T H E R M O P T I M ®

GETTING STARTED

Productive structure editor

VERSION 2.6

CONTENTS

GETTING STARTED

The aim of this guide is to allow users to quickly familiarize themselves with the productive structure editor of THERMOPTIM.

This Getting started Guide is for readers already familiar firstly using Thermoptim, and secondly with the basics of productive structures. You will find lots of information on these topics in the Thermoptim-UNIT portal (http://thermoptim.org) and, for the productive structures, in Chapter 10 (Part 3) of the book Energy Systems[1].

In addition, volume 4 of the Thermoptim reference manual deals specifically with the editor of productive structures.

The productive structure can very well be inferred from the physical sketch (Thermoptim diagram) and thermodynamic parameters (Thermoptim project). Provided that the temperature T_0 of the surroundings is properly initialized (Help menu / global settings of the simulator), it serves to distinguish the exergy providers and reducers, and calculate exergy balances of productive or dissipative unit (PDU).

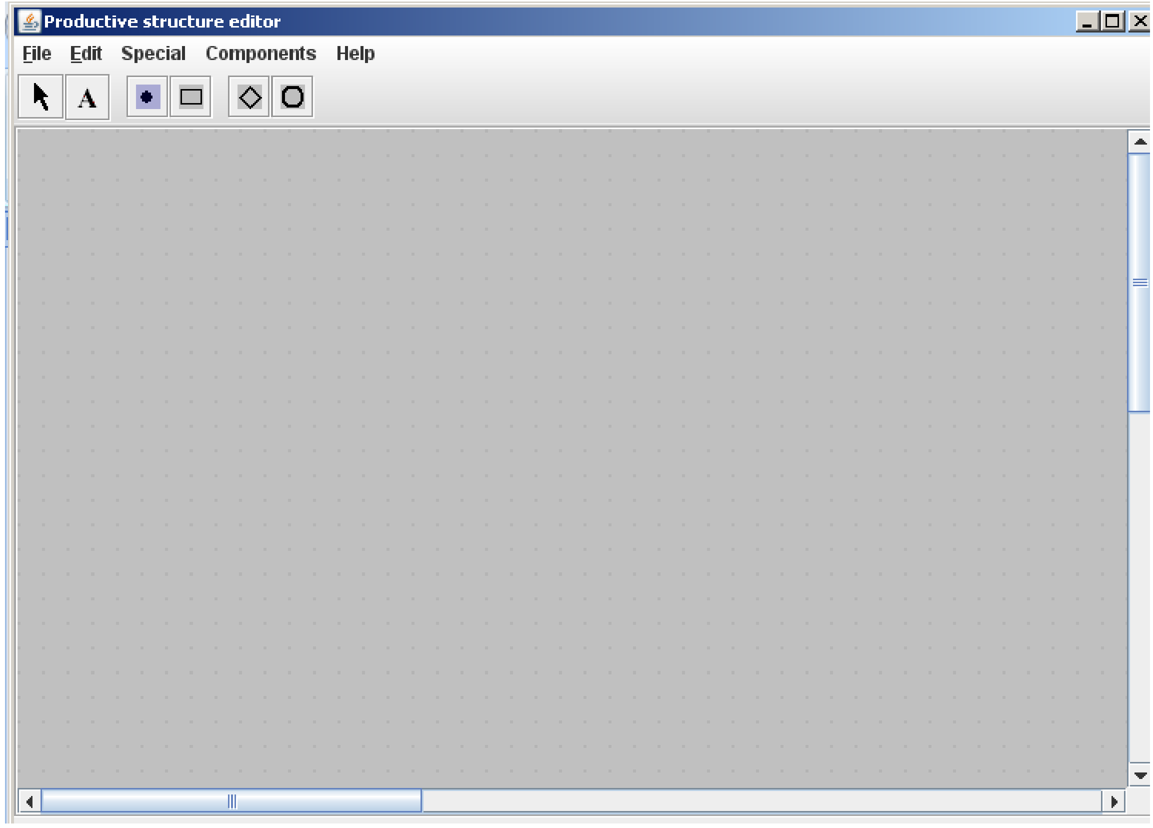

Figure 1: Productive structure editor

We will present three examples in this guide, whose productive structures we will build:

- Steam power plant;
- Refrigeration machine;
- Gas turbine with cogeneration.

We refer you to the three getting started guides explaining how to model them in Thermoptim.
Thermoptim corresponding files are included in the software installation folder. The productive structure fils, with exptension .str, are by default stored in the folder "struc."

[1] GICQUEL R., Energy Systems: A New Approach to Engineering Thermodynamics, January 2012, CRC Press, ISBN-13: 978-0415685009.

2 PRODUCTIVE STRUCTURE EDITOR

A new editor including the various components used in the productive structures has been developed (figure 5.1).
It is accessible from the "Special" menu of the simulator screen (Ctrl B). Its palette provides icons for process-points to represent inlet and outlet flows, for PDUs, and for junctions and branches.

This productive structure editor being analogous to the diagram editor, the details of its basic functionality is given in Volume 1 of Thermoptim reference manual.

2.1 Steam cycle example

In order to build a productive structure, a Thermoptim project and its diagram should have been previously opened and recalculated.

The diagram of the facility and the value of key parameters are given in figure 2.

To create the productive structure, open the productive structure editor screen (figure 1).

In a first step, by selecting the line "Diagram transfer " of menu "Special", it creates all production units.

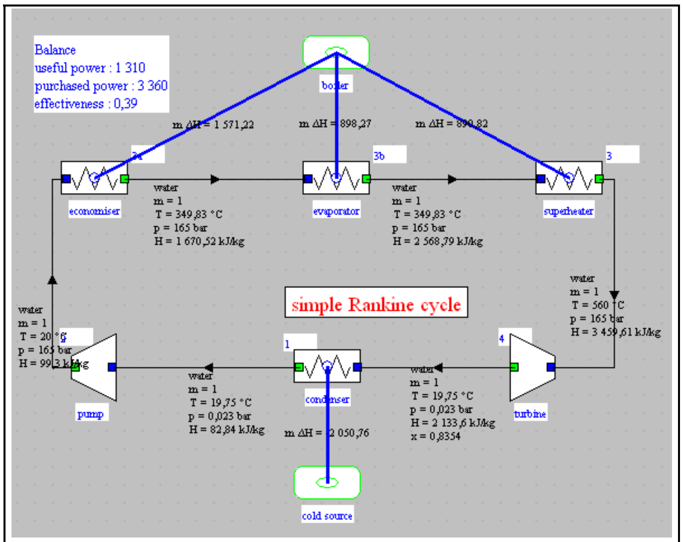

Figure 2: Physical diagram

The productive structure you get is given figure 3.

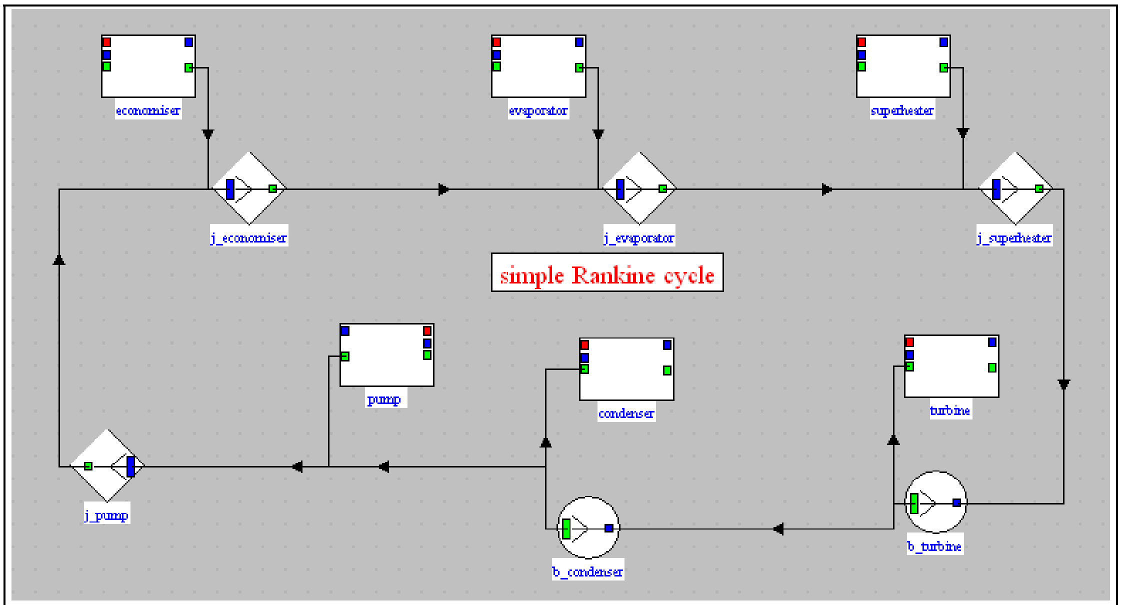

Figure 3: Automatically generated productive structure of a steam cycle

This way of doing often results in the introduction of junctions in series and/or of branches in series, which may be grouped in order to simplify the productive structure. This happens when several providers or several receivers appear sequentially in the physical diagram. This is for instance the case when a phase change heat exchanger such as a steam generator is represented by three exchangers in series (economizer, vaporizer, superheater).

It is therefore possible, in a second step, to select the pseudo-nodes in series the structure editor, and group them by selecting the line "Suppression of nodes in excess" of menu "Special". In order to avoid errors, you can choose not to automatically remove the real nodes appearing in the physical structure, knowing that they can be removed by hand in a second time. The production structure becomes that of Figure 4.

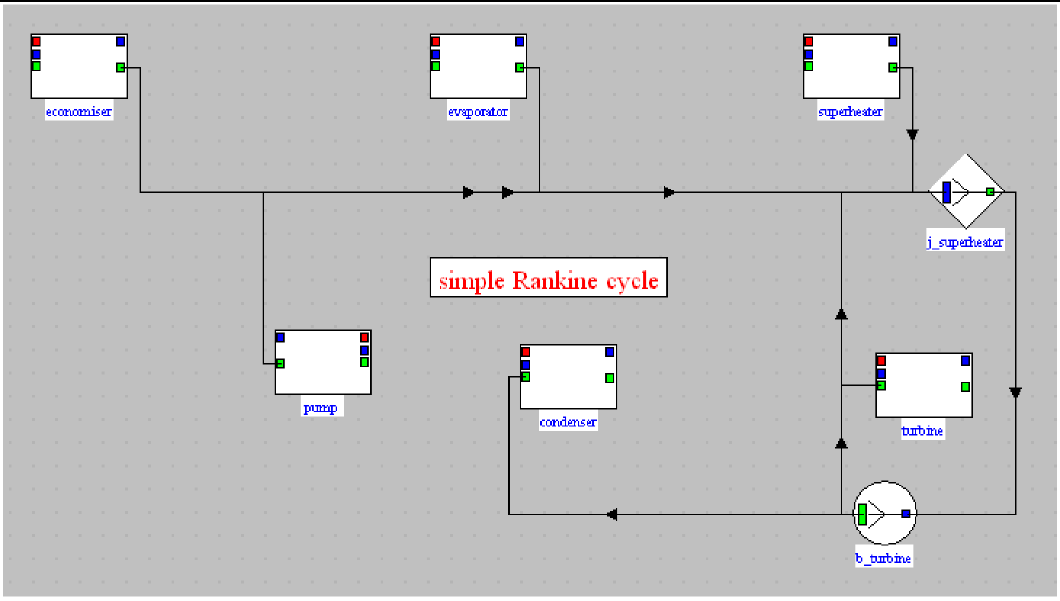

Figure 4: Productive structure of the steam cycle, excess nodes removed

Rework the structure for better readability, by shifting components from left to right or right to left. Result you get is close to that of Figure 5.

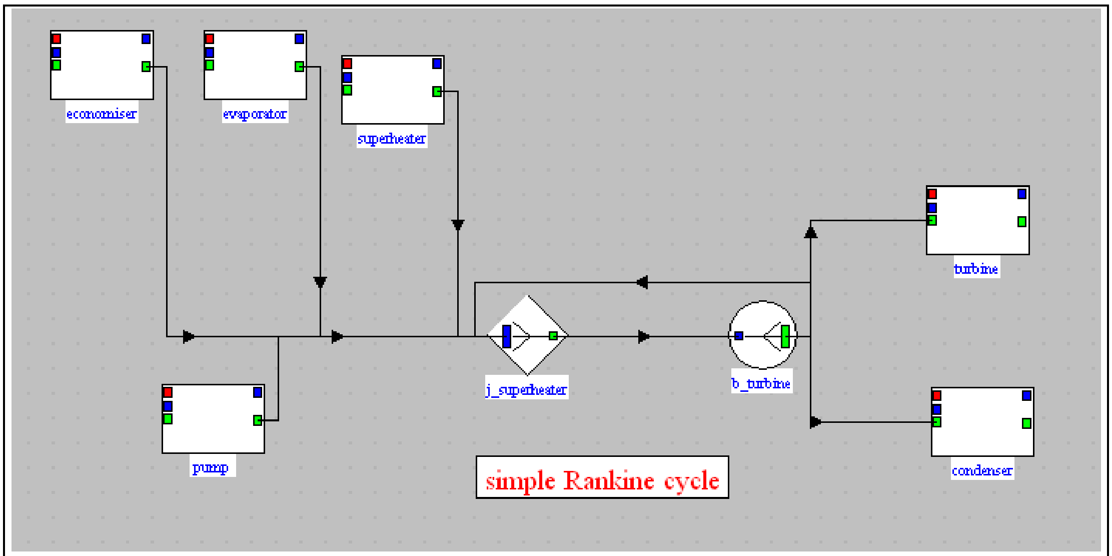

Figure 5: Productive structure of steam cycle, slightly reworked

This diagram is not yet completely set. If we try to build the full project exergy balance by selecting the line "Project exergy balance" of menu "Special", we obtain the result in Figure 6.

The last column, titled "settings", gives some summary information on the settings considered: the pump is an external exergy input, because it is not connected to the turbine and the condenser and the boiler are considered exchanging heat-exergy with a source at 0 °C, which is obviously absurd.

component	Resource	Product	Exergy efficiency	Irreversibilities	% total	settings
turbine	1,556.221	1,326.014	0.852073	230.207	-0.1667	
pump	16.797	16.47	0.980537	0.3269	-0.0002367	compr
economiser	0	566.951	0	-653.216	0.473	Tk = 0 °C
evaporator	0	482.724	0	-532.052	0.3852	Tk = 0 °C
superheater	0	523.337	0	-572.256	0.4143	Tk = 0 °C
condenser	33.261	-112.617	-3.38589	145.878	-0.1056	Tk = 0 °C
global	16.797	2,786.409	83.224	-1,381.112	1	

Figure 6: Exergy balance before setting

In the productive structure, the mechanical coupling between the turbine and the pump is missing. We represent it by a divider at the turbine outlet, with two branches, one representative of this coupling, and the other of the net power available (Figure 7).

This productive structure is interpreted as follows: the steam power plant is a machine which receives an external exergy input in the boiler, and by internal recycling, exergy is provided to the pump, which are the two production units in the left of the screen.

This exergy is partly converted into mechanical form in the turbine and partly dissipated in the condenser. The net work is the fraction of mechanical power not recycled.

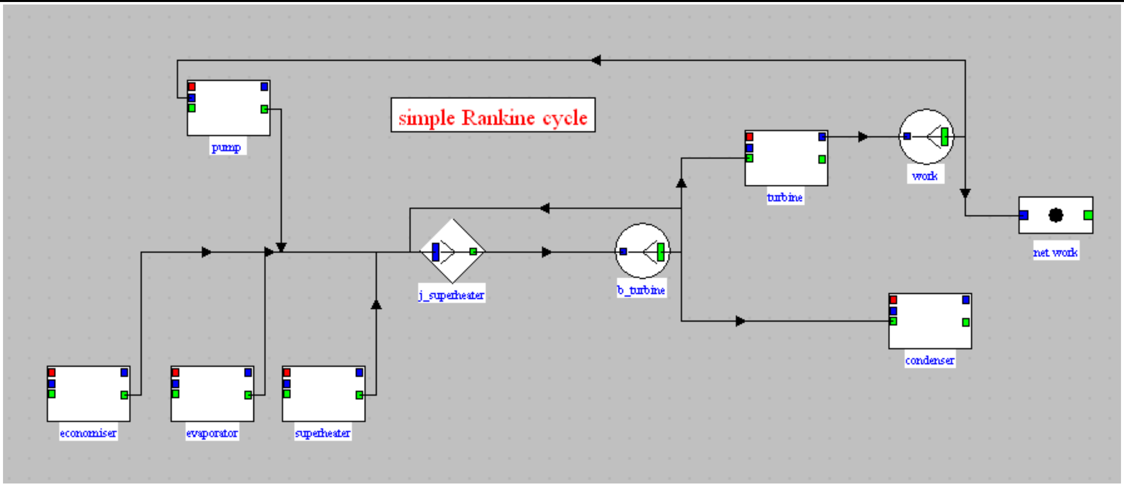

Figure 7: Productive structure of steam cycle with mechanical coupling

To end up building the productive structure, we still have to set the temperature of outside sources with which heat-exergy is exchanged, i.e. the boiler and condenser. We will respectively choose 1600 K (1326.85 °C) and 288.15 K (15 °C). To do this, double-click the corresponding PDU, select "External Source" and enter these values (in ° C).

component	Resource	Product	Exergy efficiency	Irreversibilities	% total	settings
pump	16.797	16.47	0.980537	0.3269	0.0002261	
turbine	1,556.221	1,326.014	0.852073	230.207	0.1592	
economiser	1,287.979	566.951	0.440186	721.028	0.4988	Tk = 1,326.85 °C
evaporator	736.501	482.724	0.655429	253.777	0.1755	Tk = 1,326.85 °C
superheater	730.389	523.337	0.716518	207.052	0.1432	Tk = 1,326.85 °C
condenser	33.261	0	0	33.261	0.02301	Tk = 15.00 °C
global	2,754.869	1,309.217	0.4752	1,445.652	1	

Figure 8: Exergy balance of the full project

To enter these values, double-click the PDU concerned or their line in the overall exergy balance screen, and enter them into field "Source T (°C)". Then save the productive structure.

The exergy balance of the full project is given in figure 8.

2.2 Example of a refrigeration cycle

The diagram of the facility and the value of key parameters are given in figure 9.

To create the productive structure, open the productive structure editor screen (figure 1).

In a first step, by selecting the line "Diagram transfer " of menu "Special", it creates all production units.

The productive structure you get is given Figure 10.

Four nodes are in series. Select line "Suppress nodes in excess" and select, option "OK (except the physical model)". The production structure becomes that of Figure 11.

Rework the structure for better readability, by shifting components from left to right or right to left. Result you get is close to that of Figure 12.

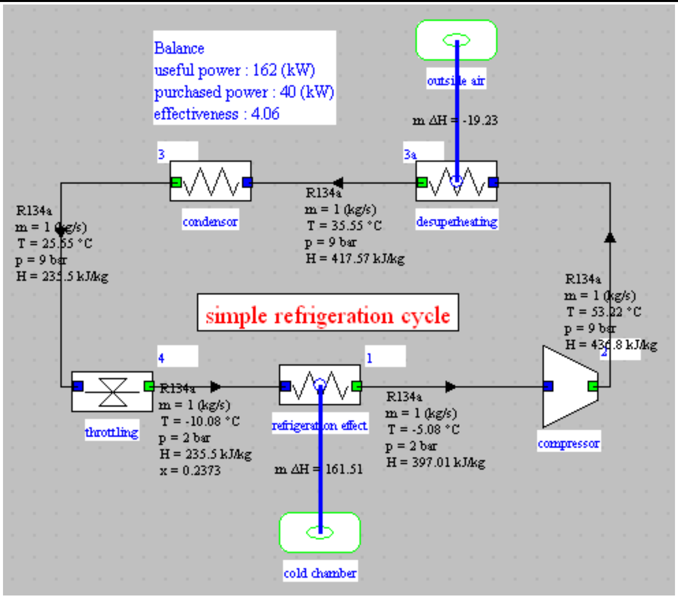

Figure 9: Physical diagram

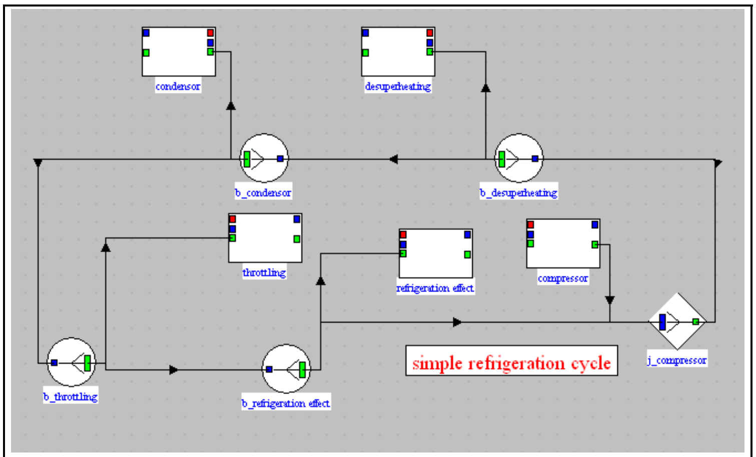

Figure 10: Automatically generated productive structure of a refrigeration cycle

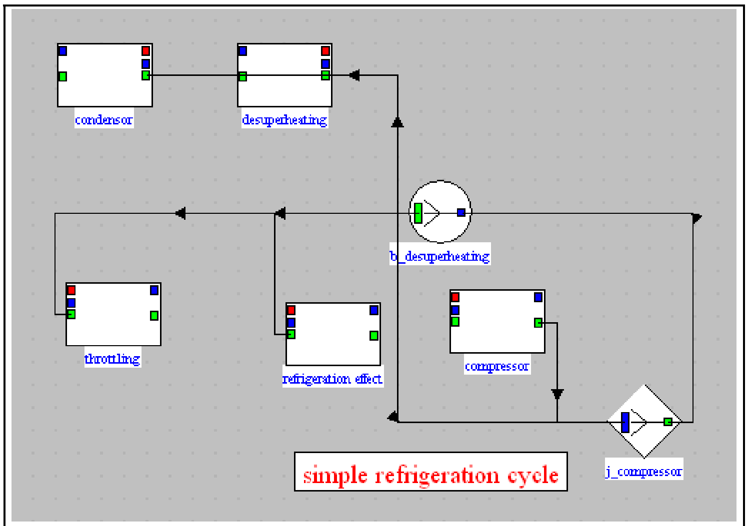

Figure 11: Productive structure of the refrigeration cycle, excess nodes removed

This productive structure is interpreted very simply: the refrigerating machine receives an external exergy input in the compressor. This exergy is partly converted into the evaporator (refrigeration effect), the rest being dissipated in the condenser and the expansion valve (throttling).

This diagram is not yet completely set. If one tries to build the full project exergy balance, we obtain the result in Figure 13.

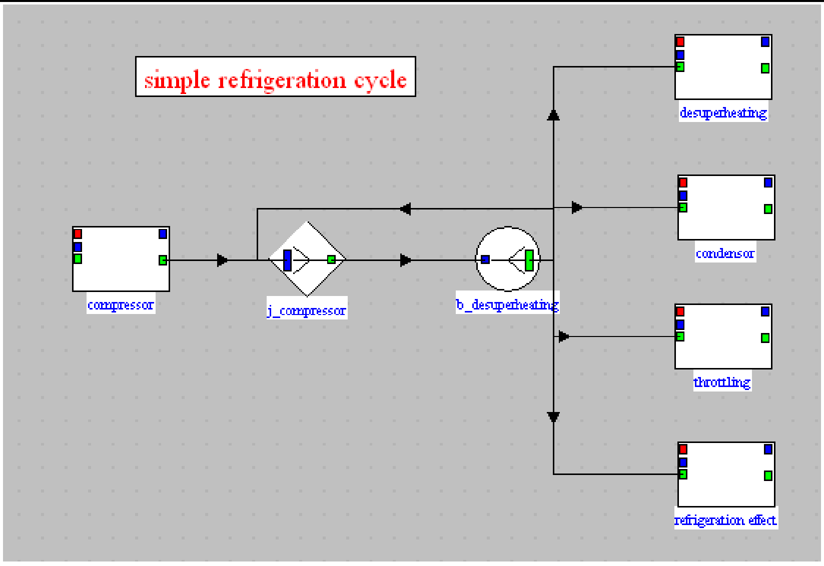

Figure 12: Productive structure of refrigeration cycle, slightly reworked

component	Resource	Product	Exergy efficiency	Irreversibilities	% total	settings
throttling	4.024	0	0	4.024	0.1992	
compressor	39.797	32.845	0.825308	6.952	0.3441	compr
desuperheating	1.681	-1.056	-0.628162	2.738	0.1355	Tk = 0 °C
refrigeration eff...	15.358	8.869	0.577504	6.489	0.3212	Tk = 0 °C
global	39.797	7.813	0.4923	20.203	1	

Figure 13: Exergy balance before settings

The last column, titled "settings", gives some summary information on the settings considered: the compressor is an external exergy input, and the condenser and evaporator are considered exchanging heat-exergy with a source at 0 ° C, which is obviously absurd.

To end up building the productive structure, we still have to set the temperature of outside sources with which heat-exergy is exchanged, i.e. the evaporator and condenser. We will respectively choose 270.15 K (-3 °C) and 288.15 K (15 °C). To do this, double-click the corresponding PDU, select "External Source" and enter these values (in ° C).

The exergy balance of the full project can be recalculated. It is given in figure 14.

component	Resource	Product	Exergy efficiency	Irreversibilities	% total	settings
throttling	4.024	0	0	4.024	0.1386	
compressor	39.797	32.845	0.825308	6.952	0.2394	compr
desuperheating	1.681	0	0	1.681	0.05789	Tk = 15.00 °C
condensor	11.782	0	0	11.782	0.4058	Tk = 15.00 °C
refrigeration eff...	15.358	10.761	0.700701	4.597	0.1583	Tk = -3.00 °C
global	39.797	10.761	0.2704	29.036	1	

Figure 14: Exergy balance of the full project

2.3 Example of the cogeneration gas turbine

We have modeled in Thermoptim a cogeneration gas turbine example. The diagram and parameter values are given in figure 15.

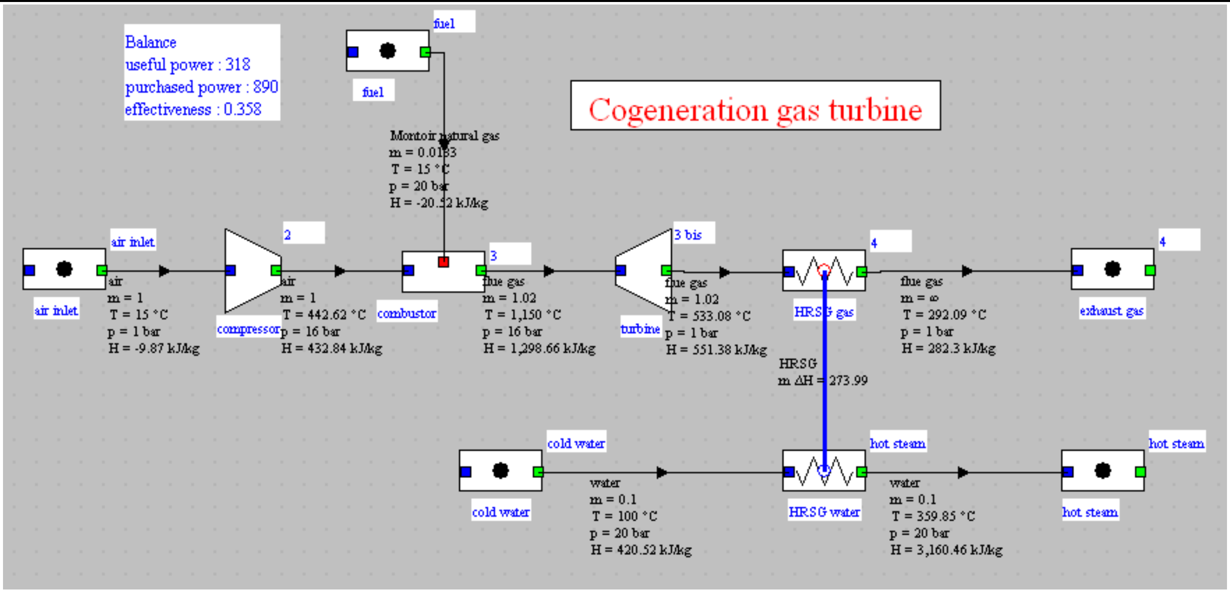

Figure 15: Physical diagram

The production structure that we built is given figure 16.

Having identified the missing settings (you must indicate that the hot steam is valued (Valuable exergy) and not lost) and added the links representing the mechanical couplings, we obtain the productive structure of Figure 16.

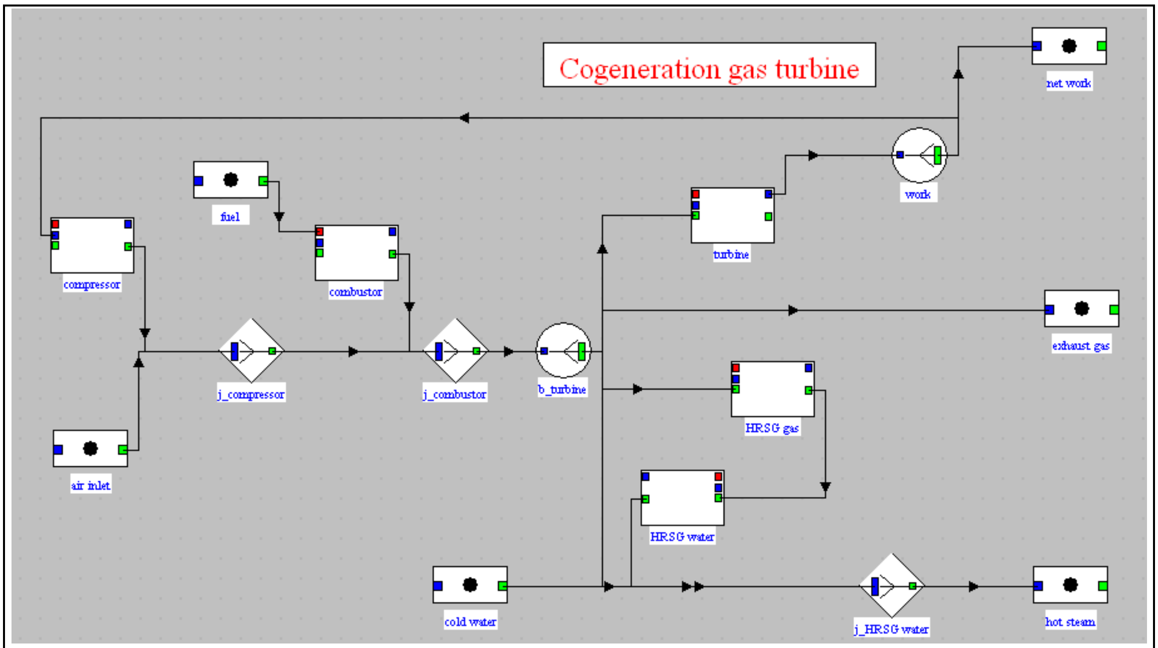

Figure 16: Productive structure

This production structure is interpreted as follows: the gas turbine receives a chemical exergy supply from the fuel, and by internal recycling, exergy is provided to the compressor. This exergy is converted partly into mechanical form in the turbine and partly into heat in the recovery steam generator HRSG, the remainder being dissipated by discharge into the atmosphere. The net work is the fraction of mechanical power not recycled.

In the exergy balance of the project, the variations of exergy of streams coupled by a exchanger (HRSG in the physical sketch) are shown enclosed by brackets, the two exchange processes being grouped together next to one another to clarity

The exergy balance of the full project is given Figure 17.

component	Resource	Product	Exergy efficiency	Irreversibilities	% total	settings
fuel	897.041	0	0	0	0	
compressor	442.713	402.238	0.908574	40.476	0.08269	
turbine	796.411	760.935	0.955456	35.475	0.07248	
combustor	0	613.556	0.683978	275.989	0.5639	
cold water	4.593	0	0	0	0	
hot steam	114.66	114.66	0	0	0	
HRSG gas	157.841	0	0	(157.841)	(0.3225)	HRSG
HRSG water	0	110.067	0	(-110.067)	(-0.2249)	HRSG
exhaust gas	0	0	0	89.749	0.1834	loss
global	901.634	432.882	0.4571	489.463	1	

Figure 17: Exergy balance of the full project