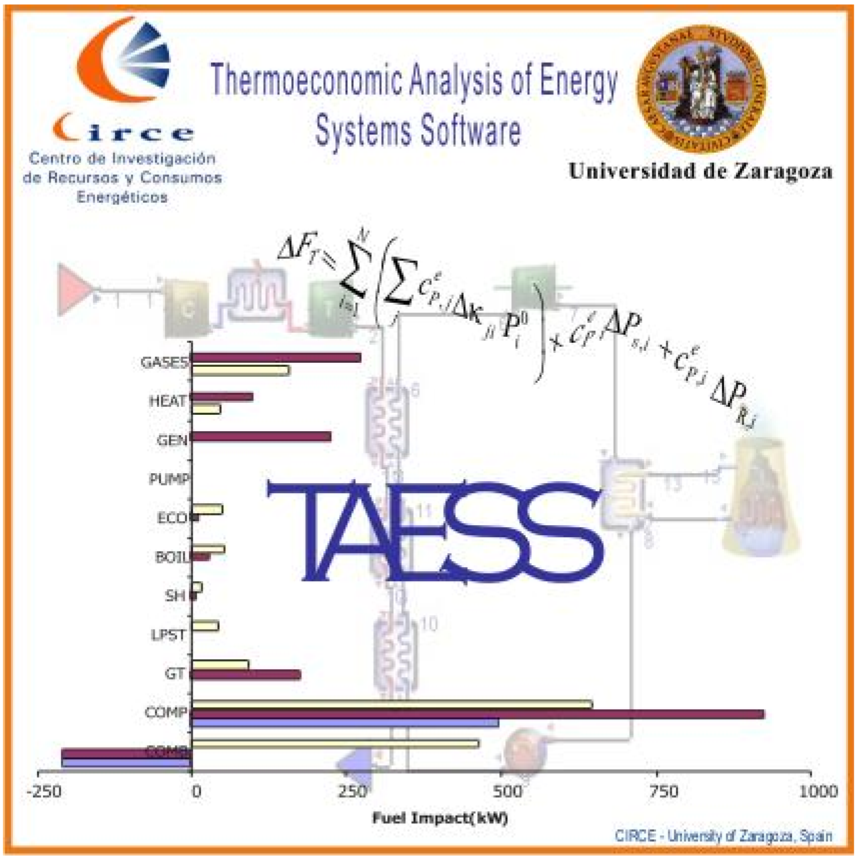

User Guide

Version 1.0

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Revision Control Page

Version	Date	Changes
0	15/05/07	Initial Document
1	29/10/07	Adding new section (Use EES with TAESS)

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Introduction

TAESS is a software tool designed to make the thermoeconomic analysis of energy systems from their thermodynamic model and productive structure.

It is based on the works on Termoeconomics developed in CIRCE and the Dpt. of Mechanical Engineering of the University of Zaragoza (Spain), since 1986. Their main characteristics are:

- User Interface based on Excel.
- Exergy Cost computation.
- Automatic generation of the Fuel-Product Table.
- Cost decomposition and formation process of products and residues analysis.
- Fuel Impact analysis.
- Irreversibility variation analysis.

This manual explains the software installation, the basic handling of the application and the structure of the reports and results that are obtained.

The present version of TAESS is designed as a prototype of a more extensive project. Although this version is limited in the size of systems that can handle (max. 25 equipment) has all the functionality available and can be used for educative purposes.

Detailed documentation about the algorithms used and a collection of examples could be found at http://www.exergoecology.com.

1 TAESS Setup

TAESS is an application based on Visual Basic macros for Microsoft Excel ©. There is a setup program: Setup_TAESS.exe that could be obtained from:

http://www.exergoecology.com/taess

1.1 Requirements

To install and execute this application is required:

- Microsoft Windows © 2000 or XP operating system
- Microsoft Excel © 2000 or 2003

1.2 Regional Settings

TAESS is designed to work with the number options defined by the regional settings "English (US)". These options set the Decimal symbol to a . (point) and the Digit grouping symbol to a , (comma) in both the Numbers and Currency tab sheets.

The first and quickest is to change your Windows Regional settings to one of the ANSI languages such as English US, English UK etc.

Select the Windows Start, Settings, Control Panel, Regional Settings menus to bring up the current settings, and then Select English(US).

You also could find a useful tool, call PointComma at:

http://www.et.web.mek.dtu.dk/Software/PointComma/Index.html

1.3 Microsoft Office Excel Configuration

To work with this application you must verify the Excel macro security level. If Excel has a macro security level of HIGH, macros will not open. Within Excel click on Tools\Macro\Security and set the security level to medium (safer) or low.

1.4 TAESS Setup

After download the file Setup_TAESS.exe, double click the icon shown in Figure 1

Figure 1. TAESS Setup icon

This program copy the files in the selected folder, by default "Program Files/TAESS", but you could change it during installation. Optionally, it creates Start menu link folder, which contains::

- The launch program to create the excel workbook
- The help file
- A web access to the program page.

- An uninstall program.

Before to start the application you should setup properly the number settings in the regional options and the security level for the Excel macros.

The installed software includes an “Examples” folder, with:

- A standalone program for a simple thermodynamic model of a gas turbine: tgas.exe
- CSV data files, whose contain the output results of the thermodynamic model to use as input data in TAESS
- The workbook of the example.

You can found more examples in the web page of TAESS.

2 Starting TAESS

TAESS starts opening a dialog window (Figure 2), from which you have access to:

- The application [Help].
- New Excel workbook. [Continue]

The handling of TAESS is conceived around a work case: a reference state, a operation state or both. The application makes, under user request, the calculations to obtain a termoeconomic diagnosis report.

The new Excel workbook, generated by TAESS, uses a template which contains all the required macros and two initial sheets:

- Physical Structure
- General Data.

Once, the workbook is created, it can be managed as any other Excel workbook. You can save it with a specific name that can be opened later. .

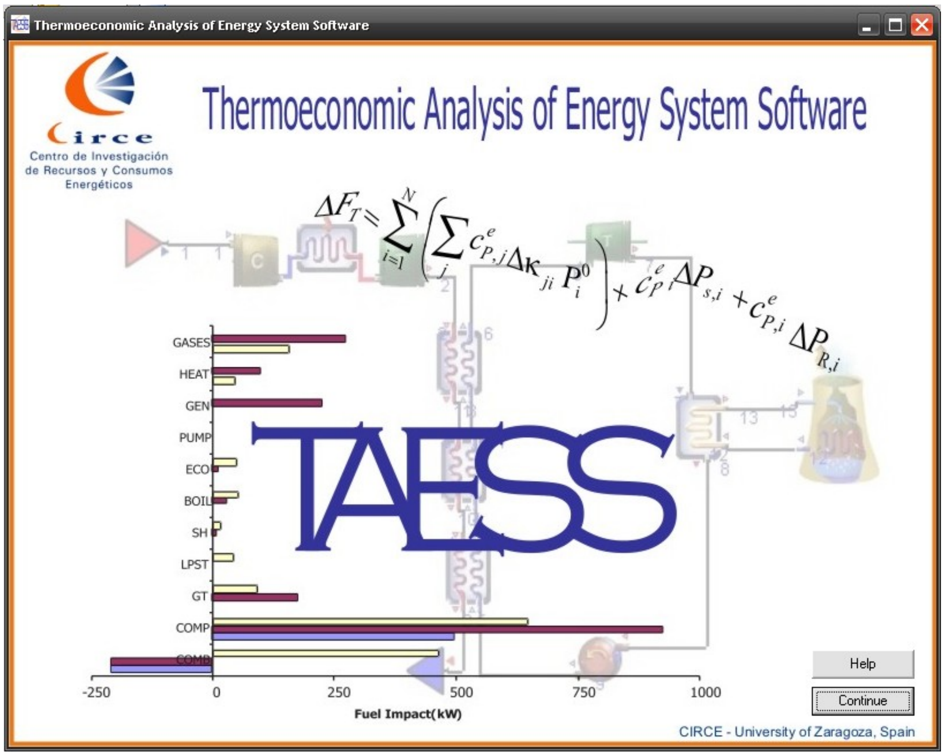


Figure 2. TAESS start window

2.1 Physical Structure

In this worksheet the diagram of the physical structure of the system could be pasted. It will serve as reference for the user.

We will use an example of Gas Turbine Cycle TGAS, to illustrate the functionality of the program.

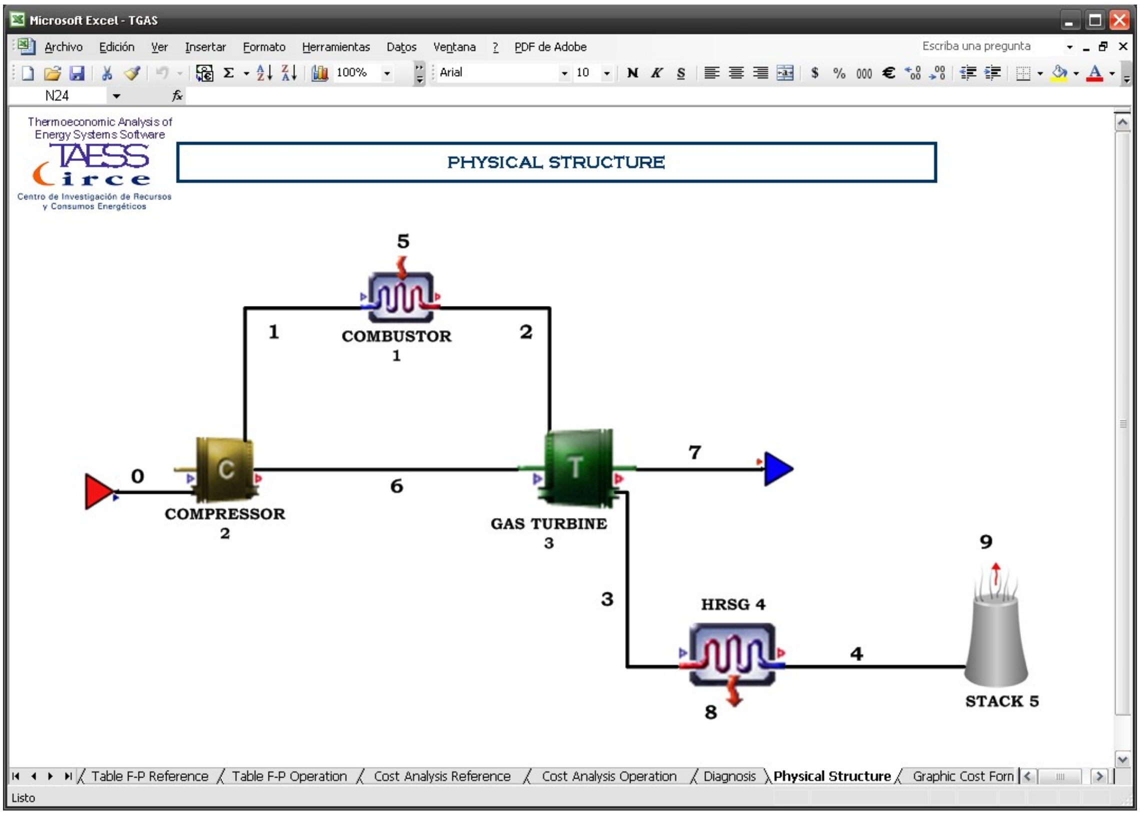


Figure 3. Physical Structure of TGAS plant

2.2 General Data

General Data is the main sheet (**¡Error! No se encuentra el origen de la referencia.**), and its divided in three parts (Figure 4):

- o New Configuration Definition.
- o Device Names.
- o Flow properties definition.

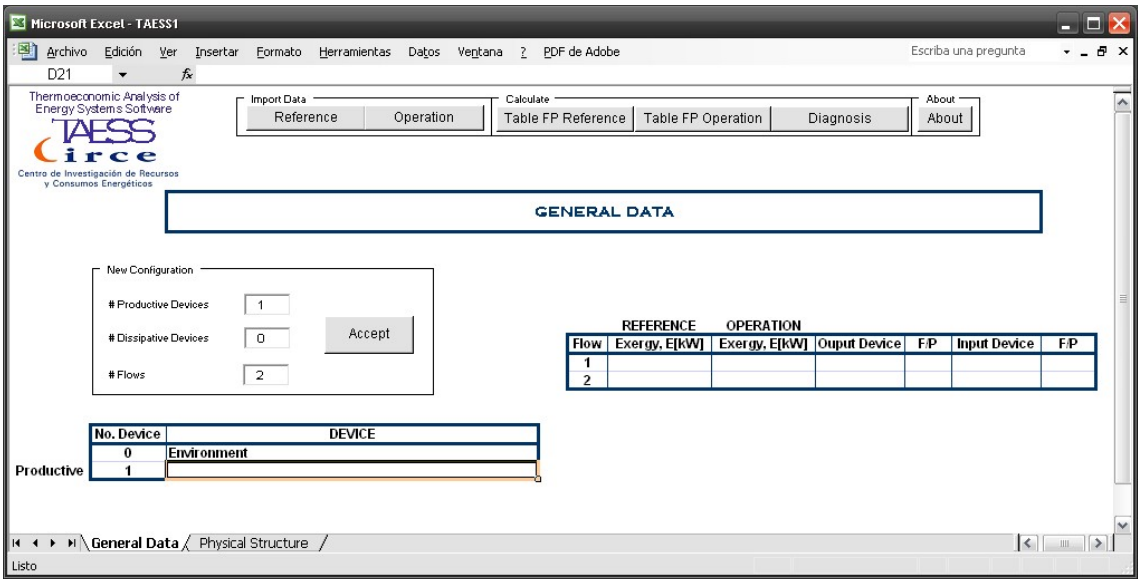


Figure 4. General Data

2.2.1 New Configuration Definition

The dimension of the system is provided in this block. You must enter:

- The number of flows
- The number of productive devices
- The number of dissipative devices

In order to make a good definition of the system configuration you should known which devices are productives and which are dissipatives

- Productive devices: Their purpose is to obtain products that will be used in further processes or becomes the final product of the system, e.g.:
  - Compressor: Its purpose is to compress the air, which is used in the combustor.
  - Turbine: Its purpose is to produce mechanical energy used in the generator.
- Disipative devices: Their purpose is to reduce or eliminate the environmental impacto f the residues generated in other devices, e.g.:
  - Condenser: Its purpose is to disipate the heat (entropy) generated in a steam cycle.
  - Stack: Its function is to reduce the temperatute and pressure of the combustión gases and expel it to the environment.

In our example there are five devices (4 productive and 1 dissipative) and 9 flows, see Figure 5

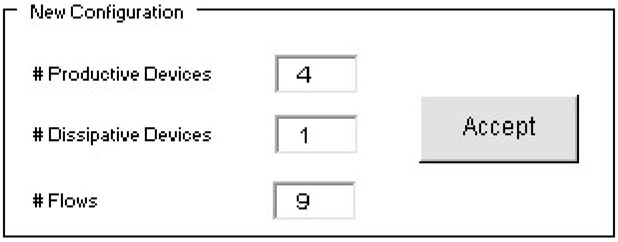


Figure 5. TGAS configuration

A table, which contains the number, name and type of devices, is shown in Figure 6

	No. Device	DEVICE
	0	Environment
Productive	1	Combustor
	2	Compressor
	3	Gas Turbine
	4	HRSG
Dissipative	5	Stack

Figure 6. Device Description

2.2.2 Flows Exergy.

In order to make the thermoeconomic analysis of the system it is necessary to have the exergy of each the flow of the system, those are obtained from an external thermodynamic model.

The application allows defining two datasets of thermodynamic states: a “reference” state and “operational” or current state.

2.2.3 Phisical Structure

The definition of the physical structure consists of indicating the pair of devices each flow of the plant connects. Every flow of the plant outputs from a device and inputs to another device. The environment is considered as the device “0”..

The physical structure of the TGAS plant, according to the enumeration depicted in Figure 3 is:.

- Flow#1 outputs from device#2 and input to device#1
- Flow#2 outputs from device#1 and input to device#3
- Flow#3 outputs from device#3 and input to device#4
- Flow#4 outputs from device#4 and input to device#5
- Flow#5 outputs from device#0 and input to device#1
- Flow#6 outputs from device#3 and input to device#2
- Flow#7 outputs from device#3 and input to device#0
- Flow#8 outputs from device#4 and input to device#0
- Flow#9 outputs from device#5 and input to device#0

2.2.4 Productive Structure

Each component or process of the system has a productive purpose. It is established by means of the definition of its efficiency:

Efficiency = Product / Resources

that measures the quality of a process. This is to say, there is an implicit classification of the flows crossing the boundary of the system, the flows that are the production objective, and those that are the resources required to carry out the production.

For each process or component of the system is necessary to identify the flow streams that constitute its *product streams*, and the flow streams used to obtain them, called *fuel streams*. Accordingly, it can be said that the *fuel* is the amount of exergy provided by the fuel streams, and the *product* is the exergy provided by the product streams.

To describe the *productive structure* we must identify, for every component, one or several fuel and product streams as the collection of the flows that constitute them.

The TGAS productive process starts in the combustor, where the combustion process is performed, it uses natural gas and compressed air to obtain hot gases, which are expanded in the turbine to produce work. Part of the work is used in the compressor to compress the air used in the combustion. The output gasses of the turbine are used in the Heat Recovery Steam Generator to boil the water and the exhausted gases are expelled to the environment in the stack.

Device#0 is the environment, it extends everything outside the limits of the system (control volume). The resources of the environment are all the system outputs and its products are all the system inputs, so the productive definition of the environment is:

- Flow#0 outputs as Product.
- Flow#5 outputs as Product.
- Flow#7 inputs as Fuel.
- Flow#8 inputs as Fuel.
- Flow#9 inputs 0 as Fuel.

Device#1. Combustor, its purpose is to obtain heat gases by means of the combustion of natural gas:

F[1] = E[0] + E[5]
P[1] = E[1]

- Flow#5 inputs to device#1 as Fuel.
- Flow#0 inputs as Fuel
- Flow#2 outputs as Product.

Device#2. Compressor: Its purpose is to compress the air used in the combustion; it uses part of the work produced by the turbine:

F[2] = E[6]
P[2] = E[2]

- Flow#6 inputs as Fuel.
- Flow#3 outputs as Product

Device#3. Turbina. Its purpose is to obtain work expanding the combustion gases.

F[3] = E[2]-E[3]
P[3] = E[6]+E[7]

- Flow#2 inputs as Fuel
- Flow#3 outputs as Fuel (exhausted)
- Flow#6 outputs as Product
- Flow#7 outputs as Product

Device#4. The función of the HRSG is to recover the gases heat to produce steam.

F[4] = E[3] - E[4]
P[4] = E[8]

- Flow#3 inputs as Fuel
- Flow#4 outputs as Fuel (exhausted)
- Flow#8 outputs as Product

Device#5. The purpose of the stack is to expel the exhausted gases of the HRSG:

F[5] = E[4]
P[5] = E[9]

- Flow#4 inputs as Fuel
- Flow#9 outputs as Residue

The productive definition of TGAS is shown in Figure 7

	REFERENCE	OPERATION				
Flow	Exergy, E[kW]	Exergy, E[kW]	Ouput Device	F/P	Input Device	F/P
1	2765.6863	2821.6579	2	P	1	P
2	9932.5704	10079.3868	1	P	3	F
3	4080.1127	4140.4221	3	F	4	F
4	509.5528	551.1457	4	F	5	F
5	12206.7941	12349.5191	0	P	1	F
6	3046.2119	3128.1922	3	P	2	F
7	2500.0000	2500.0000	3	P	0	F
8	2357.8464	2357.8464	4	P	0	F
9	509.5528	551.1457	5	P	0	F

Figure 7. Productive Structure of TGAS

3 The TAESS Taskbar

The TAESS commands are distributed in four taskbars located at the top of the excel worksheets. See Figure 8.

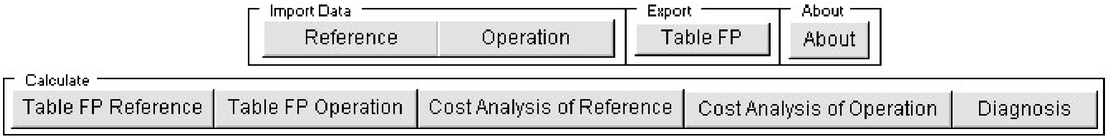


Figure 8. TAESS Taskbars

3.1 Import Data

Import Data Taskbar provides the command to import data from external applications, which made a thermodynamic analysis of the plant, like EES, ASPEN, BBlocks, or TermOptim. The import files contains the exergy values of the flows and the definition of the physical and productive structure. There are two import data options, as it is shown in Figure 9

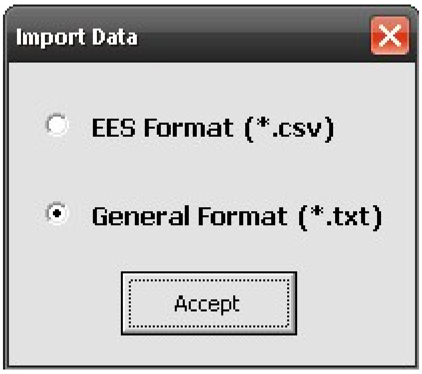


Figure 9. Import Data options

3.1.1 EES Format

EES (Engineering Equation Solver) is software developed by F-chart, which allows to user building thermodynamic models of energy systems, and export the results in CSV format (Comma Separated Values).

This files could have 3 format types of:

- Format 1. Contains the device names and the exergy values of the flows
- Format 3. Contains the devices names the exergy values of the flows and the physical structure of the system.
- Format 5. Contains the devices names the exergy values of the flows and the physical and productive structure of the system.

The archive structure is the following:

Format 1, 3 and 5:

- First row: Format type. (1,3,5)
- Second row: Nr. of flows, Nr. of productive devices and Nr. of dissipative devices.
- Third row: Device names.
- Fourth row: Flow exergy values

Format 3;

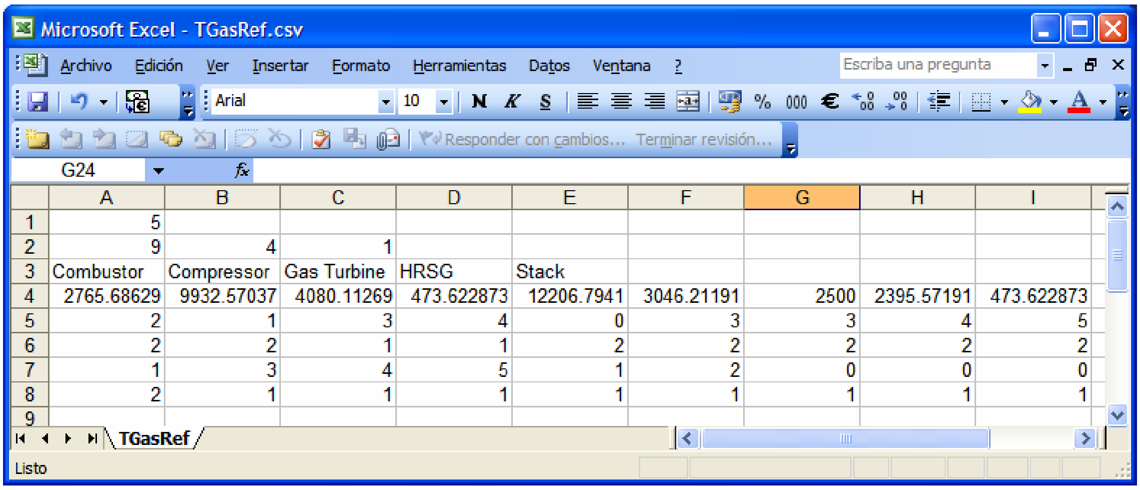
- o Fifth row: Number of the outgoing device of the flow.
- o Sixth row: Number of the ingoing device of the flow.

Format 5:

- o Fifth row: Number of the outgoing device of the flow.
- o Sixth row: F/P definition of the outgoing device of the flow.
- o Seventh row: Number of the ingoing device of the flow.
- o Eighth row: F/P definition of the ingoing device of the flow.

Note: The F/P values are representedas 1 and 2 respectively.

Figure 10 shows a the CSV file of the TGAS example.



	A	B	C	D	E	F	G	H	I
1	5								
2	9	4	1						
3	Combustor	Compressor	Gas Turbine	HRSG	Stack				
4	2765.68629	9932.57037	4080.11269	473.622873	12206.7941	3046.21191	2500	2395.57191	473.622873
5	2	1	3	4	0	3	3	4	5
6	2	2	1	1	2	2	2	2	2
7	1	3	4	5	1	2	0	0	0
8	2	1	1	1	1	1	1	1	1

Figure 10. CSV file

3.1.2 General Format

The application allows a general text format that could be easily generated by any thermodynamic modeling software, like ASPEN. It has the following format:

- o First row: Format type. (2,4,6)
- o Second row: Nr. of flows, Nr. of productive devices and Nr. of dissipative devices.
- o From the third row until end of file. It has 2, 4 or 6 columns depending of the format type.

Format 2: This format contains the flow nr. and the exergy value

- o First column: Flor number
- o Segunda columna: Exergy value

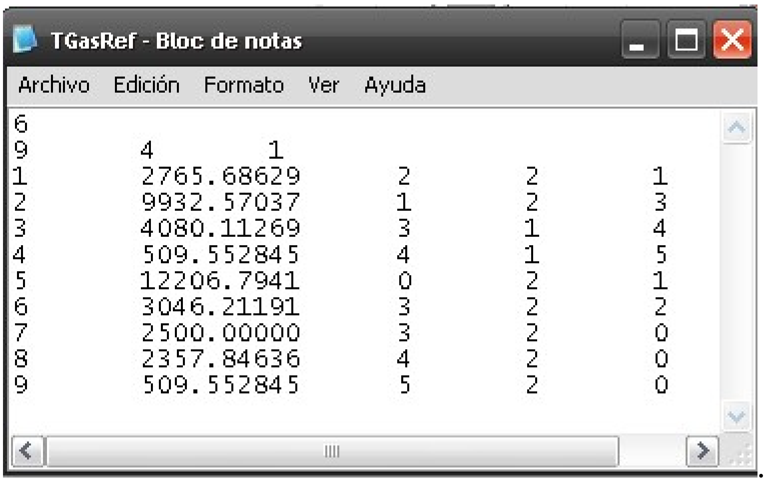
Format 4: Include the phisical structure.

- o Third column: Number of the outgoing device.
- o Fourth column: Number of the ingoing device.

Format 6: Include the productive definition.

- o Fifth column: FP definition of the outgoing device flow .
- o Sixth column: FP.definition of the ingoing device flow

Figure 11 shows the TXT format for the TGAS example.




```
6
9       4        1
1       2765.68629      2       2       1
2       9932.57037      1       2       3
3       4080.11269      3       1       4
4       509.552845      4       1       5
5       12206.7941      0       2       1
6       3046.21191      3       2       2
7       2500.00000      3       2       0
8       2357.84636      4       2       0
9       509.552845      5       2       0
```

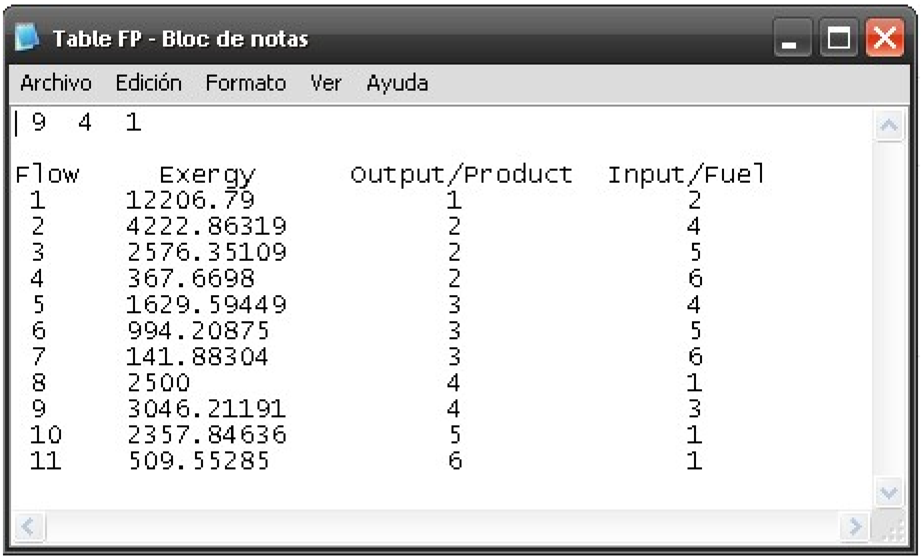
Figure 11 TXT file format

3.2 Export Data

This control creates a TXT file which contains the information of the Fuel Product Table.

The first row indicates the number of flows, number of productive devices and number of dissipative devices. From the fourth row to the end, contains 4 columns:

- First column: number of flow
- Second column: exergy value
- Number of the outgoing device
- Number of the ingoing device




```
9   4   1

Flow      Exergy       Output/Product   Input/Fuel
 1      12206.79            1              2
 2      4222.86319          2              4
 3      2576.35109          2              5
 4      367.6698            2              6
 5      1629.59449          3              4
 6      994.20875           3              5
 7      141.88304           3              6
 8      2500                4              1
 9      3046.21191          4              3
 10     2357.84636          5              1
 11     509.55285           6              1
```

Figure 12.Archivo TXT, Tabla F - P

3.3 About

It shows a panel with information about TAESS (Figure 13)

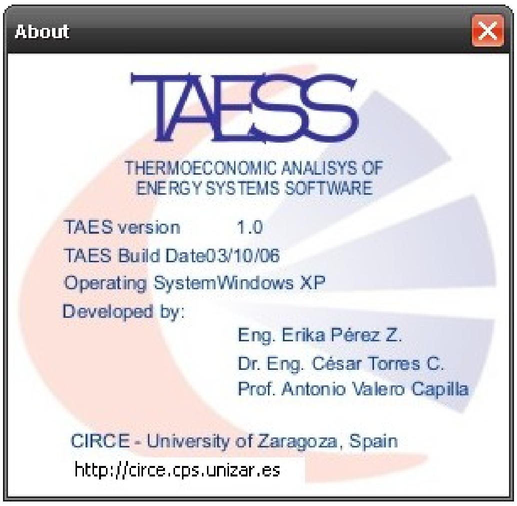


Figure 13. About dialog panel

3.4 Calculate

The buttons of the Taskbar to make the TAESS computations appears only on the worksheets where is possible to do them. There are the following of calculations:

- Table FP Reference: It generates the FP table for the reference state
- Table FP Operation: It generates the FP table for the operation or current state, only available if the operation state has been loaded.
- Cost Analysis of reference: It generate the cost reports and graphics for the reference state.
- Cost Analysis of operation: It generate the cost reports and graphics for the operation state, if available
- Diagnosis: To execute this control, you need to load both reference and operation states It generates the diagnosis reports and graphics.

When, we execute the diagnosis command from de “General Data” worksheet, all computation, reports and graphics described above are preformed.

4 TAESS Structure

The TAESS application generate three types of reports:

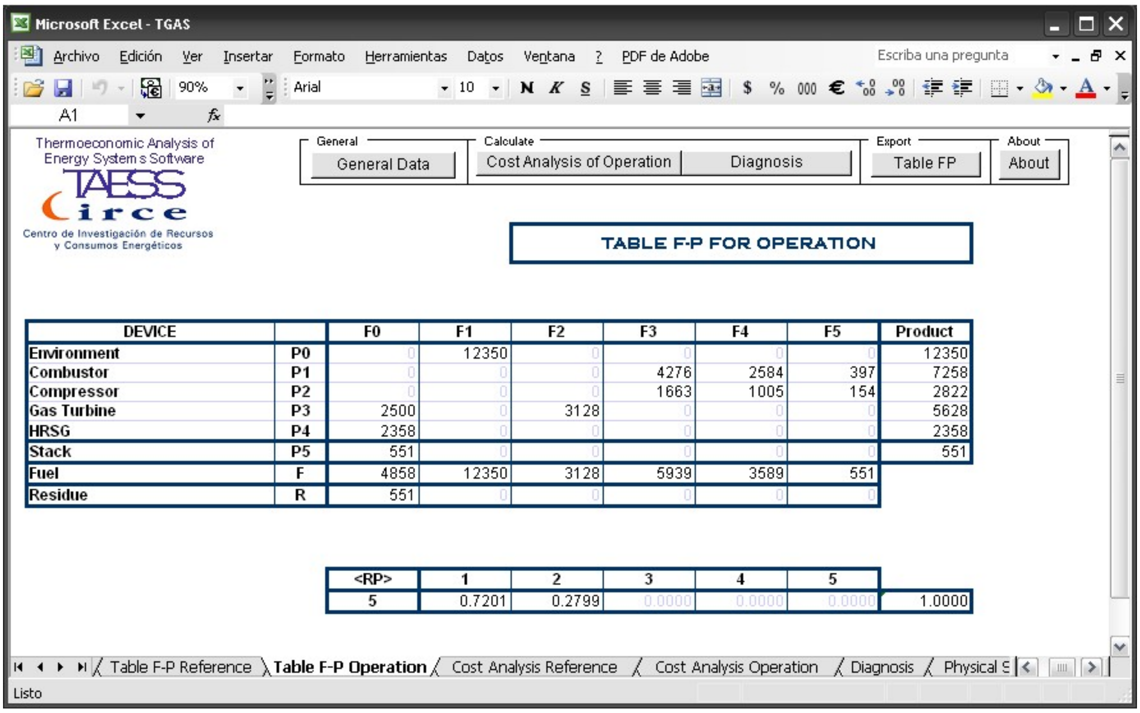
- Table F-P for each state (Reference and Operation)
- Cost Analysis for each state, which include the result report and the cost formation graph.
- Thermoeconomic Diagnosis, which includes the result report and the fuel impact and irreversibility analysis graphs.

To access to each worksheet generated by TAESS, you must click on the corresponding tab, located on the bottom of the workbook. See Figure 14.

Figure 14. TAESS Woorksheets access

4.1 Table F–P

The F-P table worksheet, Figure 15, contains the F-P table and the residues distribution ratios matrix <RP>.



DEVICE		F0	F1	F2	F3	F4	F5	Product
Environment	P0	0	12350	0	0	0	0	12350
Combustor	P1	0	0	0	4276	2584	397	7258
Compressor	P2	0	0	0	1663	1005	154	2822
Gas Turbine	P3	2500	0	3128	0	0	0	5628
HRSG	P4	2358	0	0	0	0	0	2358
Stack	P5	551	0	0	0	0	0	551
Fuel	F	4858	12350	3128	5939	3589	551	
Residue	R	551	0	0	0	0	0	

<RP>	1	2	3	4	5	
5	0.7201	0.2799	0.0000	0.0000	0.0000	1.0000

Figure 15. F-P Table worksheet

The F-P table is the adjacency matrix of the productive graph of the plant. It provides information about the resources and product distribution. Each cell E(i,j) represents the portion of the product of the component i-th becomes fuel of the j-th component. It is divided in three parts:

- The P0 row, which contains the external resources of the system.
- The F0 row, which contains the system outputs, both final products and residues.
- The [FP] matrix, which represents the internal distribution of the product.

Figure 15 shows the FP table of the TGAS system. The external resources enter in the combustor cell P0-F1 (12350kW). It has two final product: the net mechanical work of the turbine F0-P3 (2500kW), and the exergy generated in the HRSG F0-P4 (2358kW). The exergy dissipated in the stack is 551 kW (cell F0-P5).

If the system has dissipative units, we need to define the residue cost distribution ratios matrix <RP>. By default the application distribute the cost of the residues proportional to the exergy of the productive unit processed in the dissipative units: RP(r,i)=E(i,r)/F(r).

Figure 16, shows the <RP> matrix for the TGAS plant. The costs of the residues dissipated of the stack are allocated to the combustor and compressor in a relation 72% and 28%.

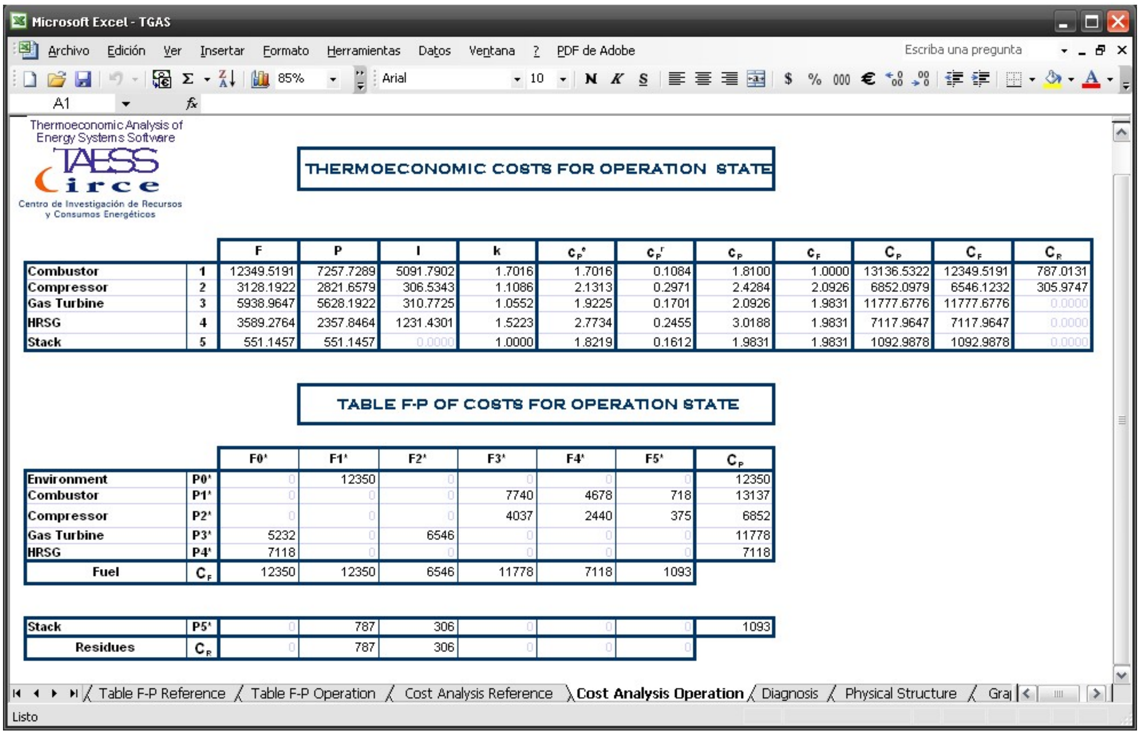
<RP>	1	2	3	4	5	
5	0.7201	0.2799	0.0000	0.0000	0.0000	1.0000

Figure 16. Matrix <RP>

4.2 Exergy Cost Analysis.

The “Cost Analysis” worksheet (Figura 16) shows two tables:

- Termoeconomic indexes (exergy and cost) for each device.
- Table FPR of cost



		F	P	I	k	c_P^e	c_P^r	c_P	c_F	C_P	C_F	C_R
Combustor	1	12349.5191	7257.7289	5091.7902	1.7016	1.7016	0.1084	1.8100	1.0000	13136.5322	12349.5191	787.0131
Compressor	2	3128.1922	2821.6579	306.5343	1.1086	2.1313	0.2971	2.4284	2.0926	6852.0979	6546.1232	305.9747
Gas Turbine	3	5938.9647	5628.1922	310.7725	1.0552	1.9225	0.1701	2.0926	1.9831	11777.6776	11777.6776	0.0000
HRSG	4	3589.2764	2357.8464	1231.4301	1.5223	2.7734	0.2455	3.0188	1.9831	7117.9647	7117.9647	0.0000
Stack	5	551.1457	551.1457	0.0000	1.0000	1.8219	0.1612	1.9831	1.9831	1092.9878	1092.9878	0.0000

		F0'	F1'	F2'	F3'	F4'	F5'	C_P
Environment	P0'	0	12350	0	0	0	0	12350
Combustor	P1'	0	0	0	7740	4678	718	13137
Compressor	P2'	0	0	0	4037	2440	375	6852
Gas Turbine	P3'	5232	0	6546	0	0	0	11778
HRSG	P4'	7118	0	0	0	0	0	7118
Fuel	C_F	12350	12350	6546	11778	7118	1093	
Stack	P5'	0	787	306	0	0	0	1093
Residues	C_R	0	787	306	0	0	0	

Figura 1. Hoja Cost Analysis

The indexes shown in each column of the first table are:

F Exergy of fuel (kW)

P Exergy of product (kW)

I Irreversibility (kW)

K Unit consumption F/P (kW)

c_P Unit exergy cost of product (kW/kW)

c_P^e Unit production cost due to irreversibilities (kW/kW)

c_P^r Unit production cost due to residues (kW/kW)

c_F Unit exergy cost of fuel (kW/kW)

C_P Exergy cost of product (kW)

C_F Exergy cost of fuel (kW)

C_R Exergy cost of residues (kW).

Figure 17 shows the exergetic indexes for each component

		F	P	I	k
Combustor	1	12349.5191	7257.7289	5091.7902	1.7016
Compressor	2	3128.1922	2821.6579	306.5343	1.1086
Gas Turbine	3	5938.9647	5628.1922	310.7725	1.0552
HRSG	4	3589.2764	2357.8464	1231.4301	1.5223
Stack	5	551.1457	551.1457	0.0000	1.0000

Figure 17. Exergetic indexes

The unit exergy cost of the product is decomposed in two contributions. The first is due to the irreversibilities and the second to the residues. Figure 18, shows the unit exergy cost for the TGAS system.

		c_P^e	c_P^r	c_P	c_F
Combustor'	1	1.7016	0.1084	1.8100	1.0000
Compressor'	2	2.1313	0.2971	2.4284	2.0926
Gas Turbine'	3	1.9225	0.1701	2.0926	1.9831
HRSG'	4	2.7734	0.2455	3.0188	1.9831
Stack'	5	1.8219	0.1612	1.9831	1.9831

Figure 18. Unit exergy costs

Figure 19, shows the FPR costs table. Each cell C(i,j) represents the cost of the product of the i-th component becomes fuel of the j-th component. For example, P1-F3 contains the cost of the product of the combustor that is used in the turbine..

		F0*	F1*	F2*	F3*	F4*	F5*	C_P
Environment	P0*	0	12350	0	0	0	0	12350
Combustor'	P1*	0	0	0	7740	4678	718	13137
Compressor'	P2*	0	0	0	4037	2440	375	6852
Gas Turbine'	P3*	5232	0	6546	0	0	0	11778
HRSG'	P4*	7118	0	0	0	0	0	7118
Fuel	C_F	12350	12350	6546	11778	7118	1093	
Stack'	P5*	0	787	306	0	0	0	1093
Residues	C_R	0	787	306	0	0	0	

Figure 19. Tabla F-P of costs

Furthermore, an additional worksheet is created. It contains the cost formation graph. The unit exergy cost of the product is decomposed in the contributions of the irreversibilities of each components and the contribution of each residue.

Figure 20 shows this graph in the case of the TGAS. The combustor is the first component of the production process and its irreversibilities are charged to the cost of all components. Meanwhile the irreversibilities of HRSG are only charged to itself.

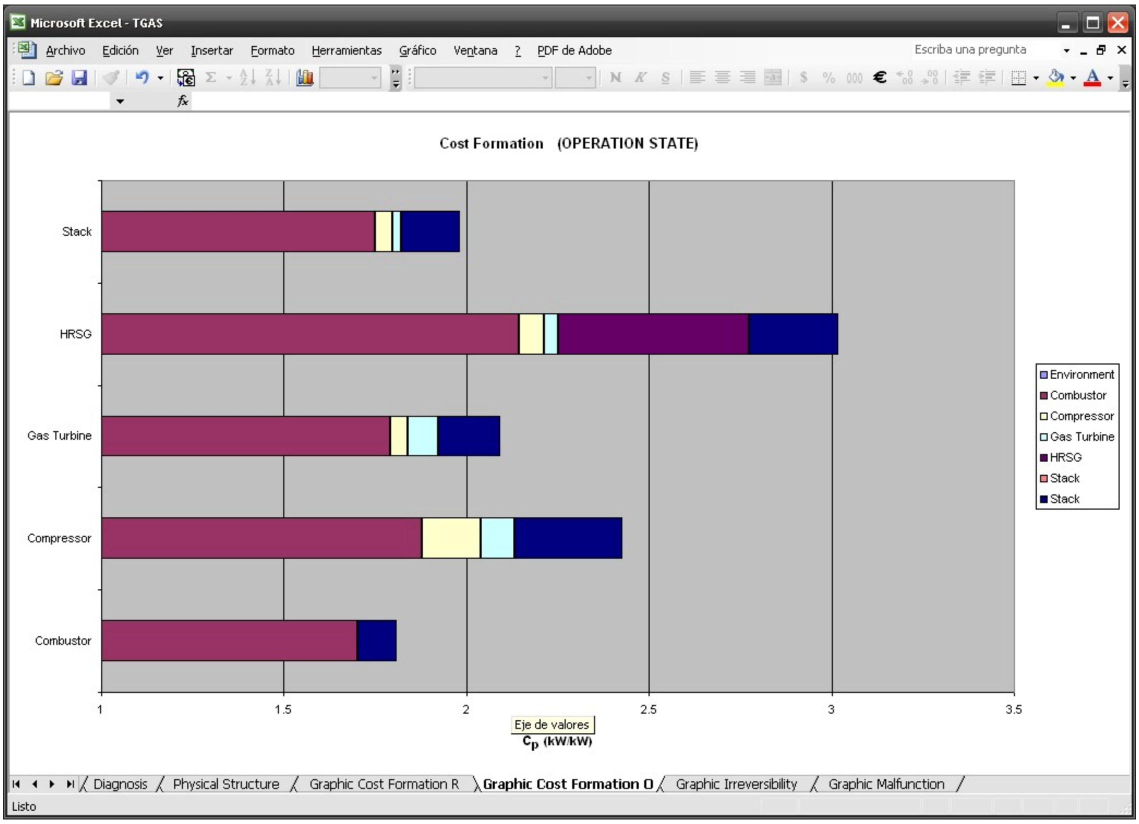


Figure 20. Cost Formation Graph

4.3 Termoeconomic Diagnosis

The objective of the thermoeconomic diagnosis is the location and quantification of the anomalies causing the reduction of the system efficiency.

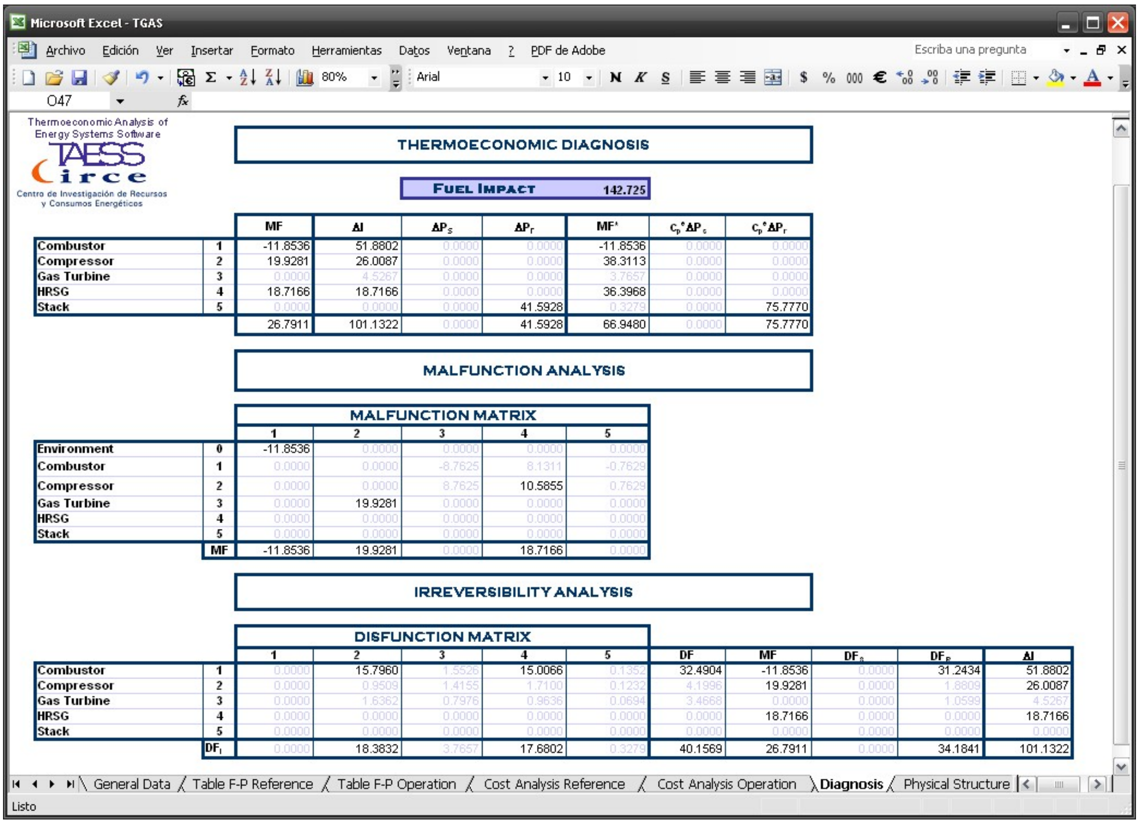
The thermoeconomic analysis of a plant is performed through the comparison of two thermoeconomic states. The presence of anomalies in the operation or current state is determined by the deviation on some indexes with respect to a reference state.

This methodology allows obtaining a common set of indexes for every component of the system, whose could be used in combination with other local parameter to provide useful information for the plant operation.

We need to load two dataset, one for reference and other for the operation state, to execute the thermoeconomic diagnosis.

It generates three worksheets:

- A report worksheet, which contains the thermoeconomic diagnosis indexes.
- Fuel Impact graph
- Irreversibility analysis graph.



		MF	AI	ΔP_S	ΔP_r	MF*	$c_p{}^*\Delta P_s$	$c_p{}^*\Delta P_r$
Combustor	1	-11.8536	51.8802	0.0000	0.0000	-11.8536	0.0000	0.0000
Compressor	2	19.9281	26.0087	0.0000	0.0000	38.3113	0.0000	0.0000
Gas Turbine	3	0.0000	4.5267	0.0000	0.0000	3.7657	0.0000	0.0000
HRSG	4	18.7166	18.7166	0.0000	0.0000	36.3968	0.0000	0.0000
Stack	5	0.0000	0.0000	0.0000	41.5928	0.3279	0.0000	75.7770
		26.7911	101.1322	0.0000	41.5928	66.9480	0.0000	75.7770

MALFUNCTION MATRIX

		1	2	3	4	5
Environment	0	-11.8536	0.0000	0.0000	0.0000	0.0000
Combustor	1	0.0000	0.0000	-8.7625	8.1311	-0.7629
Compressor	2	0.0000	0.0000	8.7625	10.5855	0.7629
Gas Turbine	3	0.0000	19.9281	0.0000	0.0000	0.0000
HRSG	4	0.0000	0.0000	0.0000	0.0000	0.0000
Stack	5	0.0000	0.0000	0.0000	0.0000	0.0000
	MF	-11.8536	19.9281	0.0000	18.7166	0.0000

DISFUNCTION MATRIX

		1	2	3	4	5	DF	MF	DF_S	DF_P	AI
Combustor	1	0.0000	15.7960	1.5526	15.0066	0.1352	32.4904	-11.8536	0.0000	31.2434	51.8802
Compressor	2	0.0000	0.9509	1.4155	1.7100	0.1232	4.1996	19.9281	0.0000	1.8809	26.0087
Gas Turbine	3	0.0000	1.6362	0.7976	0.9636	0.0694	3.4668	0.0000	0.0000	1.0599	4.5267
HRSG	4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	18.7166	0.0000	0.0000	18.7166
Stack	5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	DF_i	0.0000	18.3832	3.7657	17.6802	0.3279	40.1569	26.7911	0.0000	34.1841	101.1322

Figure 21. Diagnosis worksheet

Figure 21, shows the "Diagnosis" worksheet of the TGAS system. It contains three tables:

- Fuel Impact decomposition indexes.
- The Malfunction matrix
- The Dysfunction matrix.

The first table, Figure 22, shows the fuel impact decomposition, based both in the irreversibility increase and the malfunction cost.

		FUEL IMPACT			142.7291		
		ΔI	ΔP_s	ΔP_r	MF^*	$c_p^e \Delta P_s$	$c_p^e \Delta P_r$
Combustor'	1	51.8843	0.0000	0.0000	-11.8495	0.0000	0.0000
Compressor'	2	26.0087	0.0000	0.0000	38.3113	0.0000	0.0000
Gas Turbine'	3	4.5267	0.0000	0.0000	3.7657	0.0000	0.0000
HRSG'	4	18.7166	0.0000	0.0000	36.3968	0.0000	0.0000
Stack'	5	0.0000	0.0000	41.5928	0.3279	0.0000	75.7770
		101.1363	0.0000	41.5928	66.9521	0.0000	75.7770

Figure 22. Fuel Impact Indexes

The following indexes for each component are shown:

MF: Malfunction (kW)

ΔI Irreversibility variation (kW).

ΔP_s Total Product variation (kW).

ΔP_r Residues variation (kW).

The sum of the last colums is equal to the fuel impact.

MF^* Malfunction cost (kW)

$c_P^e \Delta P_s$ Final product cost variation (kW)

$c_P^e \Delta P_r$ Residue cost variation (kW).

The sum of these three columns is also equal to the fuel impact.

Figure 23 shows the malfunction matrix. Each element MF(i,j) represents the additional consumption of resources from the i-th component due to a malfunction on the j-th component. The malfunction of a component is the sum of the variation of the resources consumptions. For example, MF(3,2) equals to 19.92kW, represents the additional consumption of mechanical work from turbine due to a malfunction in the compressor.

		MALFUNCTION MATRIX				
		1	2	3	4	5
Environment	0	-11.8536	0.0000	0.0000	0.0000	0.0000
Combustor	1	0.0000	0.0000	-8.7625	8.1311	-0.7629
Compressor	2	0.0000	0.0000	8.7625	10.5855	0.7629
Gas Turbine	3	0.0000	19.9281	0.0000	0.0000	0.0000
HRSG	4	0.0000	0.0000	0.0000	0.0000	0.0000
Stack	5	0.0000	0.0000	0.0000	0.0000	0.0000
	MF	-11.8536	19.9281	0.0000	18.7166	0.0000

Figure 23. Malfunción Matrix

Each element DF(i,j) of the dysfunction matrix (Figure 24) represents the irreversibility variation of the i-th component due to a malfunction of the j-th component. For example DF(1,2) means that the combustor has a irreversibility increase of 15.79kW due to the malfunction of the compressor.

		DISFUNCTION MATRIX					
		1	2	3	4	5	DF
Combustor'	1	0.0000	15.7960	1.5526	15.0066	0.1352	32.4904
Compressor'	2	0.0000	0.9509	1.4155	1.7100	0.1232	4.1996
Gas Turbine'	3	0.0000	1.6362	0.7976	0.9636	0.0694	3.4668
HRSG'	4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Stack'	5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
		0.0000	18.3832	3.7657	17.6802	0.3279	40.1569

Figure 24. Dysfunction Matrix

The irreversibility variation has four contributions, see Figure 25:

MF Malfunction i.e. the irreversibility increase due the variation of the efficiency of the component itself. (kW).

DF Dysfunction, i.e. the irreversibility increase due to the malfunctions of other component, whose changes the production requirements of the component. (kW)

DF_S Irreversibility increase due to the variation of the system production (kW).

DF_R Irreversibility increase due to the variation of the residues (kW).

		DF	MF	DF_S	DF_R	ΔI
Combustor'	1	32.4904	-11.8495	0.0000	31.2434	51.8843
Compressor'	2	4.1996	19.9281	0.0000	1.8809	26.0087
Gas Turbine'	3	3.4668	0.0000	0.0000	1.0599	4.5267
HRSG'	4	0.0000	18.7166	0.0000	0.0000	18.7166
Stack'	5	0.0000	0.0000	0.0000	0.0000	0.0000
		40.1569	26.7952	0.0000	34.1841	101.1363

Figure 25. Irreversibility Analysis

In addition to the diagnostic tables, two types of graphs are shown:

- The irreversibility analysis.
- The Fuel Impact analysis.

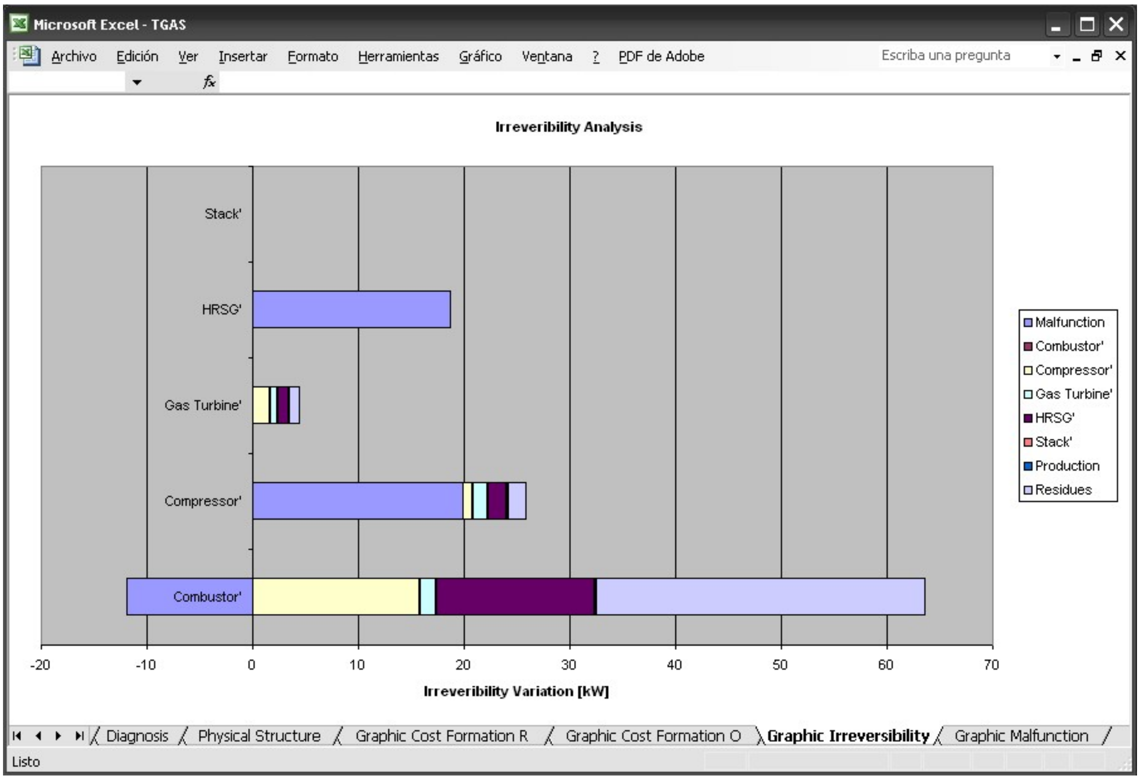


Figure 26. Irreversibility analysis graph

In the irreversibility analysis graph, Figure 26, the contribution to the irreversibility increase of each component due to its malfunction, the malfunctions of the other components and the residues variation.

In this example, the combustor has the biggest irreversibility of the system. It is due to the malfunctions of the compressor and HRSG, and the residues variation.

The Fuel Impact analysis graph, Figure 27, compares the irreversibility increase and the malfunction cost of each component. In this example is shown that the cost of the residue increase is the biggest contribution to the fuel impact, caused by the malfunction of the compressor and HRSG.

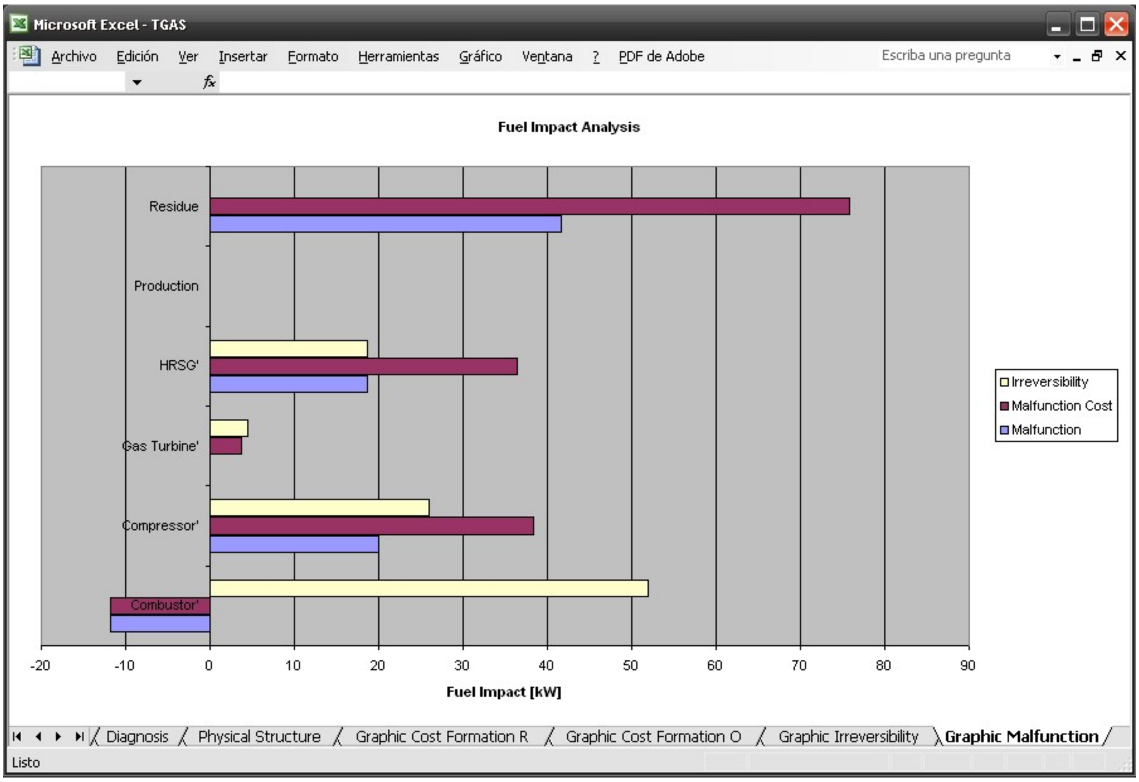


Figure 27. Fuel impact analysis graph

5 Use TAESS with EES

As we have shown in section 4.2 TAESS has the capability to import data from EES. If you want to prepare your EES model to generate files for TAESS you must be follow the following rules:

- Use arrays to save the information to interchange with TAESS. In particular the exergy of the flows.
- Define a string array to keep the names of the components
- Define two arrays to keep the physical structure, as is explained in section 3.2

In the case of the TGAS example, they look as:

```
{Physical structure definition}
Name$[2]=’Environment’
DevFrom[5]=0;
DevTo[7]=0;
DevTo[8]=0;
DevTo[9]=0;

Name$[1]='Combustor'
DevFrom[2]=1;
DevTo[1]=1;
DevTo[5]=1;

Name$[2]='Compressor'
DevFrom[1]=2;
DevTo[6]=2;

Name$[3]='Gas Turbine'
DevFrom[3]=3;
DevFrom[6]=3;
DevFrom[7]=3;
DevTo[2]=3;

Name$[4]='HRSG'
DevFrom[4]=4;
DevFrom[8]=4;
DevTo[3]=4;

Name$[5]='Stack'
DevFrom[9]=5;
DevTo[4]=5;
```

You also must include some additional variables to include the File Format Type, the number of Flows and the number of productive and dissipative devices:

```
{Interface con TAESS}
Type=3
Flows=9
ProductiveDev=4
DisipativeDev=1
```

Last, you must include the EES command $EXPORT to write the information to an external file with CSV format, according the format described in section 3.2. The name of the file could be fixed, or a string variable that could be defined as a input variable in the diagram window.

```
{File$='TGas.csv'}
$export File$ Type
$export /A File$ Flows,ProductiveDev,DisipativeDev
$export /A File$ Name$[1..5]
$export /A File$ E[1..9]
$export /A File$ DevFrom[1..9]
$export /A File$ FromFP[1..9]
$export /A File$ DevTo[1..9]
$export /A File$ ToFP[1..9]
```

Then when you execute the EES model you get a file, call in this example `“TGas.csv”` which could be import by TAESS.

In the web page of TAESS http://www.exergoecology.com/taess/taess_docs/ you can find examples of this feature.

6 Error Messages

When TAESS is running, it can be generated de following errors:

The format of the file is not been worth. This error is generated when the type of format of the file is not correct. For CSV archives the allowed type formats are: 1, 3 and 5; and the TXT are: 2, 4 and 6.

The F-P definition is not correct. This error can be due to:

- The import archives represent Fuel and Product as 1 and 2 respectively. If the FP definition has some flows that are represented with a different value, it will be marked as error.
- If a device has not defined at least an input and a output.
- If a devices has not defined at least a fuel and a product.

The configuration is not well defined. This error will appear when the number of devices is greater that the number of flows

There is not enough data available. This error indicates that not all the values of the flows have been provided.

There definition of <RP> matrix is not correct. This error indicates that the sum of distribution of residues of the dissipative devices is different to one.