Getting started with Simulis® Pinch

Energy module

Use Case 2: Energy integration of an esterification process – Advanced use of 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 optional constraints with Simulis Pinch Energy to perform an advanced 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 1: Energy integration of an esterification process – First steps with Simulis Pinch Energy"

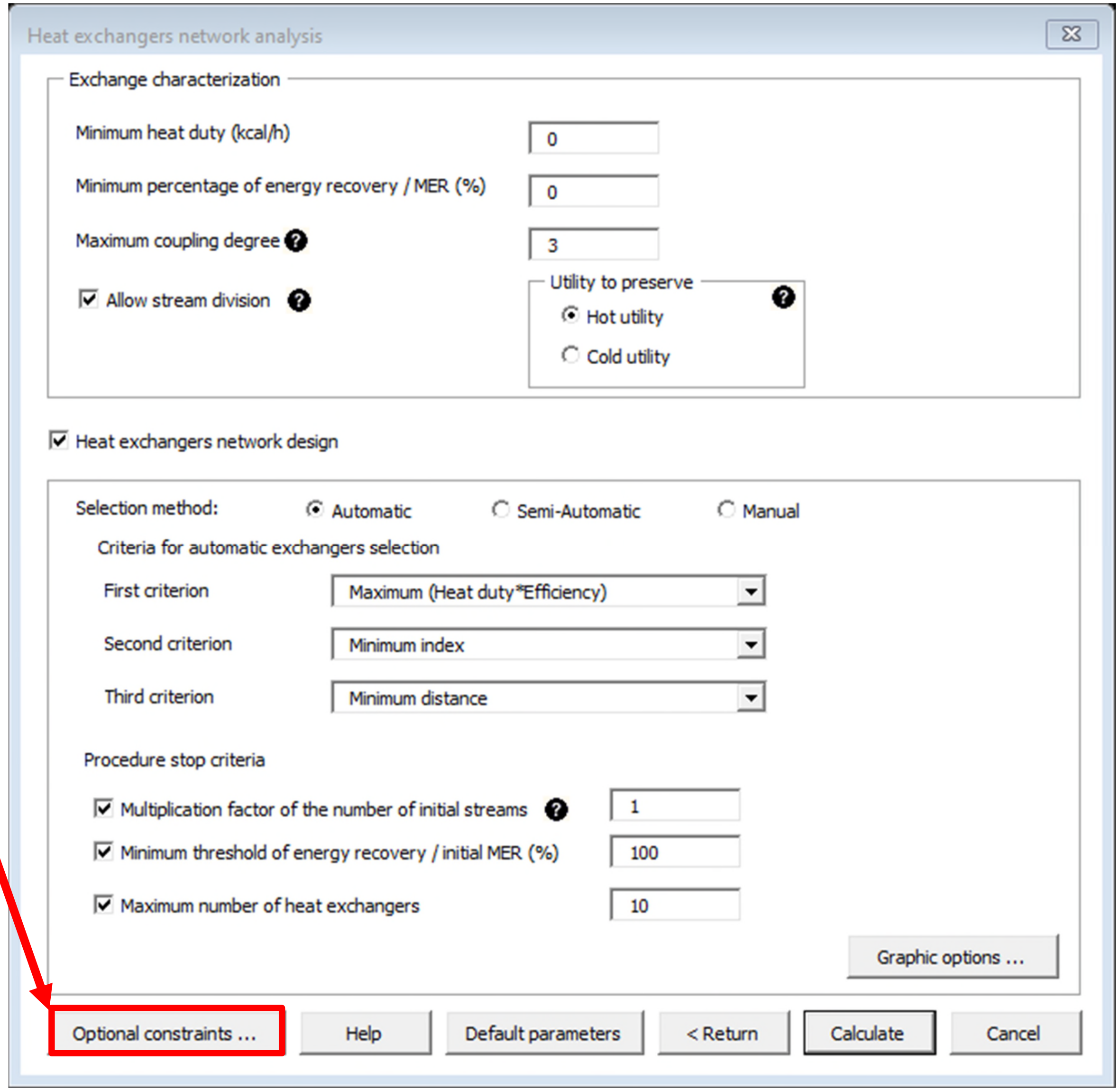
This guide is organized as follows:

- Step 1: Adding a constraint on zones
- Step 2: Adding a distance constraint between streams
- Step 3: Adding an incompatibility matrix
- Step 4: Adding a constraint of "difficulty" between streams
- Step 5: Adding economic assessment

Introduction

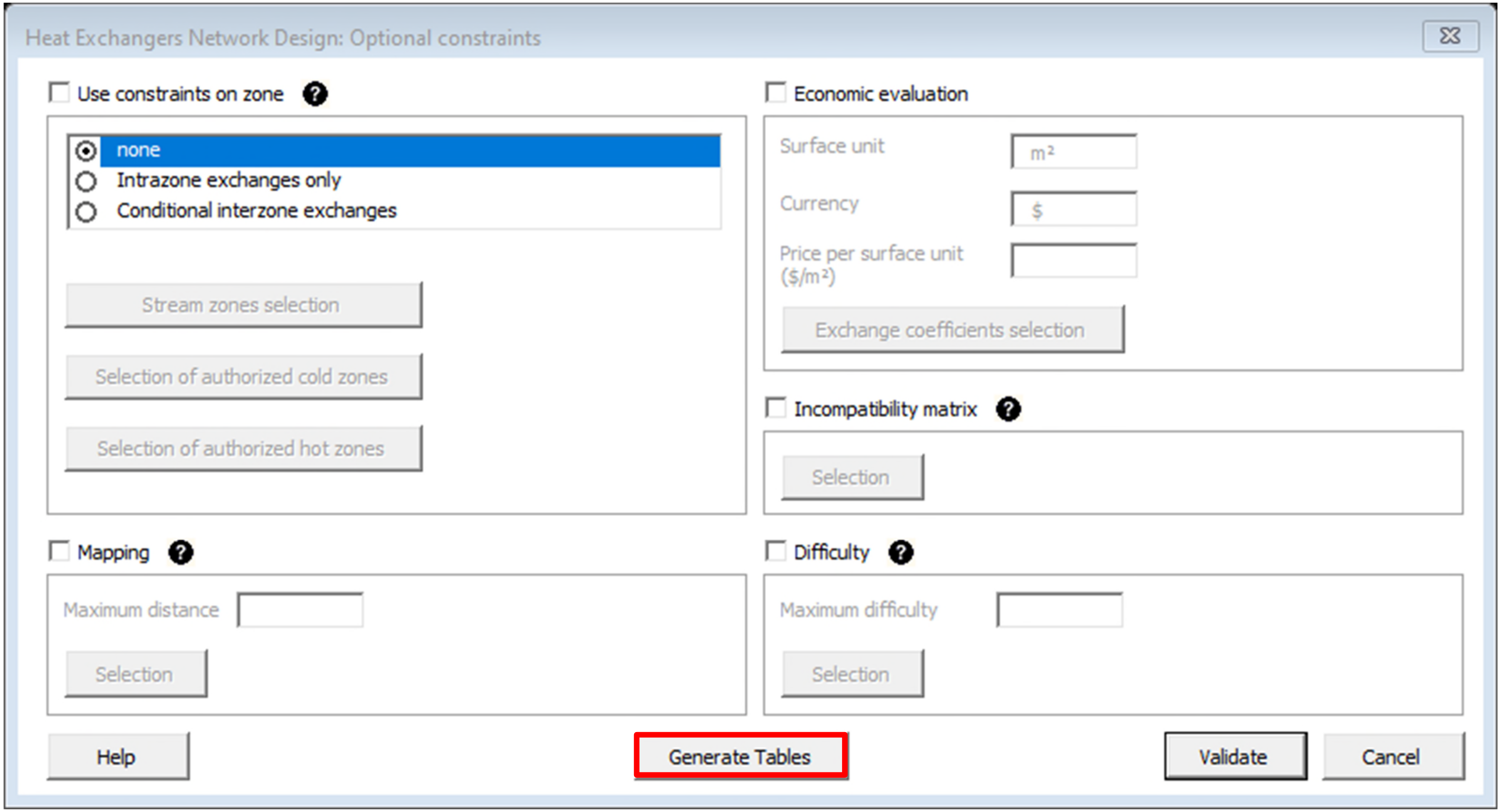
A first step before the use of optional constraints is to reshape the MS-Excel sheet input data:

1. Click on the ***Optional constraints*** button



Introduction

2. Click on the ***Generate tables*** button



Introduction

The input data (stream names, physical state, F*Cp, Tin and Tout) are then reshaped and optional tables are generated in a "Optional Tables" sheet:

Input data				
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

Difficulty

Exchange coefficients (kcal/h/°C/m²)

Geom(x)	Geom(y)	Geom(z)

Background picture size bounds			
Xmin	Xmax	Ymin	Ymax

Step 1: Adding a constraint on zones

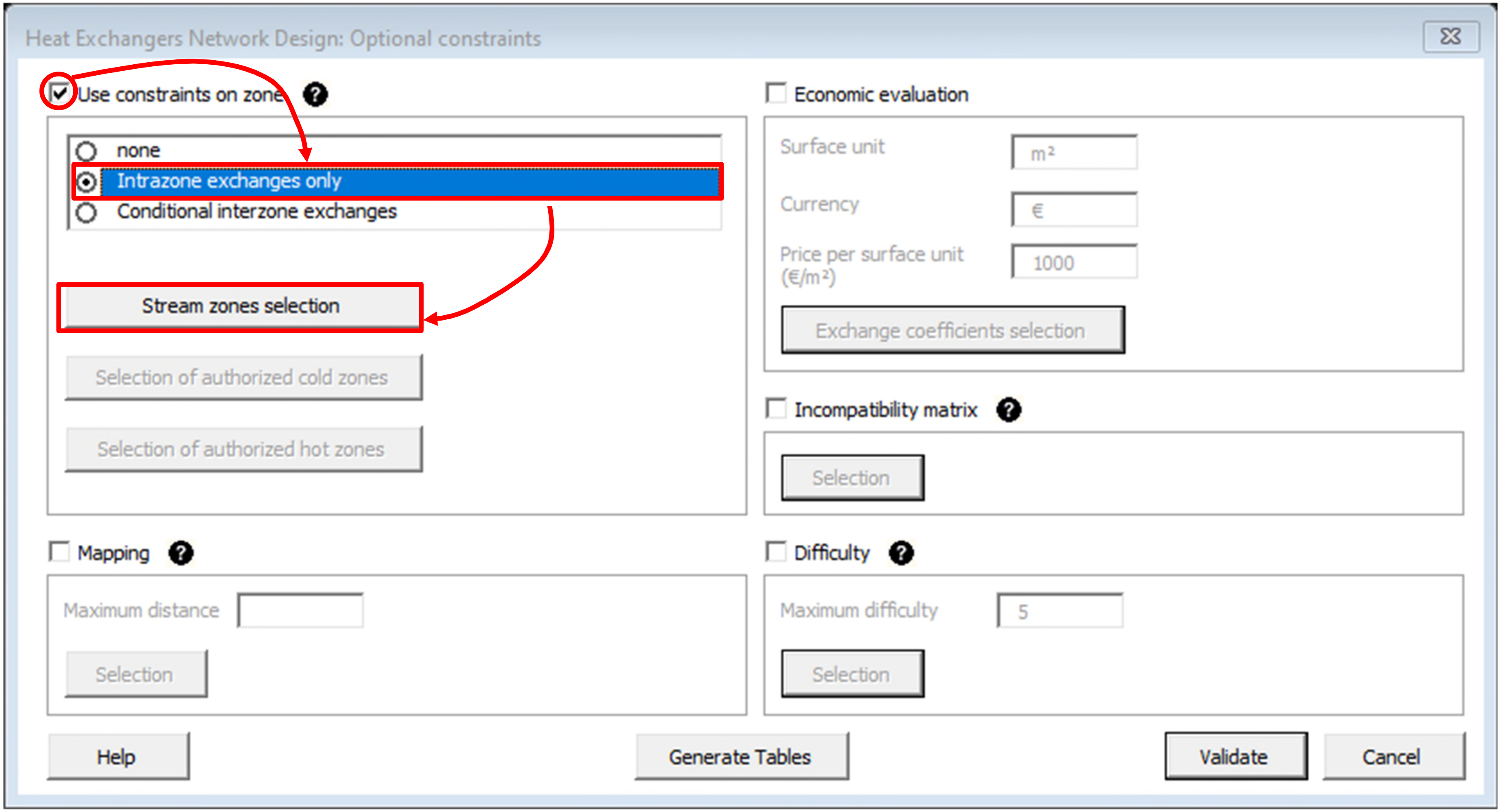
The user defines the areas in which the different streams are present. In the case of this esterification process, three areas are described (esterification, demethanolisation and glycerin purification)

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

Step 1: Adding a constraint on zones

In the optional constraints window:

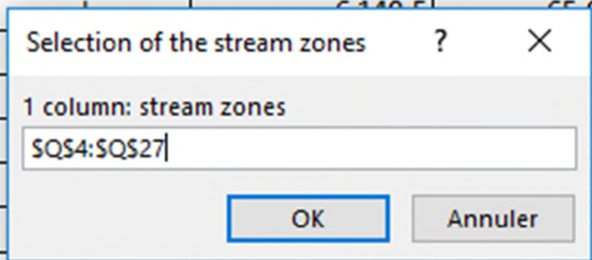
1. Check ***Use constraints on zone*** box
2. Select the constraint to have only intrazone exchanges (the proposed exchangers are made only between the streams of the same zone)
3. Click on the button ***Stream zones selection*** button

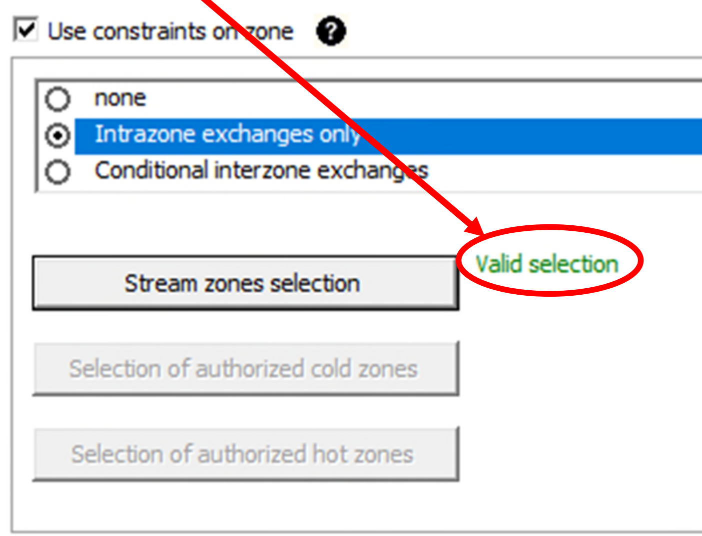


Step 1: Adding a constraint on zones

Selection of the zones:

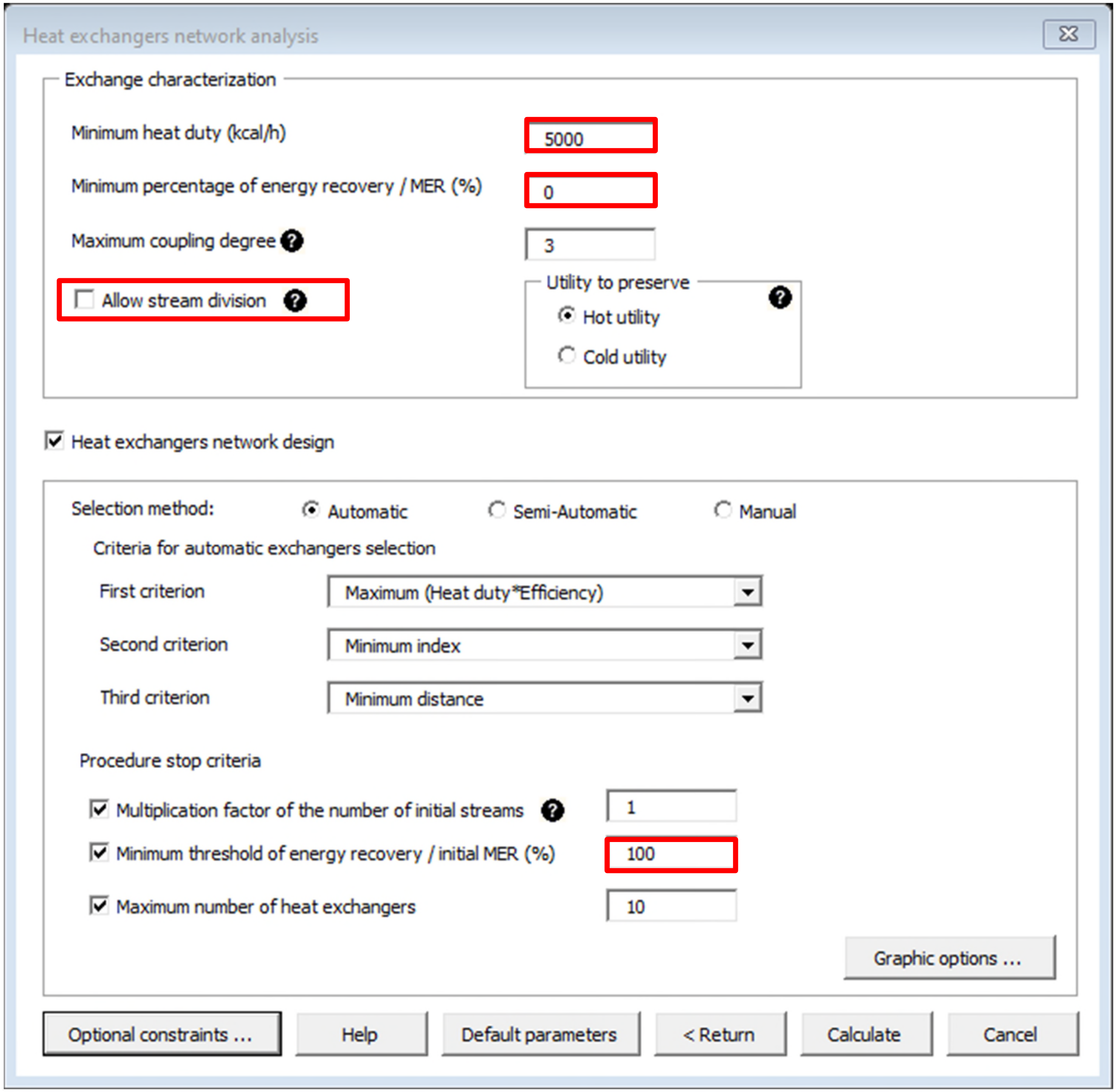
Input data					
Stream names	Physical state	F*Cp (kcal/h/°C)	Input T (°C)	Target T (°C)	Stream Zone
C1	L	5 598,5	25,0	135,0	1
C16	L	12 863,6	45,0	54,0	1
C4	L	17 535,5	96,0	200,0	1
C7	LV	53 389,9	90,8	100,0	1
C17	L	13 172,4	54,0	61,8	1
C13	[illegible]	[illegible]	[illegible]	88,0	1
C23	[illegible]	[illegible]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





Step 1: Adding a constraint on zones

The input data (modified from the default values) are as follows:



Step 1: Adding a constraint on zones

The results obtained by Simulis Pinch Energy are the following: 5 heat exchangers in the zone 1, 3 in the Zone 2, and 2 in the zone 3

SUMMARY FOR THE HEAT EXCHANGER NETWORK

Initial number of possible exchanges:	40
Multiplication factor for the initial number of streams:	0,9
Cumulative percentage of energy recovery:	83,25
Number of heat exchangers:	10
Total energy recovery (Mcal/h):	1 778 655,6
Energy to recover (Mcal/h):	56 689,8
Additional required amount of cold utility (Mcal/h):	5 168 683,2
Additional required amount of hot utility (Mcal/h):	5 058 488,3
Hot utility exchangers number:	8
Cold utility exchangers number:	13

Display exchangers

RESULTS FOR THE AUTOMATIC DESIGN OF THE HEAT EXCHANGER NETWORK

Exchanger Item	INPUT DATA							
	Cold Stream				Hot Stream			
	Name	Input T (°C)	Target T (°C)	Target Q (Mcal/h)	Name	Input T (°C)	Target T (°C)	Target Q (Mcal/h)
	C29	70,0	150,0	552 205,7	C36	150,0	79,8	408 208,4
2	C28	38,6	70,0	408 208,4	C33	150,0	25,0	642 947,8
	C1	25,0	135,0	615 829,7	C43	100,0	82,1	1 556 510,7
	C23	76,6	200,0	1 915 438,4	C43	95,8	82,1	1 192 611,4
5	C13	65,0	88,0	141 286,3	C10	100,0	80,0	141 286,3
6	C16	45,0	54,0	115 772,8	C43	94,2	82,1	1 050 307,4
7	C17	54,0	61,8	102 886,1	C11	80,0	65,0	102 886,1
	C29	128,9	150,0	145 410,0	C33	150,0	127,9	113 477,2
9	Rebo.C301	83,9	136,2	650 000,0	C50	140,0	70,0	49 098,9
10	Rebo.C301	86,5	136,2	617 665,7	C52	140,0	11,0	24 471,3

Using zones constraints, proposed 10 exchangers can recover 83.25% of the initial MER

→ *Network efficiency has been degraded when adding constraints*

Step 2: Adding a distance constraint between streams

With Simulis Pinch Energy, it is possible to go beyond the concept of zones. The user can define coordinates of streams on the industrial site. For example, on a 2D plane:

Input data				
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

Difficulty
4
2
4
2
2
2
2
2
2
4
2
2
2
4
2
4
4
2
2
3
4
2
2
4

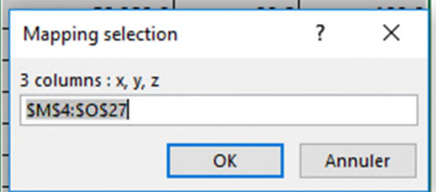
Geom(x)	Geom(y)	Geom(z)
200	80	
170	80	
130	100	
170	110	
90	120	
60	200	
60	190	
85	200	
75	140	
85	140	
60	200	
85	190	
200	115	
140	110	
40	55	
60	15	
40	70	
70	60	
80	100	
45	15	
20	60	
55	5	
85	50	
75	120	

Step 2: Adding a distance constraint between streams

In the optional constraints window, the user must:

1. Select the coordinates

Input data					Difficulty	Geom(x)	Geom(y)	Geom(z)
Stream names	Physical state	F*Cp (kcal/h/°C)	Input T (°C)	Target T (°C)				
C1	L	5 598,5	25,0	135,0	4	200	80	
C16	L	12 863,6	45,0	54,0	2	170	80	
C4	L	17 535,5	96,0	200,0	4	130	100	
C7	LV				2	170	110	
C17	L				2	90	120	
C13	L				2	60	200	
C23	L				2	60	190	
C28	LV				2	85	200	
C29	LV				2	75	140	
Rebo.C301	L	12 420,4	83,9	136,2	4	85	140	
C61	LV	865,0	116,9	140,0	2	60	200	
C10	L	7 064,3	100,0	80,0	2	85	190	
C11	L	6 859,1	80,0	65,0	2	200	115	
C43	V	86 842,1	100,0	82,1	4	140	110	
C26	LV	225,0	76,7	76,7	2	40	55	
C30	V	42 039,9	76,7	25,0	4	60	15	
C33	V	5 143,6	150,0	25,0	4	40	70	
C36	L	5 811,4	150,0	79,8	2	70	60	
C39	L	5 149,4	79,8	57,3	2	80	100	
Cond.C301	V	152 710,2	48,4	38,5	3	45	15	
C52	V	189,7	140,0	11,0	4	20	60	
C62	L	4 952,8	57,7	20,0	2	55	5	
C51	L	623,5	70,0	20,0	2	85	50	
C50	L	701,4	140,0	70,0	4	75	120	



The units of coordinates information and the maximum distance are identical (it is why they do not appear)

2. Give the maximum distance between two streams

In this example, the constraint is 100 m

Step 2: Adding a distance constraint between streams

Simulis Pinch Energy proposes a new heat exchanger network. For each proposed heat exchanger, the distance between the streams is displayed

SUMMARY FOR THE HEAT EXCHANGER NETWORK

Initial number of possible exchanges:	47
Multiplication factor for the initial number of streams:	0,8
Cumulative percentage of energy recovery:	68,72
Number of heat exchangers:	7
Total energy recovery (kcal/h):	1 468 288,0
Energy to recover (kcal/h):	509 794,7
Additional required amount of cold utility (kcal/h):	5 479 050,7
Additional required amount of hot utility (kcal/h):	5 368 855,8
Hot utility exchangers number:	9
Cold utility exchangers number:	11

Display exchangers network

RESULTS FOR THE AUTOMATIC DESIGN OF THE HEAT EXCHANGER NETWORK

Exchanger Item	INPUT DATA								Distance
	Cold Stream				Hot Stream				
	Name	Input T (°C)	Target T (°C)	Target Q (kcal/h)	Name	Input T (°C)	Target T (°C)	Target Q (kcal/h)	
1	C29	70,0	150,0	552 205,7	C36	150,0	79,8	408 208,4	80,2
2	C1	25,0	135,0	615 829,7	C43	100,0	82,1	1 556 510,7	67,1
3	Rebo.C301	83,9	136,2	650 000,0	C33	150,0	25,0	642 947,8	83,2
4	C13	65,0	88,0	141 286,3	C10	100,0	80,0	141 286,3	26,9
5	C16	45,0	54,0	115 772,8	C43	95,8	82,1	1 192 611,4	42,4
6	C17	54,0	61,8	102 886,1	C43	95,8	83,4	1 076 838,6	51,0
7	C28	38,6	70,0	408 208,4	C50	140,0	70,0	49 098,9	80,6

This distance constraint will not be used later in the example presented in this document

Step 3: Adding an incompatibility matrix

After adding distance constraints for local integration (steps 1 and 2 of the document), the user can add constraints of incompatibility. On site, the flash drums (C26 and C29 streams) are heated and cooled by a jacket. Only an ***Utility*** fluid can be used for heating or cooling the equipment.

It is then possible to add constraints of incompatibility (the streams C26 and C29 do not exchange with any other process streams)

Stream Zone	Authorized cold stream zones	Authorized hot stream zones
1		
1		
1		
1		
1		
1		
1		
2		
2		
3		
3		
1		

Incompatibility matrix	C10	C11	C43	C26	C30	C33	C36	C39	Cond.C301	C52	C62	C51	C50
C1	0	0	0	1	0	0	0	0	0	0	0	0	0
C16	0	0	0	1	0	0	0	0	0	0	0	0	0
C4	0	0	0	1	0	0	0	0	0	0	0	0	0
C7	0	0	0	1	0	0	0	0	0	0	0	0	0
C17	0	0	0	1	0	0	0	0	0	0	0	0	0
C13	0	0	0	1	0	0	0	0	0	0	0	0	0
C23	0	0	0	1	0	0	0	0	0	0	0	0	0
C28	0	0	0	1	0	0	0	0	0	0	0	0	0
C29	1	1	1	1	1	1	1	1	1	1	1	1	1
Rebo.C301	0	0	0	1	0	0	0	0	0	0	0	0	0
C61	0	0	0	1	0	0	0	0	0	0	0	0	0

Step 4: Adding a constraint of "difficulty" between streams

The concept of **difficulty** allows to represent different concepts (viscosity, toxicity, flammability ...). In our example, some streams are more viscous and more toxic than others.
A difficulty value is given to each stream. The user then sets the maximum difficulty:

Difficulty	Geom(x)	Geom(y)	Geom(z)	Stream Zone	Authorized cold stream zones	Authorized hot stream zones
4	200	80		1		
2	170	80		1		
4	130	100		1		
2	170	110		1		
2	90	120				
2	60	200				
2	60	190				
2	85	200				
2	75	140				
4	85	140		[illegible]		
2	60	200		3		
2	85	190		1		
2	200	115		1		
4	140	110		1		
2	40	55		2		
4	60	15		2		
4	40	70		2		
2	70	60		2		
2	80	100		1		
3	45	15		3		
4	20	60		3		
2	55	5		3		
2	85	50		3		
4	75	120		3		

Difficulty selection ? ×
1 column: difficulty
$H$4:$H$27
OK Annuler

The difficulty of an exchange is the sum of the difficulties of the two streams

☑ Difficulty ?
Maximum difficulty 5
Selection Valid selection

Step 5: Adding economic assessment

The user can do the economic evaluation of the addition of heat exchangers using the ***economic evaluation*** option of Simulis Pinch Energy.

To calculate the cost of the heat exchanger, it is necessary to provide the stream heat transfer coefficients.

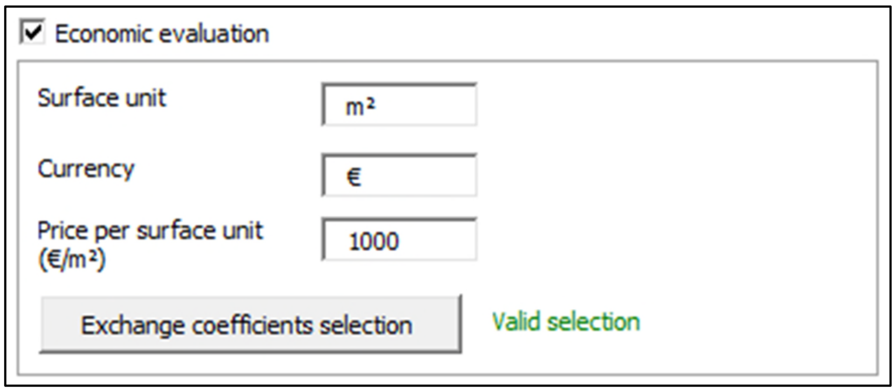
The user must provide these values and select them:

Input data						
Stream names	Physical state	F*Cp (kcal/h/°C)	Input T (°C)	Target T (°C)	Difficulty	Exchange coefficients (kcal/h/°C/m²)
C1	L	5 598,5	25,0	135,0	4	600
C16	L	12 863,6	45,0	54,0	2	800
C4	L	17 535,5	96,0	200,0	4	700
C7	LV	53 389,9	90,8	100,0	2	12000
C17	L	13 172,4	54,0	61,8	2	800
C13	L	6 140,5	65,0	88,0	2	350
C23	L	15 527,9	76,6	200,0	2	500
C28	LV	12 990,1	38,6	70,0	2	20000
C29	LV	6 902,6	70,0	150,0	2	20000
Rebo.C301	L	12 420,4	83,9	136,2	4	260
C61	LV	865,0	116,9	140,0	2	10000
C10	L	7 064,3	100,0	80,0	2	350
C11	L	6 859,1	80,0	65,0	2	350
C43	V	86 842,1	100,0	82,1	4	150
C26	LV	225,0	76,7	76,7	2	15000
C30	V	42 039,9	76,7	25,0	4	170
C33	V	5 143,6	150,0	25,0	4	80
C36	L	5 811,4	150,0	79,8	2	170
C39	L	5 149,4	79,8	57,3	2	180
Cond.C301	V	152 710,2	48,4	38,5	3	200
C52	V	189,7	140,0	11,0	4	140
C62	L	4 952,8	57,7	20,0	2	110
C51	L	623,5	70,0	20,0	2	120
C50	L	701,4	140,0	70,0	4	130

Step 5: Adding economic assessment

The user must also provide:

1. The surface unit
2. The currency
3. The price per area unit (in this example 1000 € / m²)



Step 5: Adding economic assessment

The price of each heat exchanger is calculated and displayed in the results sheet

SUMMARY FOR THE HEAT EXCHANGER NETWORK

Initial number of possible exchanges:	18
Multiplication factor for the initial number of streams:	0,8
Cumulative percentage of energy recovery:	35,95
Number of heat exchangers:	4
Total energy recovery (kcal/h):	768 153,6
Energy to recover (kcal/h):	1 077 894,2
Additional required amount of cold utility (kcal/h):	6 179 185,2
Additional required amount of hot utility (kcal/h):	6 068 990,3
Hot utility exchangers number:	10
Cold utility exchangers number:	10
Global exchange area (m^2):	153,8
Global investment (€):	153 809,5

Display exchangers network

RESULTS FOR THE AUTOMATIC DESIGN OF THE HEAT EXCHANGER NETWORK

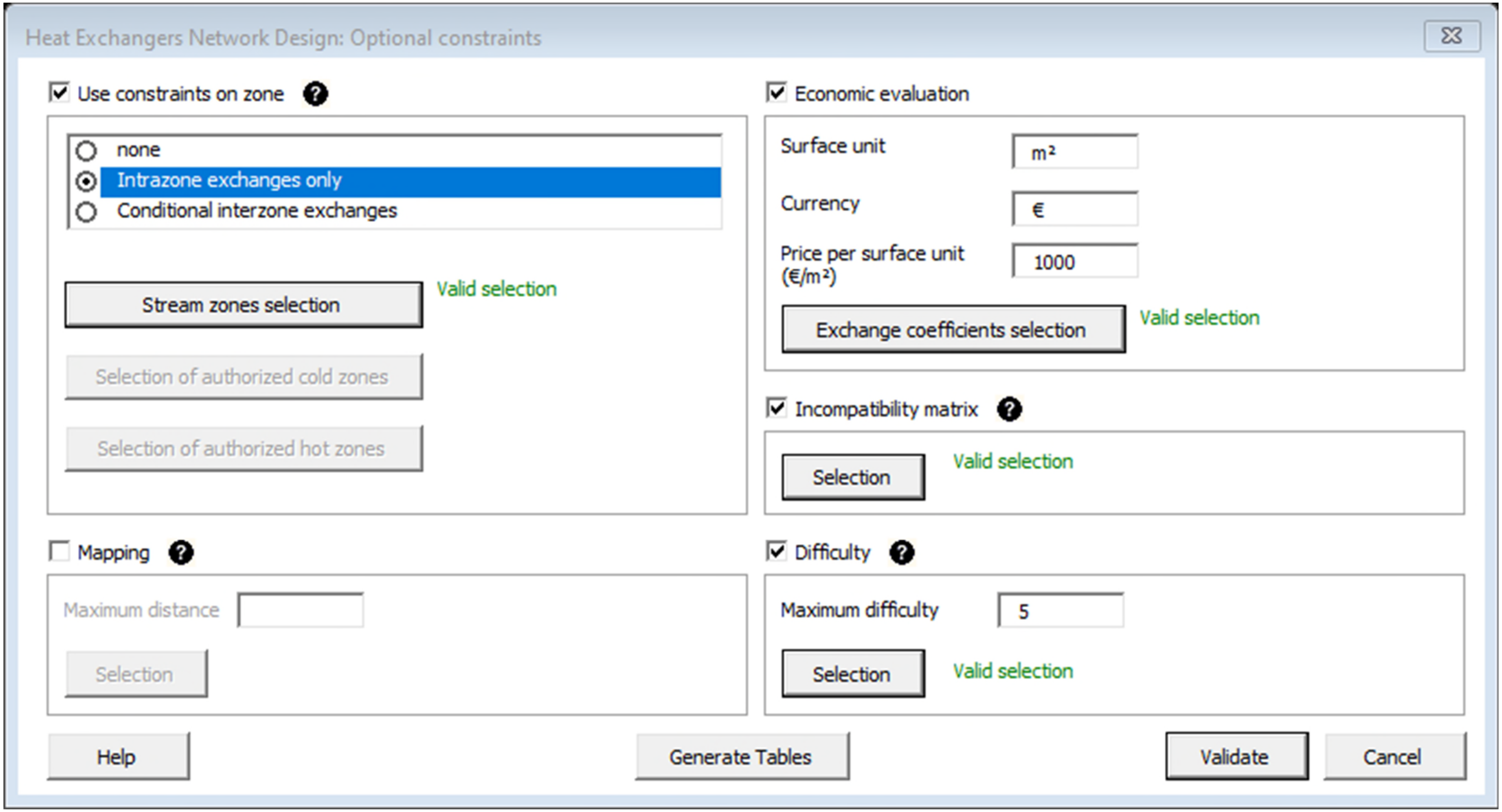
Exchanger Item	INPUT DATA								INVESTMENT (€)
	Cold Stream				Hot Stream				
	Name	Input T (°C)	Target T (°C)	Target Q (kcal/h)	Name	Input T (°C)	Target T (°C)	Target Q (kcal/h)	
1	C28	38,6	70,0	408 208,4	C36	150,0	79,8	408 208,4	41 425,0
2	C13	65,0	88,0	141 286,3	C10	100,0	80,0	141 286,3	60 073,4
3	C16	45,0	54,0	115 772,8	C39	79,8	57,3	115 772,8	43 314,1
4	C17	54,0	61,8	102 886,1	C11	80,0	65,0	102 886,1	8 996,9

Step 6: New heat exchanger network

The constraints used are:

- Interzone exchange only (step 1)
- Use of utilities for flash drums heat exchanges (step 3)
- Incompatibility between some streams (step 4)

In addition, an economic evaluation is performed to estimate the capital cost of heat exchangers (step 5).



Step 6: New heat exchanger network

Adding different constraints modifies the heat exchanger network. The proposed network has 4 heat exchangers. This network of 4 heat exchangers can recover ≈35% of MER.

SUMMARY FOR THE HEAT EXCHANGER NETWORK

Initial number of possible exchanges:	18
Multiplication factor for the initial number of streams:	0,8
Cumulative percentage of energy recovery:	35,95
Number of heat exchangers:	4
Total energy recovery (kcal/h):	768 153,6
Energy to recover (kcal/h):	1 077 894,2
Additional required amount of cold utility (kcal/h):	6 179 185,2
Additional required amount of hot utility (kcal/h):	6 068 990,3
Hot utility exchangers number:	10
Cold utility exchangers number:	10
Global exchange area (m²):	153,8
Global investment (€):	153 809,5

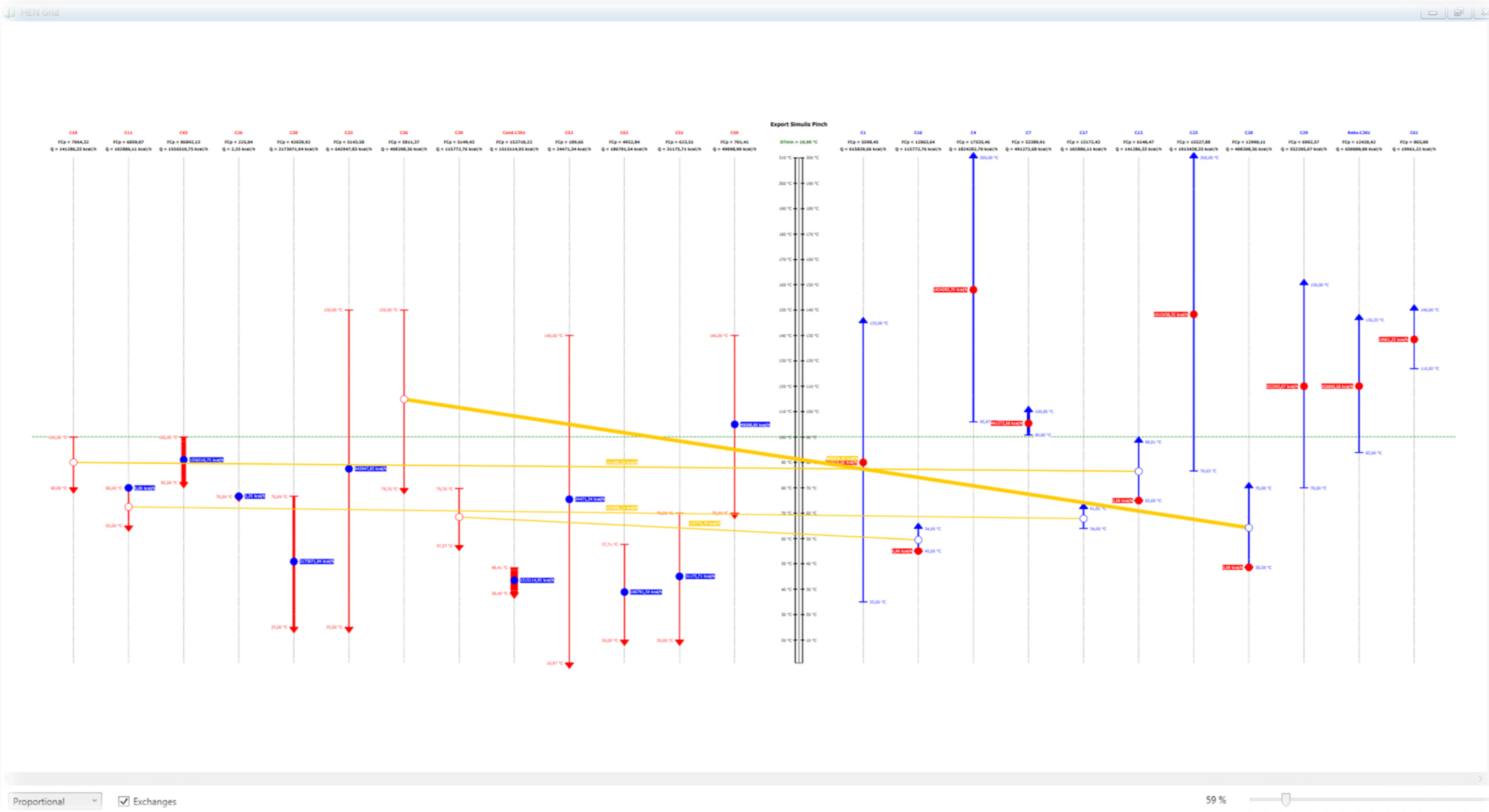
Display exchangers network

RESULTS FOR THE AUTOMATIC DESIGN OF THE HEAT EXCHANGER NETWORK

Exchanger Item	INPUT DATA								INVESTMENT (€)
	Cold Stream				Hot Stream				
	Name	Input T (°C)	Target T (°C)	Target Q (kcal/h)	Name	Input T (°C)	Target T (°C)	Target Q (kcal/h)	
1	C28	38,6	70,0	408 208,4	C36	150,0	79,8	408 208,4	41 425,0
2	C13	65,0	88,0	141 286,3	C10	100,0	80,0	141 286,3	60 073,4
3	C16	45,0	54,0	115 772,8	C39	79,8	57,3	115 772,8	43 314,1
4	C17	54,0	61,8	102 886,1	C11	80,0	65,0	102 886,1	8 996,9

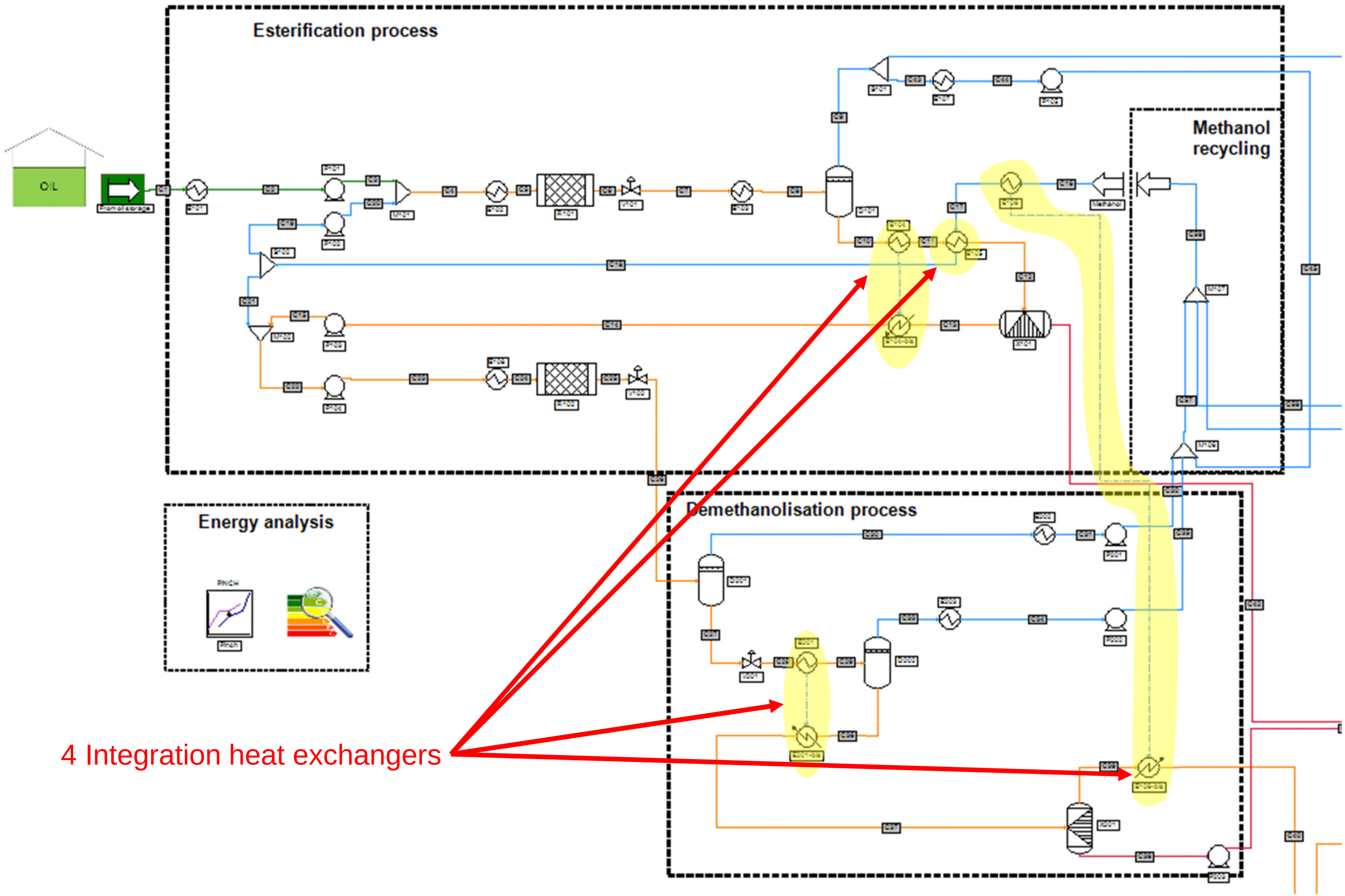
Step 6: New heat exchanger network

The proposed network is presented by Simulis Pinch Energy



Step 6: New heat exchanger network

The proposed network is shown in ProSimPlus example: ***PSPS_E30_EN - Esterification Process.pmp3***



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