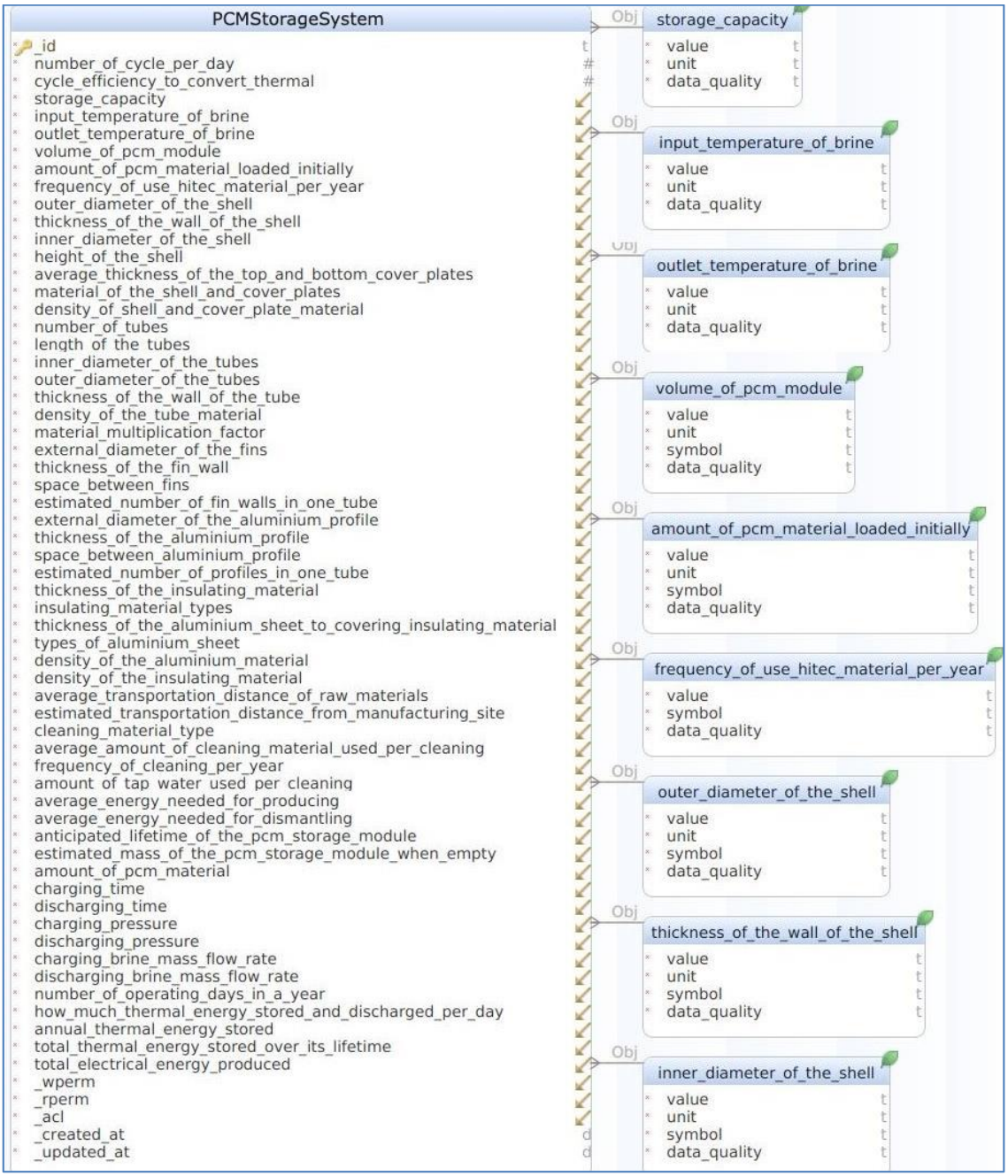


Figure 0.1 ER diagram of PCM storage system entity

3. KBS DATABASE DEVELOPMENT

The relational database implementation is completed using Postgres, an open-source database suitable for managing a large volume of data. It also uses Parse Server, which enables the design and development of database tables in Postgres. While developing database tables on Parse Server, each table is treated as a class and the table's attributes as the class's attributes. The codes to create the tables in Postgres via the Parse Server API were written in Ruby. A database management system has also been developed to manage data from user-friendly graphical interfaces.

Figure 3.1 shows a concrete example of the class, which corresponds to the relational database table PCM storage system. The figure depicts that the PCM storage system is a class that inherits the attributes from the

class Parse Object. This figure provides an example to show how to instantiate the PCM storage system class using Ruby. Another example, PCM_storage_system.save, illustrates how to save the already created instance of the PCM storage system.

Figure 0.1 also demonstrates that the class definition of a PCM storage system consists of various attributes, such as the amount of tap water used per cleaning, annual thermal energy stored, amount of PCM material, average amount of cleaning material, input temperature of brine, and outlet temperature of brine. A list of classes and their definitions is provided in Appendix B.

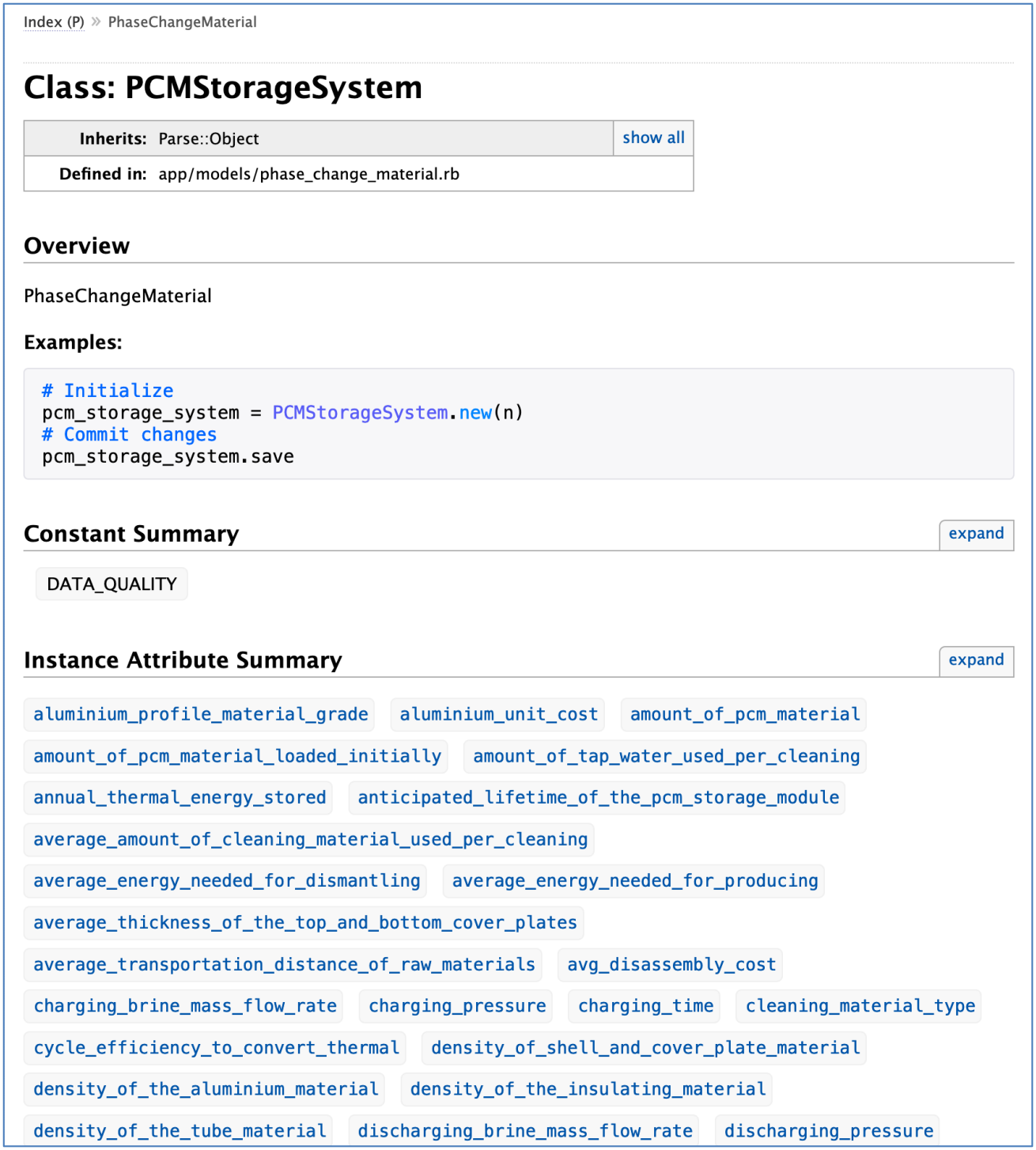


Figure 0.1 The PCM storage system class documentation (a partial view).

4. KBS DATABASE POPULATION

4.1 Overview

Data about thermal energy storage (TES) systems, scaling reduction systems, New IP separator, and adiabatic cooling systems from the experimental results into the database was populated in two ways: automatic and manual. For the automatic data population, easy-to-use RESTful Application Programming Interfaces (APIs) were developed. For adding data manually, a data management tool with an intuitive user interface was built.

4.2 RESTful APIs

A group of RESTful Application Programming Interfaces (APIs) or RESTful web services is developed to programmatically upload data to the relational database. These facilitate importing data from a comma-separated value (CSV), tab-separated value (TSV), or excel file.

The GET command is implemented to read information about the schema of the relational database. A database schema consists of all the tables and relationships between them. As shown in Figure 0.1, Figure 0.2, and Figure 0.3, the GET and POST commands are implemented for each table.

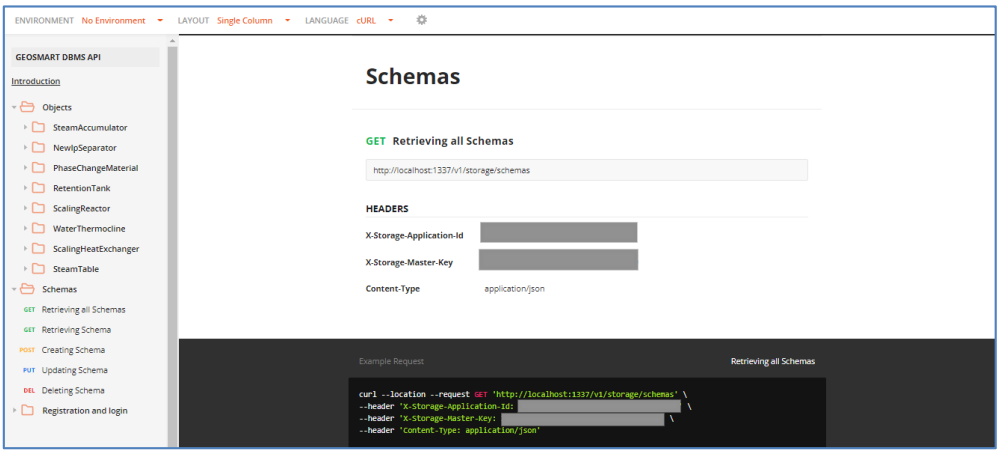


Figure 0.1 RESTful Web Services for the database schema and tables.

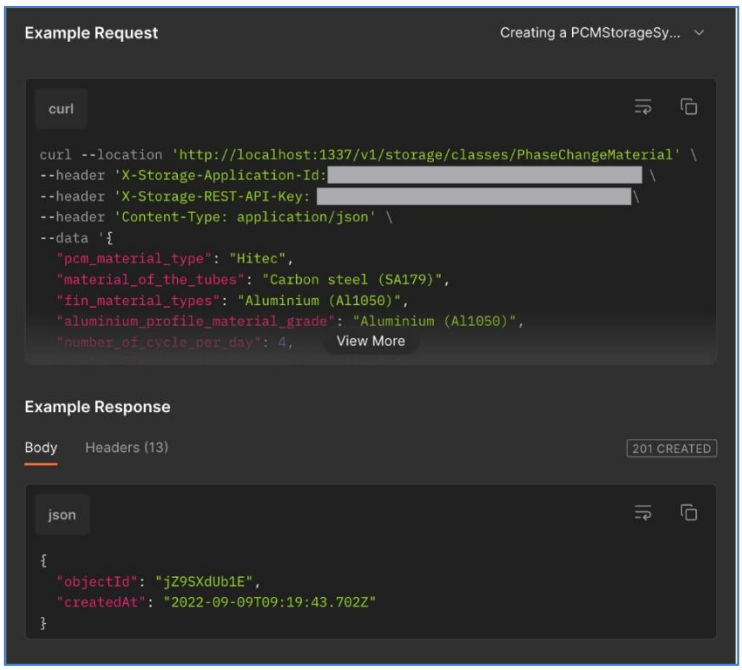


Figure 0.2 A sample GET request to read all the PCM storage system from the GeoSmart relational database.

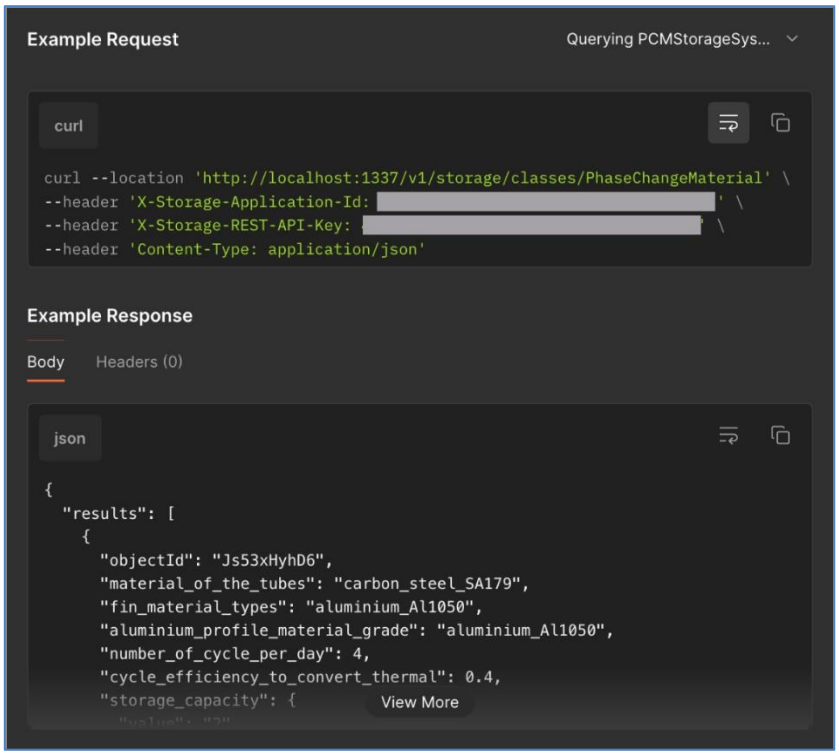


Figure 0.3 A sample POST request to create a PCM storage system in the GeoSmart relational database.

4.3 Data management tool

A web-based data management tool is created to allow users to populate information about one entity at a time into the relational database. The tool supports the read, update and delete operations along with the data population. As shown in Figure 0.4, the user interface of the tool is designed using a dashboard layout for ease

of management of data. Under the utility tab, data about system users and steam tables can be viewed, added, updated, and deleted. Figure 0.5 demonstrates a part of steam tables data from the GeoSmart database.

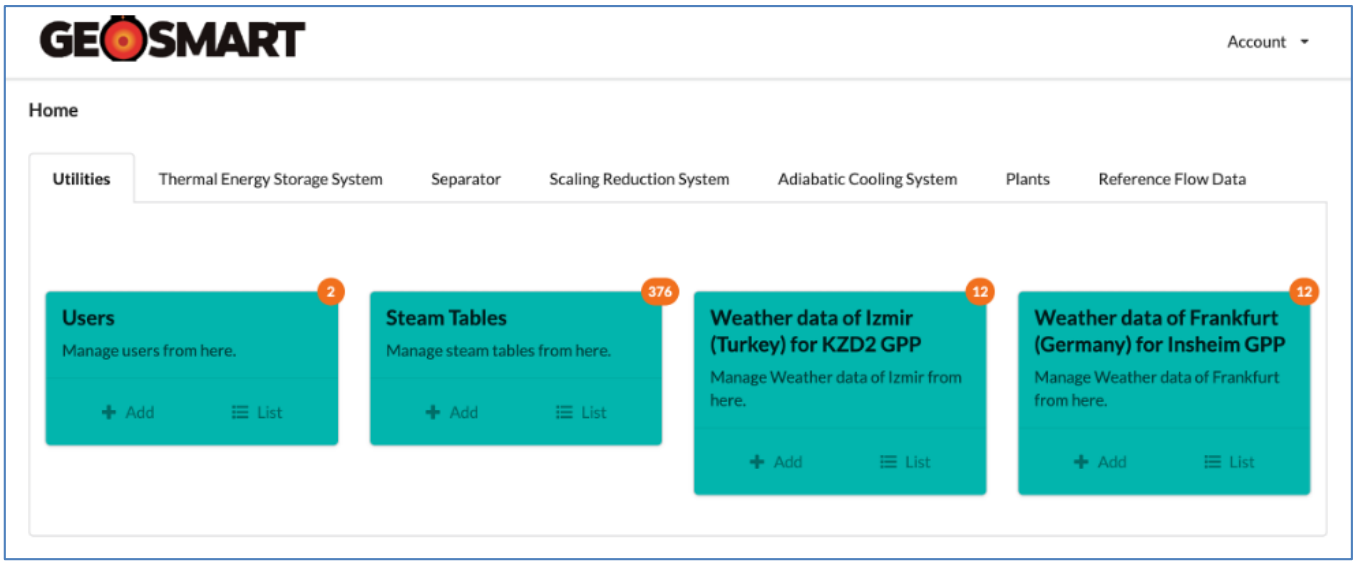
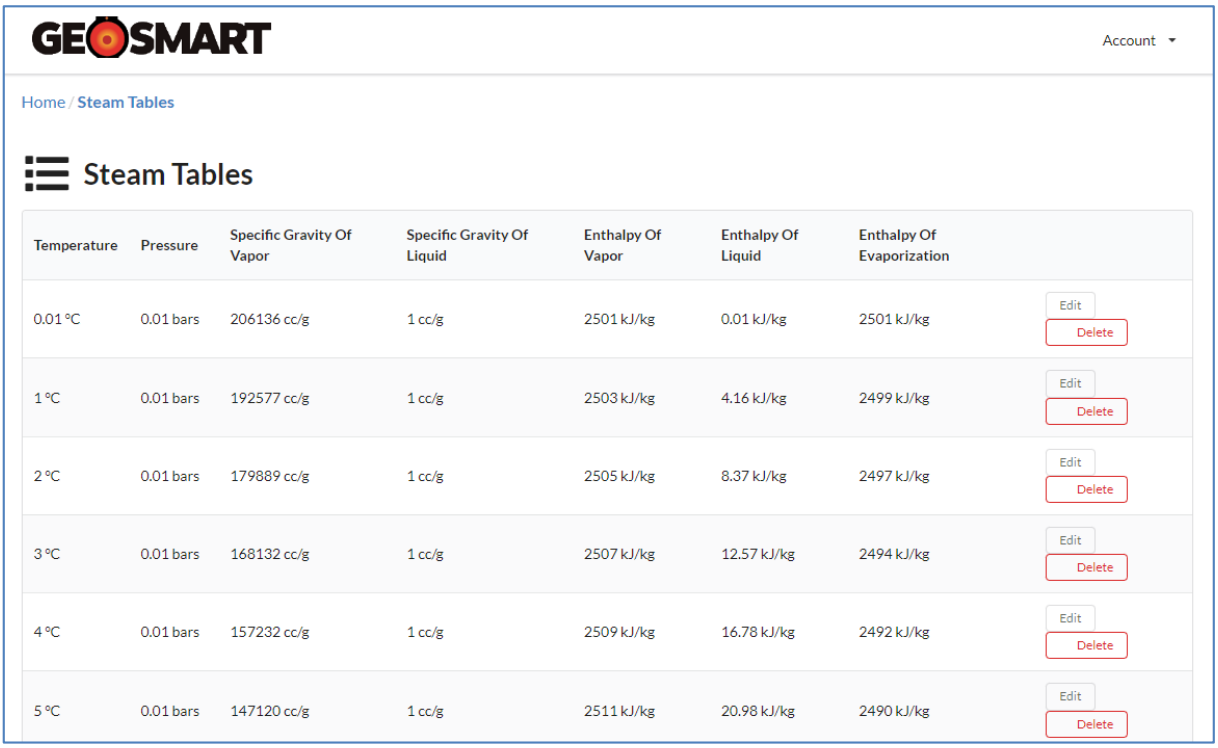


Figure 0.4 Homepage of the GeoSmart database management tool.



Temperature	Pressure	Specific Gravity Of Vapor	Specific Gravity Of Liquid	Enthalpy Of Vapor	Enthalpy Of Liquid	Enthalpy Of Evaporization	
0.01 °C	0.01 bars	206136 cc/g	1 cc/g	2501 kJ/kg	0.01 kJ/kg	2501 kJ/kg	Edit Delete
1 °C	0.01 bars	192577 cc/g	1 cc/g	2503 kJ/kg	4.16 kJ/kg	2499 kJ/kg	Edit Delete
2 °C	0.01 bars	179889 cc/g	1 cc/g	2505 kJ/kg	8.37 kJ/kg	2497 kJ/kg	Edit Delete
3 °C	0.01 bars	168132 cc/g	1 cc/g	2507 kJ/kg	12.57 kJ/kg	2494 kJ/kg	Edit Delete
4 °C	0.01 bars	157232 cc/g	1 cc/g	2509 kJ/kg	16.78 kJ/kg	2492 kJ/kg	Edit Delete
5 °C	0.01 bars	147120 cc/g	1 cc/g	2511 kJ/kg	20.98 kJ/kg	2490 kJ/kg	Edit Delete

Figure 0.5 List showing a part of steam tables from the GeoSmart database.

Figure 0.6 demonstrates the GeoSmart thermal energy storage system data management component that supports the data management of steam accumulator, PCM storage, and water thermocline.

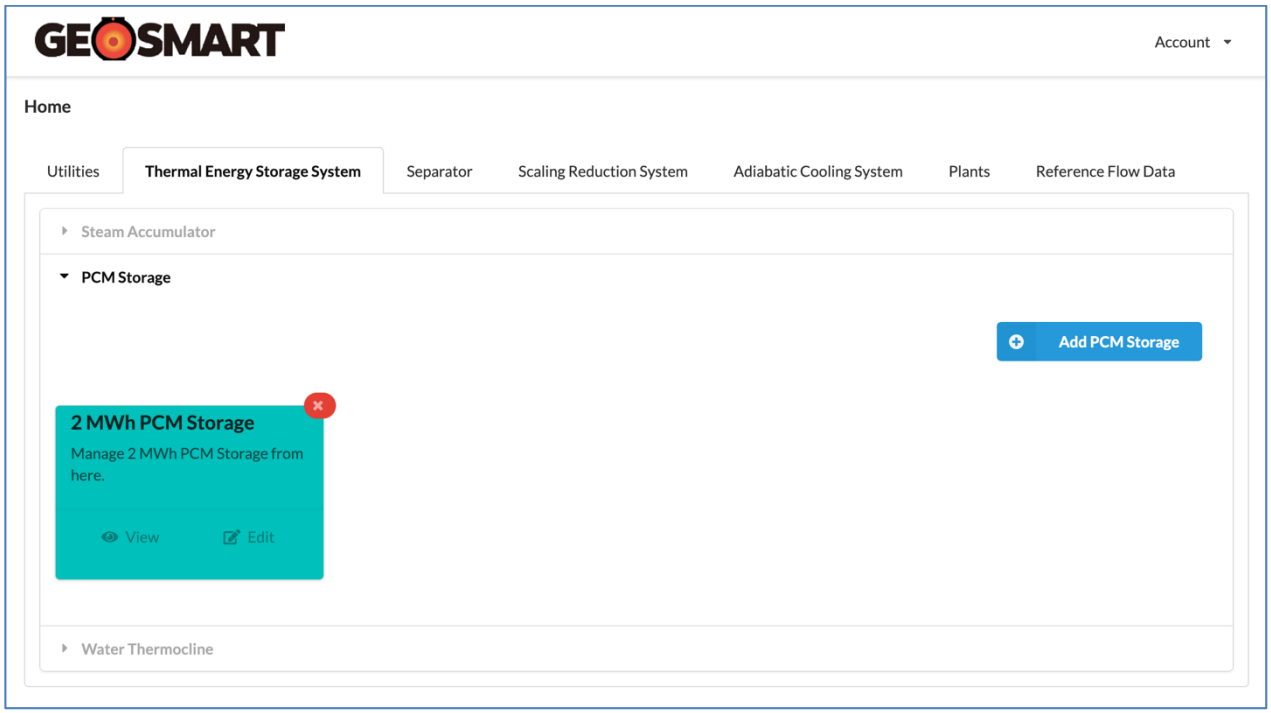
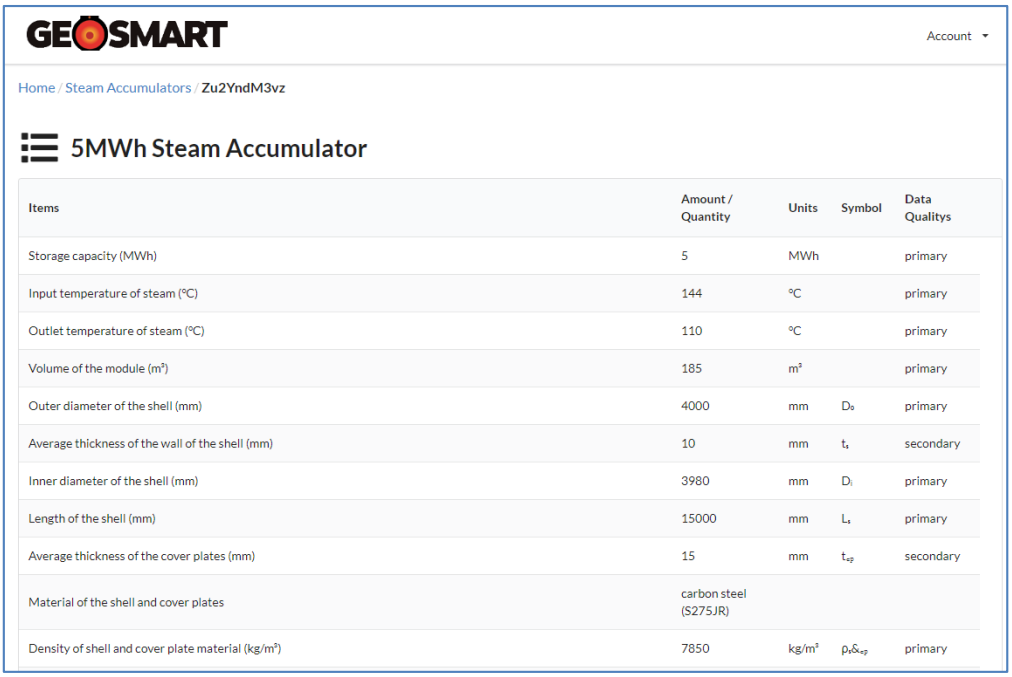


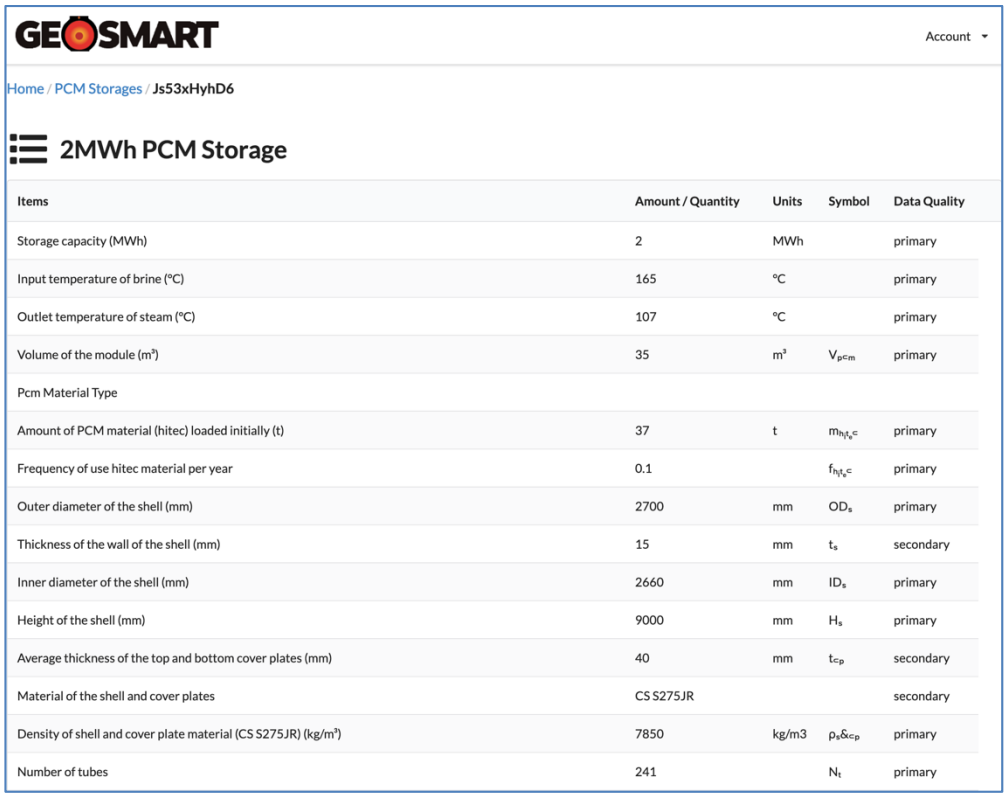
Figure 0.6 The GeoSmart data management component for the thermal energy storage system

Figure 0.7, Figure 0.8, and Figure 0.9 show various populated data of steam accumulator, PCM storage, and water thermocline developed for the GeoSmart project.



Items	Amount / Quantity	Units	Symbol	Data Qualitys
Storage capacity (MWh)	5	MWh		primary
Input temperature of steam (°C)	144	°C		primary
Outlet temperature of steam (°C)	110	°C		primary
Volume of the module (m^3)	185	m^3		primary
Outer diameter of the shell (mm)	4000	mm	D_o	primary
Average thickness of the wall of the shell (mm)	10	mm	t_s	secondary
Inner diameter of the shell (mm)	3980	mm	D_i	primary
Length of the shell (mm)	15000	mm	L_s	primary
Average thickness of the cover plates (mm)	15	mm	t_{cp}	secondary
Material of the shell and cover plates	carbon steel (S275JR)			
Density of shell and cover plate material (kg/m^3)	7850	kg/m^3	$\rho_s \delta_{cp}$	primary

Figure 0.7 Example data of steam accumulator (5MWh)



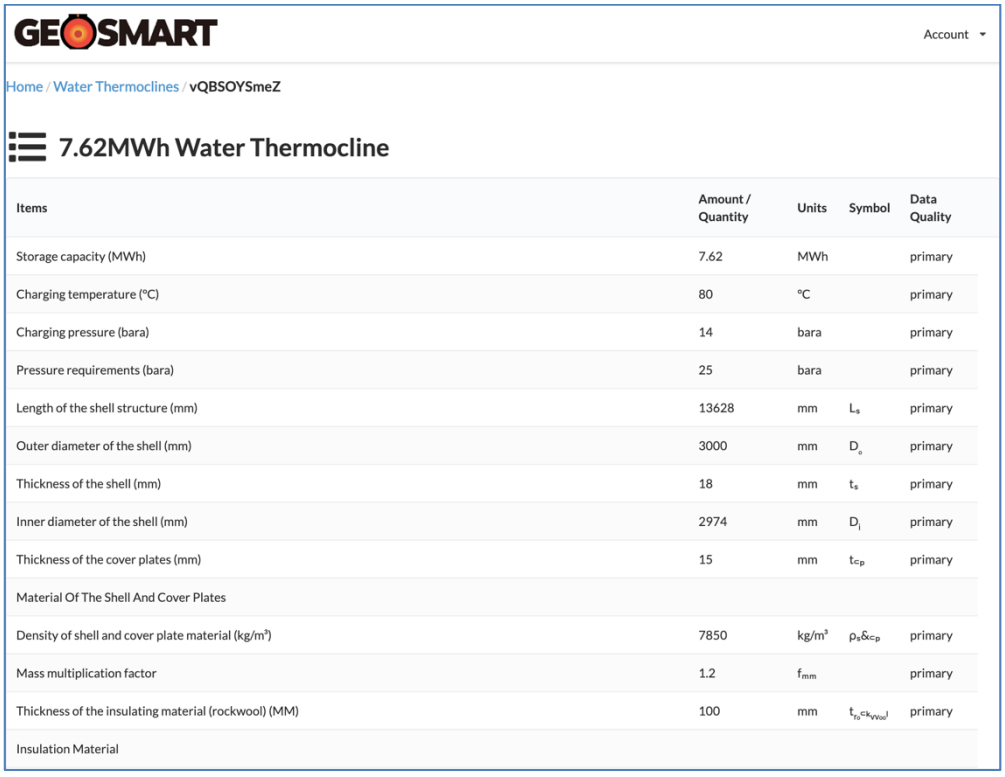
GEOSMART Account

Home / PCM Storages / Js53xHyhD6

2MWh PCM Storage

Items	Amount / Quantity	Units	Symbol	Data Quality
Storage capacity (MWh)	2	MWh		primary
Input temperature of brine (°C)	165	°C		primary
Outlet temperature of steam (°C)	107	°C		primary
Volume of the module (m^3)	35	m^3	V_{pcm}	primary
Pcm Material Type				
Amount of PCM material (hitec) loaded initially (t)	37	t	m_{hitec}	primary
Frequency of use hitec material per year	0.1		f_{hitec}	primary
Outer diameter of the shell (mm)	2700	mm	OD_s	primary
Thickness of the wall of the shell (mm)	15	mm	t_s	secondary
Inner diameter of the shell (mm)	2660	mm	ID_s	primary
Height of the shell (mm)	9000	mm	H_s	primary
Average thickness of the top and bottom cover plates (mm)	40	mm	t_{cp}	secondary
Material of the shell and cover plates	CS S275JR			secondary
Density of shell and cover plate material (CS S275JR) (kg/m^3)	7850	kg/m3	ρ_s&$_{cp}$	primary
Number of tubes	241		N_t	primary

Figure 0.8 Example data of PCM storage (2MWh)



GEOSMART Account

Home / Water Thermoclines / vQBSOYSmeZ

7.62MWh Water Thermocline

Items	Amount / Quantity	Units	Symbol	Data Quality
Storage capacity (MWh)	7.62	MWh		primary
Charging temperature (°C)	80	°C		primary
Charging pressure (bara)	14	bara		primary
Pressure requirements (bara)	25	bara		primary
Length of the shell structure (mm)	13628	mm	L_s	primary
Outer diameter of the shell (mm)	3000	mm	D_o	primary
Thickness of the shell (mm)	18	mm	t_s	primary
Inner diameter of the shell (mm)	2974	mm	D_i	primary
Thickness of the cover plates (mm)	15	mm	t_{cp}	primary
Material Of The Shell And Cover Plates				
Density of shell and cover plate material (kg/m^3)	7850	kg/m^3	ρ_s&$_{cp}$	primary
Mass multiplication factor	1.2	f_{mm}		primary
Thickness of the insulating material (rockwool) (MM)	100	mm	t_{ins}	primary
Insulation Material				

Figure 0.9 Example data of water thermocline (7.62MWh)

An example of data creation of a PCM storage system is depicted in Figure 0.10. Database administrators and partners involved in the GeoSmart project can use data creation forms to populate data for thermal energy storage (TES) systems, scaling reduction systems, new IP separator, and adiabatic cooling system.

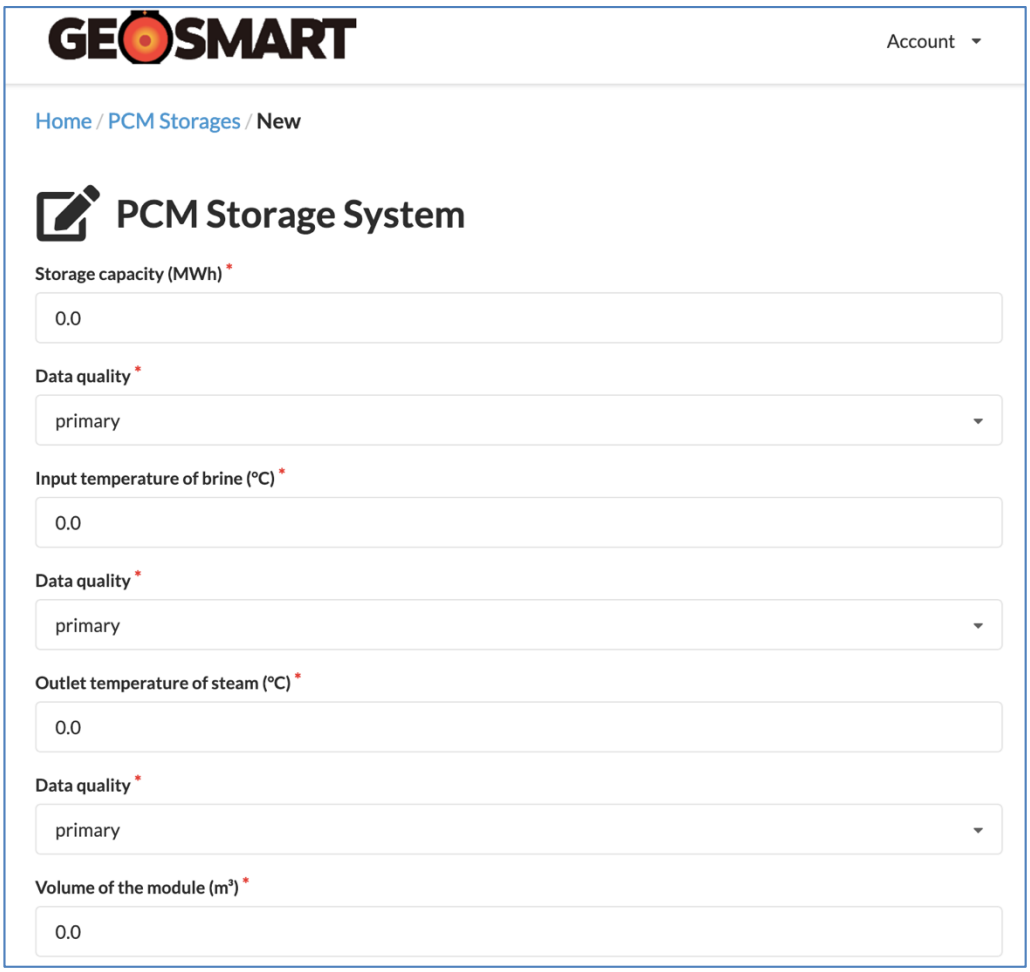


Figure 0.10 Example data entry of PCM storage system

Figure 0.11 demonstrates the GeoSmart separator data management component, where data of the new IP separator can be managed. Example data of 3.04m³ New IP Separator is depicted in Figure 0.12.

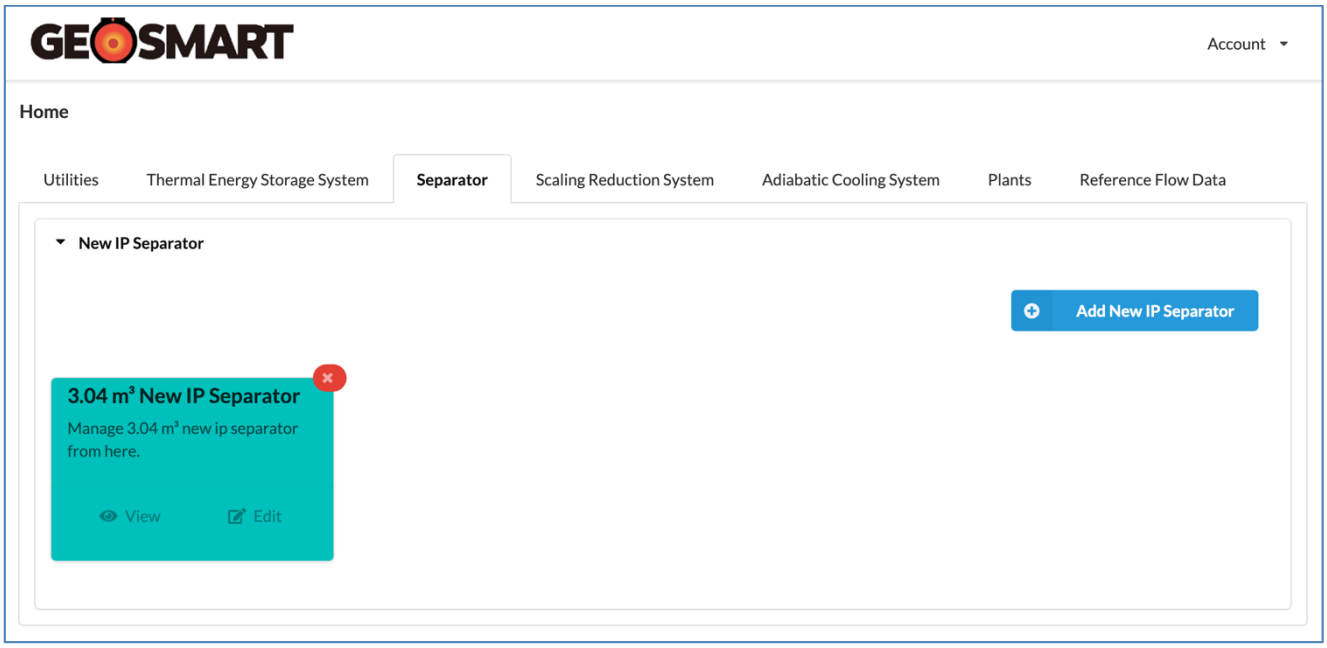
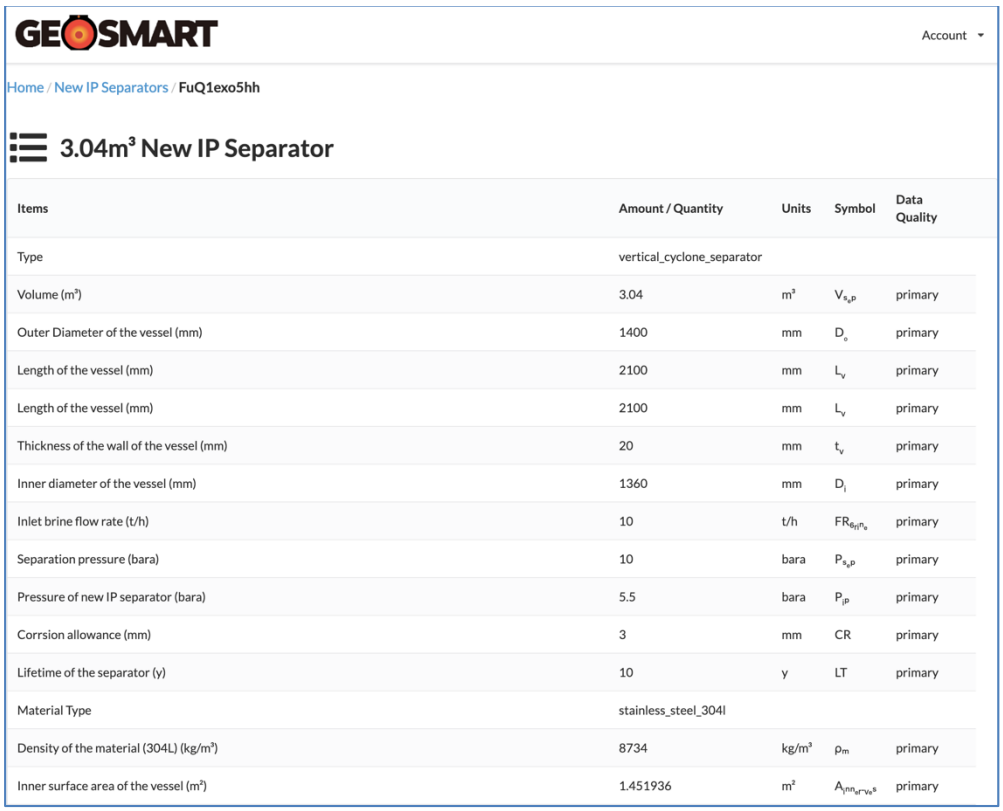


Figure 0.11 The GeoSmart data management component for separator



Items	Amount / Quantity	Units	Symbol	Data Quality
Type	vertical_cyclone_separator			
Volume (m^3)	3.04	m^3	$V_{s,p}$	primary
Outer Diameter of the vessel (mm)	1400	mm	D_o	primary
Length of the vessel (mm)	2100	mm	L_v	primary
Length of the vessel (mm)	2100	mm	L_v	primary
Thickness of the wall of the vessel (mm)	20	mm	t_v	primary
Inner diameter of the vessel (mm)	1360	mm	D_i	primary
Inlet brine flow rate (t/h)	10	t/h	FR_{in}	primary
Separation pressure (bara)	10	bara	$P_{s,p}$	primary
Pressure of new IP separator (bara)	5.5	bara	P_{ip}	primary
Corrsion allowance (mm)	3	mm	CR	primary
Lifetime of the separator (y)	10	y	LT	primary
Material Type	stainless_steel_304l			
Density of the material (304L) (kg/m^3)	8734	kg/m^3	ρ_m	primary
Inner surface area of the vessel (m^2)	1.451936	m^2	$A_{inner-vessel}$	primary

Figure 0.12 Example data of new IP separator ($3.04m^3$)

Other data management components, such as scaling reduction systems, and adiabatic cooling systems, have been listed in

Appendix D.

5. CONCLUSIONS

The relational database design, development, and population are based on the data published in WP2, WP3, and WP4 project deliverables. Clarifications about the data are sought from the partners as often as needed during the database design and population tasks. The database design has been updated with the updated data available from the partners. The crucial web links related to this deliverable are provided below:

- The GeoSmart Database Management Tool: http://138.68.144.219:3000/login (for consortium members to manage data).
- The RESTful APIs of the database: RESTful APIs. The complete list of RESTful APIs is provided in Appendix C

REFERENCES

[1] "PostgreSQL: The World's Most Advanced Open Source Relational Database," [Online]. Available: https://www.postgresql.org/. [Accessed 12 August 2022].

[2] "Parse Platform," [Online]. Available: https://parseplatform.org/. [Accessed 12 August 2022].

[3] "What is a REST API?" [Online]. Available: https://www.redhat.com/en/topics/api/what-is-a-rest-api. [Accessed 20 July 2022].

Appendix A

ER diagrams

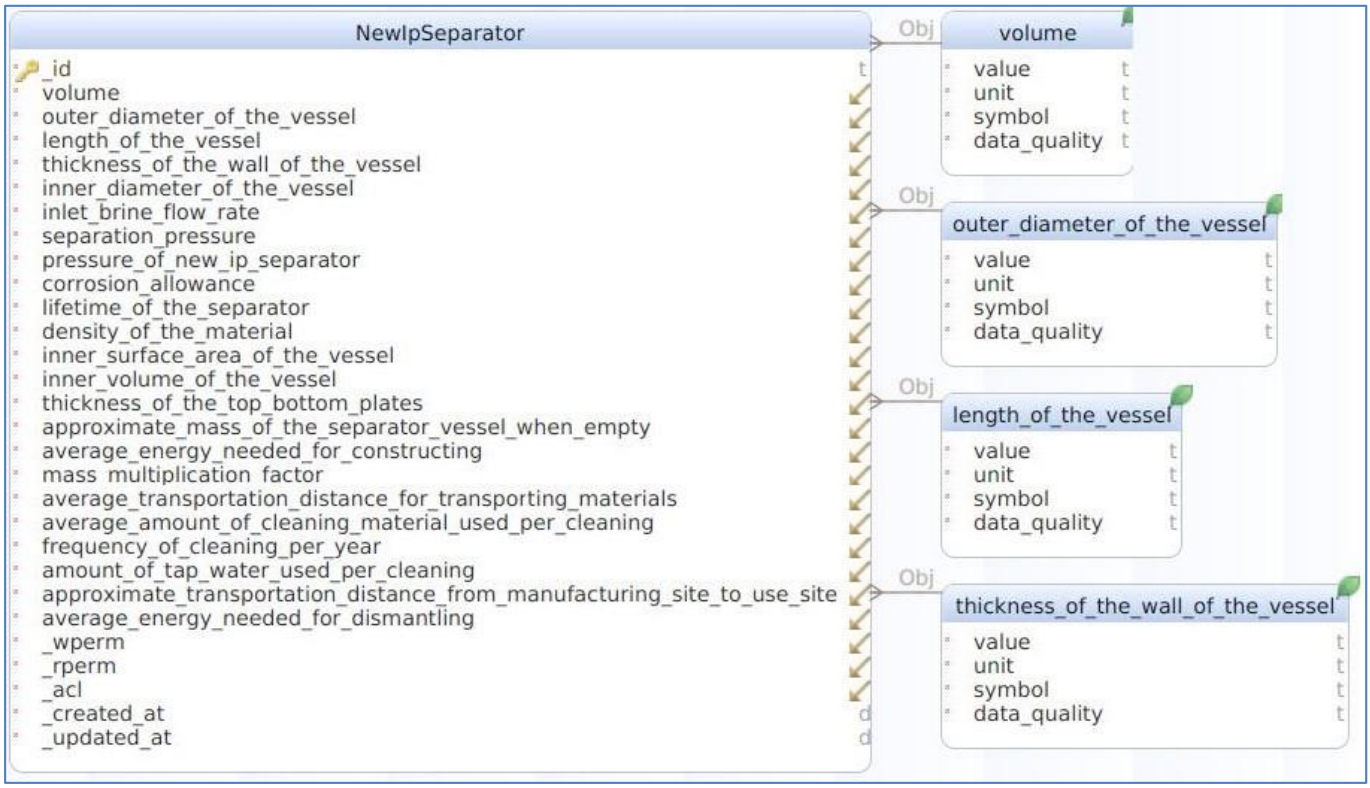


Figure A1 ER diagram of new IP separator table

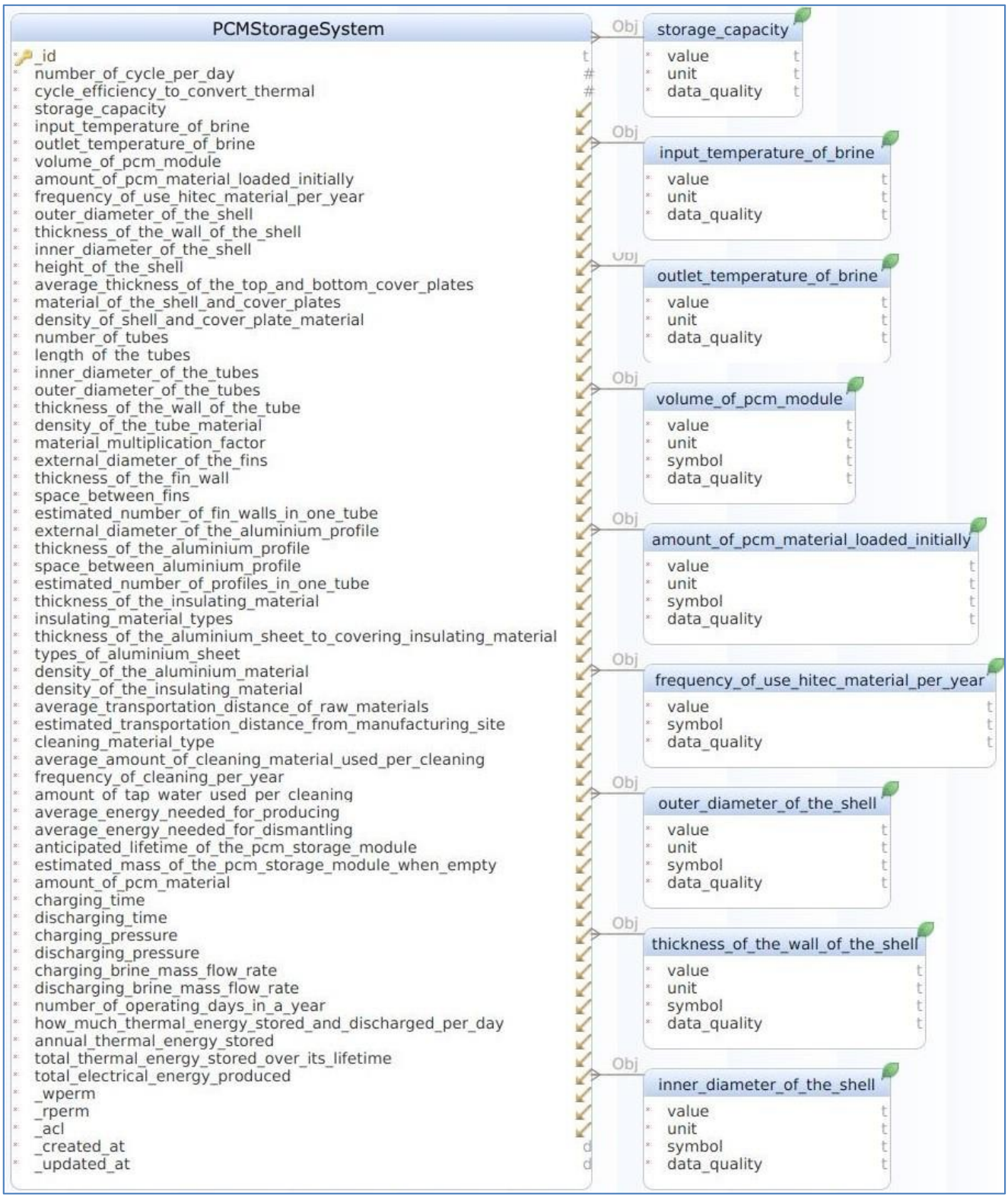


Figure A2 ER diagram of PCM storage system table

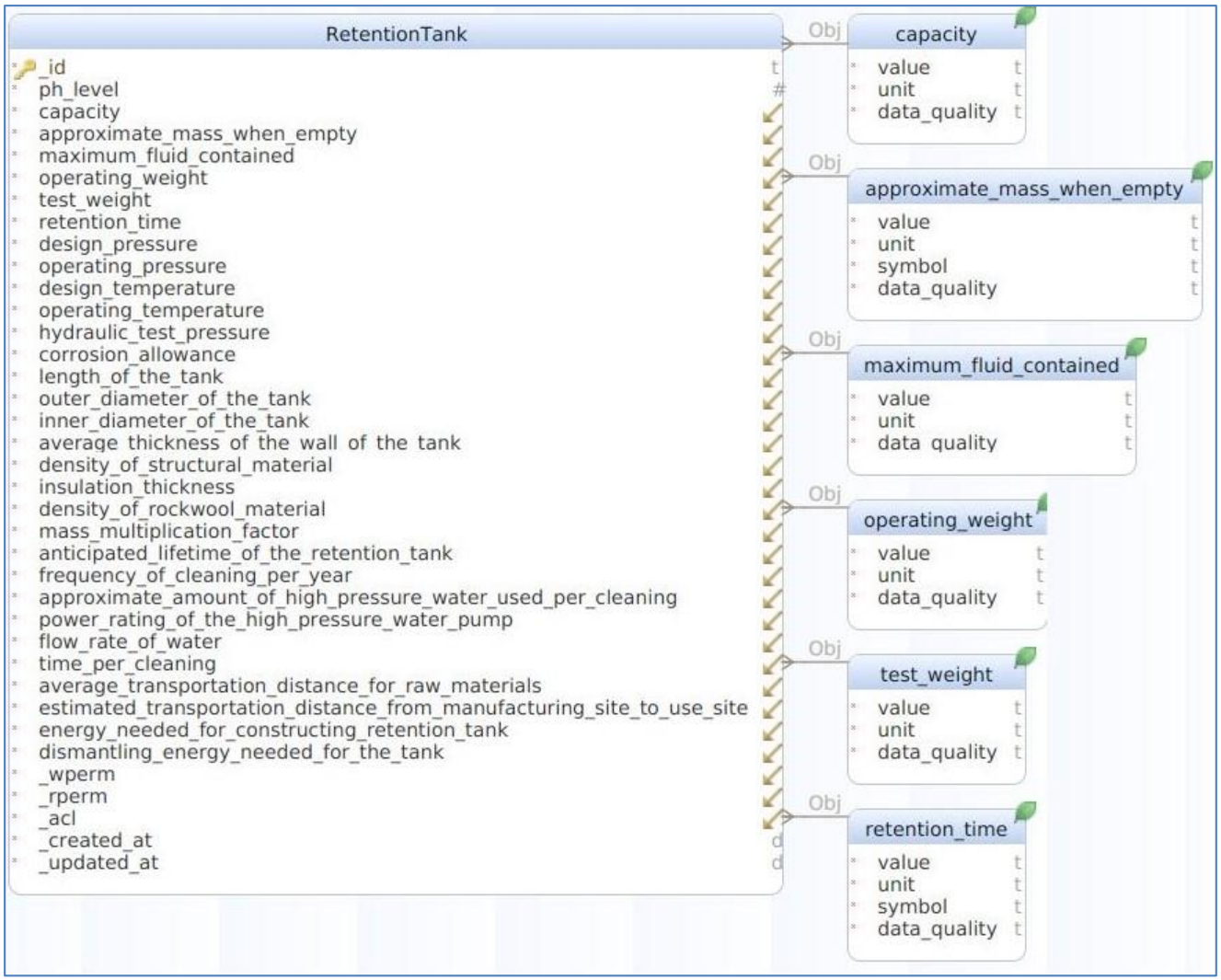


Figure A3 ER diagram of retention tank table

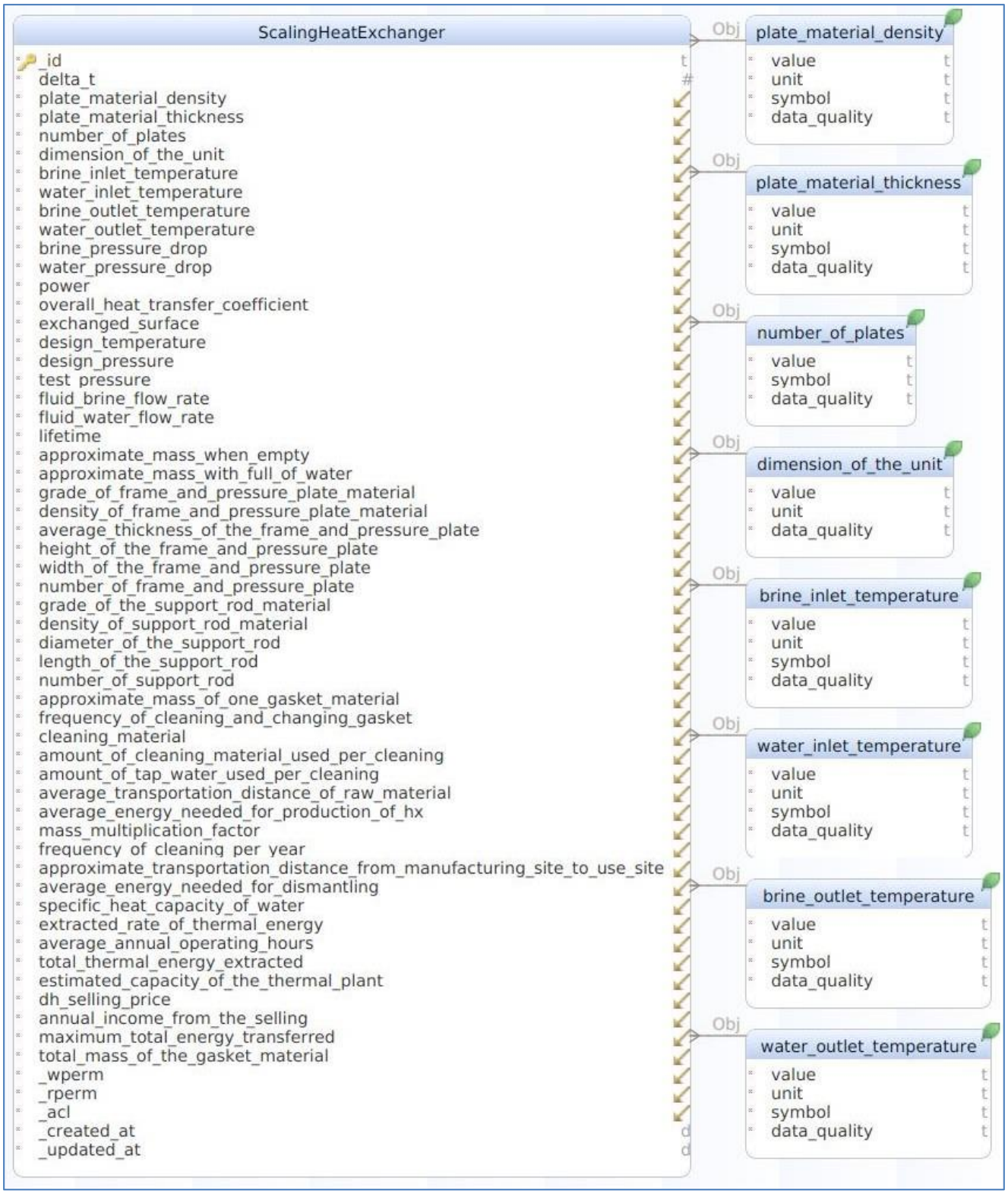


Figure A4 ER diagram of scaling heat exchanger table

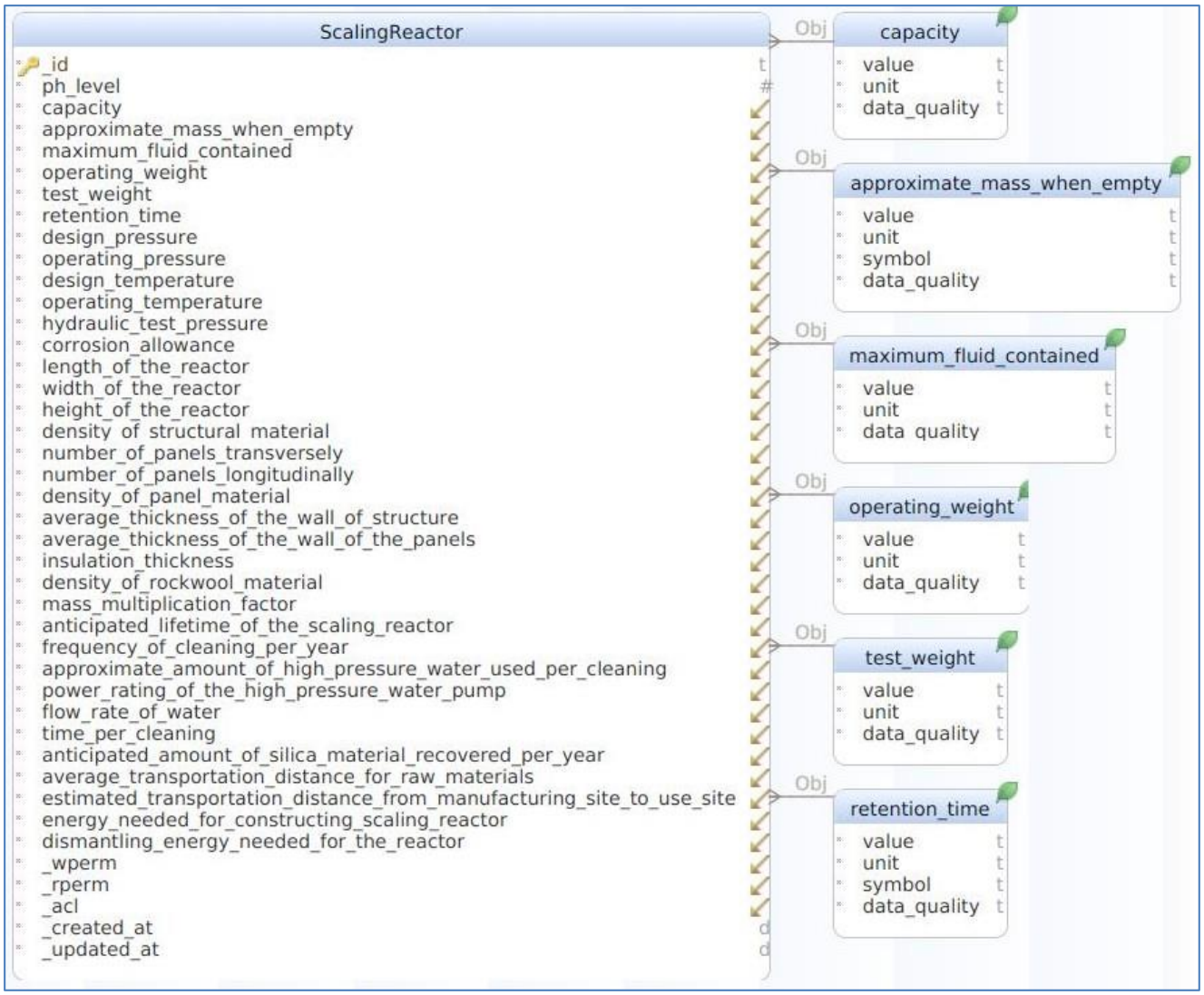


Figure A5 ER diagram of scaling reactor table

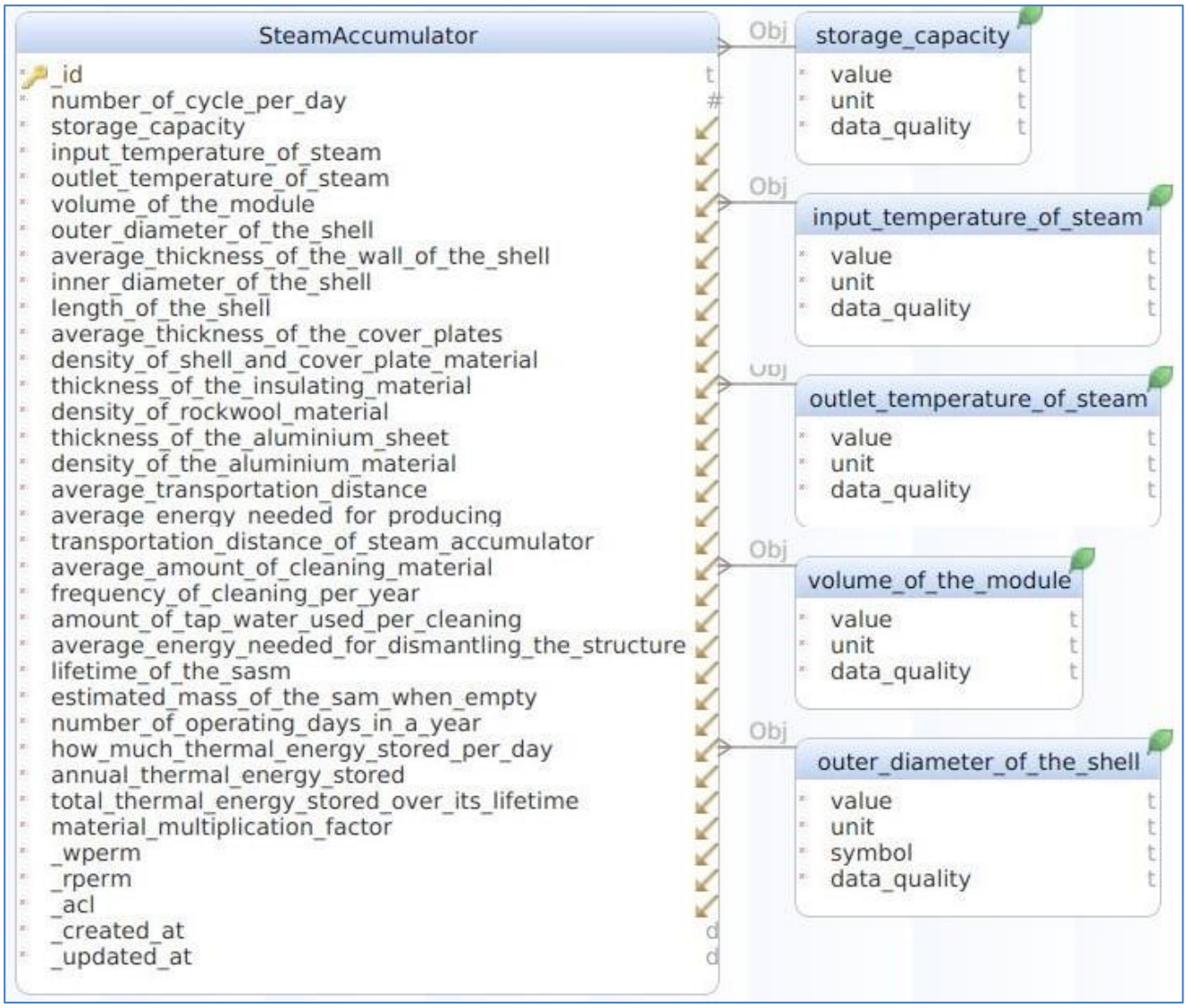


Figure A6 ER diagram of steam accumulator table

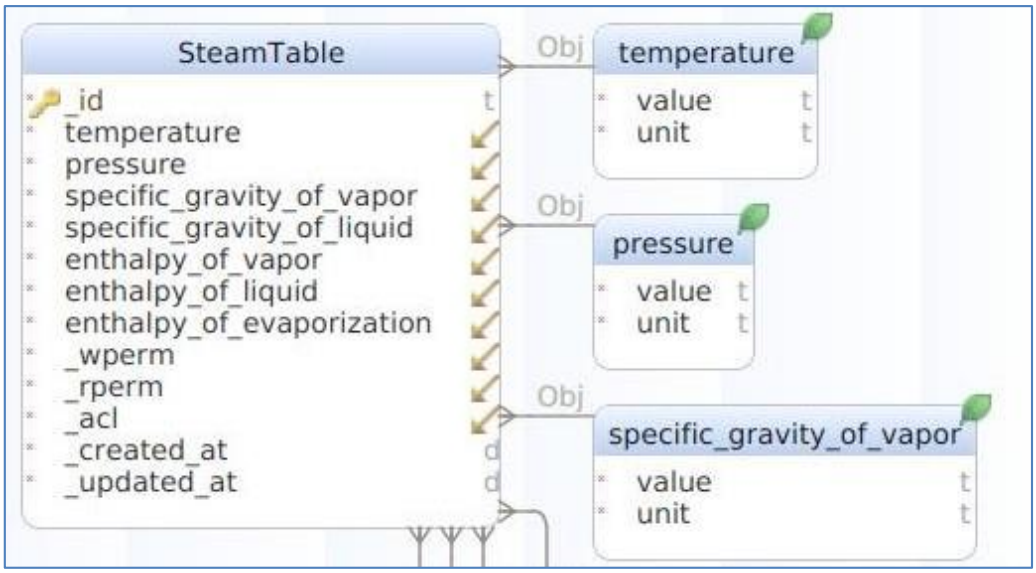


Figure A7 ER diagram of steam table

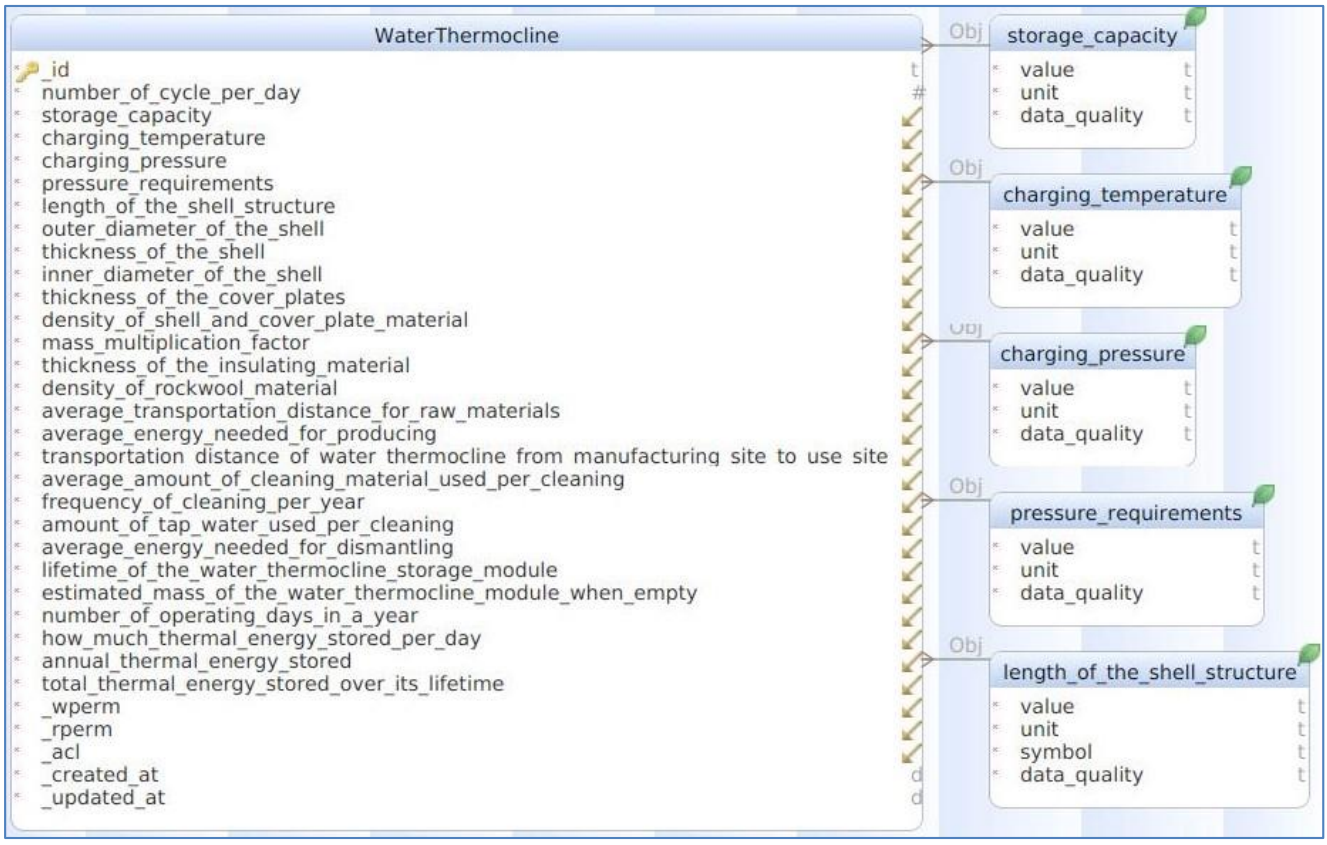


Figure A8 ER diagram of water thermocline table

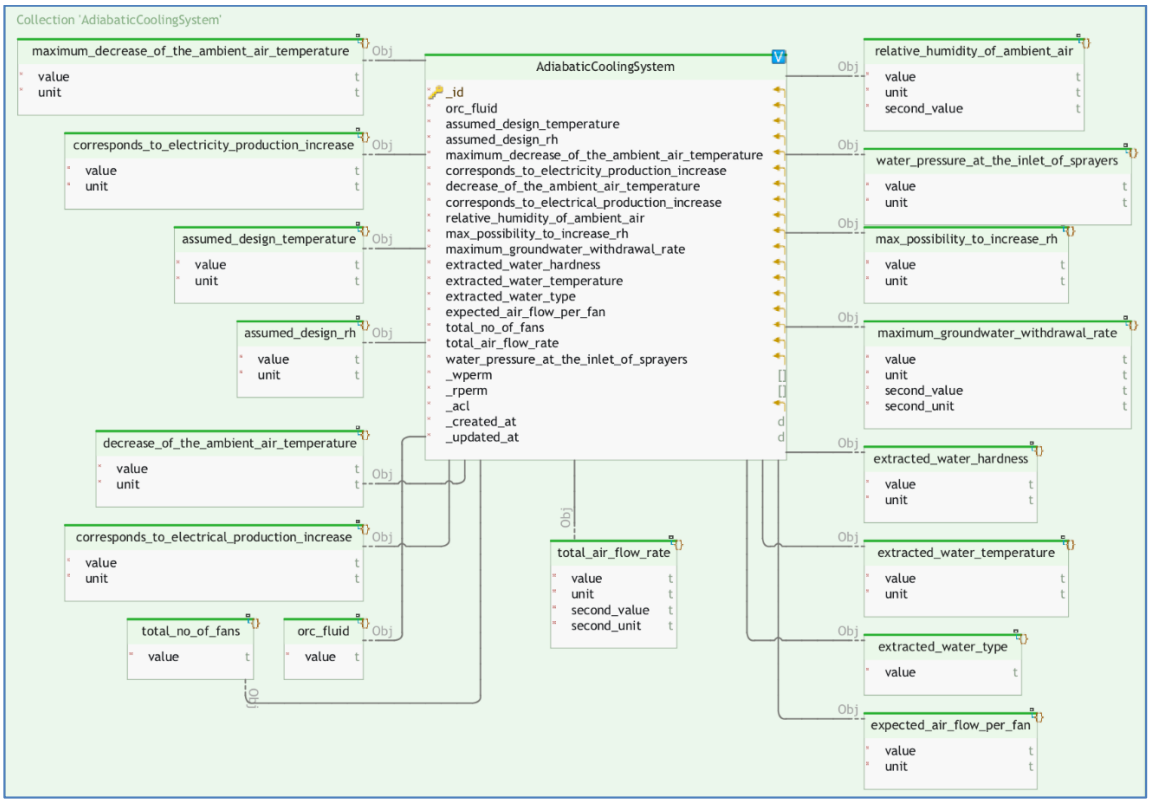


Figure A9 ER diagram of adiabatic cooling system table

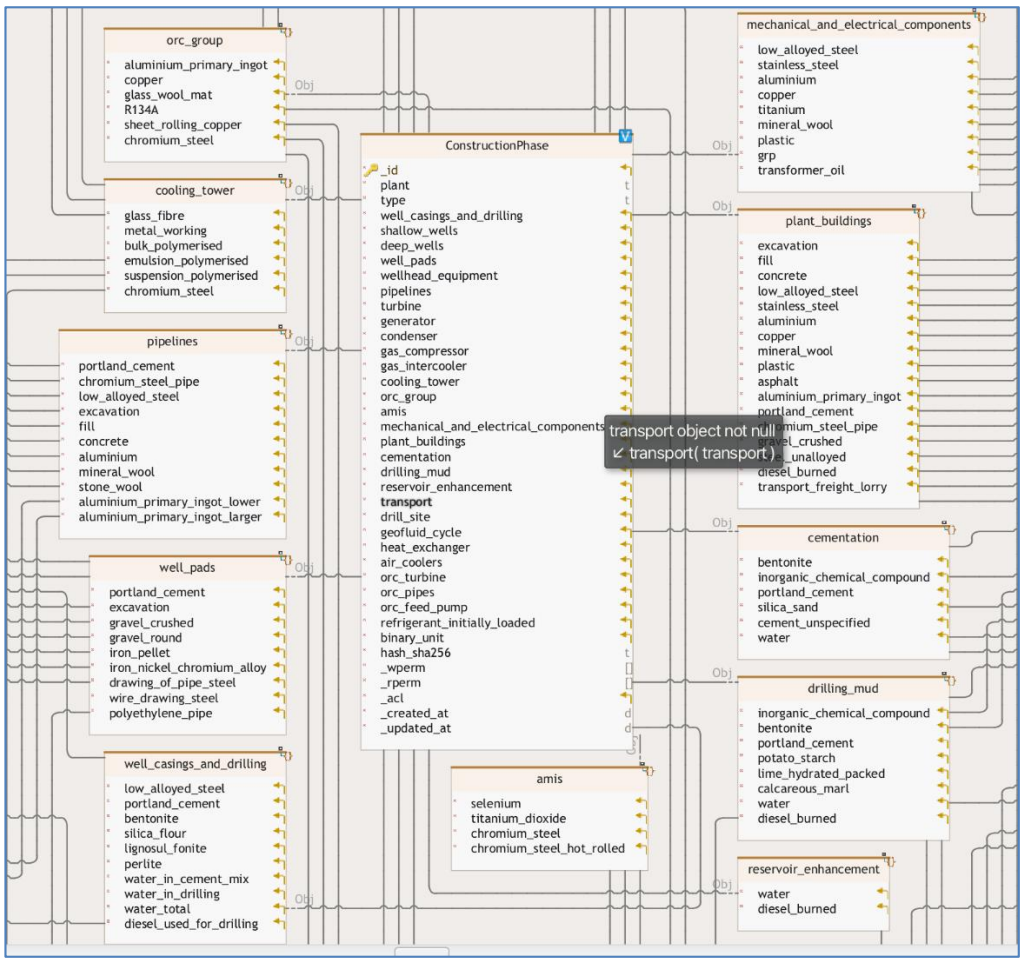


Figure A10 ER diagram of reference flow data for construction phase (a partial view)

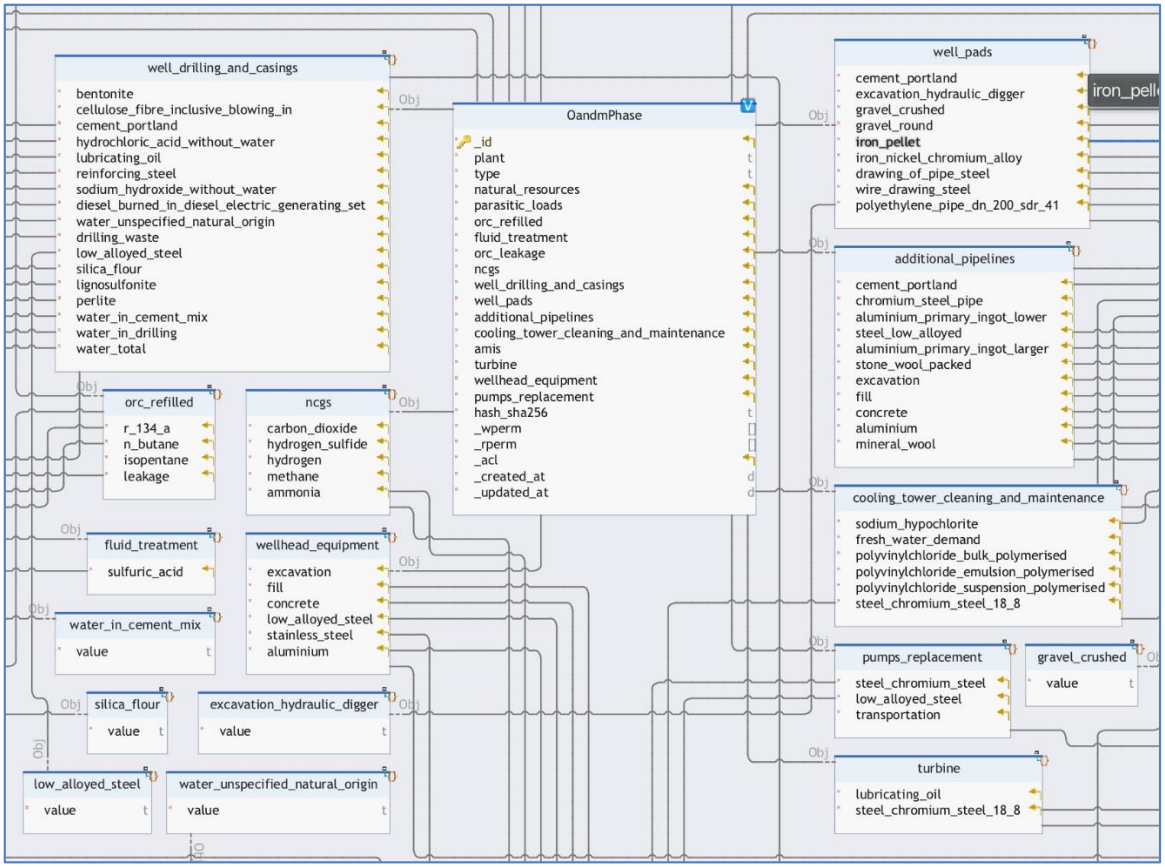


Figure A11 ER diagram of reference flow data for operation and maintenance phase (a partial view)

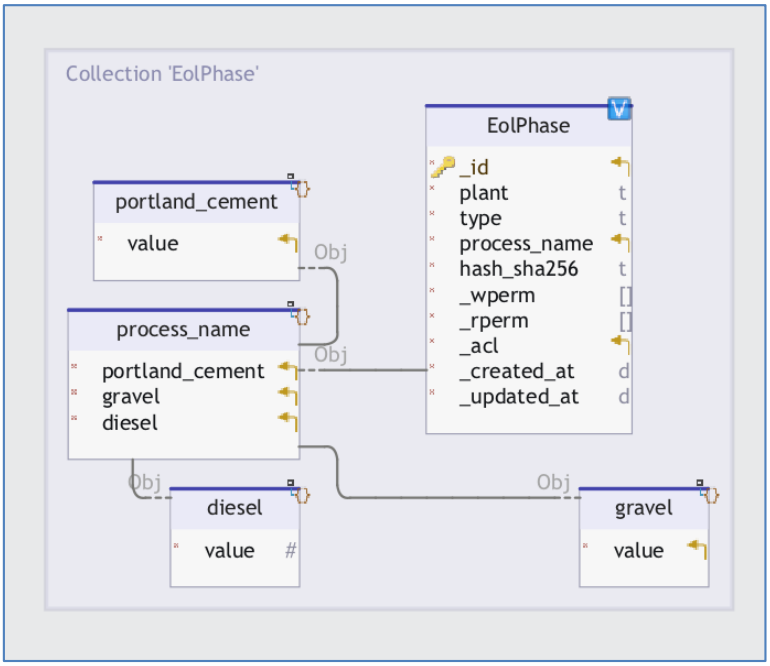


Figure A12 ER diagram of reference flow data for end-of-life phase (a partial view)

Appendix B

Class documentation

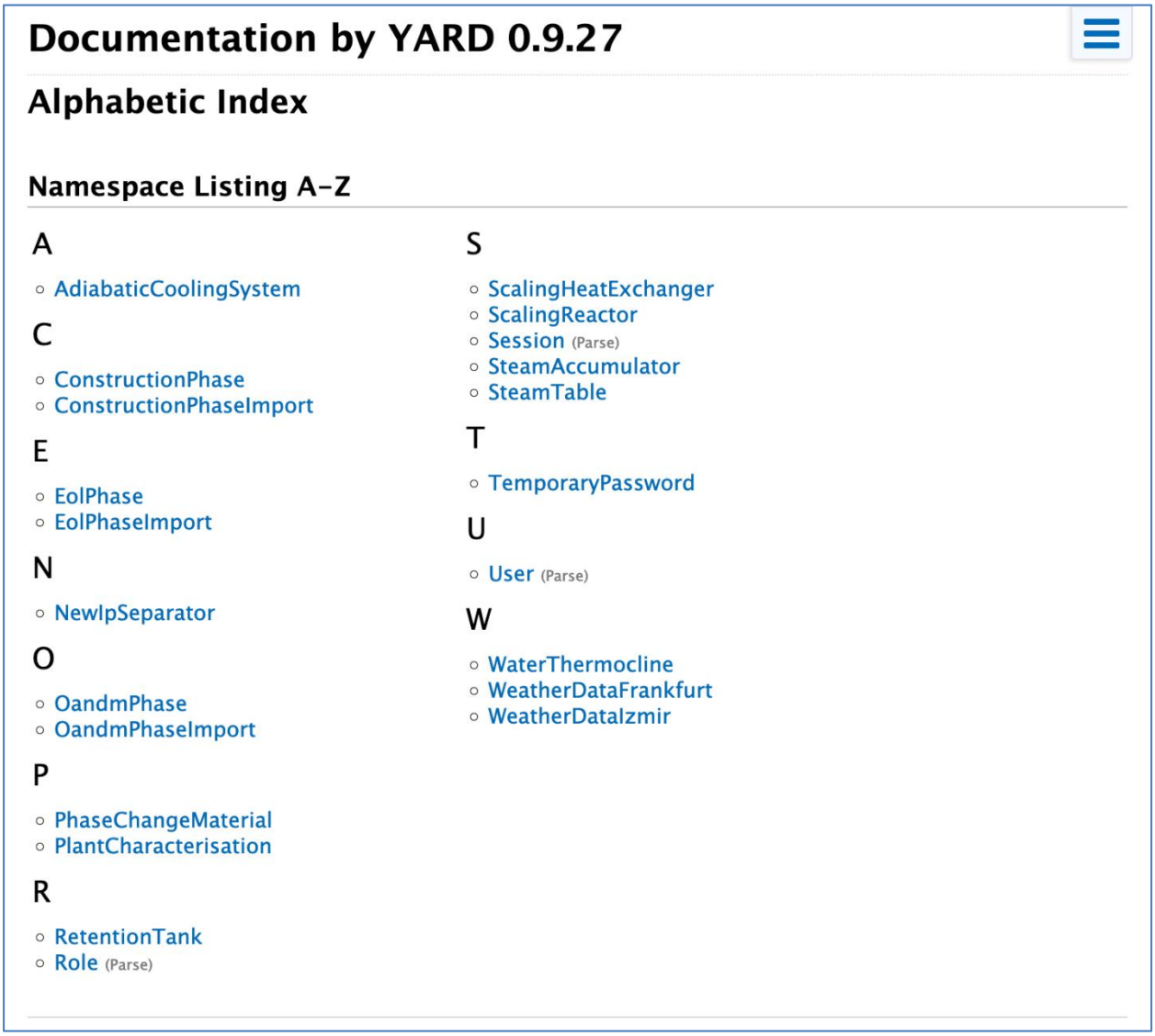


Figure B1 Class documentation homepage

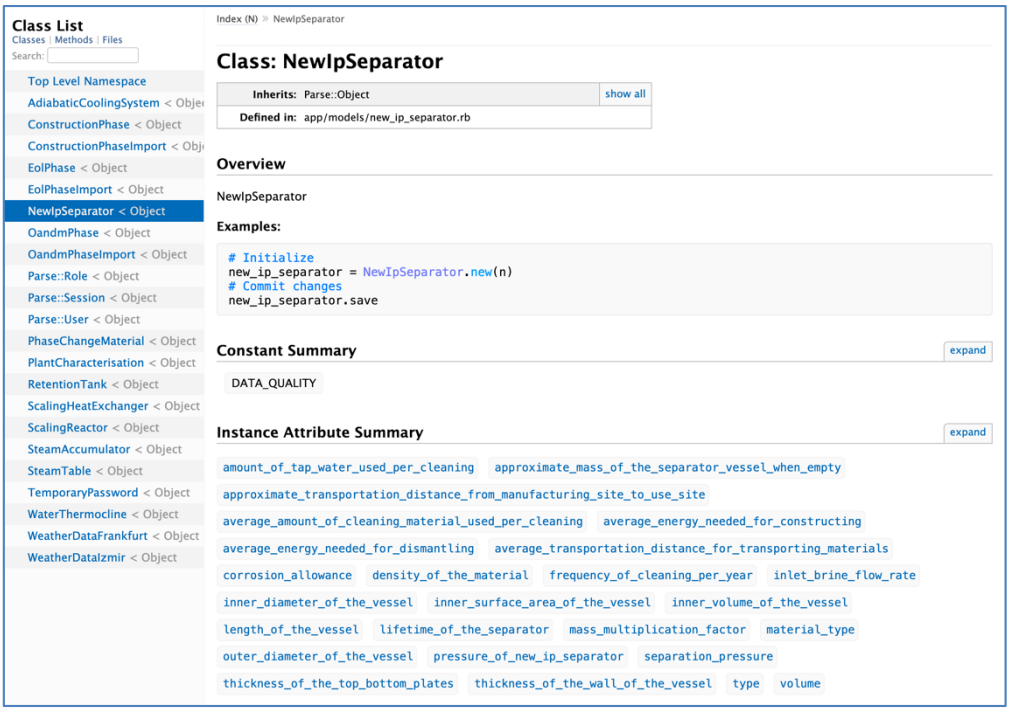


Figure B2 Class documentation of new IP separator

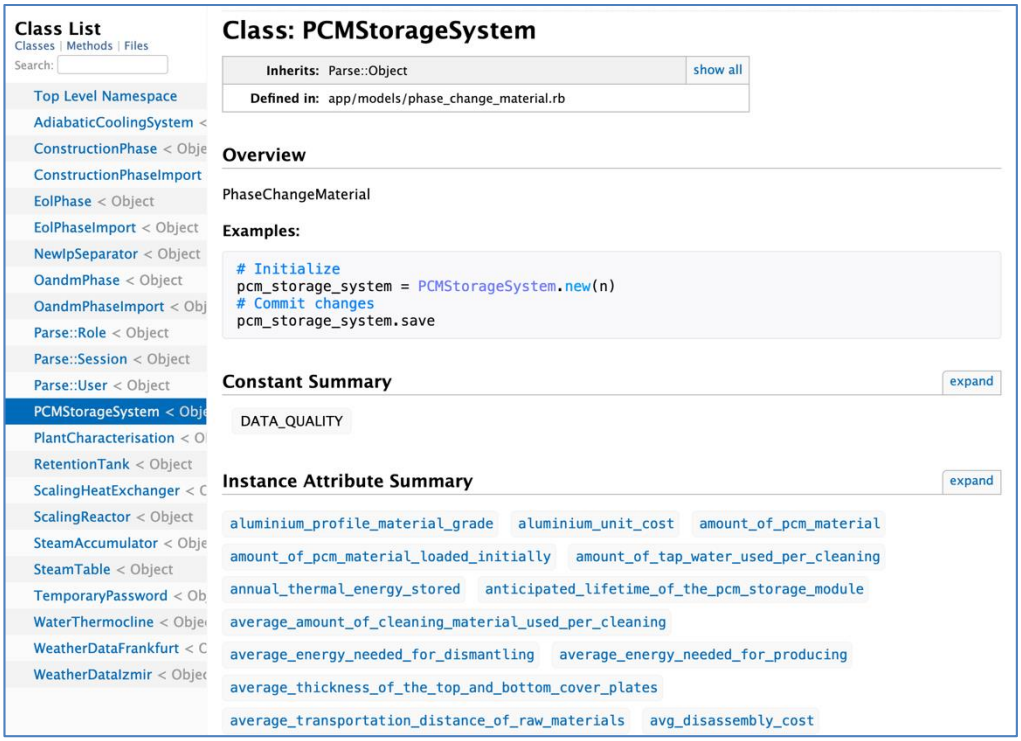


Figure B3 Class documentation of PCM storage system

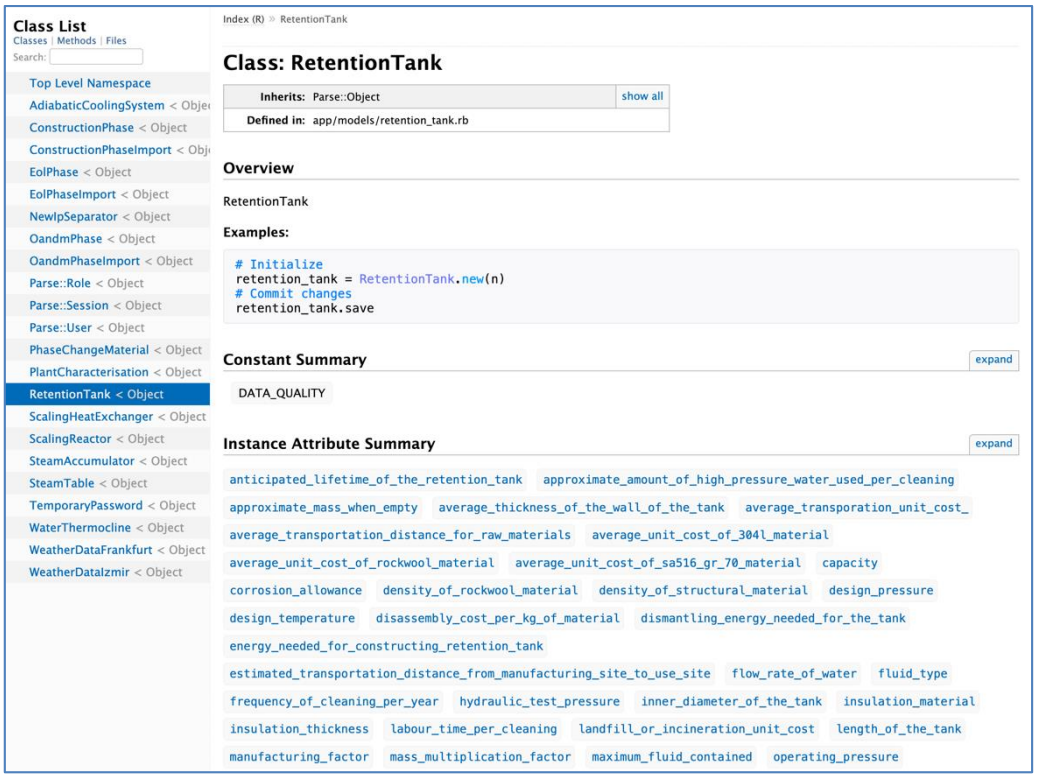


Figure B4 Class documentation of retention tank

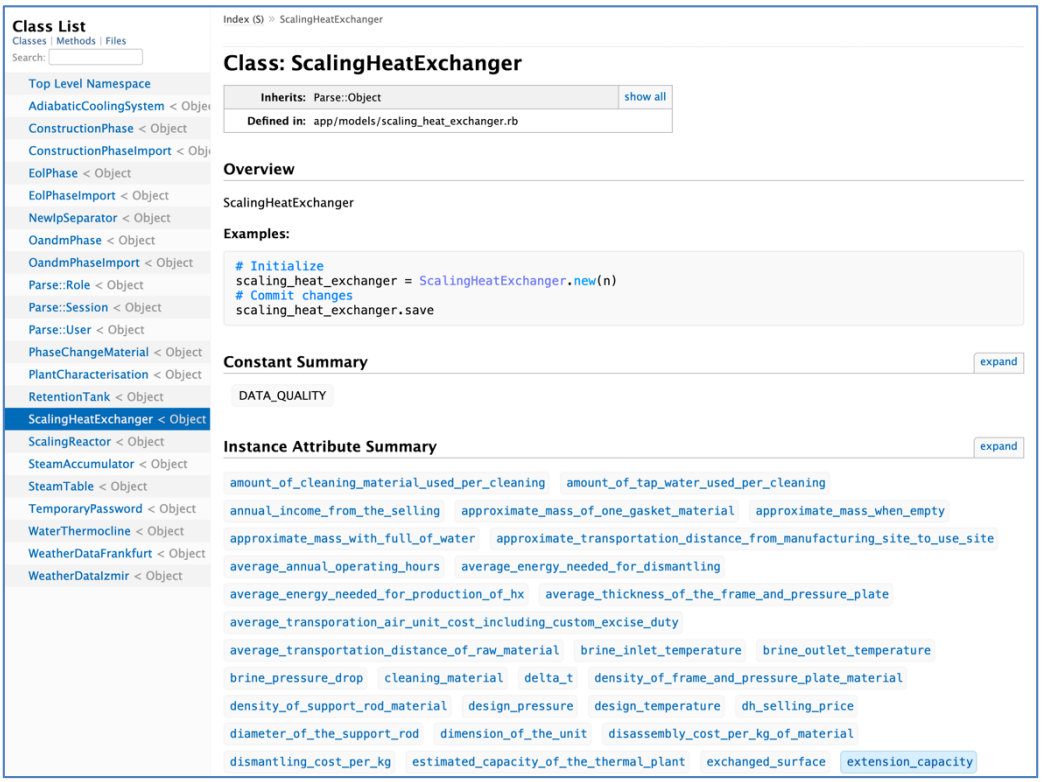


Figure B5 Class documentation of scaling heat exchanger

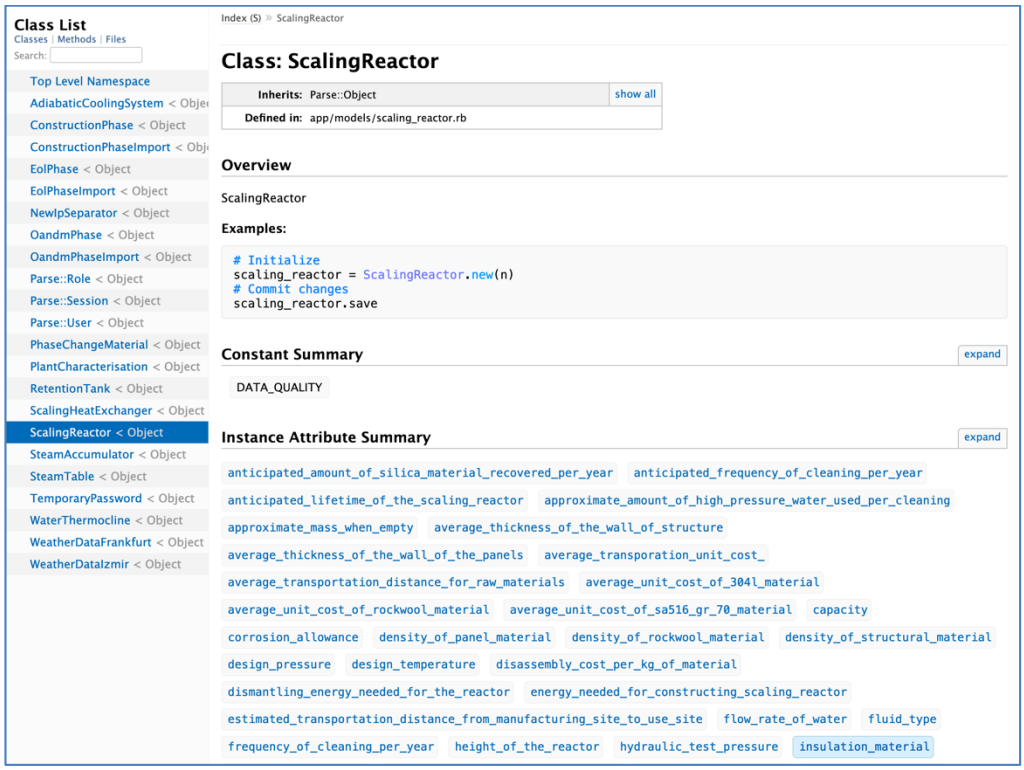


Figure B6 Class documentation of scaling reactor

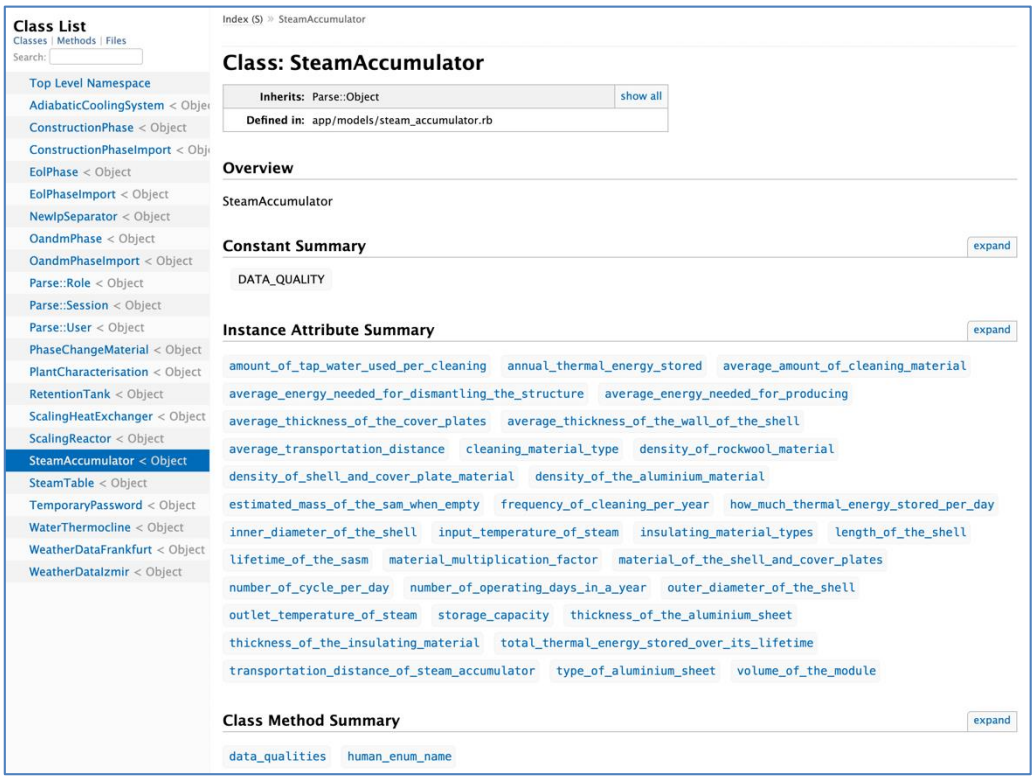


Figure B7 Class documentation of steam accumulator

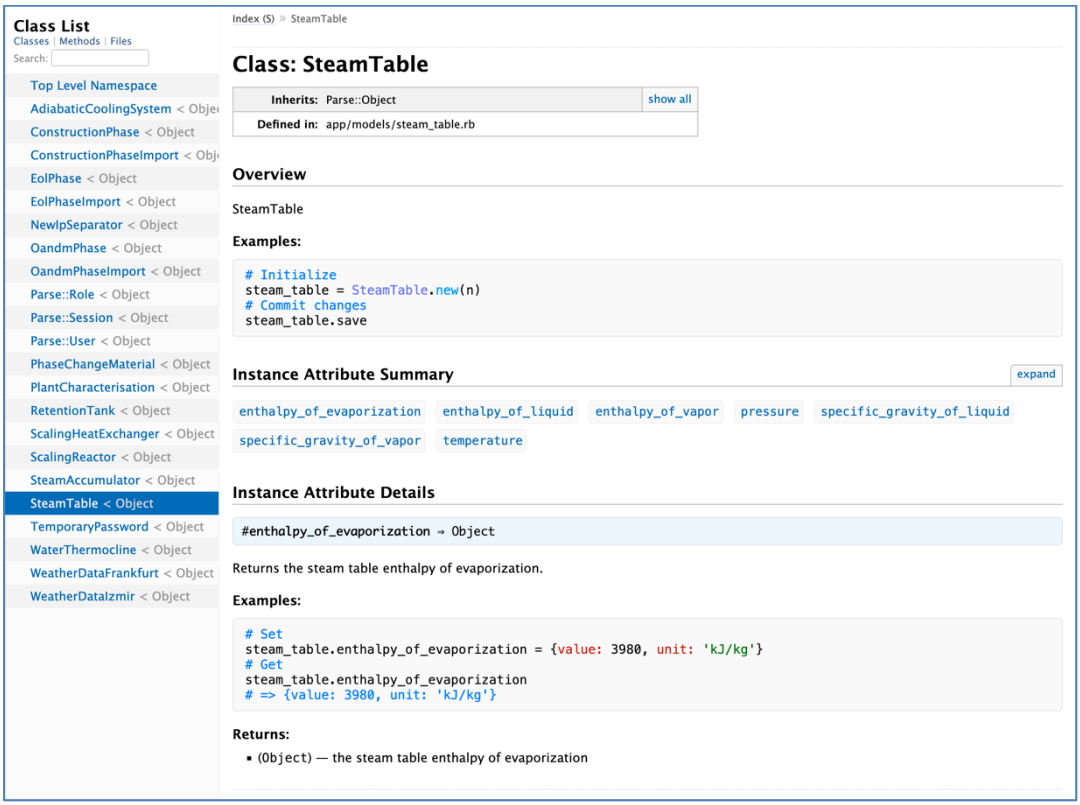


Figure B8 Class documentation of steam table

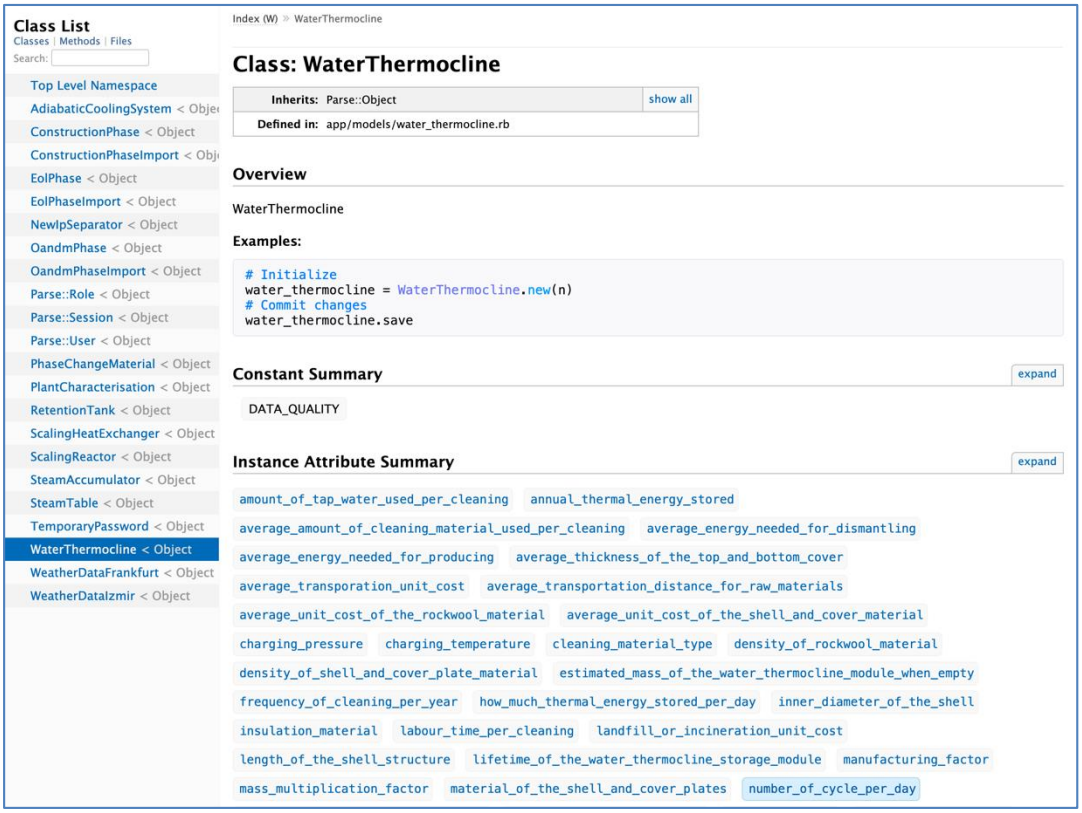


Figure B9 Class documentation of water thermocline

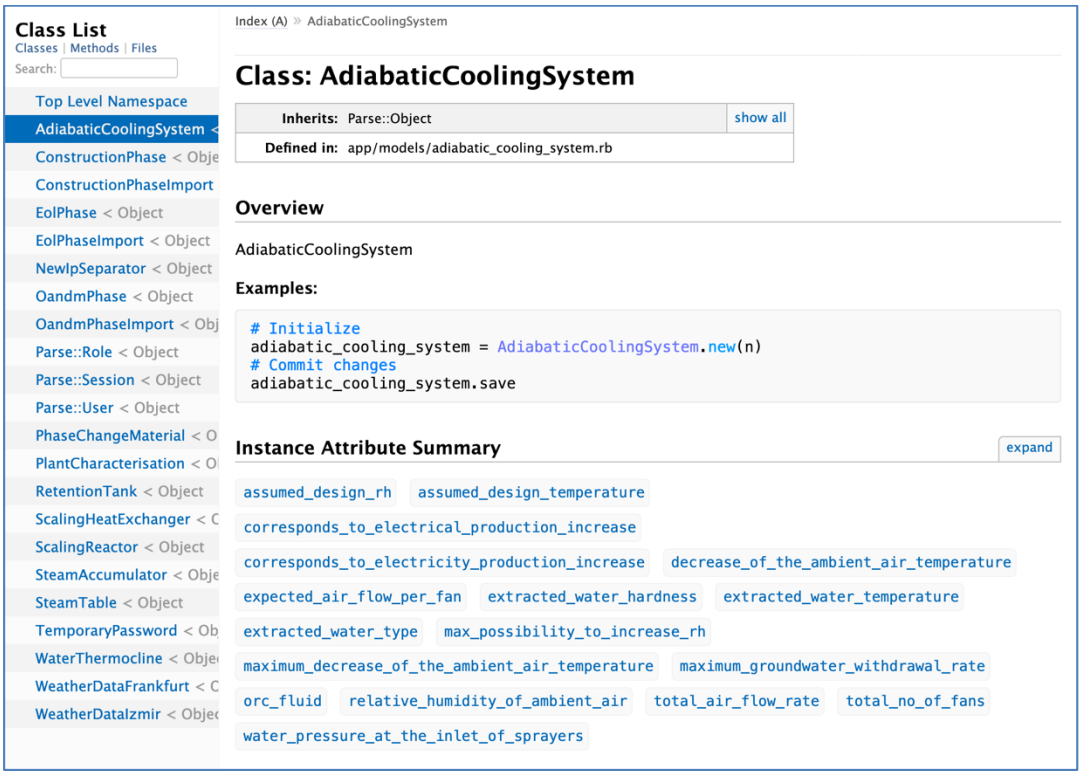


Figure B10 Class documentation of adiabatic cooling system

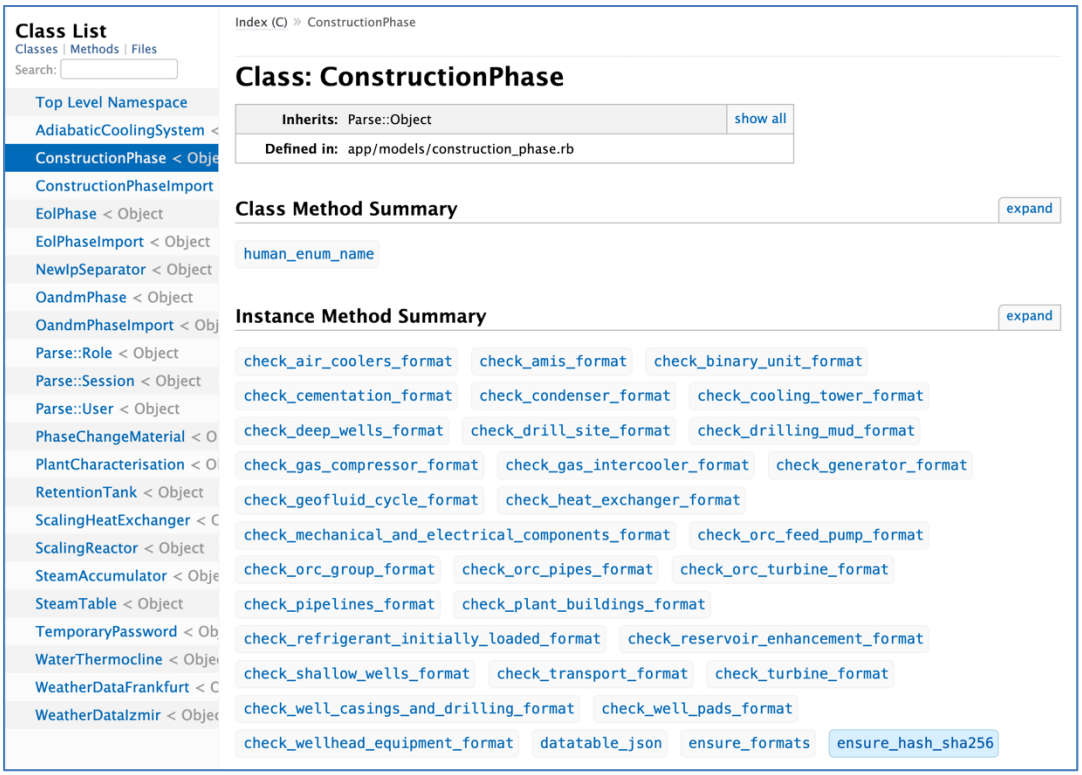


Figure B11 Class documentation of reference flow data for construction phase

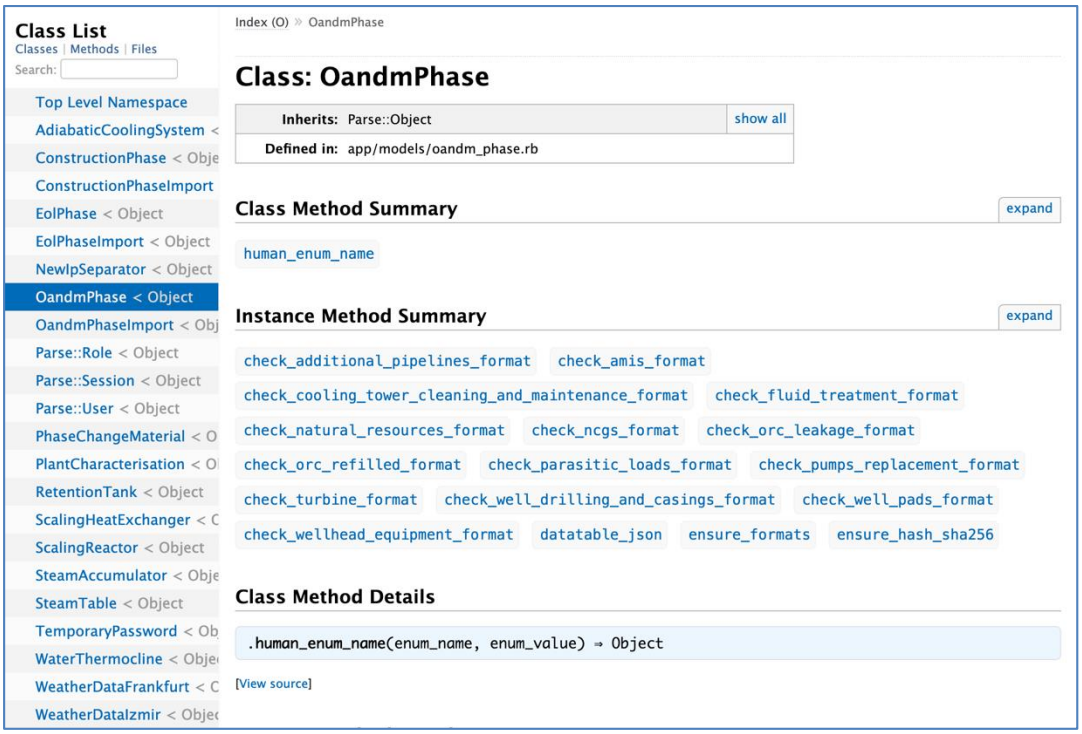


Figure B12 Class documentation of reference flow data for operation & maintenance phase

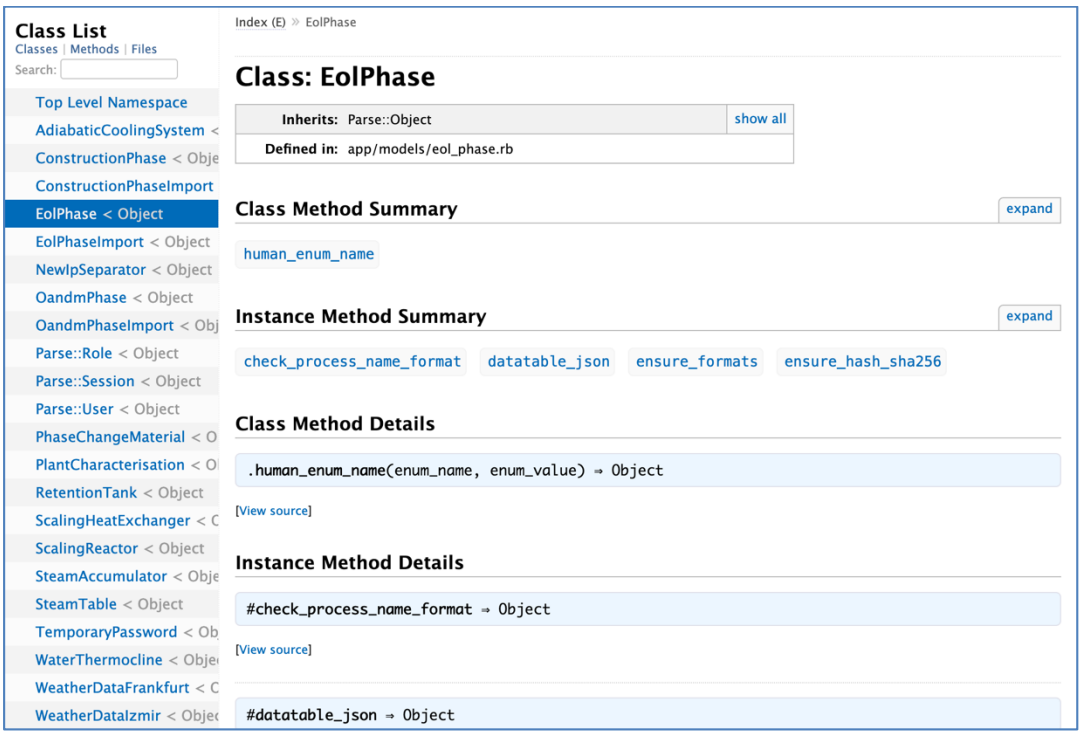


Figure B13 Class documentation of reference flow data for end-of-life phase

Appendix C

RESTFUL API LIST

Method	URI	Description
GET	/v1/storage/schemas	Retrieving all Schemas
GET	/v1/storage/schemas/:className	Retrieving a Class schema
POST	/v1/storage/schemas	Creating a Class schema
PUT	/v1/storage/schemas/:className	Updating a Class schema
DELETE	/v1/storage/schemas/:className	Deleting a Class schema
POST	/v1/storage/classes/SteamTable	Creating a SteamTable object
PUT	/v1/storage/classes/SteamTable/:objectId	Updating a SteamTable object
GET	/v1/storage/classes/SteamTable/:objectId	Retrieving a SteamTable object
GET	/v1/storage/classes/SteamTable	Querying SteamTable objects
DELETE	/v1/storage/classes/SteamTable/:objectId	Deleting a SteamTable object
POST	/v1/storage/classes/WeatherDataIzmir	Creating a WeatherDataIzmir object
PUT	/v1/storage/classes/WeatherDataIzmir/:objectId	Updating a WeatherDataIzmir object
GET	/v1/storage/classes/WeatherDataIzmir/:objectId	Retrieving a WeatherDataIzmir object
GET	/v1/storage/classes/WeatherDataIzmir	Querying WeatherDataIzmir objects
DELETE	/v1/storage/classes/WeatherDataIzmir/:objectId	Deleting a WeatherDataIzmir object
POST	/v1/storage/classes/WeatherDataFrankfurt	Creating a WeatherDataFrankfurt object
PUT	/v1/storage/classes/WeatherDataFrankfurt/:objectId	Updating a WeatherDataFrankfurt object
GET	/v1/storage/classes/WeatherDataFrankfurt/:objectId	Retrieving a WeatherDataFrankfurt object
GET	/v1/storage/classes/WeatherDataFrankfurt	Querying WeatherDataFrankfurt objects
DELETE	/v1/storage/classes/WeatherDataFrankfurt/:o	Deleting a WeatherDataFrankfurt

	bjectId	object
POST	/v1/storage/classes/SteamAccumulator	Creating a SteamAccumulator object
PUT	/v1/storage/classes/SteamAccumulator/:objectId	Updating a SteamAccumulator object
GET	/v1/storage/classes/SteamAccumulator/:objectId	Retrieving a SteamAccumulator object
GET	/v1/storage/classes/SteamAccumulator	Querying SteamAccumulator objects
DELETE	/v1/storage/classes/SteamAccumulator/:objectId	Deleting a SteamAccumulator object
POST	/v1/storage/classes/PhaseChangeMaterial	Creating a PhaseChangeMaterial object
PUT	/v1/storage/classes/PhaseChangeMaterial/:objectId	Updating a PhaseChangeMaterial object
GET	/v1/storage/classes/PhaseChangeMaterial/:objectId	Retrieving a PhaseChangeMaterial object
GET	/v1/storage/classes/PhaseChangeMaterial	Querying PhaseChangeMaterial objects
DELETE	/v1/storage/classes/PhaseChangeMaterial/:objectId	Deleting a PhaseChangeMaterial object
POST	/v1/storage/classes/WaterThermocline	Creating a WaterThermocline object
PUT	/v1/storage/classes/WaterThermocline/:objectId	Updating a WaterThermocline object
GET	/v1/storage/classes/WaterThermocline/:objectId	Retrieving a WaterThermocline object
GET	/v1/storage/classes/WaterThermocline	Querying WaterThermocline objects
DELETE	/v1/storage/classes/WaterThermocline/:objectId	Deleting a WaterThermocline object
POST	/v1/storage/classes/NewIpSeparator	Creating a NewIpSeparator object
PUT	/v1/storage/classes/NewIpSeparator /:objectId	Updating a NewIpSeparator object
GET	/v1/storage/classes/NewIpSeparator /:objectId	Retrieving a NewIpSeparator object
GET	/v1/storage/classes/NewIpSeparator	Querying NewIpSeparator objects

DELETE	/v1/storage/classes/NewIpSeparator /:objectId	Deleting a NewIpSeparator object
POST	/v1/storage/classes/ScalingHeatExchanger	Creating a ScalingHeatExchanger object
PUT	/v1/storage/classes/ScalingHeatExchanger/:objectId	Updating a ScalingHeatExchanger object
GET	/v1/storage/classes/ScalingHeatExchanger/:objectId	Retrieving a ScalingHeatExchanger object
GET	/v1/storage/classes/ScalingHeatExchanger	Querying ScalingHeatExchanger objects
DELETE	/v1/storage/classes/ScalingHeatExchanger/:objectId	Deleting a ScalingHeatExchanger object
POST	/v1/storage/classes/RetentionTank	Creating a RetentionTank object
PUT	/v1/storage/classes/RetentionTank/:objectId	Updating a RetentionTank object
GET	/v1/storage/classes/RetentionTank/:objectId	Retrieving a RetentionTank object
GET	/v1/storage/classes/RetentionTank	Querying RetentionTank objects
DELETE	/v1/storage/classes/RetentionTank/:objectId	Deleting a RetentionTank object
POST	/v1/storage/classes/ScalingReactor	Creating a ScalingReactor object
PUT	/v1/storage/classes/ScalingReactor/:objectId	Updating a ScalingReactor object
GET	/v1/storage/classes/ScalingReactor/:objectId	Retrieving a ScalingReactor object
GET	/v1/storage/classes/ScalingReactor	Querying ScalingReactor objects
DELETE	/v1/storage/classes/ScalingReactor/:objectId	Deleting a ScalingReactor object
POST	/v1/storage/classes/AdiabaticCoolingSystem	Creating a AdiabaticCoolingSystem object
PUT	/v1/storage/classes/AdiabaticCoolingSystem/:objectId	Updating a AdiabaticCoolingSystem object
GET	/v1/storage/classes/AdiabaticCoolingSystem/:objectId	Retrieving a AdiabaticCoolingSystem object
GET	/v1/storage/classes/AdiabaticCoolingSystem	Querying AdiabaticCoolingSystem objects
DELETE	/v1/storage/classes/AdiabaticCoolingSystem/:objectId	Deleting a AdiabaticCoolingSystem object

POST	/v1/storage/classes/PlantCharacterisation	Creating a PlantCharacterisation object
GET	/v1/storage/classes/PlantCharacterisation/:objectId	Retrieving a PlantCharacterisation object
GET	/v1/storage/classes/PlantCharacterisation	Querying PlantCharacterisation objects
DELETE	/v1/storage/classes/ PlantCharacterisation /:objectId	Deleting a PlantCharacterisation object
POST	/v1/storage/classes/EolPhase	Creating a EolPhase object
PUT	/v1/storage/classes/EolPhase/:objectId	Updating a EolPhase object
GET	/v1/storage/classes/EolPhase/:objectId	Retrieving a EolPhase object
GET	/v1/storage/classes/EolPhase	Querying EolPhase objects
DELETE	/v1/storage/classes/EolPhase/:objectId	Deleting a EolPhase object
POST	/v1/storage/classes/ConstructionPhase	Creating a ConstructionPhase object
PUT	/v1/storage/classes/ConstructionPhase/:objectId	Updating a ConstructionPhase object
GET	/v1/storage/classes/ConstructionPhase/:objectId	Retrieving a ConstructionPhase object
GET	/v1/storage/classes/ConstructionPhase	Querying ConstructionPhase objects
DELETE	/v1/storage/classes/ConstructionPhase/:objectId	Deleting a ConstructionPhase object
POST	/v1/storage/classes/OandmPhase	Creating a OandmPhase object
PUT	/v1/storage/classes/OandmPhase/:objectId	Updating a OandmPhase object
GET	/v1/storage/classes/OandmPhase/:objectId	Retrieving a OandmPhase object
GET	/v1/storage/classes/OandmPhase	Querying OandmPhase objects
DELETE	/v1/storage/classes/OandmPhase/:objectId	Deleting a OandmPhase object

Table C1 RESTful API methods, URI, and description

Appendix D

Data management components

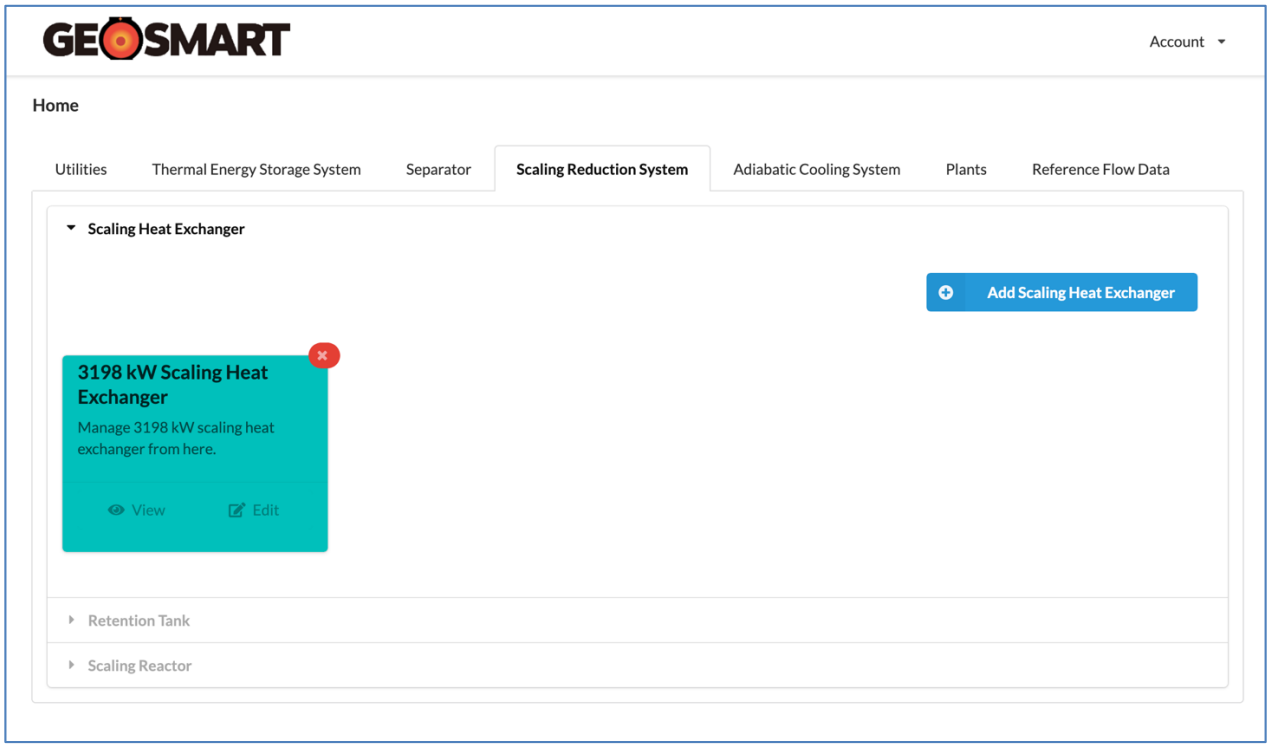


Figure D1 The GeoSmart data management component for scaling reduction system

GEOSMART Account

Home / Scaling Heat Exchangers / PfT0vLPVdb

3198kW Scaling Heat Exchanger

Items	Amount / Quantity	Units	Symbol	Data Quality
Hx Type	Plate			
Technology Options	Plate & gasketed			
Plate Material Type	Titanium			
Plate Material Grade	Ti ASME SB-265 grade 1			
Plate material density (kg/m³)	4510	kg/m³	ρ_{pl}	primary
Plate material thickness (mm)	0.6	mm	t_p	primary
Number of plates	53		N_p	primary
Gasket Material And Fixing	NBRP ClipGrip™			
Extension Capacity	17 plates			
Dimension of the unit (mm)		mm		primary
Brine Inlet temperature (°C)	105	°C	T_b^{in}	primary
Water inlet temperature (°C)	25	°C	T_w^{in}	primary
Brine Outlet temperature (°C)	50	°C	T_b^{out}	primary
Water outlet temperature (°C)	55	°C	T_w^{out}	primary
Brine Pressure drop (kPa)	34.7	kPa		primary

Figure D2 Example data of scaling heat exchanger (3198kW)

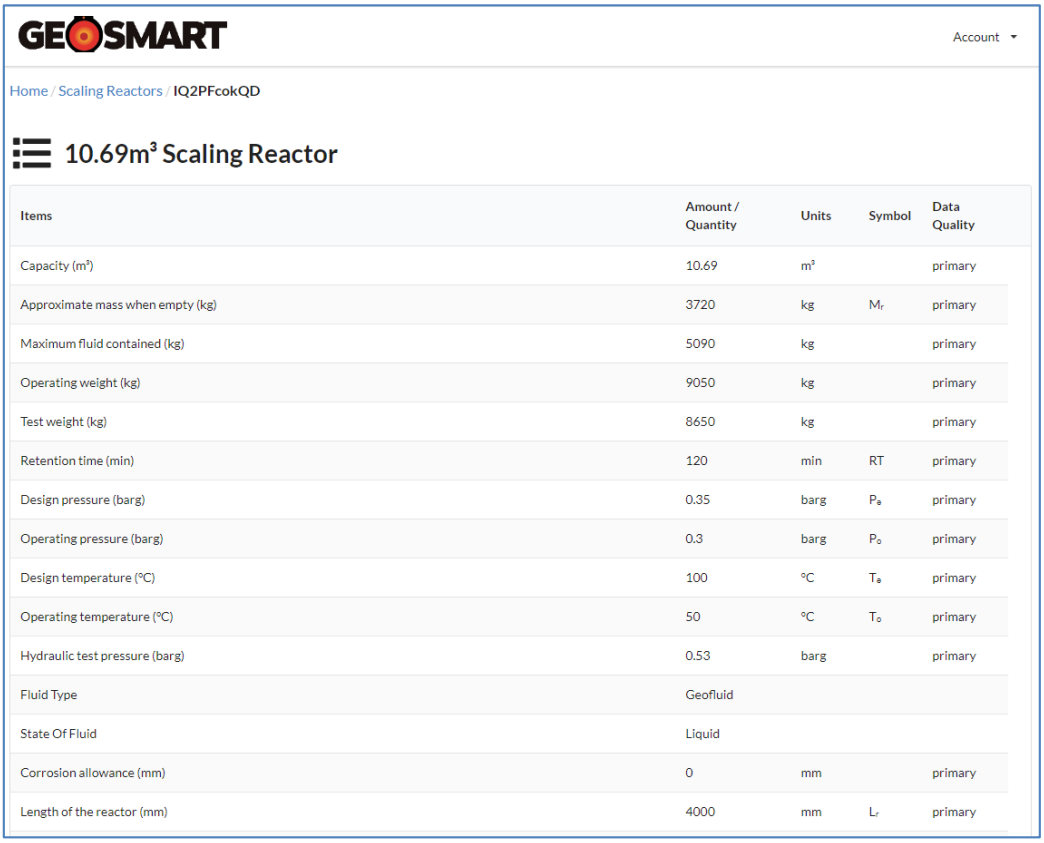
GEOSMART Account

Home / Retention Tanks / pcP8pM7oOk

10.014m³ Retention Tank

Items	Amount / Quantity	Units	Symbol	Data Quality
Capacity (m³)	10.014	m³		primary
Approximate mass when empty (kg)	1310	kg	M_t	primary
Maximum fluid contained (kg)	5040	kg		primary
Operating weight (kg)	6350	kg		primary
Test weight (kg)	6200	kg		primary
Retention time (min)	120	min	RT	primary
Design pressure (barg)	0.35	barg	P_e	primary
Operating pressure (barg)	0.3	barg	P_o	primary
Design temperature (°C)	100	°C	T_e	primary
Operating temperature (°C)	50	°C	T_o	primary
Hydraulic test pressure (barg)	0.53	barg		primary
Fluid Type	Geofluid			
State Of Fluid	Liquid			
Corrosion allowance (mm)	3	mm		primary
Length of the tank (mm)	5500	mm	L_t	primary
Outer diameter of the tank (mm)	1500	mm	OD_t	primary

Figure D3 Example data of retention tank (10.014m³)



Items	Amount / Quantity	Units	Symbol	Data Quality
Capacity (m^3)	10.69	m^3		primary
Approximate mass when empty (kg)	3720	kg	M_r	primary
Maximum fluid contained (kg)	5090	kg		primary
Operating weight (kg)	9050	kg		primary
Test weight (kg)	8650	kg		primary
Retention time (min)	120	min	RT	primary
Design pressure (barg)	0.35	barg	P_e	primary
Operating pressure (barg)	0.3	barg	P_o	primary
Design temperature (°C)	100	°C	T_e	primary
Operating temperature (°C)	50	°C	T_o	primary
Hydraulic test pressure (barg)	0.53	barg		primary
Fluid Type	Geofluid			
State Of Fluid	Liquid			
Corrosion allowance (mm)	0	mm		primary
Length of the reactor (mm)	4000	mm	L_r	primary

Figure D4 Example data of scaling reactor (10.69m^3)

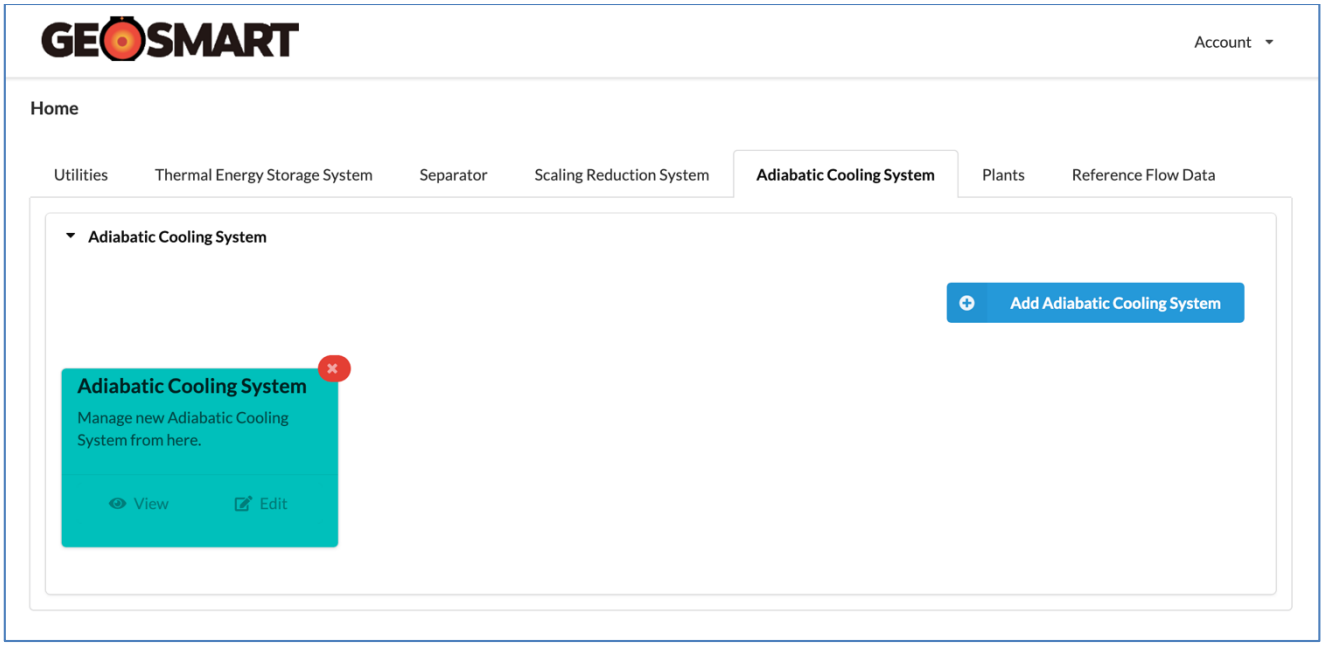
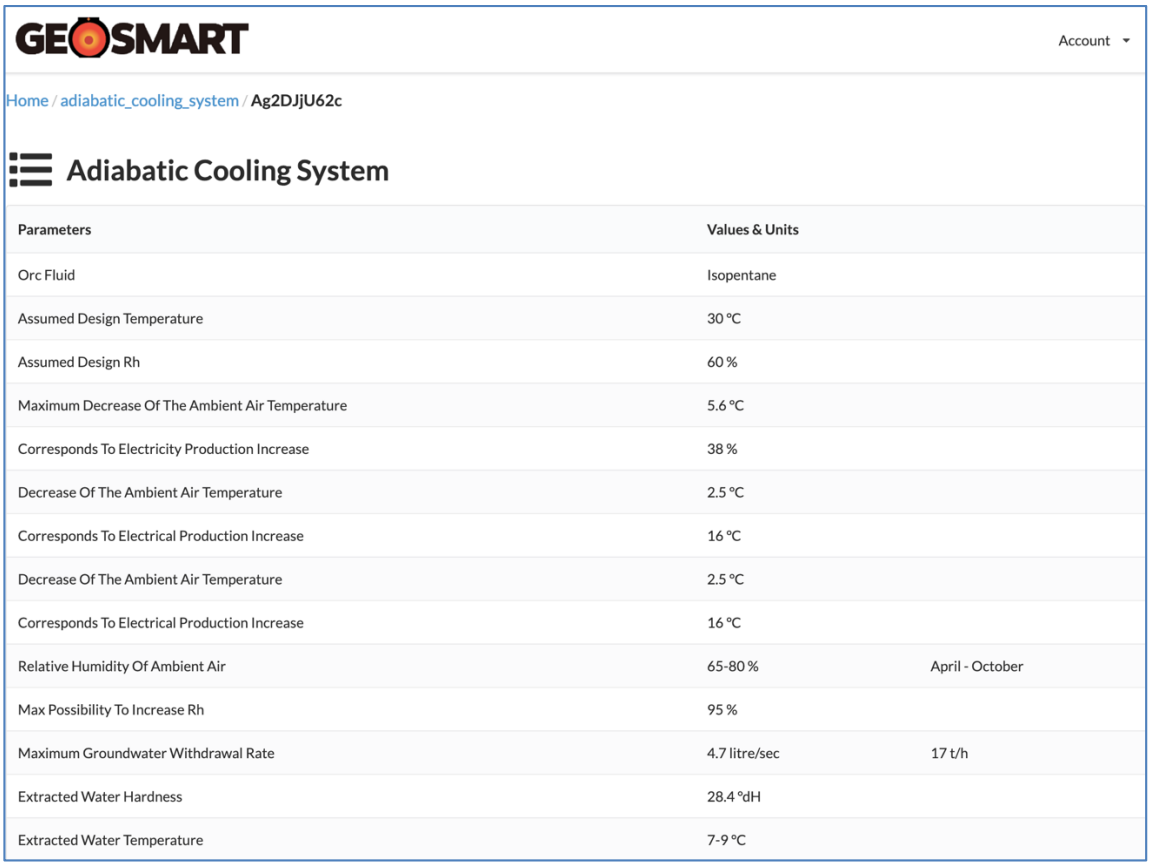


Figure D5 The GeoSmart data management component for adiabatic cooling system



Parameters	Values & Units	
Orc Fluid	Isopentane	
Assumed Design Temperature	30 °C	
Assumed Design Rh	60 %	
Maximum Decrease Of The Ambient Air Temperature	5.6 °C	
Corresponds To Electricity Production Increase	38 %	
Decrease Of The Ambient Air Temperature	2.5 °C	
Corresponds To Electrical Production Increase	16 °C	
Decrease Of The Ambient Air Temperature	2.5 °C	
Corresponds To Electrical Production Increase	16 °C	
Relative Humidity Of Ambient Air	65-80 %	April - October
Max Possibility To Increase Rh	95 %	
Maximum Groundwater Withdrawal Rate	4.7 litre/sec	17 t/h
Extracted Water Hardness	28.4 °dH	
Extracted Water Temperature	7-9 °C	

Figure D6 Example data of adiabatic cooling system

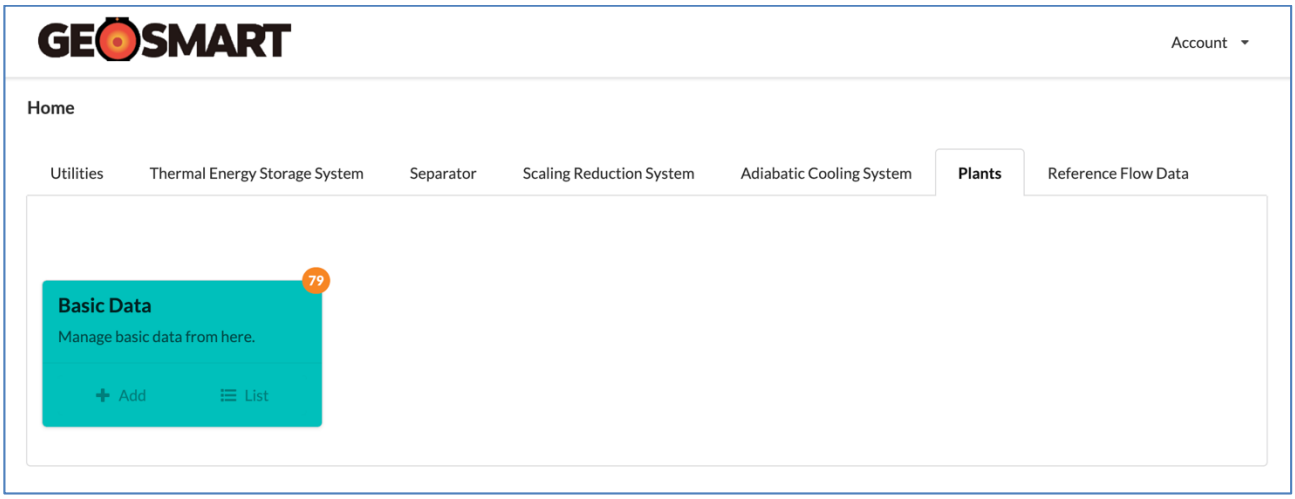


Figure D7 The GeoSmart data management component for plant basic data

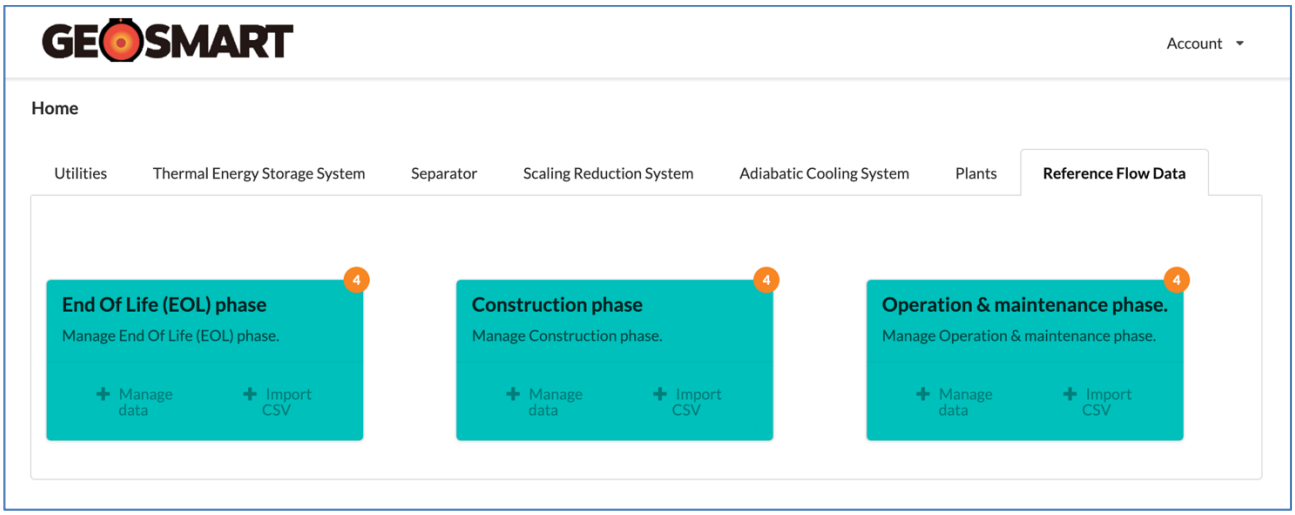


Figure D8 The GeoSmart data management component for reference flow data