Getting started with Simulis® Pinch
Energy module

Use Case 3: Energy integration of an esterification process
- Case study and specifications with Simulis Pinch Energy

Release Simulis Pinch 2.0.0

Software & Services In Process Simulation

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ProSim

Introduction

This getting started shows you the use of the **case study** functionality of Simulis Pinch Energy to perform an economic analysis of a process energy integration.

This example is linked with the ProSimPlus application example named "Energy analysis of an esterification process from vegetable oil.“

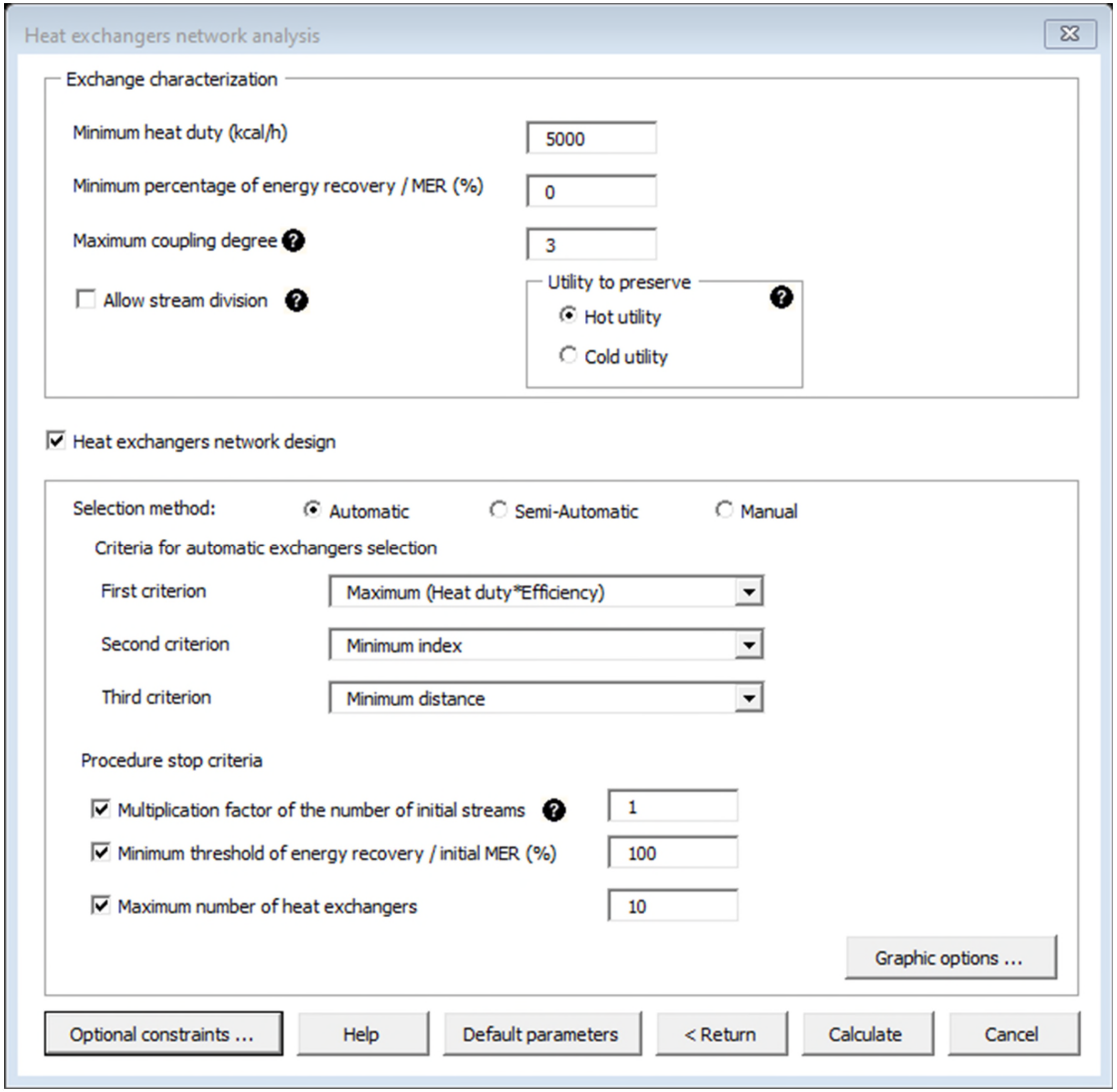
This document follows the getting started "Case 2: Energy integration of an esterification process - Advanced use of Simulis Pinch Energy "

This guide presents the following parts:

- Step 1: Use of the ***Case study*** function
- Step 2: Results analysis
- Step 3: Use of the ***Specification*** function

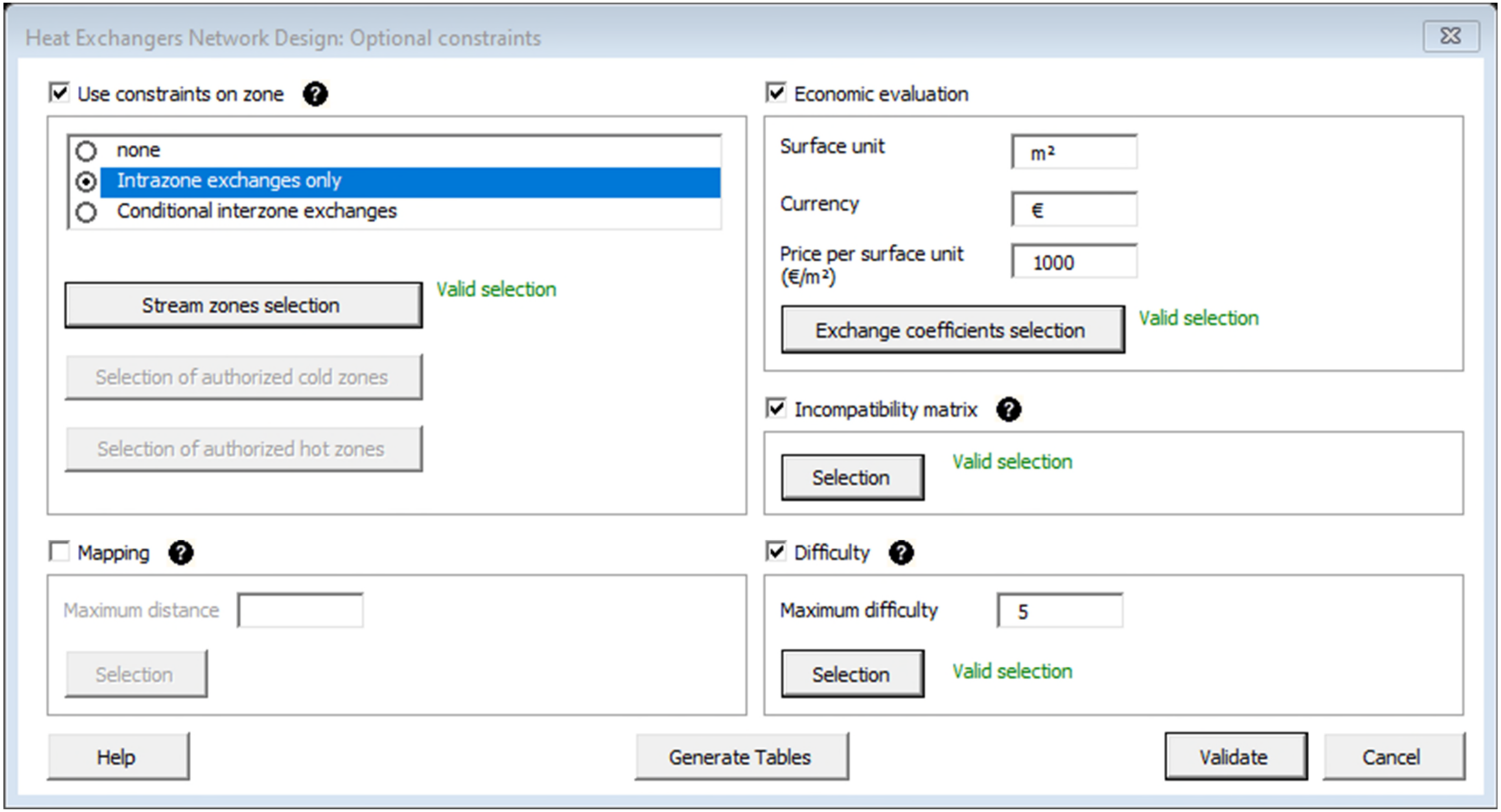
Introduction

The input data and the parameters used in this example are identical to those provided in the getting started "Case 2: Energy integration of an esterification process - Advanced use of Simulis Pinch Energy"



Introduction

Optional constraints are also identical to those presented in the getting started "Case 2: Energy integration of an esterification process - Advanced use of Simulis Pinch Energy "



Step 1: Use of the Case study function

To access to the ***Case study*** function with Simulis Pinch Energy, it is necessary to run the calculations one time to obtain results sheets.

In the sheet "Input data" generated as a result of calculations, the function is available by clicking on the ***Case study*** button:

PINCH

Pinch value	10	(°C)	Case study	Specification
Heat duty unit	(kcal/h)			

Stream names	Physical state	F*Cp (kcal/h/°C)	Input T (°C)	Target T (°C)
C1	L	5 598,5	25,0	135,0
C16	L	12 863,6	45,0	54,0
C4	L	17 535,5	96,0	200,0
C7	LV	53 389,9	90,8	100,0
C17	L	13 172,4	54,0	61,8
C13	L	6 140,5	65,0	88,0
C23	L	15 527,9	76,6	200,0
C28	LV	12 990,1	38,6	70,0
C29	LV	6 902,6	70,0	150,0
Rebo.C301	L	12 420,4	83,9	136,2
C61	LV	865,0	116,9	140,0
C10	L	7 064,3	100,0	80,0
C11	L	6 859,1	80,0	65,0
C43	V	86 842,1	100,0	82,1
C26	LV	225,0	76,7	76,7
C30	V	42 039,9	76,7	25,0
C33	V	5 143,6	150,0	25,0
C36	L	5 811,4	150,0	79,8
C39	L	5 149,4	79,8	57,3
Cond.C301	V	152 710,2	48,4	38,5
C52	V	189,7	140,0	11,0
C62	L	4 952,8	57,7	20,0
C51	L	623,5	70,0	20,0
C50	L	701,4	140,0	70,0

Step 1: Use of the Case study function

As presented and explained in the sheet, the user has to define the parameters that he wants to change to perform the case study.

For this example, the pinch value is the variable of the case study.

The following pinch values will be used: 5, 10, 12, 15, 20, 25, 30, 35, 40 and 50°C.

Case study

1) Fill one or more cells for parameters (blue cells)
2) Press button to complete with default values (if necessary)
3) Press button to execute the calculation
Note: To use a solver resolution, refer to the 'Specification' button on the input data sheet

Complete with default paramaters

Modifiable input data list

Input sheet name	Input data				
Type of pinch analysis	Energy				
1 Pinch value (°C)	5	10	12	15	20
2 Minimum heat duty (kcal/h)					
3 Minimum percentage of energy recovery / MER (%)					
4 Maximum coupling degree					
5 Allow stream division					
6 Multiplication factor of the number of initial streams					
7 Minimum threshold of energy recovery / initial MER (%)					
8 Maximum number of heat exchangers					

Step 1: Use of the Case study function

When the different pinch values are indicated, the ***Complete with default parameters*** button is displayed. Click on this button to fill the missing parameters necessary for the case study

Case study

1) Fill one or more cells for parameters (blue cells)
2) Press button to complete with default values (if necessary)
3) Press button to execute the calculation
Note: To use a solver resolution, refer to the 'Specification' button on the input data sheet

Complete with default paramaters

Modifiable input data list

Input sheet name	Input data				
Type of pinch analysis	Energy				
1 Pinch value (°C)	5	10	12	15	20
2 Minimum heat duty (kcal/h)					
3 Minimum percentage of energy recovery / MER (%)					
4 Maximum coupling degree					
5 Allow stream division					
6 Multiplication factor of the number of initial streams					
7 Minimum threshold of energy recovery / initial MER (%)					
8 Maximum number of heat exchangers					

The case study can also be multifactorial (e.g. change of the value of the pinch and the maximum number of heat exchangers)

Step 1: Use of the function Case study

When all input data has been provided, the ***Execute case study*** button is displayed.

Click on this button to run the case study

Case study

1) Fill one or more cells for parameters (blue cells)

2) Press button to complete with default values (if necessary)

3) Press button to execute the calculation

Note: To use a solver resolution, refer to the 'Specification' button on the input data sheet

Execute case study

Modifiable input data list

Input sheet name	Input data				
Type of pinch analysis	Energy				
1 Pinch value (°C)	5	10	12	15	20
2 Minimum heat duty (kcal/h)	5000	5000	5000	5000	5000
3 Minimum percentage of energy recovery / MER (%)	0	0	0	0	0
4 Maximum coupling degree	3	3	3	3	3
5 Allow stream division	False	False	False	False	False
6 Multiplication factor of the number of initial streams	1	1	1	1	1
7 Minimum threshold of energy recovery / initial MER (%)	100	100	100	100	100
8 Maximum number of heat exchangers	10	10	10	10	10

The parameters used to complete the input data are the ones of the "Input Data" sheet

Step 1: Use of the Case study function

After clicking on the button for the case study run, Simulis Pinch Energy performs the calculation loops on each case (several runs are achieved):

Modifiable input data list

Input sheet name	Input data			
Type of pinch analysis	Energy			
1 Pinch value (°C)	5	10	12	15
2 Minimum heat duty (kcal/h)	5000	5000	5000	5000
3 Minimum percentage of energy recovery / MER (%)	0	0	0	0
4 Maximum coupling degree	3	3	3	3
5 Allow stream division	False	False	False	False
6 Multiplication factor of the number of initial streams	1	1	1	1
7 Minimum threshold of energy recovery / initial MER (%)	100	100	100	100
8 Maximum number of heat exchangers	10	10	10	10

Monitored variable list

1 Initial number of possible exchanges	20	18	16	13
2 Multiplication factor for the initial number of streams	0,833333333	0,833333	0,916667	0,833333
3 Cumulative percentage of energy recovery	29,96870326	35,95188	37,03133	37,61481
4 Number of heat exchangers	4	4	4	6
5 Total energy recovery (kcal/h)	768153,5603	768153,6	761239,1	720659,4
6 Energy to recover (kcal/h)	1500420,163	1077894	1003855	904665
7 Additional required amount of cold utility (kcal/h)	6179185,203	6179185	6186100	6226679
8 Additional required amount of hot utility (kcal/h)	6068990,284	6068990	6075905	6116484
9 Hot utility exchangers number	10	10	11	10
10 Cold utility exchangers number	10	10	11	10
11 Global exchange area (m²)	153,8095191	153,8095	105,5163	74,44877
12 Global investment (€)	153809,5191	153809,5	105516,3	74448,77

Results of the case study

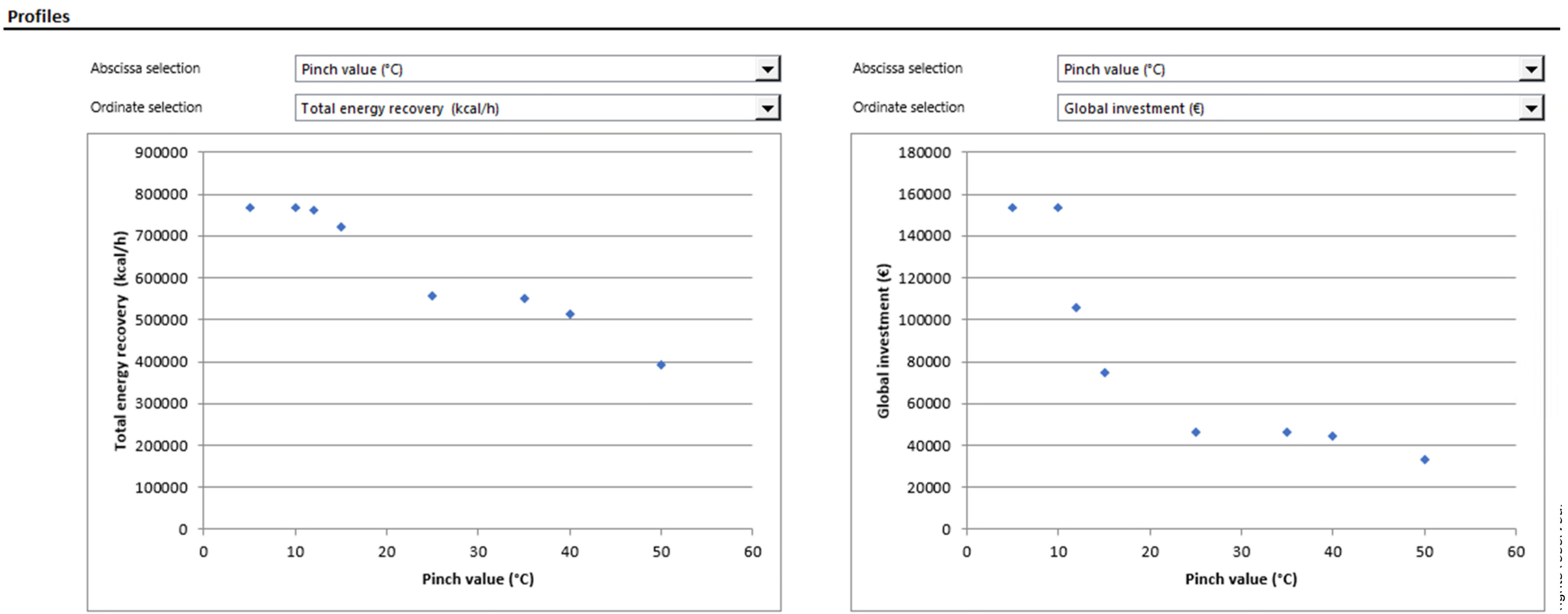
Convergence status	No acceptable exchanges were found before reaching a stop criterion!	No acceptabl e exchange s were found before	No acceptabl e exchange s were found before	No acceptabl e exchange s were found before

Convergence messages

Step 1: Use of the Case study function

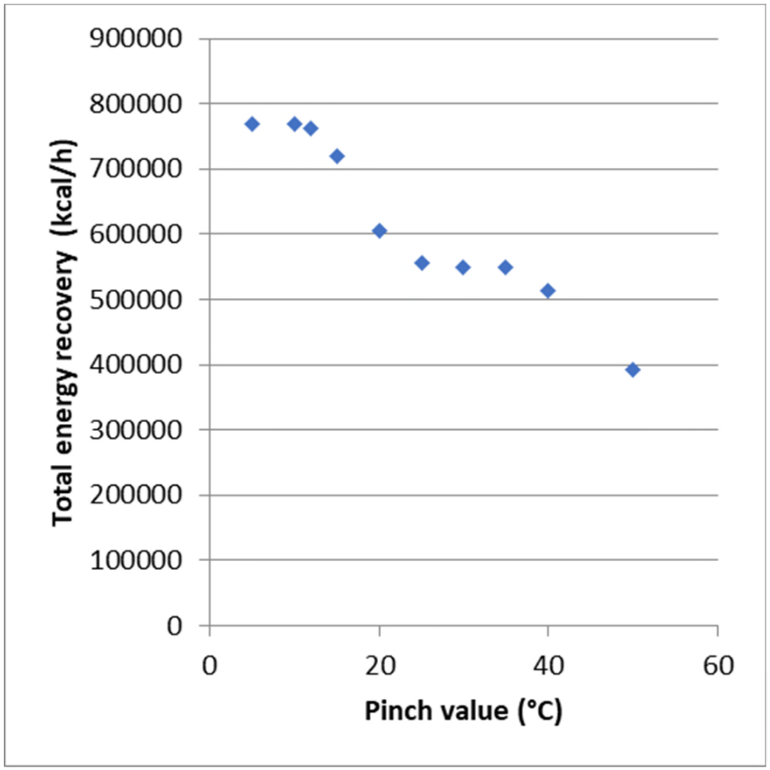
Under the results tables, you can also view the results profiles of the case study.

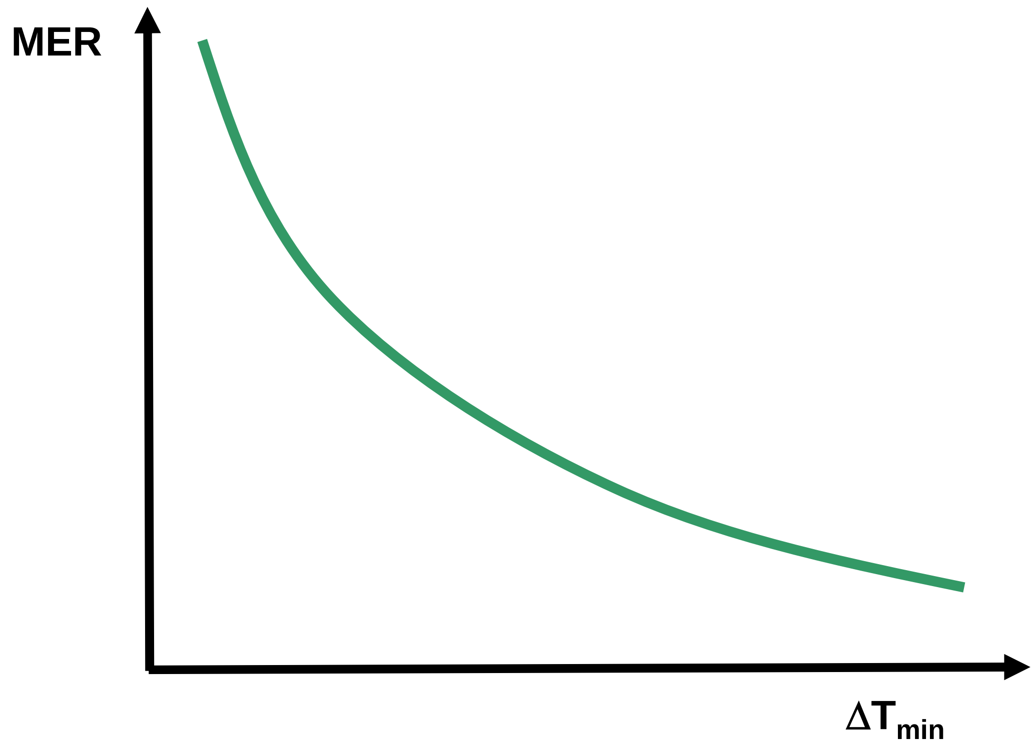
The user has the option to change the default displayed profiles. It is possible to change the x-axis and y-axis among the predefined list:



Step 2: Results analysis

Profiles automatically displayed by Simulis Pinch Energy make it easy to analyze the results.
Regarding this example, it is interesting to observe the change of the total energy recovery depending on the value of the pinch (ΔT_{min}):



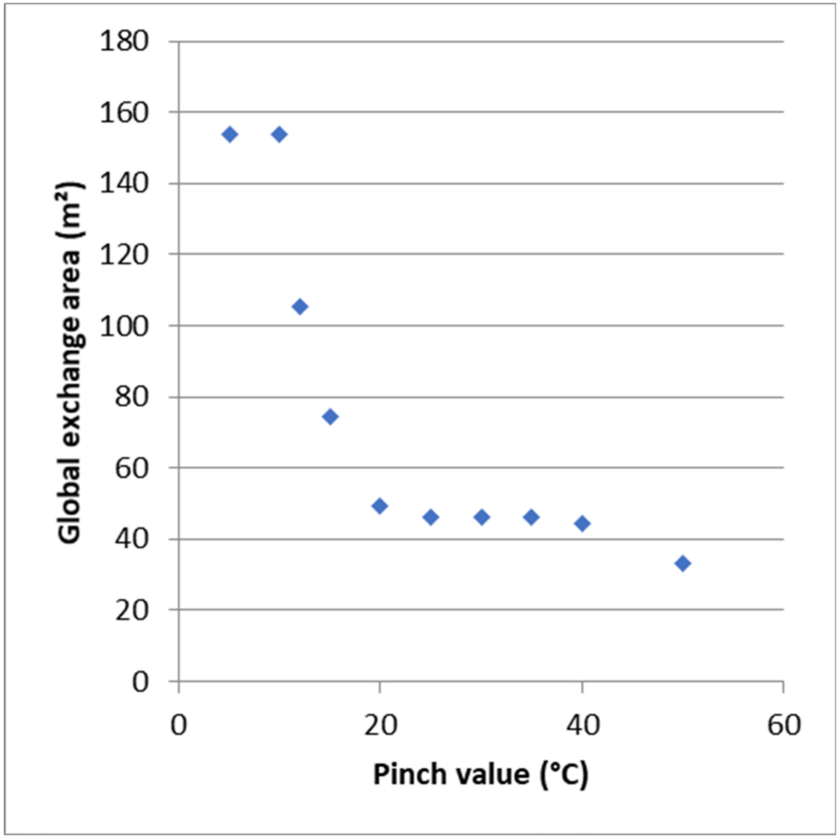


The evolution of the energy recovery compared to ΔT_{min} is consistent with the theory: the lower the pinch is, the higher MER (Maximum Energy Recovery) is. It is logical to recover more energy (with the heat exchanger network) if the MER increases.

Interesting observation: If the ΔT_{min} is less than 10°C, the MER is stagnating.
To minimize heat exchange areas, it is not necessary to decrease the pinch below 10°C because the MER does not increase.

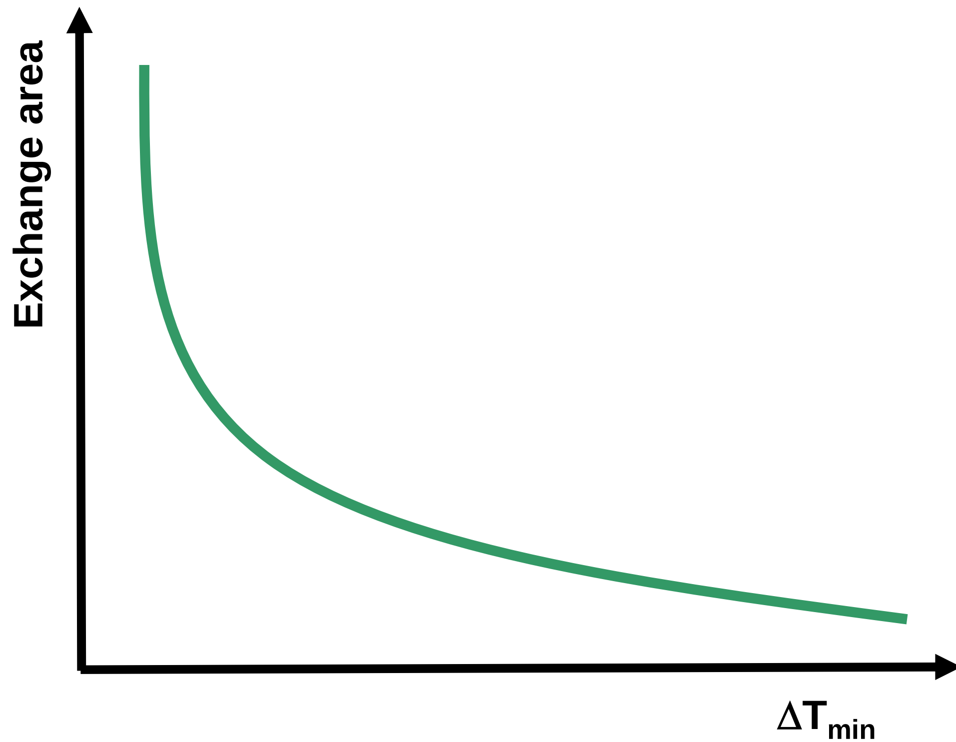
Step 2: Results analysis

The profile ***Global exchange area*** according to the ***Pinch value*** allows also to put forward a theoretical concept: the lower the pinch is, the lower the logarithmic mean temperature difference (LMTD) is and therefore the higher the heat exchange area is for the same heat duty exchanged



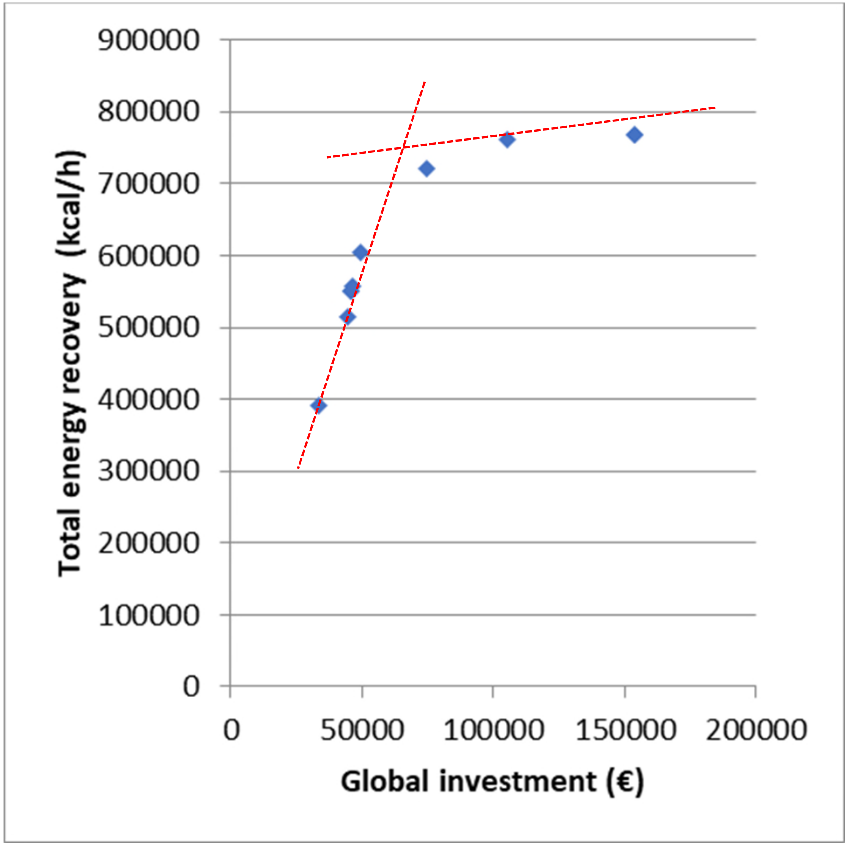
$$Q = U * A * LMTD$$

Q: Heat duty exchanged
U: Global heat transfer coefficient
A: Exchange area



Step 2: Results analysis

The user can generate, in MS-Excel, a profile of ***Total energy recovery*** depending on ***Global investment***



The analysis of this profile shows an inflection point. This inflection is between a pinch value of 12 and 15°C.

It means that:

- First part of the curve: the more the heat exchanger network can recover energy and the more the network cost is expensive
- Second part of the curve: from the inflection point, heat exchanger network costs much more but can not recover much more energy

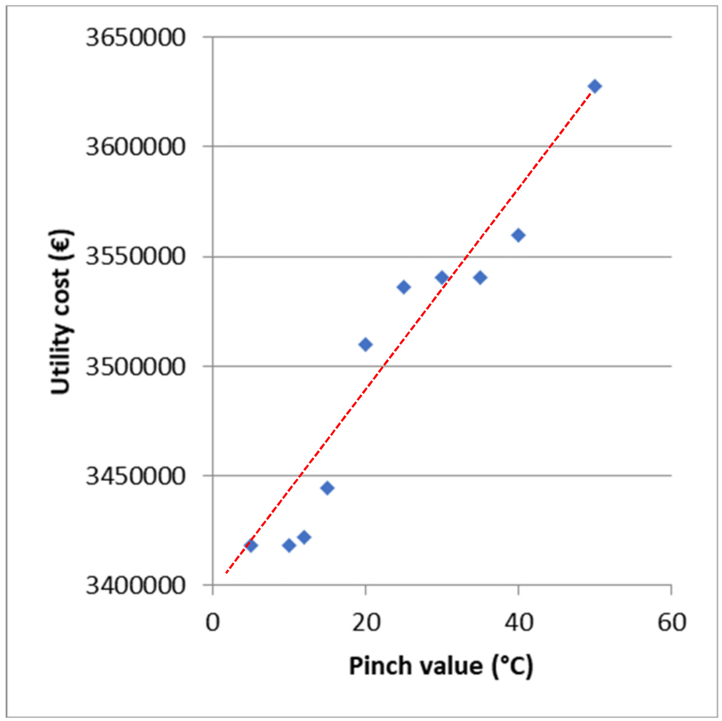
Step 2: Results analysis

The user can also perform a more advanced economic analysis directly with MS Excel.
For example, assuming a cost of cold and hot utility of 30 €/MWh, it is then possible to add the annual cost of utilities (assuming 8000 hours/year of operating time).

Monitored variable list

1	Initial number of possible exchanges	20
2	Multiplication factor for the initial number of streams	0,833333333
3	Cumulative percentage of energy recovery	29,96870326
4	Number of heat exchangers	4
5	Total energy recovery (kcal/h)	768153,5603
6	Energy to recover (kcal/h)	1500420,163
7	Additional required amount of cold utility (kcal/h)	6179185,203
8	Additional required amount of hot utility (kcal/h)	6068990,284
9	Hot utility exchangers number	10
10	Cold utility exchangers number	10
11	Global exchange area (m^2)	153,8095191
12	Global investment (€)	153809,5191
	Utility cost (€)	=0,03*(E31+E32)*8000/860

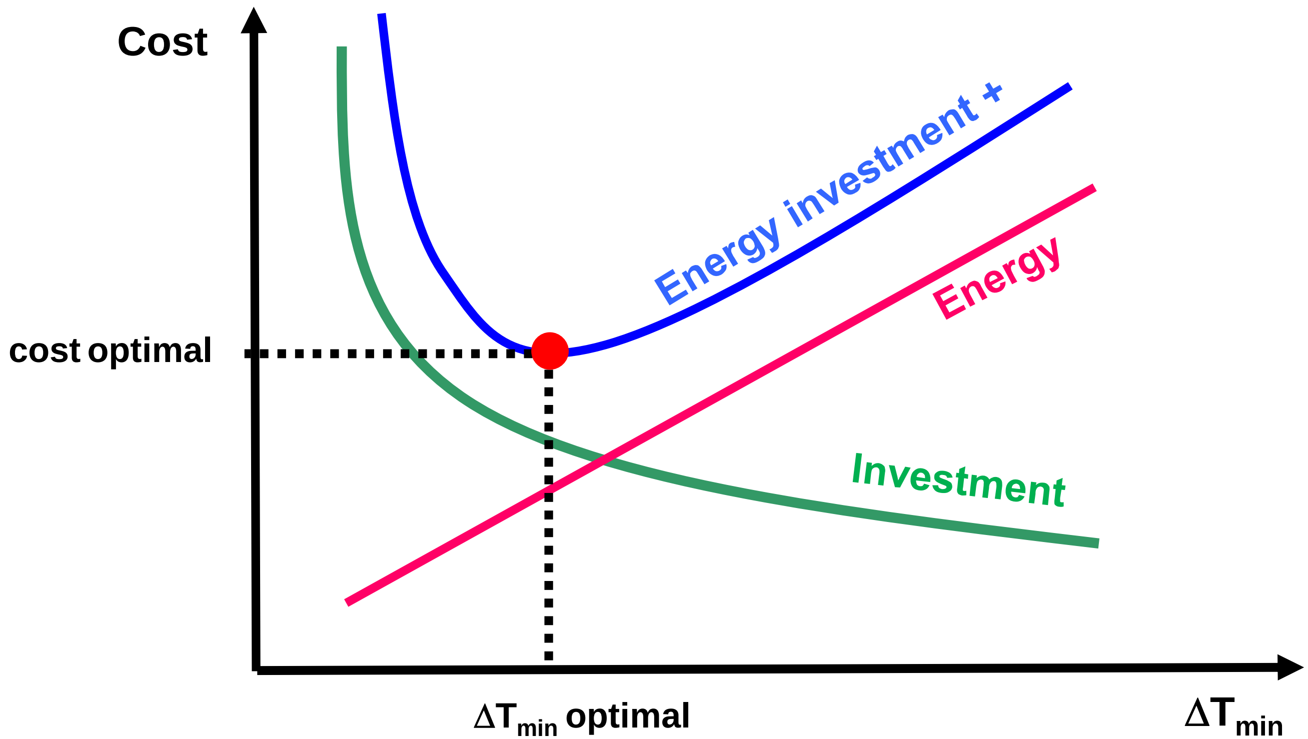
The utility cost function depending on the pinch value shows a linear curve fitting.



Step 2: Results analysis

This economic analysis shows a theoretical concept:

- The more the pinch increases, the less energy recovery is effective because the MER decreases. Therefore, the cost of energy (cost of utility) increases with the pinch increasing
- The more the pinch decreases, the more the heat exchanger network is efficient and recovers energy. But the more the pinch decreases, the more the exchange area and therefore investment increase

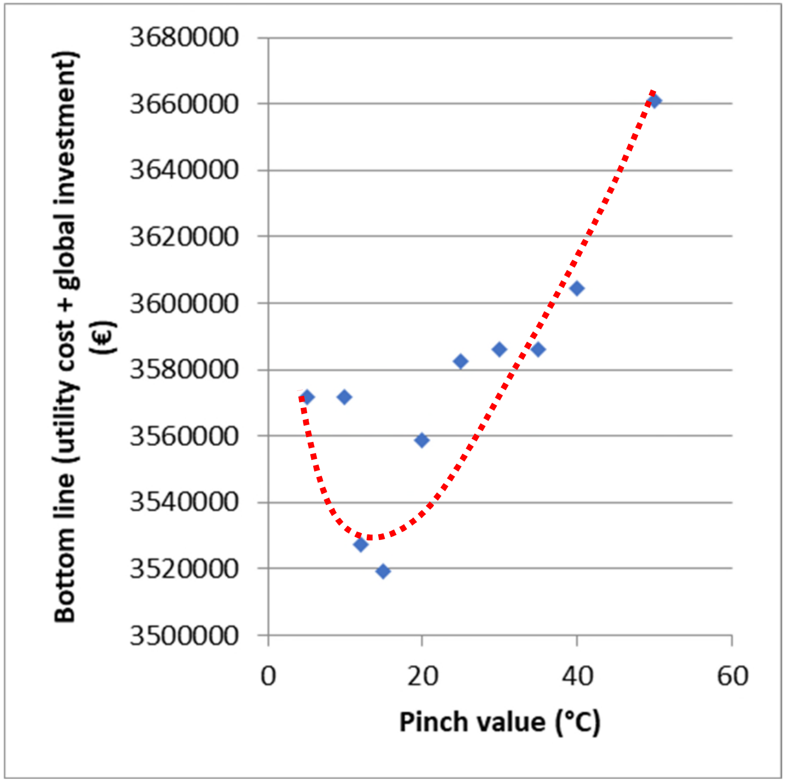


In theory, there is an optimal pinch value for which the network is optimal

Step 2: Results analysis

The economic analysis of this example highlights this theoretical concept.

If the user performs a bottom line of the costs (sum of the cost of the utility and the overall investment), the following profile can be drawn:



In theory, the optimal pinch value is between 12 and 15°C.

In this example, a pinch of 10°C was chosen to maximize energy recovery for a total investment cost close to the optimal cost.

Step 3: Use of the specification function

To access to the ***Specification*** function with Simulis Pinch Energy, it is necessary to run the calculations one time to obtain results sheets.

In the "Input data" sheet generated as a result of calculations, the function is available by clicking on the ***Specification*** button:

PINCH

Pinch value	10	(°C)
Heat duty unit	(kcal/h)	

Case study | Specification

Stream names	Physical state	F*Cp (kcal/h/°C)	Input T (°C)	Target T (°C)
C1	L	5 598,5	25,0	135,0
C16	L	12 863,6	45,0	54,0
C4	L	17 535,5	96,0	200,0
C7	LV	53 389,9	90,8	100,0
C17	L	13 172,4	54,0	61,8
C13	L	6 140,5	65,0	88,0
C23	L	15 527,9	76,6	200,0
C28	LV	12 990,1	38,6	70,0
C29	LV	6 902,6	70,0	150,0
Rebo.C301	L	12 420,4	83,9	136,2
C61	LV	865,0	116,9	140,0
C10	L	7 064,3	100,0	80,0
C11	L	6 859,1	80,0	65,0
C43	V	86 842,1	100,0	82,1
C26	LV	225,0	76,7	76,7
C30	V	42 039,9	76,7	25,0
C33	V	5 143,6	150,0	25,0
C36	L	5 811,4	150,0	79,8
C39	L	5 149,4	79,8	57,3
Cond.C301	V	152 710,2	48,4	38,5
C52	V	189,7	140,0	11,0
C62	L	4 952,8	57,7	20,0
C51	L	623,5	70,0	20,0
C50	L	701,4	140,0	70,0

Step 3: Use of the specification function

The "Specification" sheet offers the same functionality as the "Case study" sheet.
The only difference with the ***Case study*** function is that the calculation is performed automatically (autorun).
The user has to provide only one value and the calculation runs.

Specification

1) Fill one or more cells for parameters (blue cells)
2) Calculation is done automatically
Note: A solver resolution is available
A goal seek or Data table analysis is unavailable

Modifiable input data list

Input sheet name	Input data
Type of pinch analysis	Energy
1 Pinch value (°C)	10
2 Minimum heat duty (kcal/h)	
3 Minimum percentage of energy recovery / MER (%)	
4 Maximum coupling degree	
5 Allow stream division	
6 Multiplication factor of the number of initial streams	
7 Minimum threshold of energy recovery / initial MER (%)	
8 Maximum number of heat exchangers	

Only value supplied by the user

The parameters used for the calculation are the input data of the "input data" sheet

Monitored variable list

1 Initial number of possible exchanges	18
2 Multiplication factor for the initial number of streams	0,833333333
3 Cumulative percentage of energy recovery	35,95187562
4 Number of heat exchangers	4
5 Total energy recovery (kcal/h)	768153,5603
6 Energy to recover (kcal/h)	1077894,227
7 Additional required amount of cold utility (kcal/h)	6179185,203
8 Additional required amount of hot utility (kcal/h)	6068990,284
9 Hot utility exchangers number	10
10 Cold utility exchangers number	10
11 Global exchange area (m²)	153,8095191
12 Global investment (€)	153809,5191

Results of the autorun

This ***Specification*** function is interesting for the use of MS-Excel Solver or any other type of external solver with Simulis Pinch Energy.

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