Getting started with ProSimPlus®

Use Case 2: Conducting a Pinch Analysis

Software & Services In Process Simulation

We guide You to efficiency

ProSim

Introduction

The pinch analysis is a method to minimize process energy consumptions by optimizing heat transfers between unit operations. It allows to identify the minimum consumptions of utilities and respond to the following question: are there potential gains of energy?

This analysis can be conducted using the « Pinch analysis » module in ProSimPlus or using the « Simulis Pinch » Excel Add-in (provided with ProSimPlus).

This document presents the steps to follow in order to perform the calculations in ProSimPlus or in Excel:

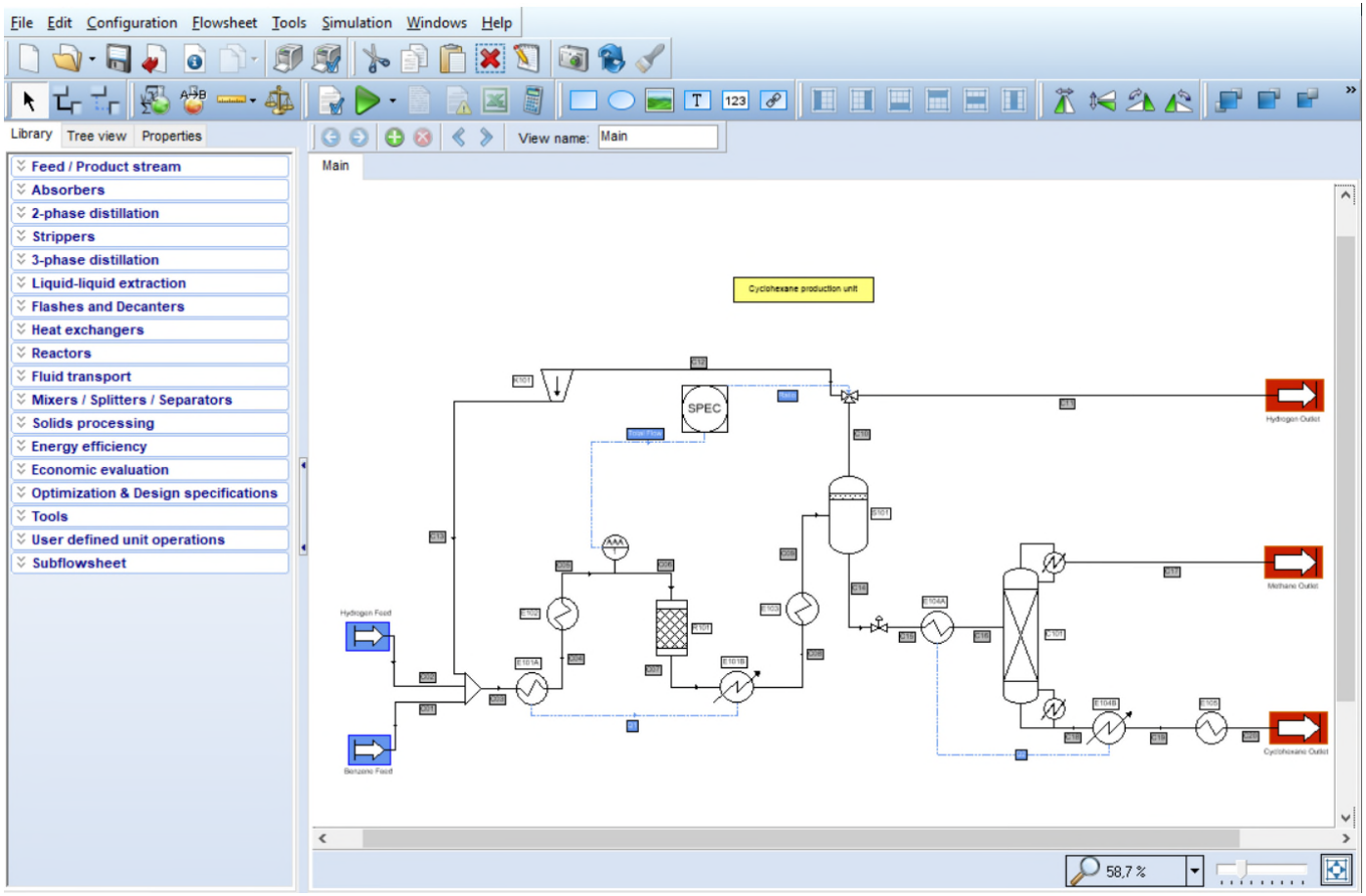
- Pinch analysis conducted in ProSimPlus
- Pinch analysis conducted with the « Simulis Pinch » Excel Add-In
- Advanced calculations...

Before studying this chapter, it is recommended to consult « Getting Started with ProSimPlus, Use Case 1 » that presents the main features of ProSimPlus.

1. Pinch analysis conducted in ProSimPlus

This document is based on the ProSimPlus application example « Cyclohexane Plant », available on ProSim website (www.prosim.net).

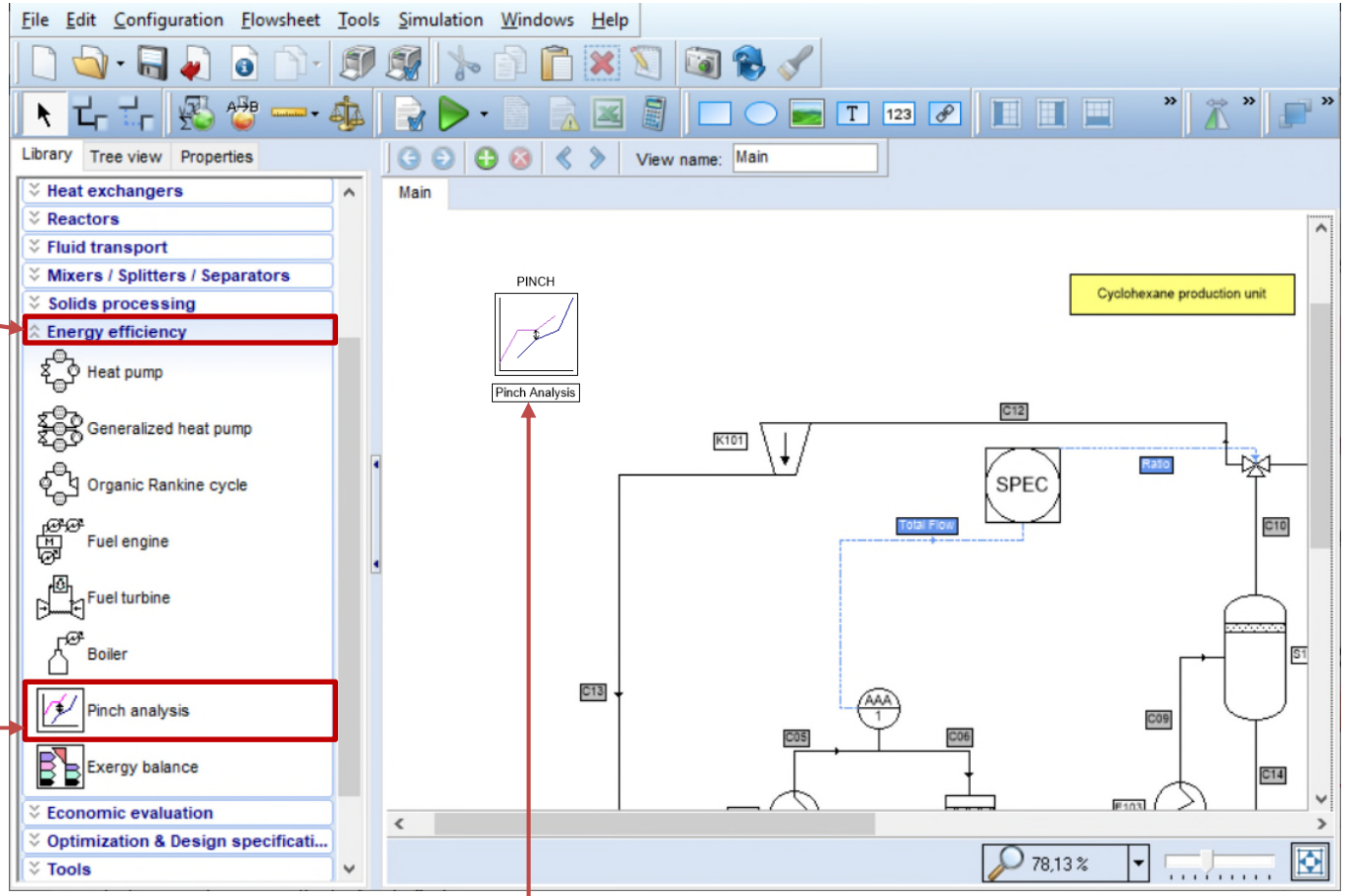
Open the example in ProSimPlus



1. Pinch analysis conducted in ProSimPlus

1. Click on the « Energy efficiency » tab

2. Select the « Pinch analysis » module

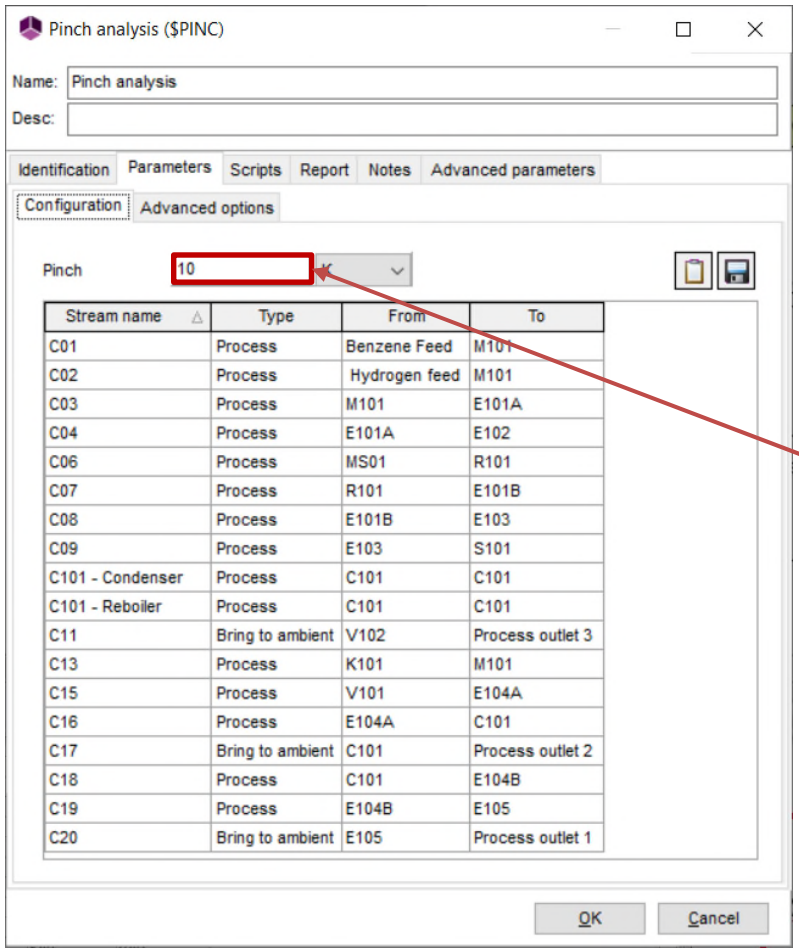


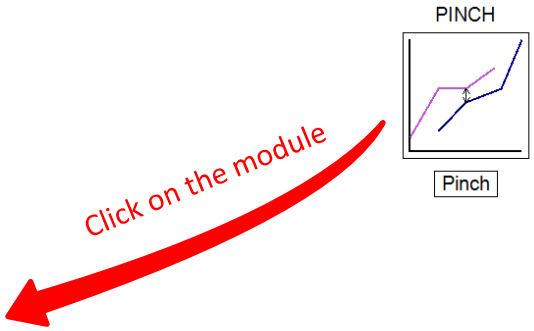
3. Drop the module in the flowsheet

The « Pinch analysis » module does not require to be connected to any module of the flowsheet. It automatically retrieves the data that is needed to perform the calculations.

1. Pinch analysis conducted in ProSimPlus

1. Double-click on the « Pinch analysis » module to open its configuration window

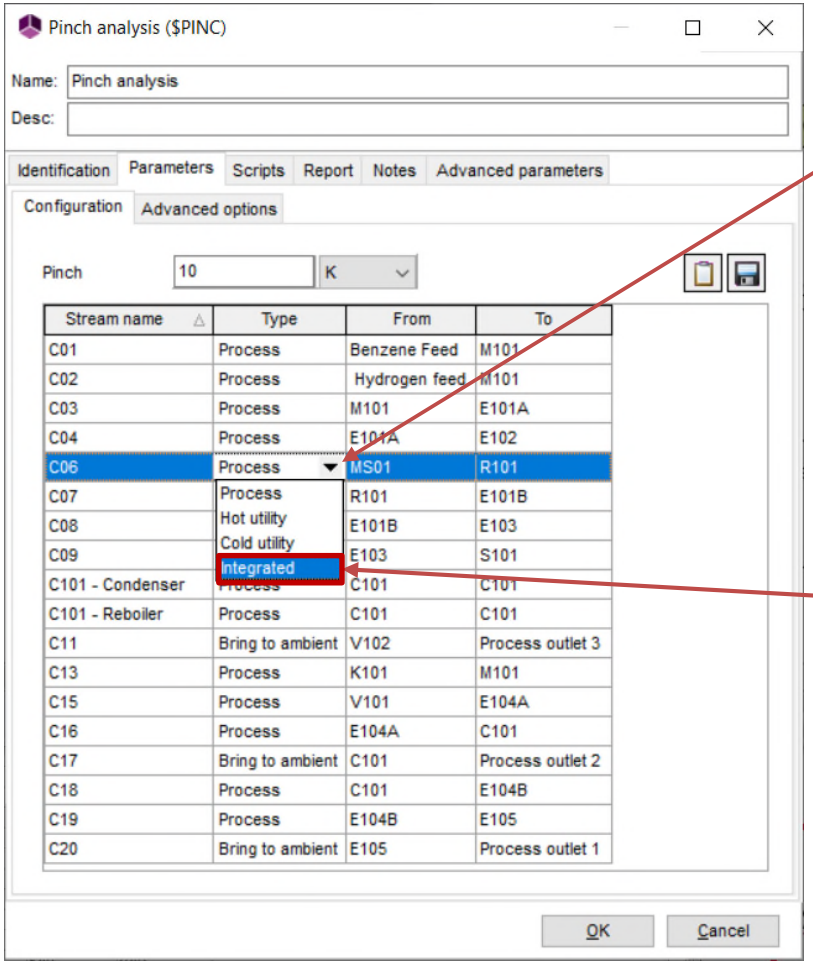




2. Fill in the pinch value (10°C by default)

Once the configuration window is open, click on « F1 » to access the help file about this module.

1. Pinch analysis conducted in ProSimPlus



All streams can be « classified »:

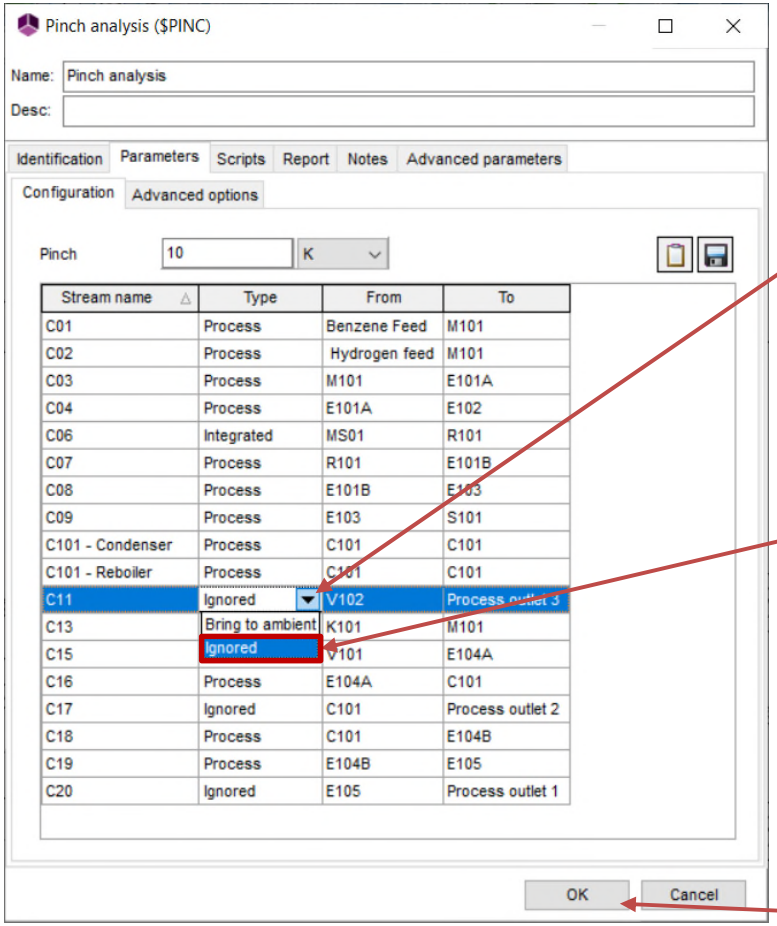
- Process
- Hot utility
- Cold utility
- Integrated

For reasons of safety and process flexibility, it is not recommended to replace the reactor thermal fluid by a « process » stream.

Change the « Type » of the C06 stream from « Process » to « Integrated ».

Only « Process » streams are taken into account in the energy integration.

1. Pinch analysis conducted in ProSimPlus



It is possible to take into account the heat that is required to bring the output streams to ambient temperature:

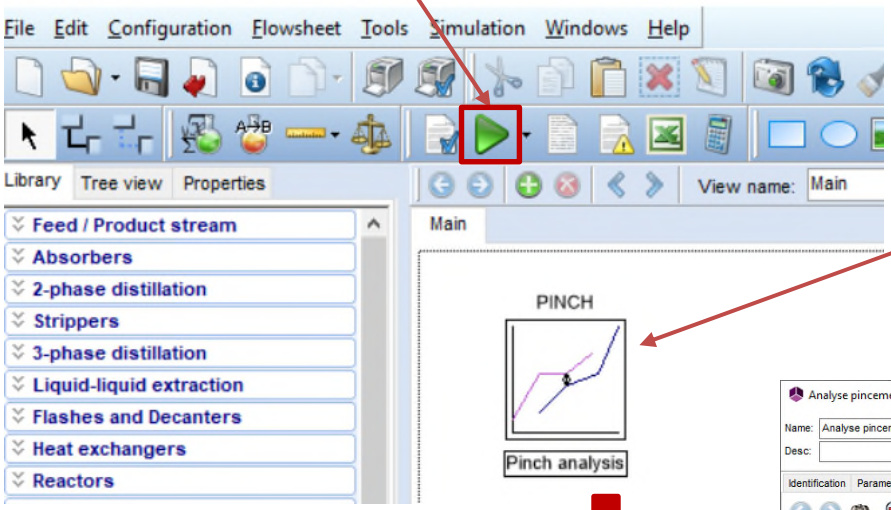
- Ignored
- Bring to ambient

1. Change the « Type » of the output streams C11, C17 and C20 to « Ignored » so that they are not taken into incount in the analysis

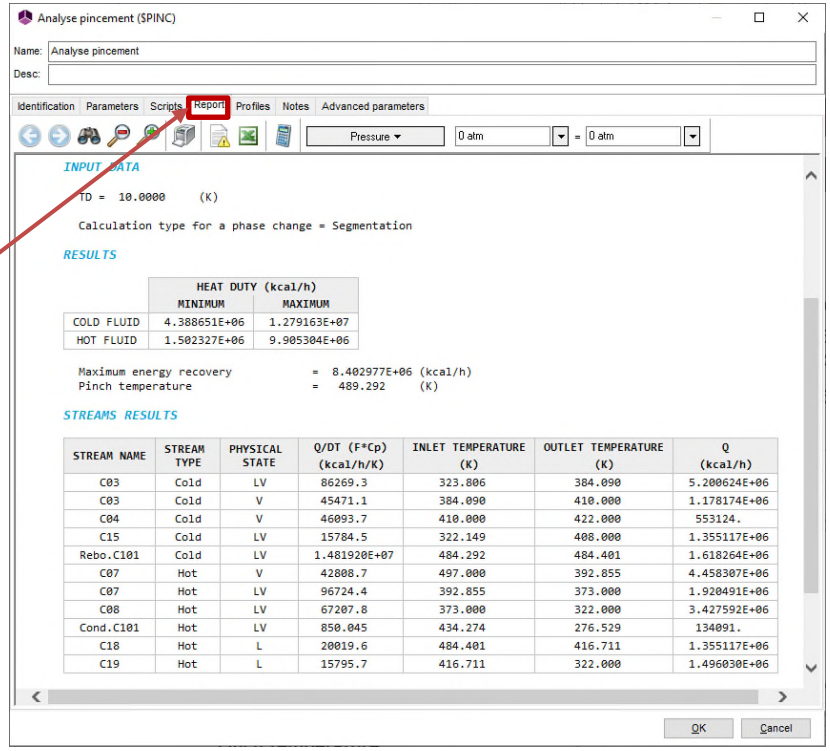
2. Click on « OK » to confirm

1. Pinch analysis conducted in ProSimPlus

1. Click on the green arrow to run the simulation



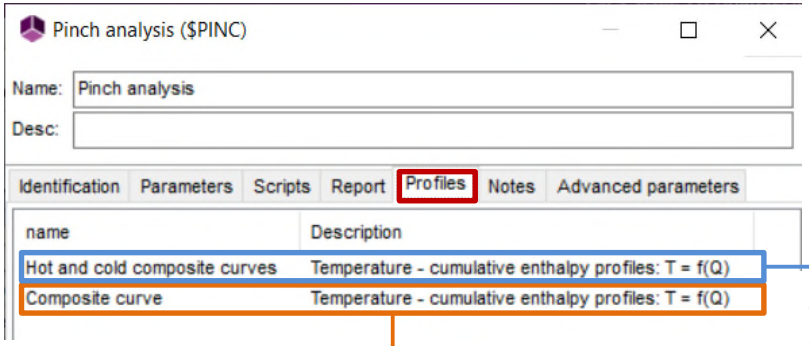
2. Once the simulation is completed, double click on the « Pinch analysis » module



3. Click on the « Report » tab to access the results:

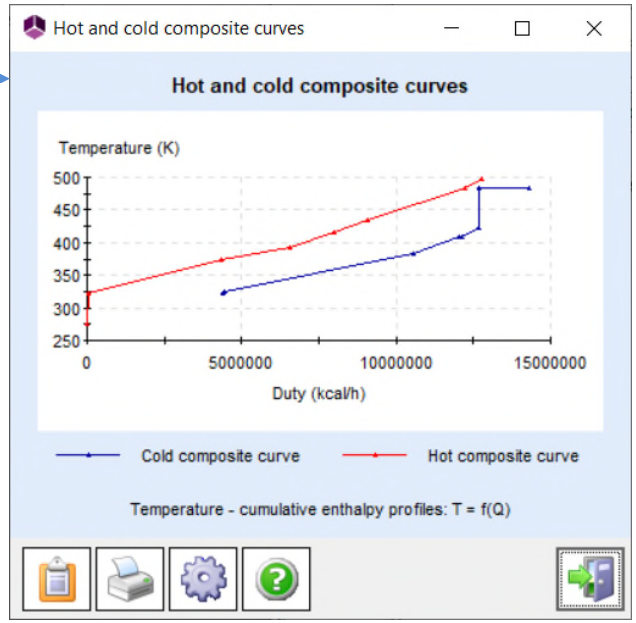
- Minimum requirement in cold and hot utilities
- Maximum recoverable energy
- Pinch temperature
- List of hot and cold streams that are used in the pinch analysis

1. Pinch analysis conducted in ProSimPlus

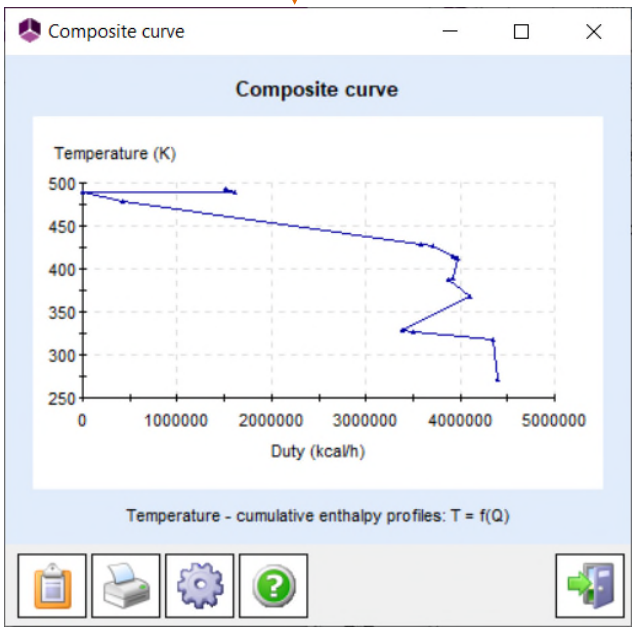


Click on the « Profiles » tab to access the curves

Double click to display the hot and cold composite curves



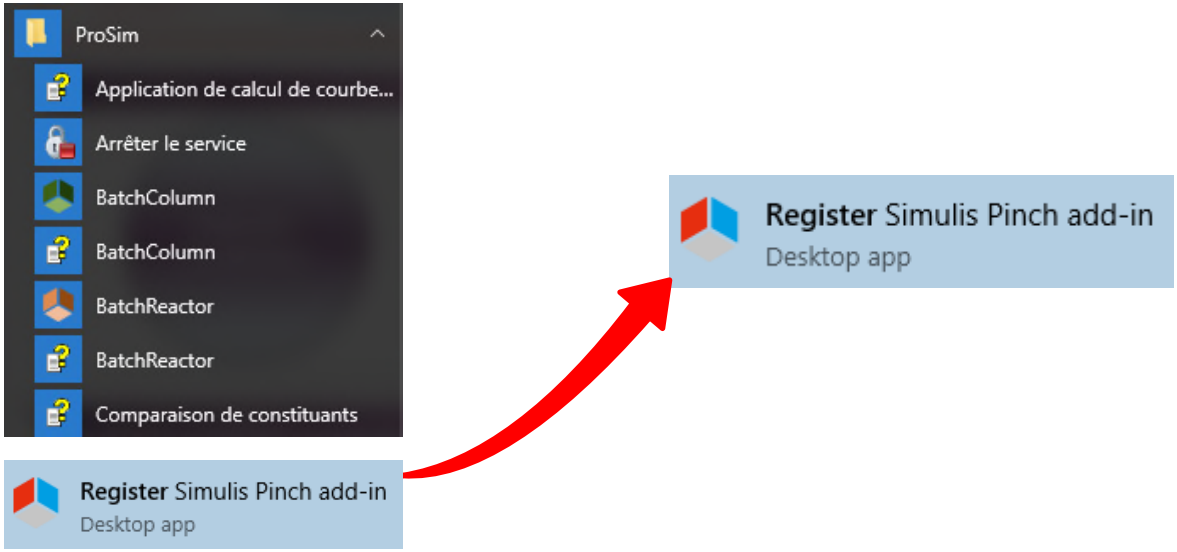
Double click to display the grand composite curve



2. Pinch analysis conducted with the Excel Add-In

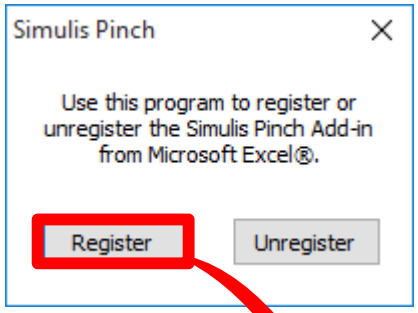
In order to use the Excel Add-In (called « Simulis Pinch ») to conduct a pinch analysis, it is necessary to register it in Excel using one of the following methods (this step has to be done only once, during the installation or the first use):

1. In the « ProSim » folder of apps, click on « Register Simulis Pinch add-in »
2. Find directly the tool « Register Simulis Pinch add-in » on your computer (using the search bar)

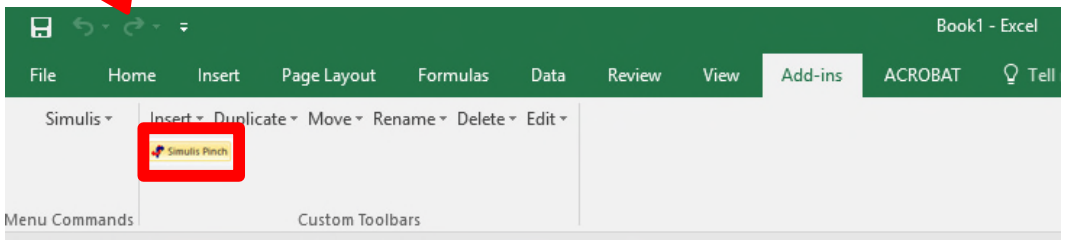


2. Pinch analysis conducted with the Excel Add-In

1. Register Simulis Pinch by clicking on « Register »

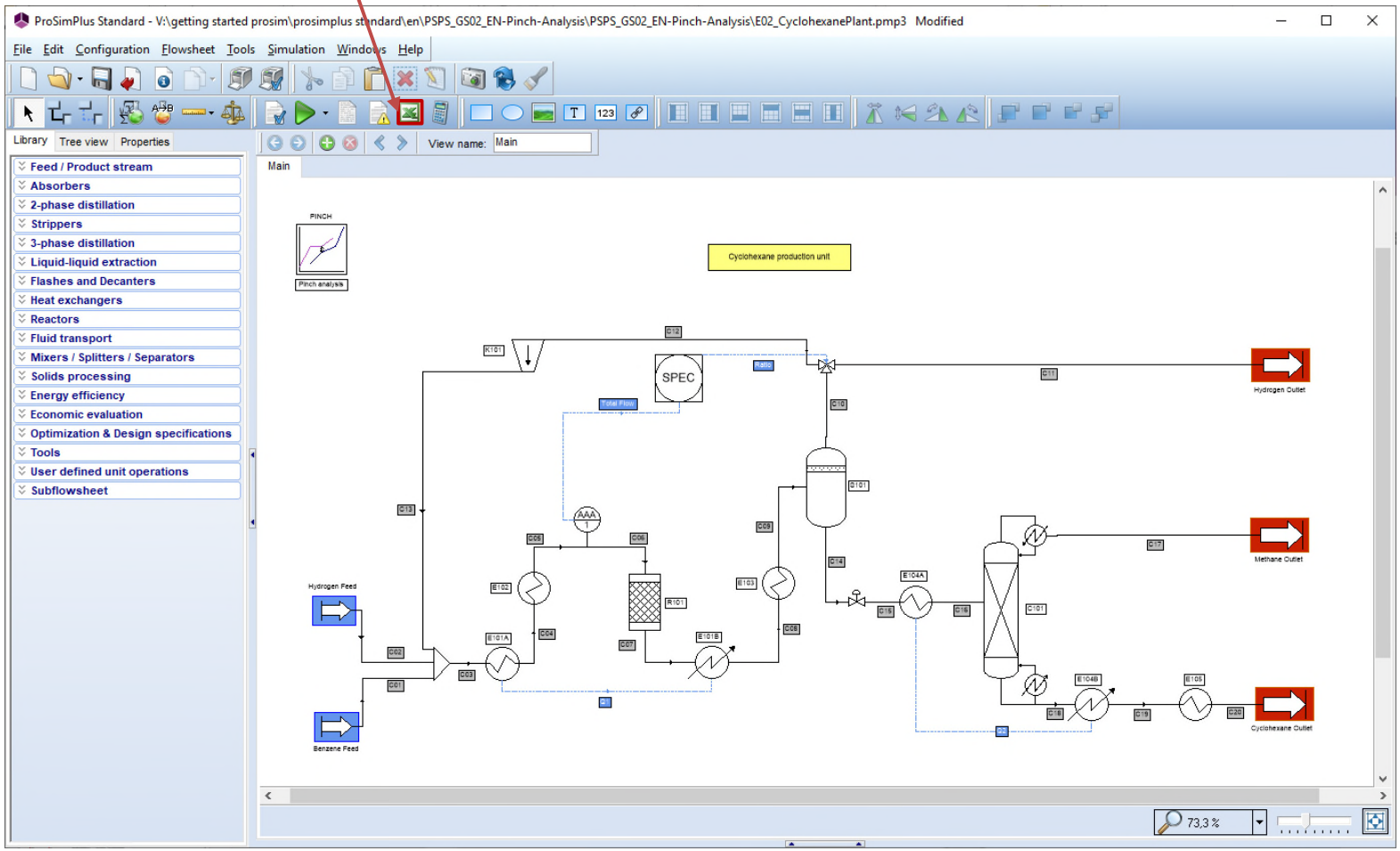


2. Once Simulis Pinch is registered, it is available in the « Add-Ins » tab of Excel



2. Pinch analysis conducted with the Excel Add-In

In ProSimPlus, click on the Excel icon



2. Pinch analysis conducted with the Excel Add-In

The data needed to perform the pinch analysis is automatically generated at the end of the Excel report.

The « **Stream** » column gives the names of the streams involving a heat transfer.

PINC

Stream	Physical state	F*Cp (kcal/h/K)	T In (K)	T Out (K)
C03	LV	86269.32059	323.8060452	384.0895964
C04	V	46093.73542	410	422
C03	V	45471.17609	384.0895964	410
C15	LV	15784.53556	322.1490638	408
Rebo.C101	LV	14819198.89	484.2917468	484.4009473
C07	V	42808.7678	497	392.8551551
C07	LV	96724.42876	392.8551551	372.9999326
C08	LV	67207.89507	372.9999326	322
Cond.C101	LV	850.0453284	434.2743775	276.5288388
C18	L	20019.60201	484.4009473	416.7114321
C19	L	15795.65715	416.7114321	322

2. Pinch analysis conducted with the Excel Add-In

The « **Physical state** » column indicates:

- « L » for liquid
- « V » for vapor
- « LV » for vapor-liquid (condensation or evaporation)

PINC

Stream	Physical state	F*Cp (kcal/h/K)	T In (K)	T Out (K)
C03	LV	86269.32059	323.8060452	384.0895964
C04	V	46093.73542	410	422
C03	V	45471.17609	384.0895964	410
C15	LV	15784.53556	322.1490638	408
Rebo.C101	LV	14819198.89	484.2917468	484.4009473
C07	V	42808.7678	497	392.8551551
C07	LV	96724.42876	392.8551551	372.9999326
C08	LV	67207.89507	372.9999326	322
Cond.C101	LV	850.0453284	434.2743775	276.5288388
C18	L	20019.60201	484.4009473	416.7114321
C19	L	15795.65715	416.7114321	322

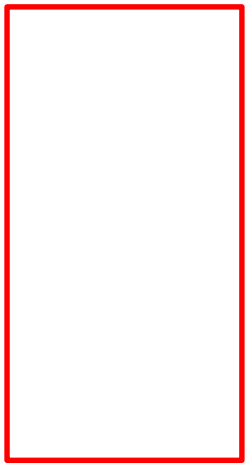
2. Pinch analysis conducted with the Excel Add-In

The « **F*Cp** » column displays the heat duty exchanged divided by ΔT (temperature difference between the inlet and the outlet of the heat exchange), expressed in kcal/hr/K.

The « F*Cp » of a stream corresponds to the mass flowrate (F) multiplied by the specific heat capacity at constant pressure (Cp).

In other words, the heat duty exchanged to heat or cool the stream (noted Q) is equal to:

$$Q = F * Cp * \Delta T = F * Cp * (T_{out} - T_{in})$$



$$Q = F * C_1$$

2. Pinch analysis conducted with the Excel Add-In

The inlet temperature (Tin) and the outlet temperature (Tout) are expressed in Kelvin.

If the temperature increases (Tout > Tin), the stream will be considered as a cold stream (needs to be heated).

If the temperature decreases (Tout < Tin), the stream will be considered as a hot stream (needs to be cooled down).

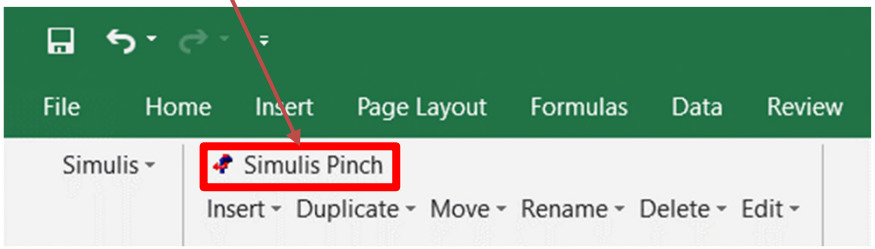
During condensation, evaporation or heat exchange at constant temperature (phase change of a pure substance, for example), the ΔT is automatically set to ± 0.01°C and the F*Cp is calculated consequently.

PINC

Stream	Physical state	F*Cp (kcal/h/K)	T In (K)	T Out (K)
C03	LV	86269.32059	323.8060452	384.0895964
C04	V	46093.73542	410	422
C03	V	45471.17609	384.0895964	410
C15	LV	15784.53556	322.1490638	408
Rebo.C101	LV	14819198.89	484.2917468	484.4009473
C07	V	42808.7678	497	392.8551551
C07	LV	96724.42876	392.8551551	372.9999326
C08	LV	67207.89507	372.9999326	322
Cond.C101	LV	850.0453284	434.2743775	276.5288388
C18	L	20019.60201	484.4009473	416.7114321
C19	L	15795.65715	416.7114321	322

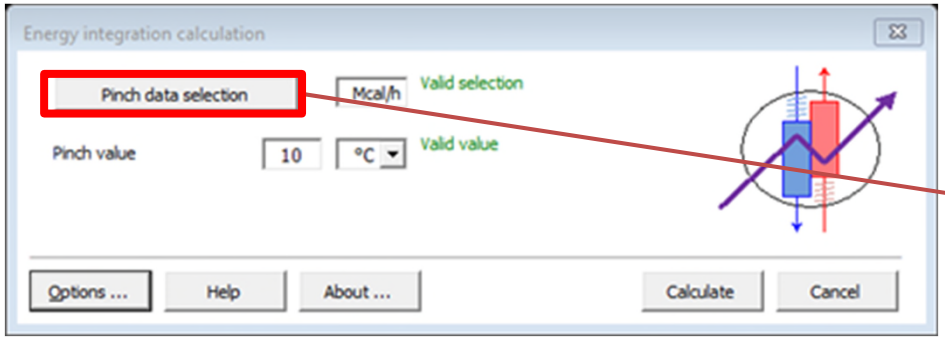
2. Pinch analysis conducted with the Excel Add-In

1. Run Simulis Pinch



Depending on the definition of the decimal separator of your computer, it might be necessary to replace points "." by comma "," so that these values are well interpreted in MS-Excel.

2. Select the columns F*Cp, Tin and Tout (only numerical values, not the column headings, as shown in the screenshots below)



PINC

Stream	Physical state	F*Cp (kcal/h/K)	T In (K)	T Out (K)
C03	LV	86269.32059	323.8060452	384.0895964
C04	V	46093.73542	410	422
C03	V	45471.17609	384.0895964	410
C15	LV	15784.53556	322.1490638	408
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C08	LV	67207.89507	372.9999326	322
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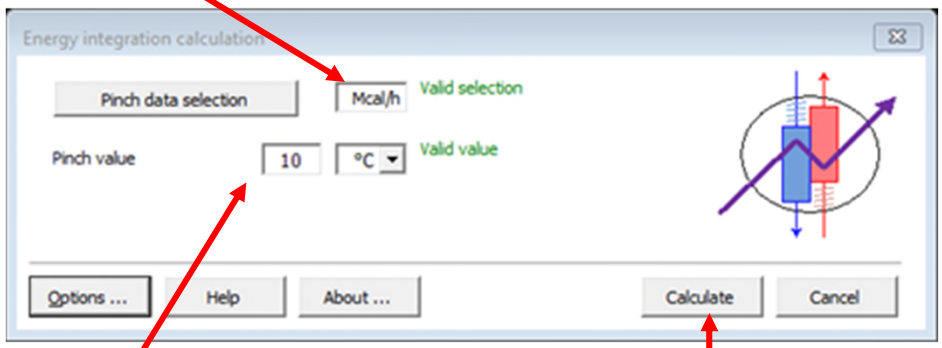
C18	L	20019.60201	484.4009473	416.7114321
C19	L	15795.65715	416.7114321	322

2. Pinch analysis conducted with the Excel Add-In

1. Change the unit to match the specified unit in the MS-Excel workbook (kcal/h in this case)



2. Provide the pinch value (10°C by default)

3. Click on « Calculate »

2. Pinch analysis conducted with the Excel Add-In

4 new spreadsheets are automatically generated in Excel:

1. The grand composite curve
2. The hot and cold composite curves
3. The streams considered in the analysis (hot and cold streams)
4. The pinch analysis results (data and results summary)

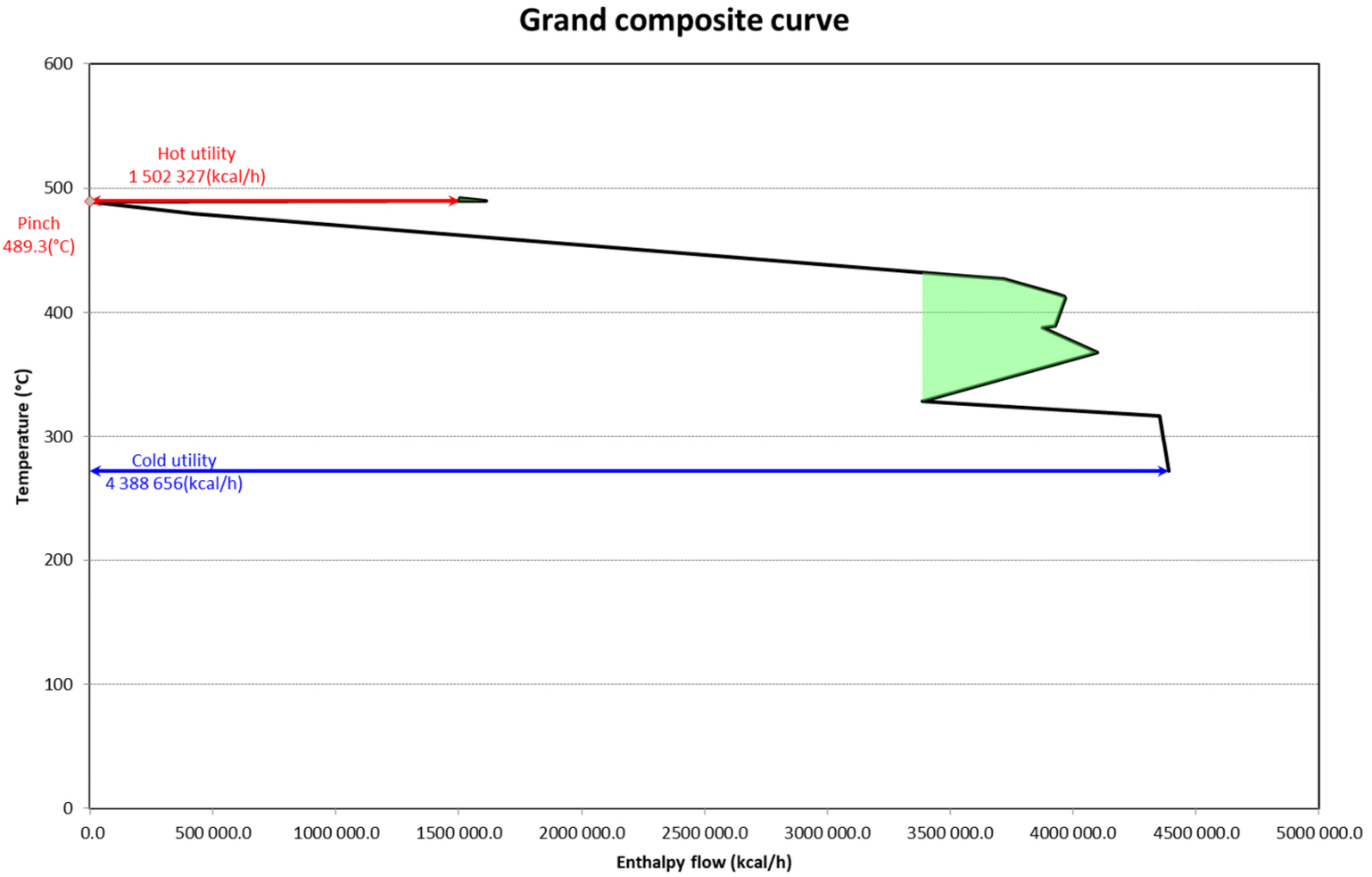
PINC

Stream	Physical state	F*Cp (kcal/h/K)	T In (K)	T Out (K)		Difficulty
C03	LV	86269.32059	323.8060452	384.0895964		
C04	V	46093.73542	410	422		
C03	V	45471.17609	384.0895964	410		
C15	LV	15784.53556	322.1490638	408		
Rebo.C101	LV	14819198.89	484.2917468	484.4009473		
C07	V	42808.7678	497	392.8551551		
C07	LV	96724.42876	392.8551551	372.9999326		
C08	LV	67207.89507	372.9999326	322		
Cond.C101	LV	850.0453284	434.2743775	276.5288388		
C18	L	20019.60201	484.4009473	416.7114321		
C19	L	15795.65715	416.7114321	322		

Grand composite curve | Composite curves (TQ) | Streams | Pinch results | PSPS_E02_EN - Cyclohexane Plant

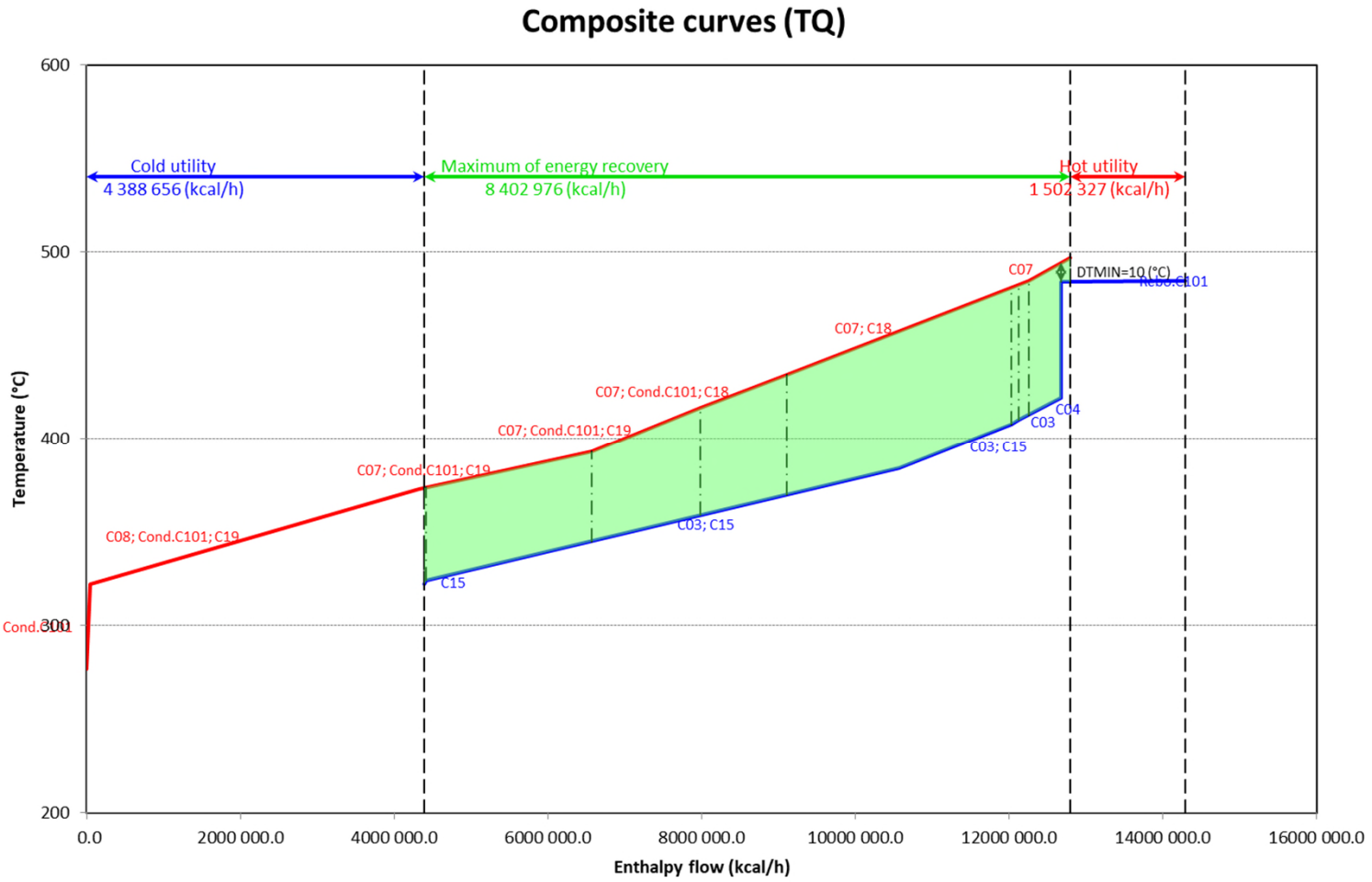
2. Pinch analysis conducted with the Excel Add-In

1. The grand composite curve:



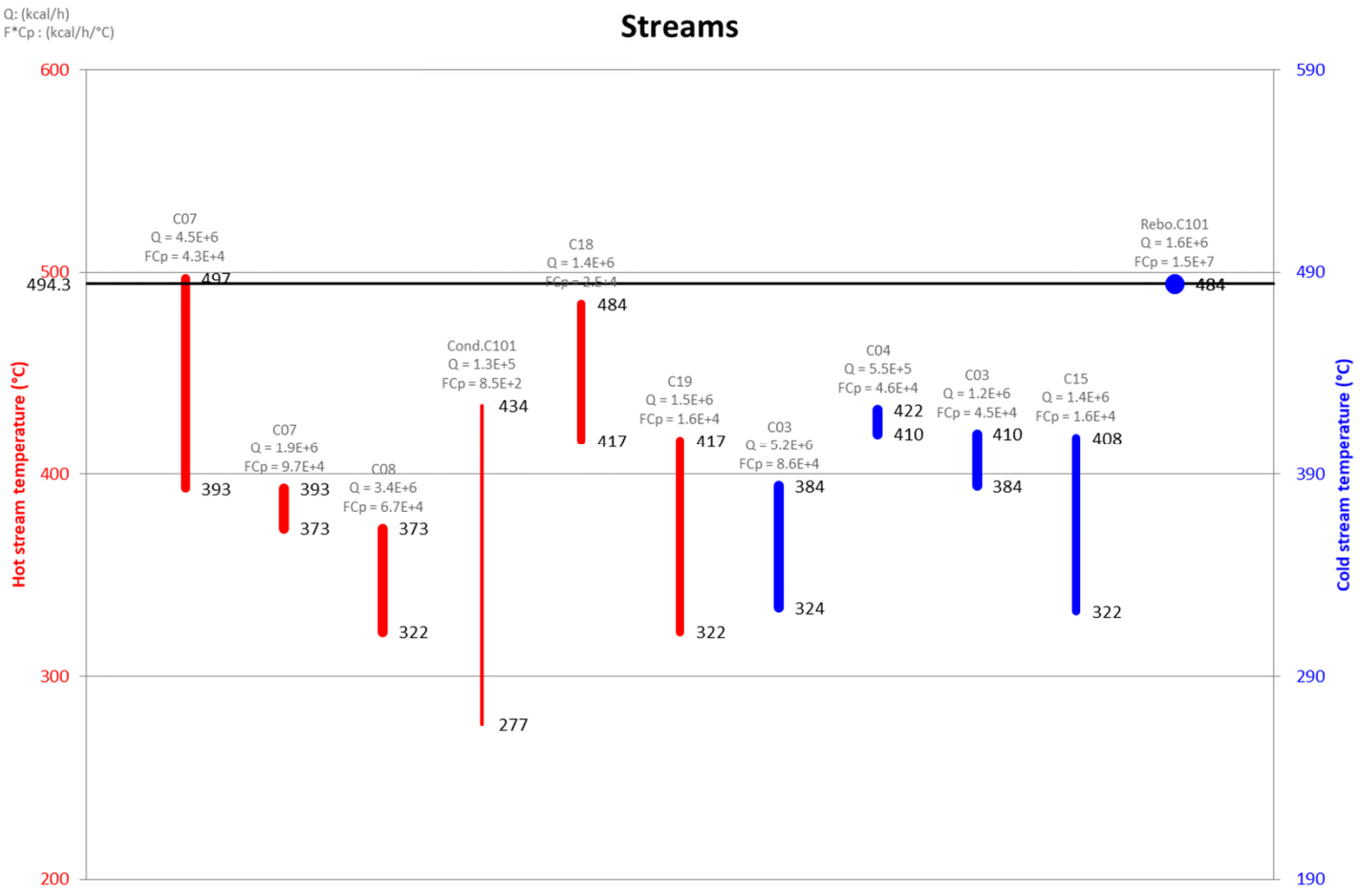
2. Pinch analysis conducted with the Excel Add-In

2. The hot and cold composite curves:



2. Pinch analysis conducted with the Excel Add-In

3. The streams (hot and cold streams):



2. Pinch analysis conducted with the Excel Add-In

4. The pinch analysis results (data and results summary):

DATA

Stream names	F*Cp (kcal/h/°C)	Temperatures Input (°C)	Target (°C)	Enthalpy flow (kcal/h)	Hot stream ?
C07	42 808.8	497.0	392.9	4458 312.5	TRUE
C07	96 724.4	392.9	373.0	1920 485.0	TRUE
C08	67 207.9	373.0	322.0	3427 598.1	TRUE
Cond.C101	850.0	434.3	276.5	134 090.9	TRUE
C18	20 019.6	484.4	416.7	1355 117.2	TRUE
C19	15 795.7	416.7	322.0	1496 029.3	TRUE
C03	86 269.3	323.8	384.1	-5200 621.0	FALSE
C04	46 093.7	410.0	422.0	-553 124.8	FALSE
C03	45 471.2	384.1	410.0	-1178 176.5	FALSE
C15	15 784.5	322.1	408.0	-1355 117.2	FALSE
Rebo.C101	14819 198.9	484.3	484.4	-1618 263.9	FALSE
		Global duty (kcal/h)		**2886 329.5**	
DTMIN (°C)	*10.0*				

RESULTS

Hot composite curve Flow (kcal/h)	Temperatures (°C)	Cold composite curve Flow (kcal/h)	Temperatures (°C)		Grand composite curve Flow (kcal/h)	Mean temperatures (°C)	
0.0	276.5	4388 656.5	322.1	Cold utility	4388 656.5	271.5	
38 652.5	322.0	4414 811.2	323.8		4350 003.9	317.0	
4315 180.4	373.0	10566 980.0	384.1		3498 968.4	327.1	
6566 169.5	392.9	12031 628.8	408.0		3386 179.3	328.8	
7984 531.9	416.7	12122 571.2	410.0		4099 518.1	368.0	
9102 912.4	434.3	12675 696.0	422.0		3874 831.0	387.9	
12252 283.1	484.4	12675 696.0	484.3		3927 417.4	389.1	
12791 633.0	497.0	14293 959.9	484.4		3968 164.8	411.7	
					3965 043.0	413.0	
					3928 628.5	415.0	
					3717 612.4	427.0	
					3572 783.6	429.3	
					423 412.9	479.4	
					0.0	**489.3**	**Pinch**
					1613 589.2	489.4	
				Hot utility	1502 327.0	492.0	

Cold temperature at the pinch (°C)	*484.3*
Pinch temperature (°C)	***489.3***
Hot temperature at the pinch (°C)	*494.3*
Cold utility (kcal/h)	*4 388 656.5*
Maximum of energy recovery (kcal/h)	*8 402 976.5*
Hot utility (kcal/h)	*1 502 327.0*
Hot utility minimum temperature (°C)	*494.4*
Cold utility maximum temperature (°C)	*266.5*

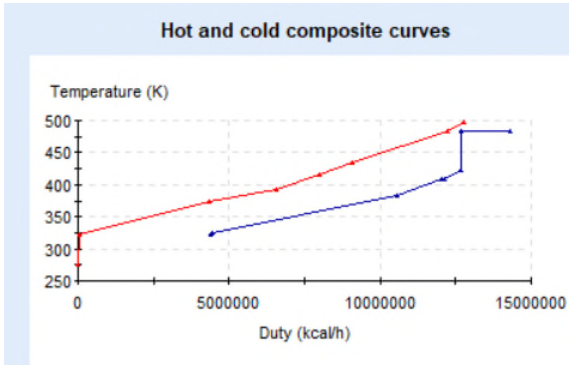
List of theoretical heat exchangers:

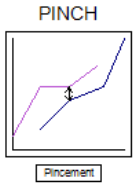
# (-)	Heat duty exchanged (kcal/h)	Cold streams Input T (°C)	Output T (°C)	*Stream(s)*	Hot streams Input T (°C)	Output T (°C)	*Stream(s)*	LMTD (K)	UA Factor (kcal/h/K)
1	26 154.7	322.1	323.8	*C15*	373.9	373.6	*C07; Cond.C101; C19*	50.8	515.0
2	2 151 358.4	323.8	344.9	*C03; C15*	392.9	373.9	*C07; Cond.C101; C19*	49.0	43 893.6
3	1 418 362.3	344.9	358.8	*C03; C15*	416.7	392.9	*C07; Cond.C101; C19*	52.8	26 867.5
4	1 118 380.5	358.8	369.7	*C03; C15*	434.3	416.7	*C07; Cond.C101; C18*	61.2	18 283.4
5	2 928 716.4	369.7	408.0	*C03; C15*	480.9	434.3	*C07; C18*	68.6	42 677.1
6	90 942.4	408.0	410.0	*C03*	482.3	480.9	*C07: C18*	72.6	1 252.4

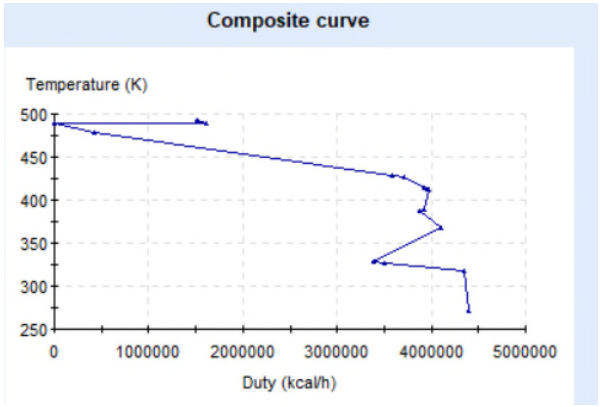
2. Pinch analysis conducted with the Excel Add-In

The results obtained using the Excel Add-in are equivalent to those obtained with the « Pinch Analysis » module in ProSimPlus

With ProSimPlus:

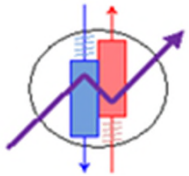


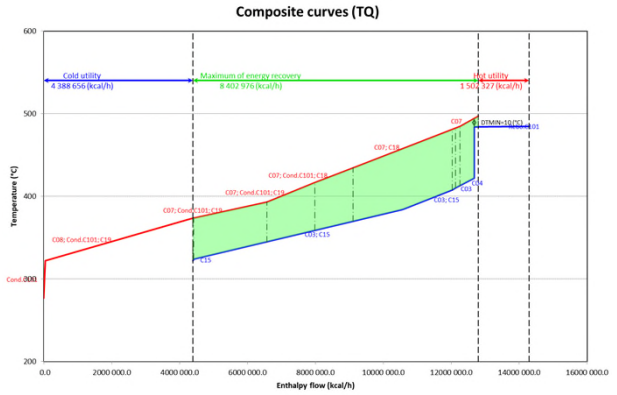


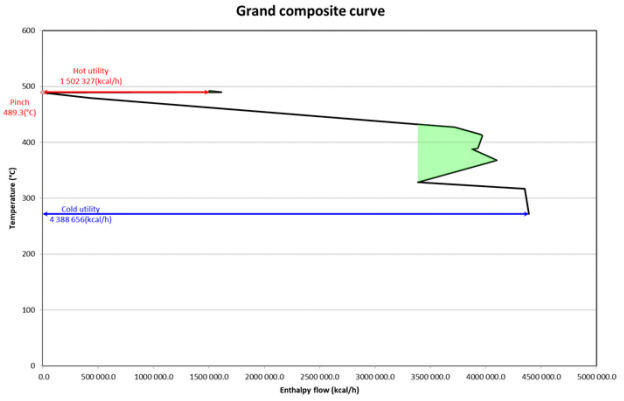


Equivalent

With the Excel Add-In:



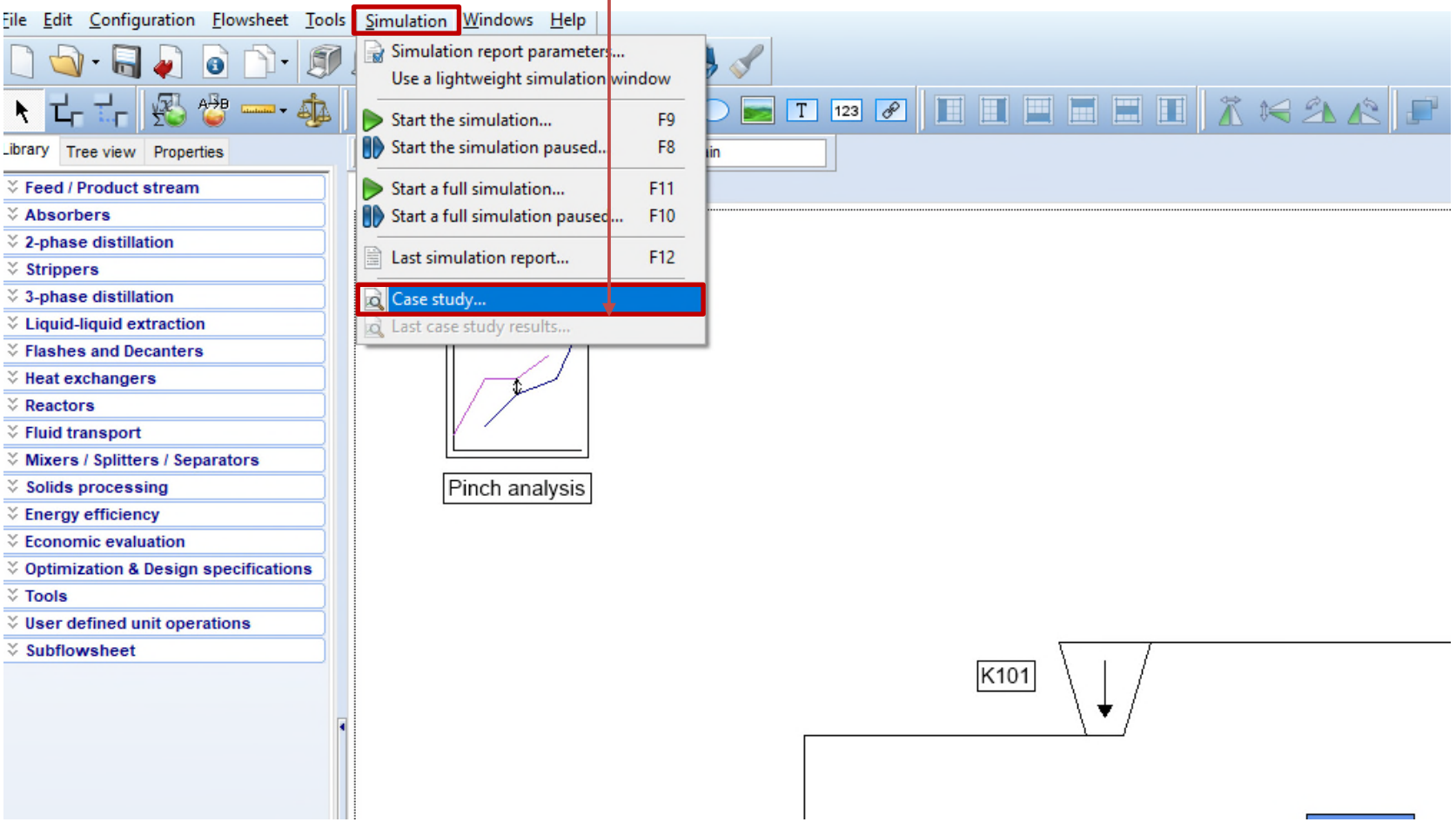




3. Advanced calculations...

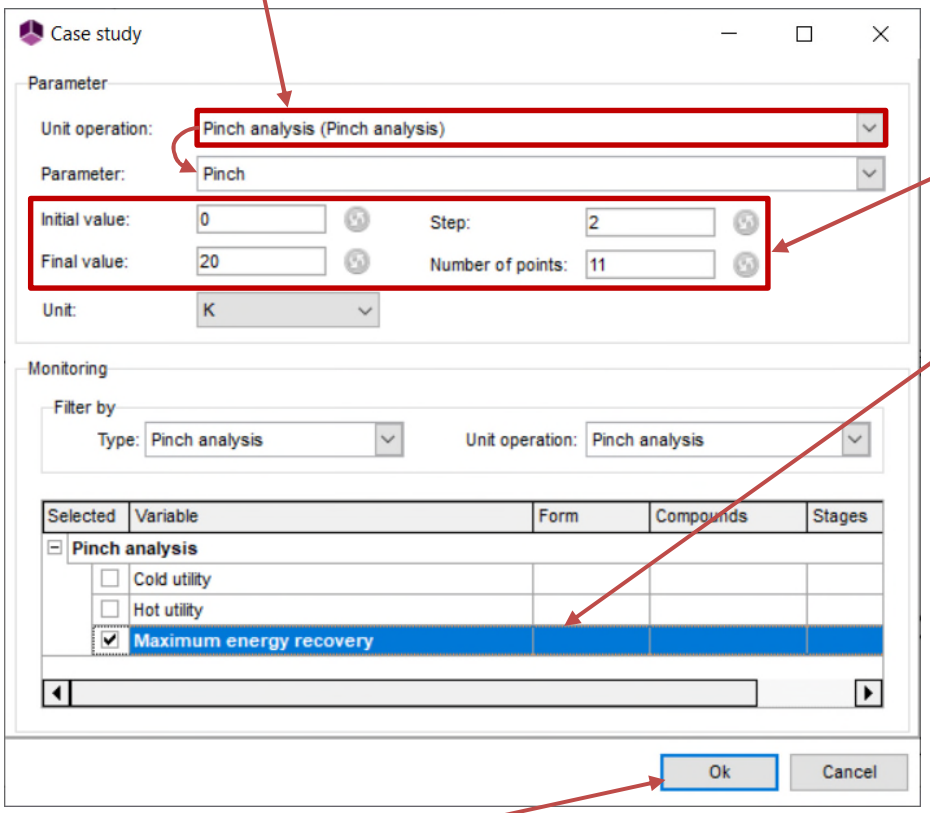
It is possible to use ProSimPlus to perform a case study focusing on the pinch value (for example).

1. Click on « Case Study » within the « Simulation » tab



3. Advanced calculations...

1. Select the « Pinch » parameter within the « Pinch analysis » unit operation

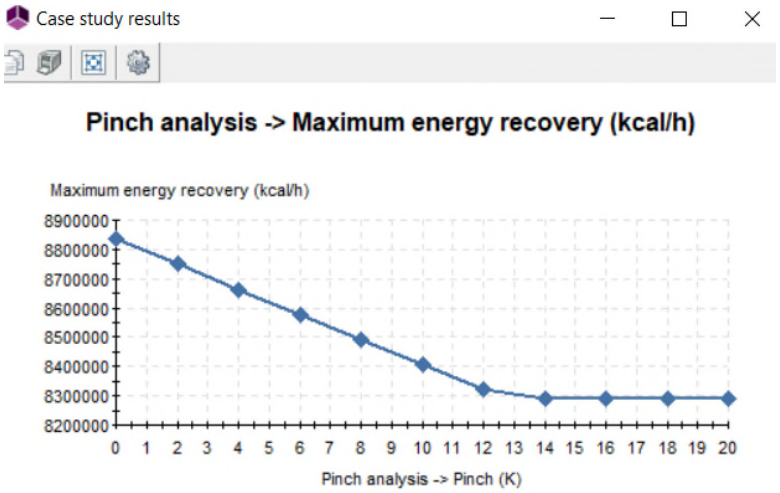


2. Select the range of pinch value: from 0°C to 20°C with a step of 2°C

3. Select the parameter(s) to monitor: for example, the « Maximum energy recovery »

4. Click on « OK »

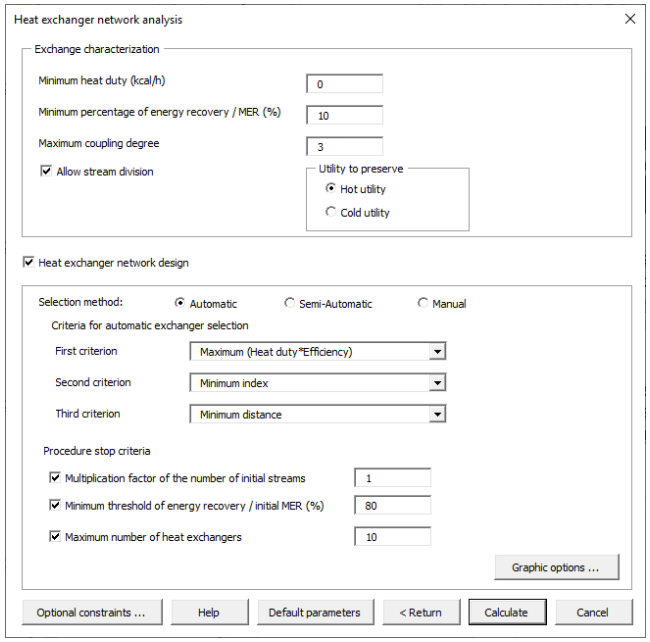
5. The results can be plotted

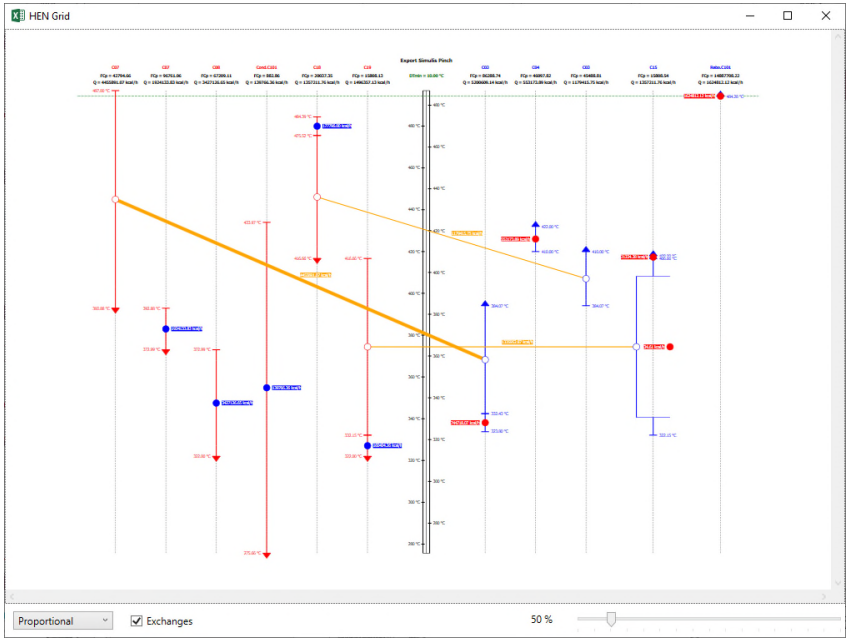


3. Advanced calculations...

So far, the calculations performed correspond to the first phase of process energy optimization: it is the energy diagnostic. At this stage, it is possible to conclude about the potential gains of energy and the advantages of changing the process configuration. A second phase will allow to generate the optimum heat exchangers network, corresponding to the best compromise between investment and operating costs as well as flexibility and process safety.

This second phase can be performed by subscribing to the full version of Simulis Pinch® (additional information is available on ProSim website: www.prosim.net). The use of Simulis Pinch® for the generation of heat exchangers network is detailed in the « Getting Started with Simulis Pinch® » documents.





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