EMB3Rs

Heat and Cold matching platform

Business Module

System and User manual

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SPIRE PROJECT

Technical References

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[1] PU = Public
PP = Restricted to other programme participants (including the Commission Services)
RE = Restricted to a group specified by the consortium (including the Commission Services)
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Summary

This report provides a comprehensive description of the Business Module developed under the EMB3Rs platform. The Business Module evaluates the financial viability of the excess heat or cold extraction and utilization project by introducing a private business perspective and a socio-economic one. The work on developing and deploying the Business Module is part of work package 3. This document is divided into two manuals: 1) System manual and 2) User manual. The system manual provides the theoretical description of the business module to understand the underlying theoretical framework and to reproduce its functionality. The system manual also provides an overview of the integration of the business module with other modules developed under the EMB3Rs platform. On the other hand, the user manual focuses on the users of this module and explains in detail the technical programming requirement of the inputs and outputs to run the module.

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1 Introduction

The business module is part of EMB3Rs platform and mainly evaluates the financial profitability of excess heat and cold extraction and utilization project under different ownership structures which represents different business models. This module requires an overview of all expected inward and outward cashflows concerning a particular excess heat project. Such cashflows are provided by the other modules under the EMB3Rs platform. Following are some of the key main features of the business module:

- Business module evaluates the financial profitability of a given excess heat utilization project by calculating following metrices:
  - Net Present Value (NPV) to get a general overview of the financial profitability of the project by looking at the discounted cashflows generated over the whole project's lifetime.
  - Internal Rate of Return (IRR); which is the discount rate at which NPV is zero meaning the minimum return the project must generate to be suitable for a given investment from a private company perspective. IRR is often used by companies for internal decision making regarding any investment and the risk associated with it.
  - Similarly, payback period on the investment is also calculated.
- This module considers socio-economic and private business perspective as two different scenarios. Each scenario considers a separate discount rate.
- Different ownership structures are incorporated under private business scenario which sever as a proxy for business model.
- Under the private business scenario, an additional metric, Levelized Cost of Heat (LCOH), is calculated for sinks. LCOH is calculated for sinks as information on revenues generated at the sink side by utilization of excess heat is not available.
- A sensitivity analysis is done on all discount rates for all scenarios.
- Different ownership structures are incorporated under private business scenario which sever as a proxy for business model. The ownership structure of each actor is input from the user. Thus, the impact of different ownership structures on project viability (NPV & IRR) can be evaluated.

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2 System Manual

This section represents the system manual that explains the theoretical background behind the business module and its interaction with other modules under the EMB3Rs platform to provide the necessary knowledge for the implementation of this module.

2.1 Theoretical Background

2.1.1 Financial profitability metrices

The business module gives insight into the profitability and the risk associated with the investment into a given excess heat or cold utilization project. For this, NPV and IRR are calculated for two scenarios that represent socio-economic and private business perspectives.

The NPV is the difference between the discounted inward and outward cash flows over the whole project lifetime. The generic equation is represented as follows:

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+r)^t} - \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} \qquad 1$$

Where R_t is the inward cash flow or revenues while C_t is the outward cash flow and n is the project lifetime. For the case of excess heat extraction and utilization, R_t represents the revenues earned from the market by selling the excess heat. Outward cashflow C_t represents the capital investments into extraction technologies, storage, and network or distribution cost. It also includes fixed operation and maintenance costs, and variable operating costs. The NPV calculations for the socio-economic scenario are as follows:

$$NPVs = \sum_{t=1}^{n} \frac{\sum_{h=1}^{y} P_h * d_h}{(1+rs)^t} - \sum_{t=1}^{n} \frac{(v+f)}{(1+rs)^t} - Ct - Cs - Cn \qquad 2$$

rs is the socio-economic discount rate. The first term with summation represents the cash inflow or revenues generated by dispatching excess heat d_h at price P_h where h represents the time steps of market module simulation, which are either hours or days in a year. The rest of the terms represent cash outflows and includes discounted fixed and variable operation and maintenance costs (f and v, respectively) and discounted capital investments into extraction technologies like heat exchangers or any additional backup capacity (Ct), storage units (Cs), and distribution network (Cn). These capital investments are assumed to be taken at the beginning of the project. However, if any capital investments are made at some other time during the project's lifetime, they should be discounted.

The dispatch of excess heat and prices are in hourly/daily resolution and are provided by the market module along with the total yearly variable operating cost. The techno-economic module provides the capital investments and yearly fixed operation and maintenance costs.

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Under a private business scenario, NPV is calculated for each commercial actor[1] i and given as follow:

$$NPVi = \sum_{t=1}^{n} \frac{\sum_{h=1}^{y} P_{hi} * d_{hi}}{(1+rp)^t} - \sum_{t=1}^{n} \frac{(v_i + f_i)}{(1+rp)^t} - Ct_i - Cs_i - Cn_i \qquad 3$$

Rp is the private business discount rate. The ownership structure, which is input from the user, determines the distribution of overall capital investments ($Ct, Cs, \& Cn$) among the actors ($Ct_i, Cs_i, \& Cn_i$). For sinks, the first summation term in eq 2 & 3, which represents the revenues or cash inflows, is not known as sinks always buy the excess heat (cash outflow). Therefore, alternatively, the Levelized Cost of Heat (LCOH) is calculated for sinks.

Similar to NPV, IRR calculations are done twice; one for the whole project representing the socio-economic scenario and another for each actor representing the private business scenario. Similar to NPV (eq 1), the general equation for IRR calculation is depicted below. The specific equation for socio-economic and private business scenarios can be derived similarly to eq 2 & 3.

$$NPV = 0 = \sum_{t=1}^{n} \frac{R_t}{(1+IRR)^t} - \sum_{t=1}^{n} \frac{C_t}{(1+IRR)^t} \qquad 4$$

The IRR is the discount rate for NPV at which NPV is equal to zero.
The payback period is also calculated for both scenarios, using following equations.

$$PBs = \frac{C_t + C_s + C_n + \sum_{t=1}^{n} {}^{v}/_{(1+rs)^t}}{\sum_{t=1}^{n} \frac{\sum_{h=1}^{y} P_h * d_h - v}{(1+rs)^t}} \qquad 5$$

$$PBi = \frac{C_{ti} + C_{si} + C_{ni} + \sum_{t=1}^{n} {}^{f_i}/_{(1+rp)^t}}{\sum_{t=1}^{n} \frac{\sum_{h=1}^{y} P_{hi} * d_{hi} - v_i}{(1+rp)^t}} \qquad 6$$

Table 1 describes the various symbol used in above equations.

Table 1: Overview of various symbols used in equations 1-4.

Symbol	Description	Input from
P_h	Price per time step (€/kWh)	MM
d_h	Dispatch per time step (kWh)	MM
C_t	Capital investment into excess heat extraction technologies (€)	TEO
C_n	Capital investment into distribution network (€)	GIS
C_s	Capital investment into storage (€)	TEO
rs	Socio-economic discount rate	User
rp	Private business discount rate	User

[1] The commercial actors are all the sources and sinks in a given excess heat or cold utilization project6.

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n	Project lifetime (years)	User
v	Variable operation cost (€/year]	MM
f	Fixed yearly operation cost (€/year)	TEO

2.1.2 Levelized cost of heat (LCOH)

Under private business scenario, sinks are tackled differently. A the above mentioned metrices (eq 1 – 6) cannot be calculated for the sinks. This is due to fact that for sinks we don't have any information on the positive cash flows. In our simulations, sinks always generate negative cash flows, they are either investing in technologies to utilise the excess heat or buying the excess heat. The positive impact and subsequent positive cash flow generated for the sinks due to excess heat utilisation is out of the scope of this simulation.

This is explained further by the help of an example. Suppose that sink is a supermarket that wants to utilise the excess heat. This supermarket may have to invest to get connected with the grid and then it'll have to buy the heat based on its consumption. Both of these cashflows, grid connection investment and heat purchase, are negative cashflows. The utilisation of excess heat may have other benefits for the supermarket like, cost saving on installing and operating a new heating system, renovation of the existing heating system, renovation of premises, fulfilling certain performance or sustainability standards, and so on. However, all of these benefits for the supermarket that can generate a positive cashflow are out of the scope of his platform. Therefore, instead of calculating above mentioned matrices for sinks, an alternative metric, levelized cost of heat or LCOH is calculated. The LCOH is calculated as follow:

$$LCOH = \frac{(C_{ni} + C_{si} + C_{ni}) + \sum_{t=1}^{n} {(f_i + f_i)}\big/{(1+rp)^t}}{\sum_{t=1}^{n} {\sum_{h=1}^{y} d_{hi}}\big/{(1+rp)^t}} \qquad 7$$

2.1.3 Ownership Structures

The private business scenario relies on grid and technology ownership structures. These structures determine the ownership of different technologies (i.e back up boilers, storages, heat exchangers etc) installed at various sources and sinks. These ownership structures form different business models.

1. **Grid ownership structure**

   Grid ownership structure represents how the cost of the heat distribution network will be shared among the actors. Actors represents the company/entities involved. If you are not sure about actors involved in your project, then each source and sink is an actor.

2. **Technology ownership structure**

   Technology ownership structure determines which actor will invest in a particular technology selected by the TEO.
   All the technologies at source side are grouped under "source extraction technologies" while all the technologies at sink side are grouped together

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under "sink utilisation technologies". Ownership structure assign these group of extraction and utilisation technologies to different actors (sources and sinks) involved.

2.2 Interaction with Other Modules

As the business module is part of the EMB3Rs platform, it is integrated with other modules, and all the inputs mentioned in the previous sections are either taken from the outputs of other modules or from the user.
The business module takes cash outflows like capital and maintenance costs from the techno-economic module, while cash inflows and other operational cash outflows are taken from the market module. The details of the integration of business module with other modules in EMB3Rs platform is graphically depicted in figure 1.

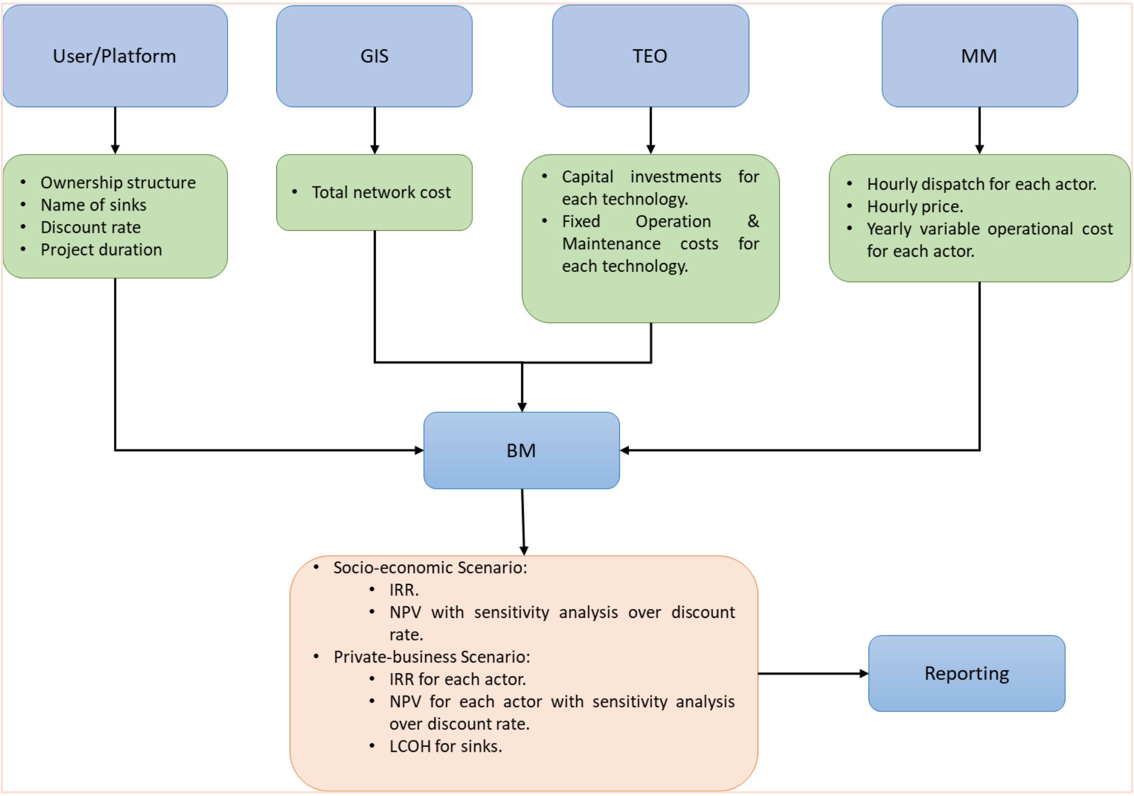

Figure 1: Details of input and output flow for the business module (BM)

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3 User manual

The user manual provides information for running this module either in standalone mode or within the EMB3Rs platform. Therefore, this section provides information from a user point of view. The technical programming description on structure and organisation for inputs and outputs is described in detail.

3.1 Module Specification

This module is build using *python 3.9*. The module uses following commonly available python libraries: *NumPy, json, jinja2*, and *NumPy_financial*.
The standalone and integrated versions of this module are available on the EMB3Rs GitHub and are accessible on this link.

3.2 Module overview

The business module implements two functions; one is called BM and it's the main function of business module with the features described above. The second function is internal heat recovery (int_heat_rec) and it is use to make NPV and LCOH calculations for internal heat recovery projects only. Internal heat recovery here is referred to the utilization of excess heat within the premises of the company or firm with excess heat. This function is a smaller version of main function BM and its primary purpose is to ease the integration of this module with the whole EMB3Rs platform as the data stream for this function is quite different from the main function.
The different inputs and outputs of the above functions are explained in detail below:

3.2.1 Inputs

As both functions calculate NPV, IRR, and LCOH, all the expected cash flows, inwards and outwards, should be provided as input. Similarly, other project characteristics like project lifetime, expected excess heat dispatch, and discount rates are also input to this module. This module also evaluates different ownership structures. Users must also specify the different actors involved and their corresponding ownership of different technology assets in a particular excess heat utilization project. Among the inputs provided by the platform user, ownership structure is an important one as it ensures that private business perspective is also considered. The input to ownership structures is discussed in detail here:

1. **Grid ownership structure**
   Grid ownership structure represents how the cost of the heat distribution network will be shared among the actors. Actors represents the company/entities involved. If you are not sure about actors involved in your project, then each source and sink is an actor.
   For example, if there are two sources and one sink then there are 3 actors in total. Grid ownership represents how the cost of network (and technologies that are connected to the grid) will be divided among these actors. If two sources share the cost of grid then input to grid ownership will be 50% cost goes to source 1 and 50% goes to source 2, while 0% to sink.

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2. Technology ownership structure

Technology ownership structure determines which actor will invest in a particular technology selected by the TEO.

All the technologies at source side are grouped under "source extraction technologies" while all the technologies at sink side are grouped together under "sink utilisation technologies". Ownership structure assign these group of extraction and utilisation technologies to different actors involved.

For example, if there are 2 sources and 1 sink, then following 2 ownership structures can be defined:

Technology ownership structure # 1

[['source 1', 'source 1 ext tech'],
['source 2', 'source 2 ext tech'],
['sink 1', 'sink 1 utl tech']]

Under this ownership structure, all the actors own (or invest in) technologies that are installed at their respective premises.

Technology ownership structure # 2

[['source 1', 'source 1 ext tech'],
['source 1', 'source 2 ext tech'],
['source 1', 'sink 1 utl tech']]

Under this ownership structure, only one actor (source 1) invests in all the technologies.

Table 2 and Table 3 represent the input for the BM and internal heat recovery functions. Appendix A and B represent examples of these input variables. Figure 1 depicts the interaction of BM function with other modules while appendix E depicts the same for internal heat recovery function.

Table 2: Input description for BM function. (TEO = Techno-economic module, MM = Market module, GIS = Graphical information system module)

Input name	Description	Units	From
capex_t_values	Capital cost of all the technologies like heat pump, backup boiler, and heat exchanger used for a given excess heat extraction projection is given in this array. All the capital costs should be discounted in case investments are made at some other time instead of the start of the project. The capital investments into storage and network are not included here.	€	TEO
capex_t_names	The code name for each technology, to connect it with different ownership structures.		TEO
capex_s_values	Capital cost for investment into storage. All the capital costs should be discounted.	€	TEO
capex_s_names	The code name for each storage unit, to connect it with different ownership structures.		TEO
sal_t_values	Salvage value at the end of project lifetime in €. The order should be the same as in capex_tt. The technologies with no salvage value at the end of the project should be represented as zero. The salvage cost for storage is not included under this variable.	€	TEO
sal_s_values	Salvage value at the end of project lifetime in €. The order should be the same as in capex_st. Only includes salvage value of storage.	€	TEO
opex_t_values	The fixed operation and maintenance cost of each technology used for excess heat utilization project.	€/year	TEO
net_cost	Total network cost in € to connect sources with sinks for a given excess heat utilization project.	€	GIS
price_h	Excess heat price in €/kWh under different market framework. Under uniform price market where each actor interacts with the same price, this should contain a time series with price for each	€/kWh each hour	MM

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	time step. Under non-uniform price mechanism where each actor interacts with a different price, then this should be a matrix with each row for each actors' price time series.		
Dispatch_ah	Dispatch of each actor in kWh. For time steps with no dispatch, zero should be added. It should be provided as 2D matrix with rows corresponding to each actor and columns should be equal to the number of time steps. The size of time steps (hours or days) must be same for dispatch_ah and price_h.	kWh each hour	MM
op_cost_i	Total variable operational cost for each actor based on the total duration of a simulation.	€/year	MM
rls	Technology ownership. A relationship matrix to determine the ownership structure of the different actors.		User
rls_map	Linking code actor names to their real names.		
discount_rate	Separate discount rates for socio-economic and private business scenarios.	%	User
project_duration	Lifetime of the project.	years	User

Table 3: Input description for the internal heat recovery function.

Input name	Description	Units	From
capex	The total capital investments for an internal excess heat recovery project.	€	CF
O&M_fix	Fixed operation cost in a year for the technologies used in internal heat recovery.	€/year	CF
duration	Project lifetime in years.	years	CF
money_sav	Total money saved by using internal excess heat. As the excess heat is going to replace some other energy, the money saved by this replacement goes into this variable.	€/year	CF
energy_dispatch	Total excess heat used in a year.	kWh/year	CF
discount_rate	The discount rate provided by the user.	%	CF
carbon_Sav_quant	Avoided carbon emissions due to utilization of excess heat.	kg/MWh	CF

3.2.2 Outputs and Reporting

The output of the BM function consists of Payback period, NPV and IRR for both socio-economic and private business scenarios. For the socio-economic scenario, only single Payback period, NPV and IRR for the whole project is calculated. The sensitivities of NPV and IRR over different values of socio-economic discount rates are also calculated. For private business scenario, Payback, NPV and IRR are calculated for each actor involved for a given ownership structure specified by the user. Sensitivity analysis is also performed over the different private business discount rates values. Under a private-business scenario, LCOH for sinks is calculated due to a lack of information on the generated cash inflows or revenues. For example, if the sink is an office building, then utilization of excess heat will bring certain benefits or revenues for that office building like reduction in heating/cooling bills etc. Such benefits/revenues are not quantified under this platform, making it impossible to calculate NPV and IRR for the sinks as information on revenues is not available. Therefore, for sinks, under the private business scenario, LCOH is calculated instead. Table 4 represents the description of outputs for BM function. Appendix C provides more technical details for these outputs, along with examples.

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Table 4: Output description for the BM function.

Output name	Description	Units
NPV_socio-economic	Net Present Value for the socio-economic scenario	€
IRR_socio-economic	Internal rate of return for the socio-economic scenario	%
Sensitivity_NPV_socio-economic	NPV for socio-economic scenario along with results of the sensitivity analysis over discount rate	€
Payback period socio_economic	Payback period of socio-economic scenario which represents the payback period of the project as a whole.	years
NPV_comm_actor	NPV for each actor under private business scenario	€
IRR_comm_actor	IRR for each actor under private business scenario	%
Payback period_comm_actor	Payback period for each actor involved.	years
Sensitivity_NPV_comm_actor	NPV for each actor under private business scenario along with the results of the sensitivity analysis over discount rate	€
Discountrate_socio	Socio-economic discount rate along with values used for sensitivity analysis	%
Discountrate_business	Private business discount rate along with values used for sensitivity analysis	%
LCOH_s	Levelized cost of heat for sinks under private-business scenario.	€ /kWh

Similarly, the output of the internal heat recovery function, presented in table 5, consists of LCOH of the heat recovery project and NPV. Appendix D provides more details for these outputs along with examples.

Table 5: Output description for the internal heat recovery function.

Output name	Description	Units
LCOH_sen	Levelized cost of heat for internal heat recovery	€ /kWh
NPV_sen	NPV for internal heat recovery along with sensitivity analysis over discount rate	€

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3.2.3 Platform interface

When running the EMB3Rs platform, an input section is dedicated for business module's input. Each input parameter has default values that can be changes as deemed necessary. The input section is displayed in the figure below.

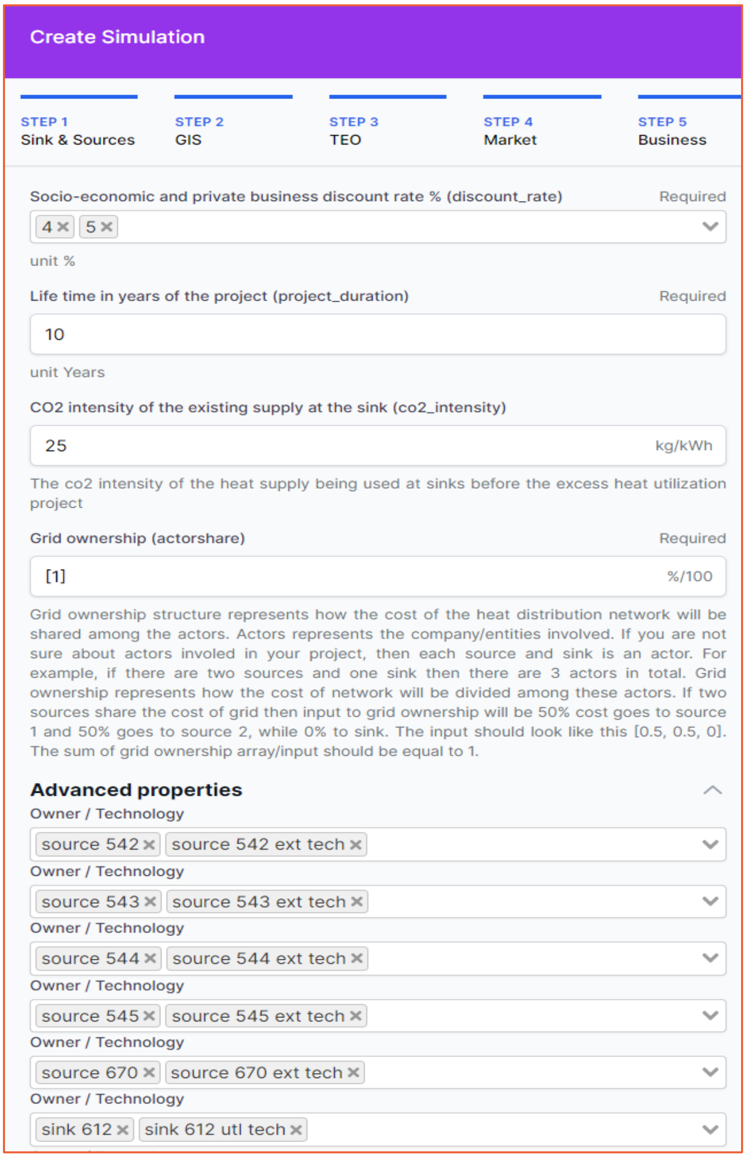

Figure 2 Screenshot of input window for business module in EMB3Rs platform.

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4 Conclusion

This report provides a detailed overview of the Business Module. The system manual provides the theoretical background for the Business Module, while the user manual explains in detail the important requisites for running the Business Module. The Business Module is closely integrated with other modules under the EMB3Rs platform. In addition to a socio-economic perspective, the Business module also introduces a private business perspective. For the private business perspective, the user needs to define the project's ownership structure, which basically defines who owns what in the whole project. The output of the Business Module includes the result of the sensitivity analysis. These outputs are displayed as graphs on the platform, providing a comprehensive overview of the profitability of a given case study.

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5 Appendix

5.1 Appendix A: Inputs with examples for BM function.

Table A: Inputs with examples for BM function.

Input name	Example	Technical Description
capex_t_values	[100, 200, 300]	1D NumPy array, with elements equal to total number of technologies used.
capex_t_names	["source_1_storage", heat exchanger_at_source32", "sink_1_storage"]	String list
capex_s_values	[10, 15]	1D NumPy array, with elements equal to total number of storages used.
capex_s_names	["stor_source", "stor_sink"]	String list
sal_t_values	[0, 5, 15]	1D NumPy array, with elements equal to total number of technology.
sal_s_values	[0, 0]	1D NumPy array, with elements equal to total number of storages.
opex_t_values	[10,20,0]	1D NumPy array with elements equal to total number of technologies.
net_cost	500	A fixed number.
price_h	[1,2,3,4,5] or [[1,2,3,4,5], [11,12,13,14,15]]	1D OR 2D NumPy array; number of column should be equal to number of hours and number of rows equal to number of actors (in case of non-uniform prices)
Dispatch_ah	[[10,20,30,40,50], [0,0,0,30,50]]	2D NumPy array; number of columns should be equal to number of hours and number of rows should be equal to number of actors.
op_cost_i	[10, 0]	1D NumPy array with elements equal to number of actors
rls	[[‘sink 1’, ‘sink 1 extraction tech’], [‘sink 1’,’sink 2 ext tech’], [‘source 2’,’source 2 utl tech’]]	String list.
Rls_map	[["sink_1", "supermarket"], [‘sink 2’, ‘office’]. [‘source 2’, ‘cement plant’]]	String list.
discount_rate	[4, 5]	1D NumPy array with two elements.
project_duration	10	A fixed number.
actorshare	[0.5, 0.5]	1 D numpy array.

5.2 Appendix B: Inputs with examples for internal heat recovery function.

Table B: Inputs with examples for internal heat recovery function

Input name	Example	Technical Description
capex	100	A fixed number.
O&M_fix	5	A fixed number.
duration	10	A fixed number.
money_sav	20	A fixed number.
energy_dispatch	300	A fixed number.
dsicount_rate	4	A fixed number.

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carbon_Sav_quant	3	A fixed number.

5.3 Appendix C: Outputs with examples for BM function.

Table C. Outputs with examples and technical details for BM function.

Output name	Example	Technical Description
NPV_socio-economic	100	A fixed number.
IRR_socio-economic	0.04	A fixed number.
Payback period socio_economic	5	A fixed number.
Sensitivity_NPV_socio-economic	[50, 75, 100, 125, 150]	1D NumPy array
NPV_comm_actor	[100, 200]	1D NumPy array
IRR_comm_actor	[0.03, 0.05]	1D NumPy array
Sensitivity_NPV_comm_actor	[[50, 75, 100, 125, 150], [150, 175, 200, 225, 250]]	2D NumPy array, with number of rows equal to number of actors.
Payback period_comm_actor	[50, 75, 100, 125, 150]	1D NumPy array
Discountrate_socio	[1, 2, 3, 4, 5]	1D NumPy array
Discountrate_business	[3, 4, 5, 6, 7]	1D NumPy array
LCOH_s	[136]	1D NumPy array, with elements equal to number of sinks

5.4 Appendix D: Outputs with examples for internal heat recovery function.

Table D: Outputs with examples and technical details for internal heat recovery function.

Output name	Example	Technical Description
LCOH_sen	[136]	1D NumPy array
NPV_sen	[1, 2, 3, 4, 5]	1D NumPy array

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5.5 Appendix E: Interaction of the internal heat recovery function with other modules

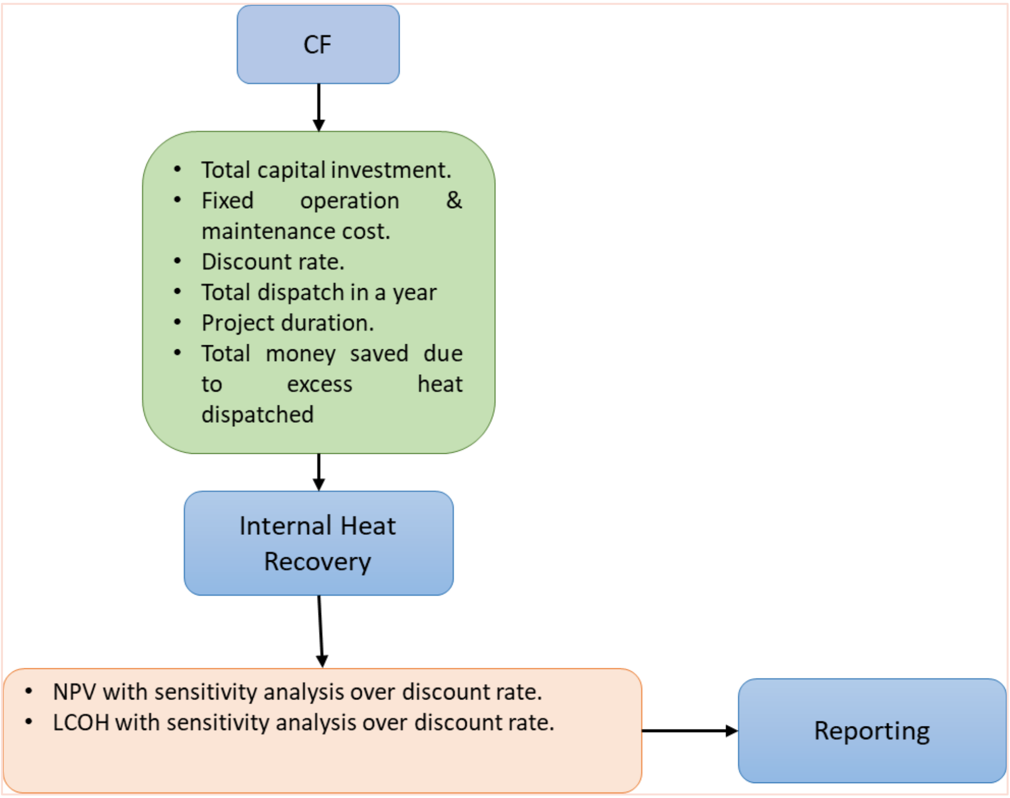

Figure E: Depiction of interaction of internal heat recovery function with other modules.

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