Thermoflow Inc.

WHAT IS GT PRO?

GT PRO is a highly automated system design tool – a heat balance program specifically intended for design of gas turbine combined cycle power plants and cogeneration systems.

- Use **GT PRO** to explore and design **combined cycles**, **cogeneration systems**, and **simple cycle gas turbine power plants.**

- In combination with **PEACE** (Plant Engineering and Cost Estimator), **GT PRO** provides engineering details and cost estimation.

- **GT PRO** performs design-point calculations only – use **GT MASTER** for simulations of part loads or other off-design conditions.

What is PEACE?

PEACE is Thermoflow's **Plant Engineering And Cost Estimator**, an additional tool that works in conjunction with Thermoflow's heat balance design and simulation programs.

What does PEACE add to GT PRO?

- **PEACE** brings regional costs, engineering details, and concerns beyond the heat balance performance into a comprehensive description of the plant.

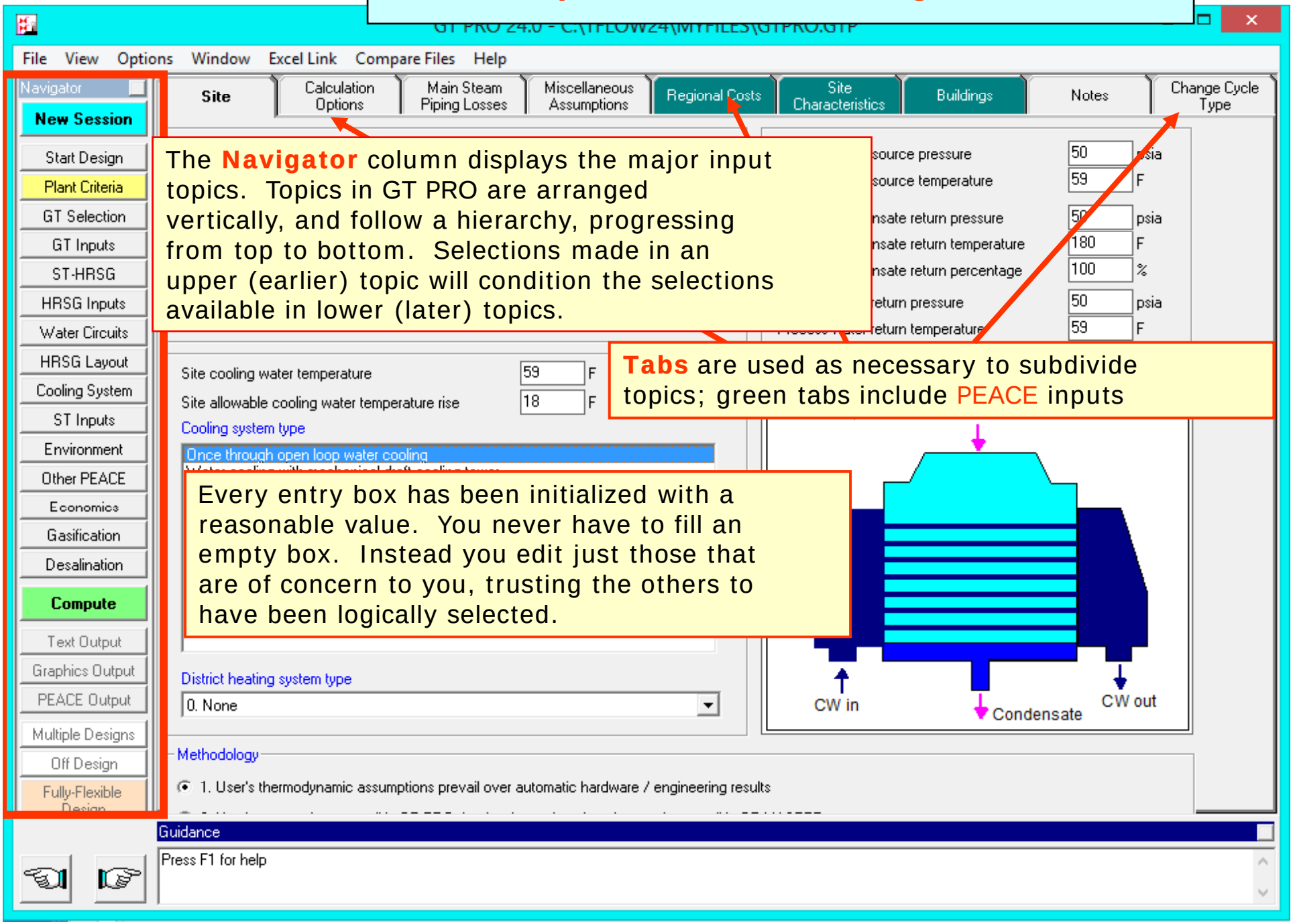
- **PEACE** provides graphic and tabular information about size, weight, and cost of plant equipment.

- **PEACE** produces a detailed total plant cost estimate.

- **PEACE** provides a simple *pro forma* financial projection to estimate cash flows, return on investment, and break-even power cost.

- **PEACE** can be used to impose more detailed hardware effects upon heat balance simulations, particularly piping and pump hardware details.

Inputs – General Arrangement



GT PRO

The program opens to the New Session topic

Select to begin a new design or to revise an existing one.

File View Options Window Excel Link Compare

Navigator

New Session

Start Design
Plant Criteria
GT Selection
GT Inputs
ST-HRSG
HRSG Inputs
Water Circuits
HRSG Layout
Cooling System
ST Inputs
Environment
Other PEACE
Economics
Gasification
Desalination

Compute

Text Output
Graphics Output
PEACE Output
Multiple Designs
Off Design
Fully-Flexible Design

New Design

- (•) Setup wizard & start visual design
- ( ) Setup wizard & start classic design
- ( ) Plant Design Expert
- ( ) Standard defaults

Existing File

- ( ) File list

Most recent file - GTPRO.GTP

Mode

- ( ) GT PRO only
- (•) GT PRO & PEACE

Approximate Plant Output

- ( ) Up to 15 MW
- (•) 50 to 200 MW
- ( ) 10 to 50 MW
- ( ) Above 200 MW

Cost / Efficiency Balance

- [x] Set automatically based on approximate plant output
- ( ) Lower cost (•) Intermediate ( ) Higher efficiency

Primary Gas Turbine Fuel

CH4 — Modify Fuel

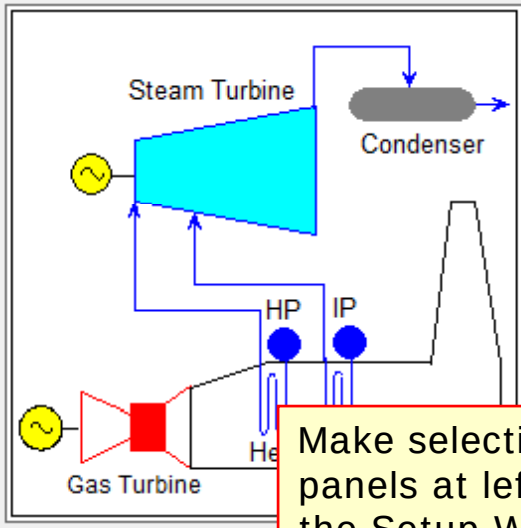
Sulphur weight % = 0

General Plant Configuration

- ( ) GT Only
- ( ) GT & HRSG only (no ST)
- ( ) GT, HRSG, and non-condensing ST
- (•) GT, HRSG, and condensing non-reheat ST
- ( ) GT, HRSG, and condensing reheat ST

- [ ] Include gasification (IGCC)
- [ ] Include pre-combustion CO2 capture
- [ ] Include post-combustion CO2 capture
- [ ] Use combustion engines instead of turbines

Desalination System: None



Left sketch is for illustration only. Steam turbine may have bleeds and additions. HRSG evaporator count and heat exchanger sequence may be modified. Various process streams may be established from ST and/or HRSG.

Make selections in each of the panels at left. These inform the Setup Wizard used to initialize many of the inputs.

Methodology

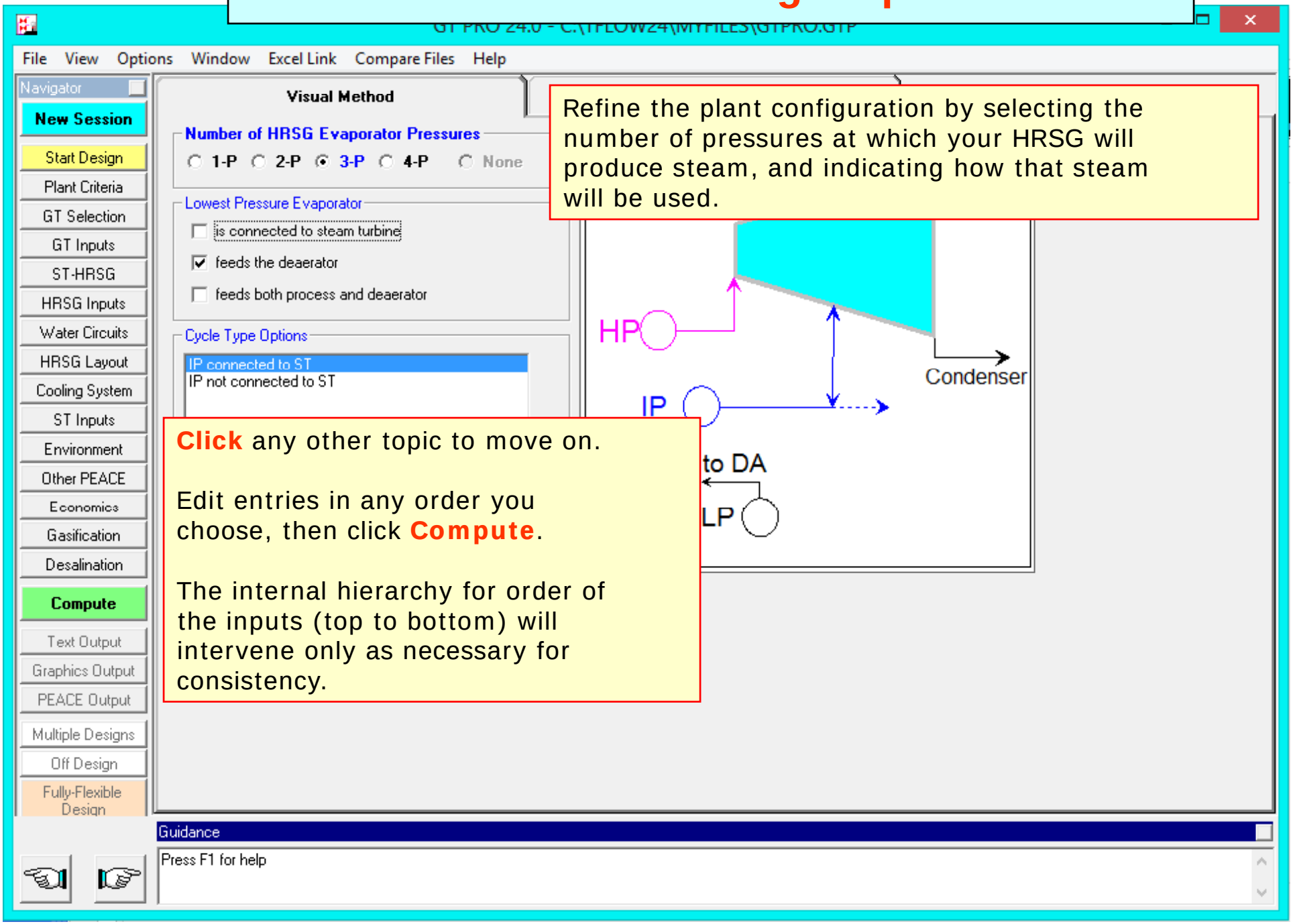
- (•) 1. User's thermodynamic assumptions prevail over automatic hardware / engineering results
- ( ) 2. User's assumptions prevail in GT PRO, but hardware / engineering results prevail in GT MASTER

Guidance

Press F1 for help

Click on Start Design to continue.

At the Start Design topic...



Refine the plant configuration by selecting the number of pressures at which your HRSG will produce steam, and indicating how that steam will be used.

Click any other topic to move on.

Edit entries in any order you choose, then click **Compute**.

The internal hierarchy for order of the inputs (top to bottom) will intervene only as necessary for consistency.

GT PRO

At the Plant Criteria topic...

File View Options Window Excel Link Compare Files Help

Navigator

New Session

Start Design
Plant Criteria
GT Selection
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ST-HRSG
HRSG Inputs
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HRSG Layout
Cooling System
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Economics
Gasification
Desalination

Compute

Text Output
Graphics Output
PEACE Output
Multiple Designs
Off Design
Fully-Flexible Design

Site | Calculation Options | Main Steam Piping Losses | Miscellaneous Assumptions | Regional Costs | Site Characteristics | Buildings | Notes | Change Cycle Type

Ambient temperature 59 F
Altitude 0 ft
Ambient pressure 14.7 psia
Ambient relative humidity 60 %
Ambient wet bulb temperature 51.48 F
Line frequency ○ 50 Hz ◉ 60 Hz

Show ASHRAE Climate Data

Import Plant Criteria Data on green PEACE Tabs 5-7

Makeup water source pressure 50 psia
Makeup water source temperature 59 F
Process condensate return pressure 50 psia
Process condensate return temperature 180 F
Process condensate return percentage 100 %
Process water return pressure 50 psia
Process water return temperature 59 F

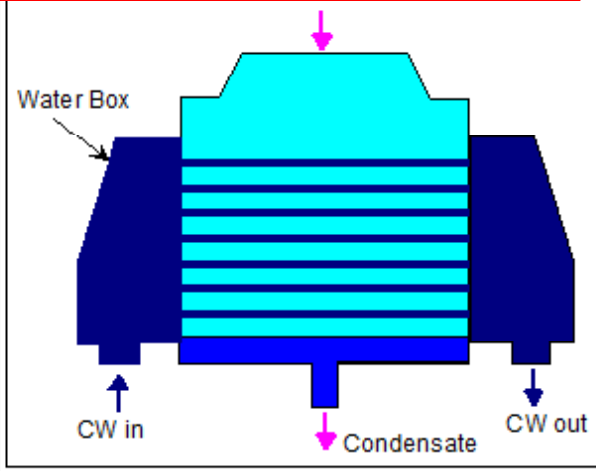
Site cooling water temperature
Site allowable cooling water ten

Cooling system type

- Once through open loop water cooling
- Water cooling with mechanical draft cooling tower
- Water cooling with wet-dry mechanical cooling tower
- Water cooling with natural draft cooling tower
- Water cooling with dry cooling tower
- Dry air cooled condenser
- Air cooled condenser with air precooled
- Air cooled condenser with continuous air saturation
- Air cooled wet surface condenser
- Direct contact condenser with dry CT (Heller System)
- No condenser, ST exhausts to process

District heating system type

0. None



Methodology

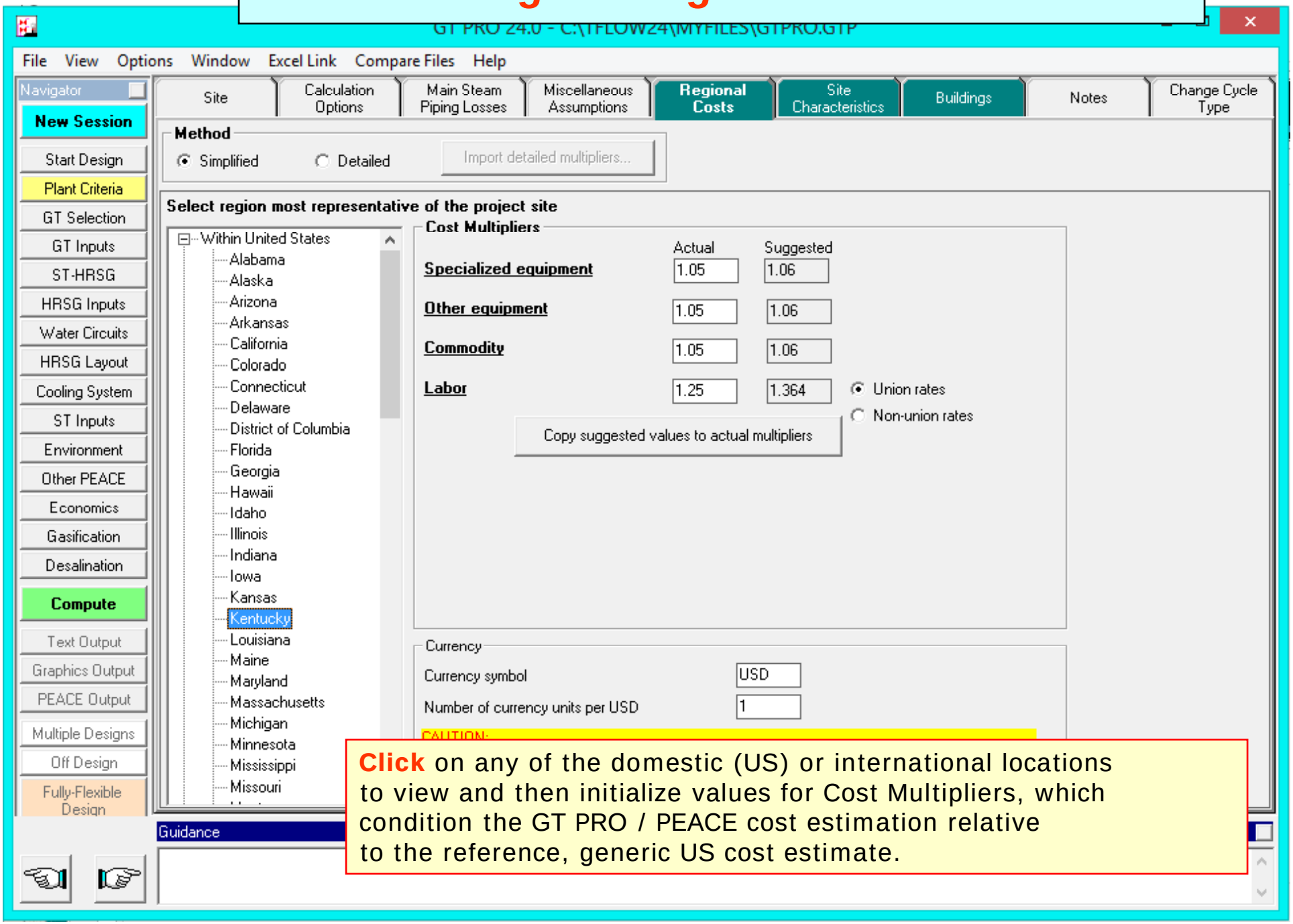
◉ 1. User's thermodynamic assumptions prevail over automatic hardware / engineering results

Of the several Tabs within this topic, the **Site** tab is of greatest importance to the thermal design.

Select the cooling system type of your choice.
The figure illustrates and confirms your selection.

GT PRO

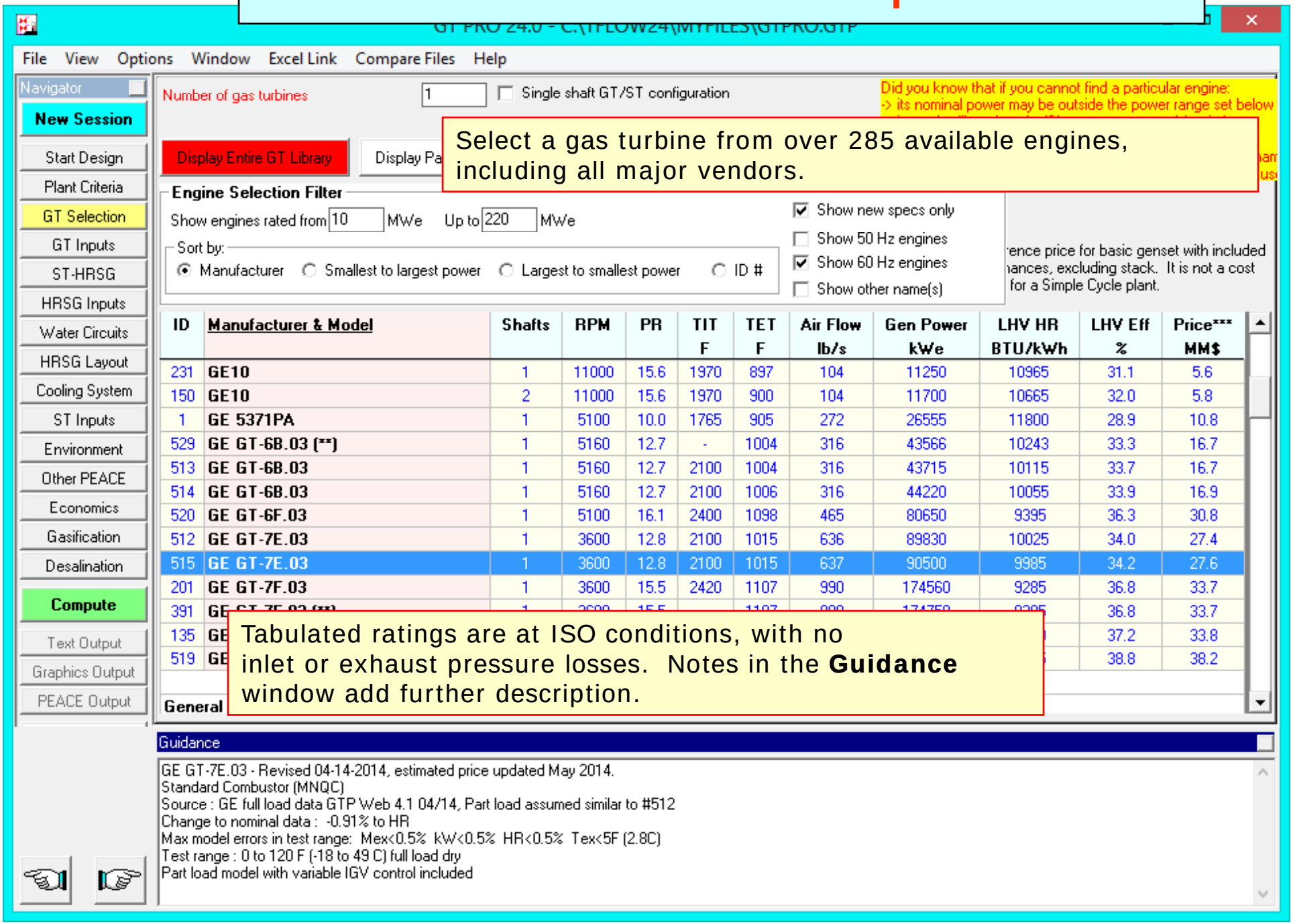
Visiting the Regional Costs tab...



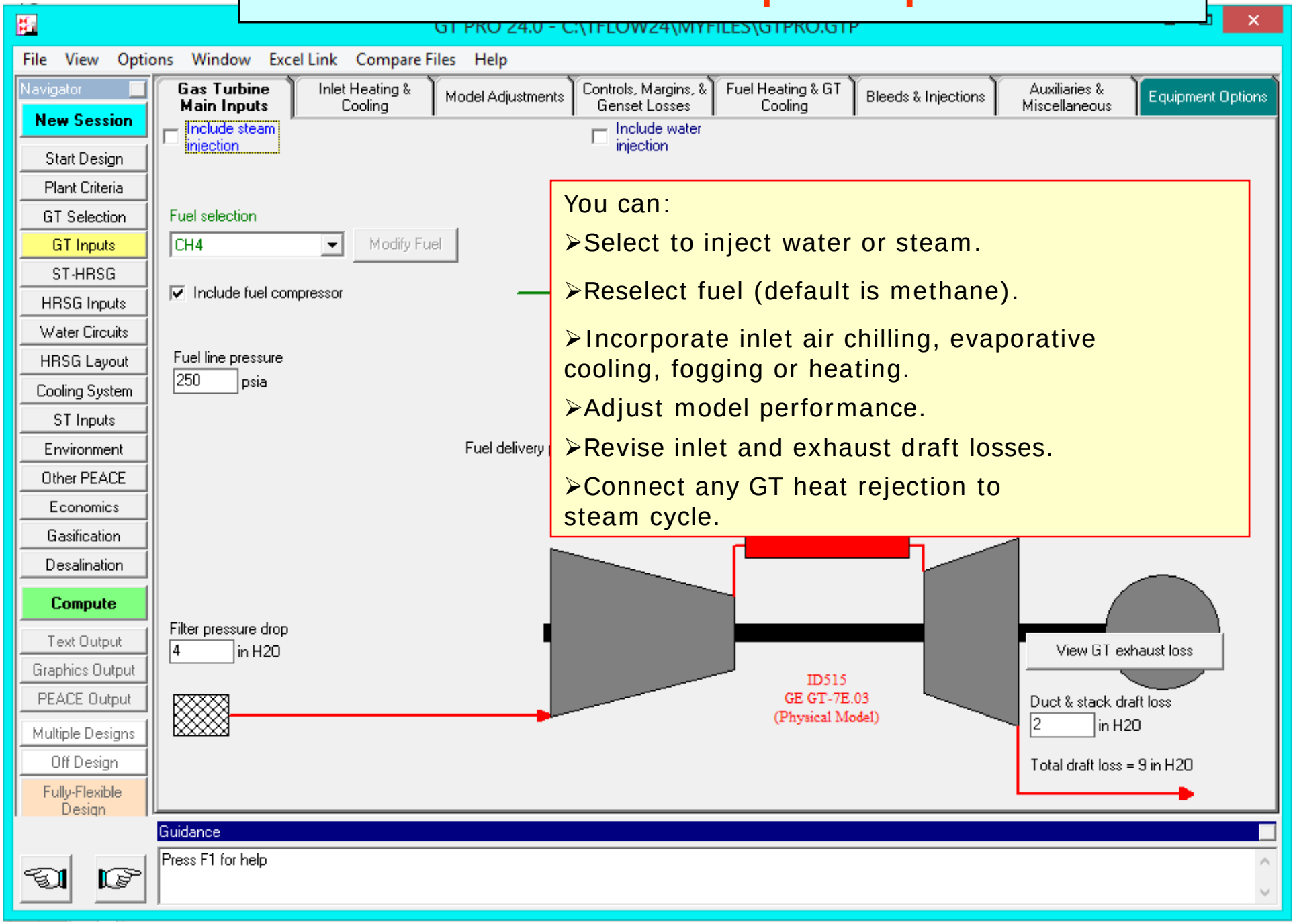
Click on any of the domestic (US) or international locations to view and then initialize values for Cost Multipliers, which condition the GT PRO / PEACE cost estimation relative to the reference, generic US cost estimate.

GT PRO

At the GT Selection topic ...



Within the GT Inputs topic ...

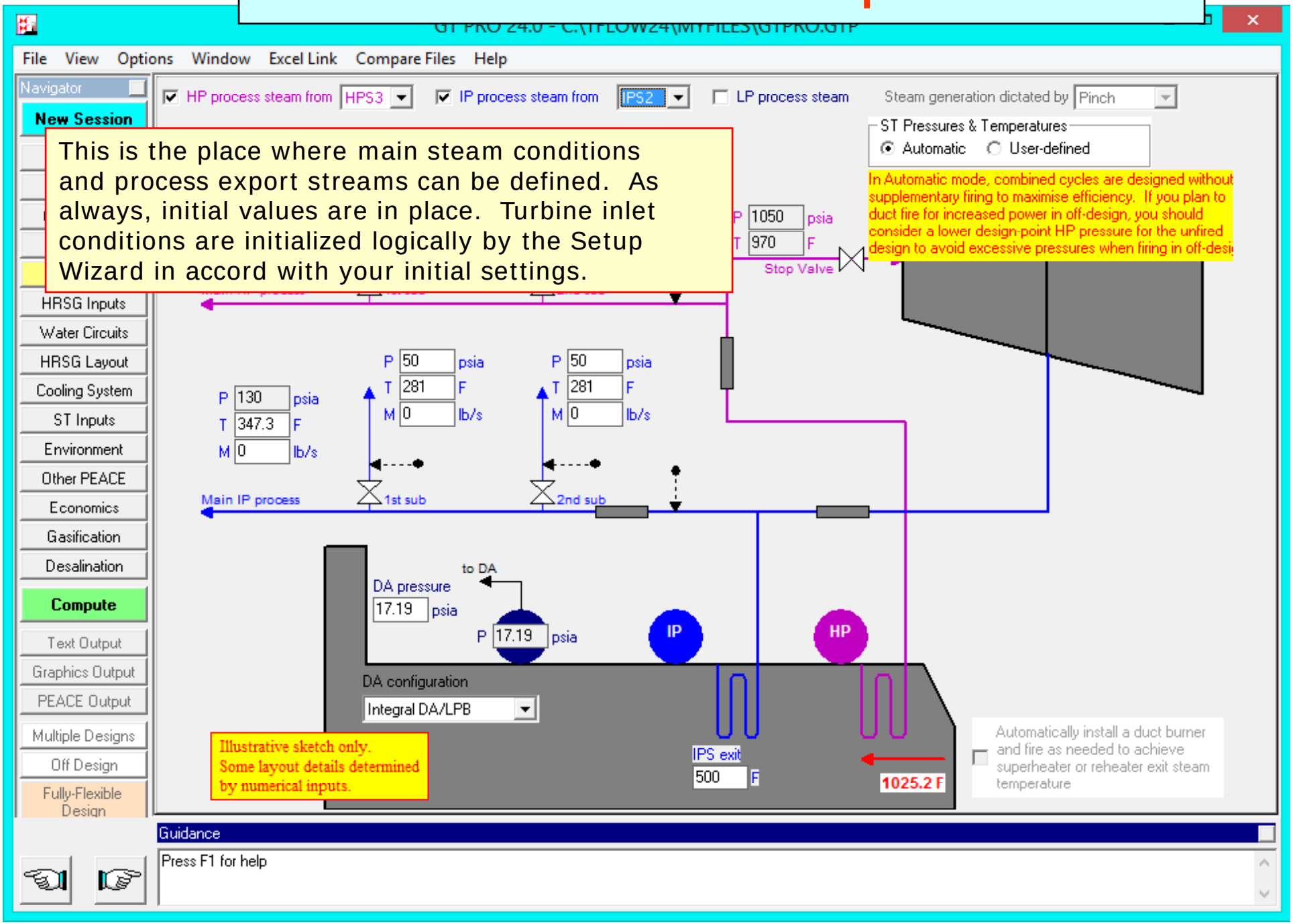


You can:

- Select to inject water or steam.
- Reselect fuel (default is methane).
- Incorporate inlet air chilling, evaporative cooling, fogging or heating.
- Adjust model performance.
- Revise inlet and exhaust draft losses.
- Connect any GT heat rejection to steam cycle.

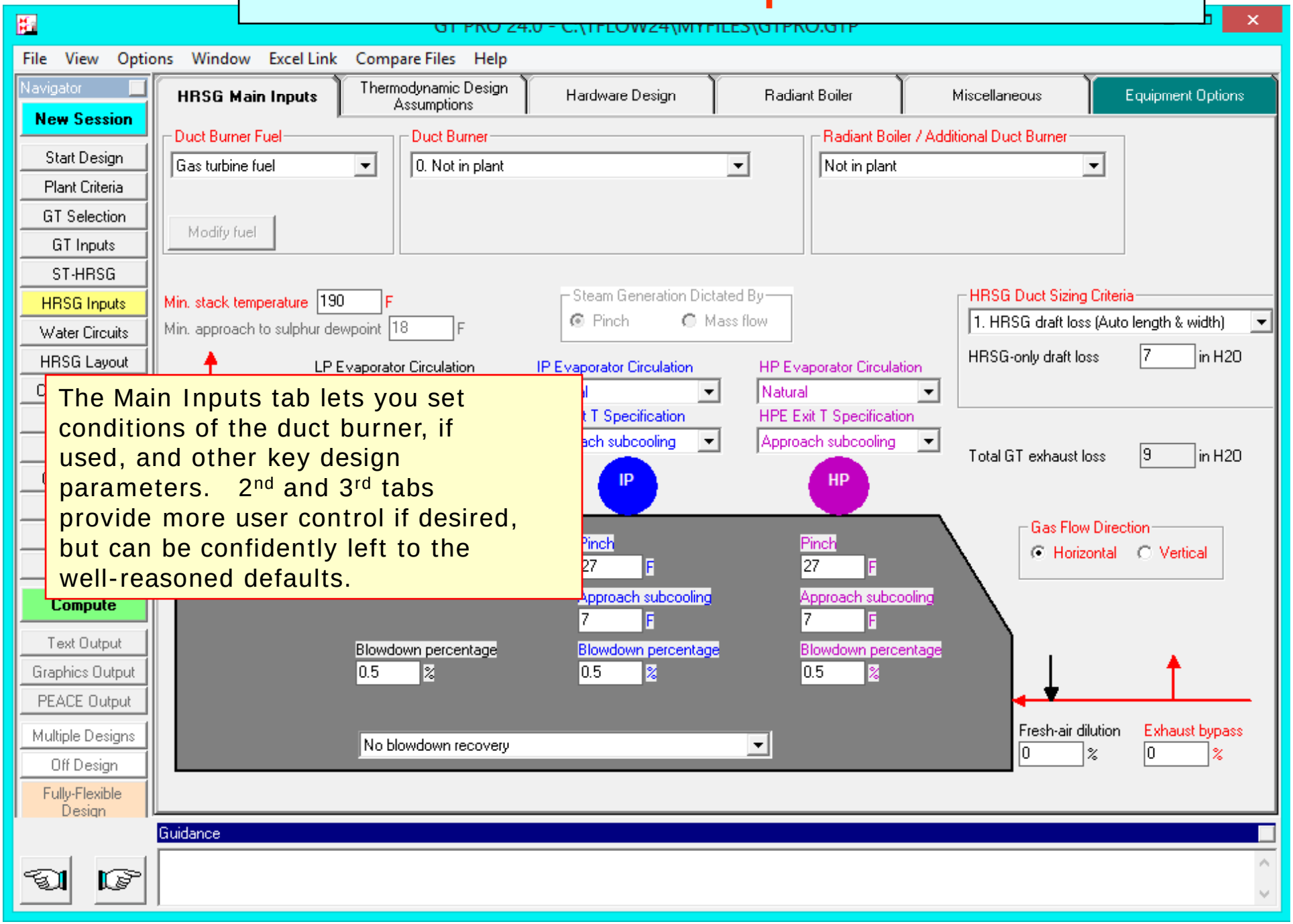
GT PRO

At the ST-HRSG topic...



GT PRO

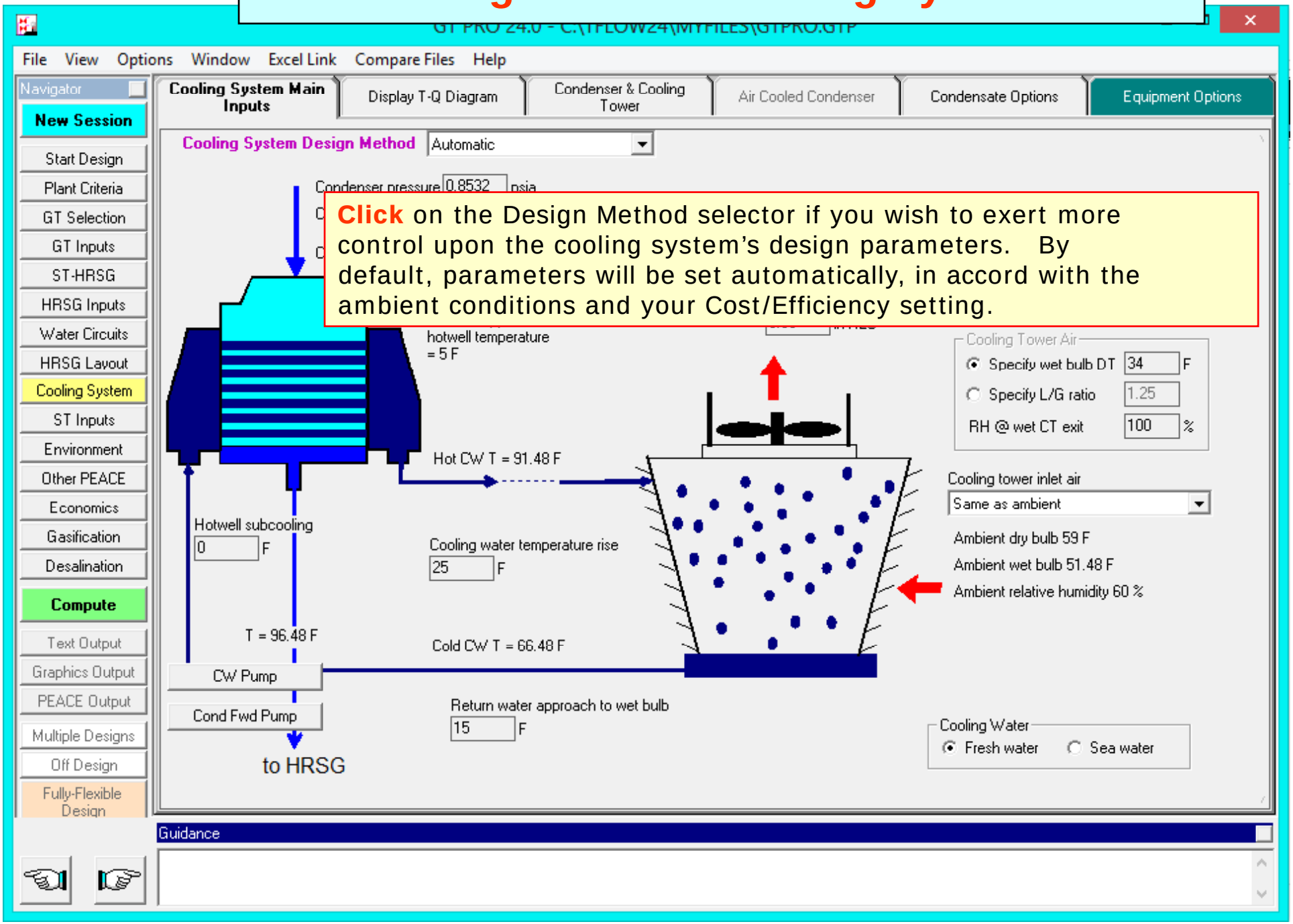
HRSG Inputs



The Main Inputs tab lets you set conditions of the duct burner, if used, and other key design parameters. 2nd and 3rd tabs provide more user control if desired, but can be confidently left to the well-reasoned defaults.

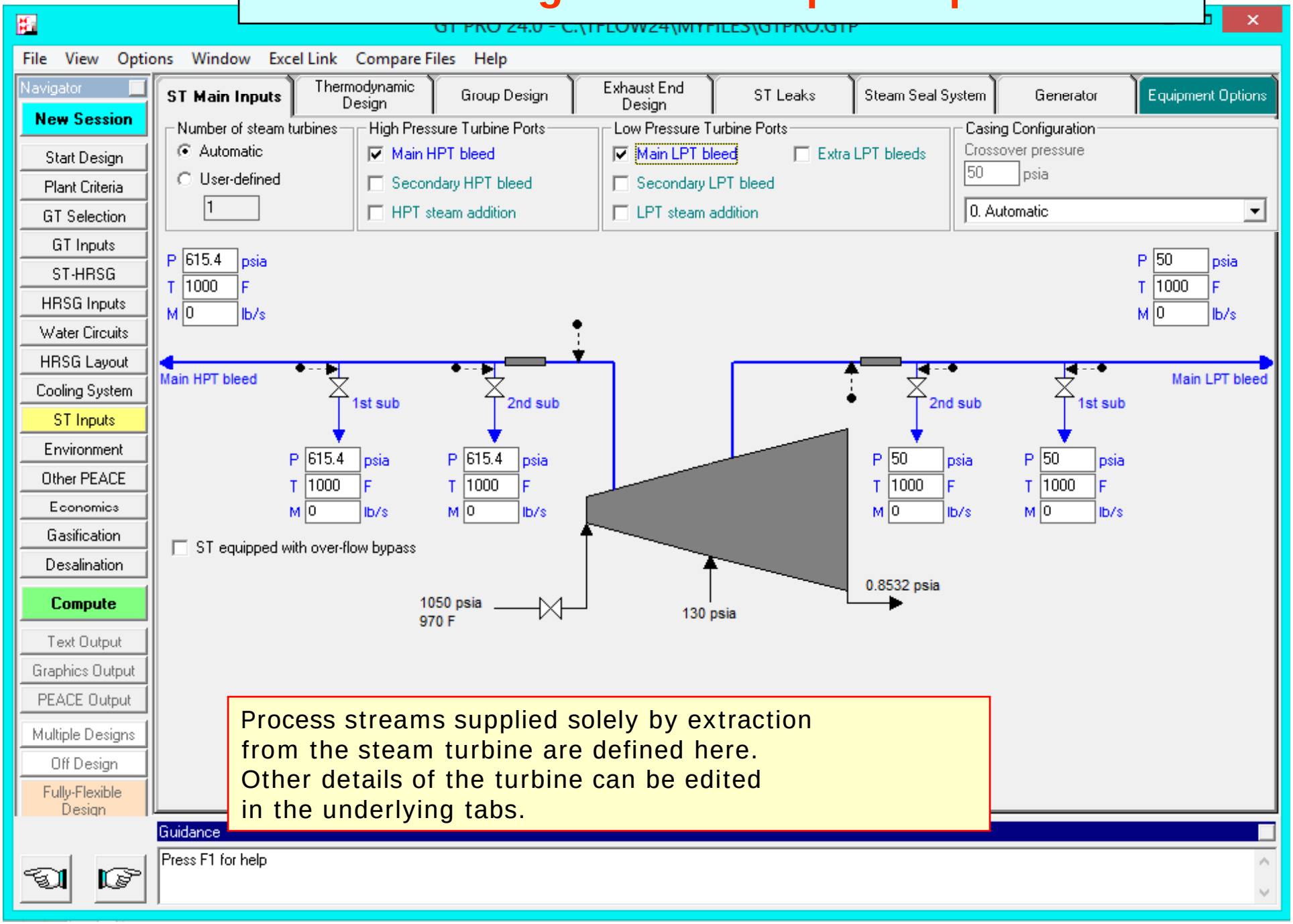
GT PRO

Moving on to the Cooling System...



GT PRO

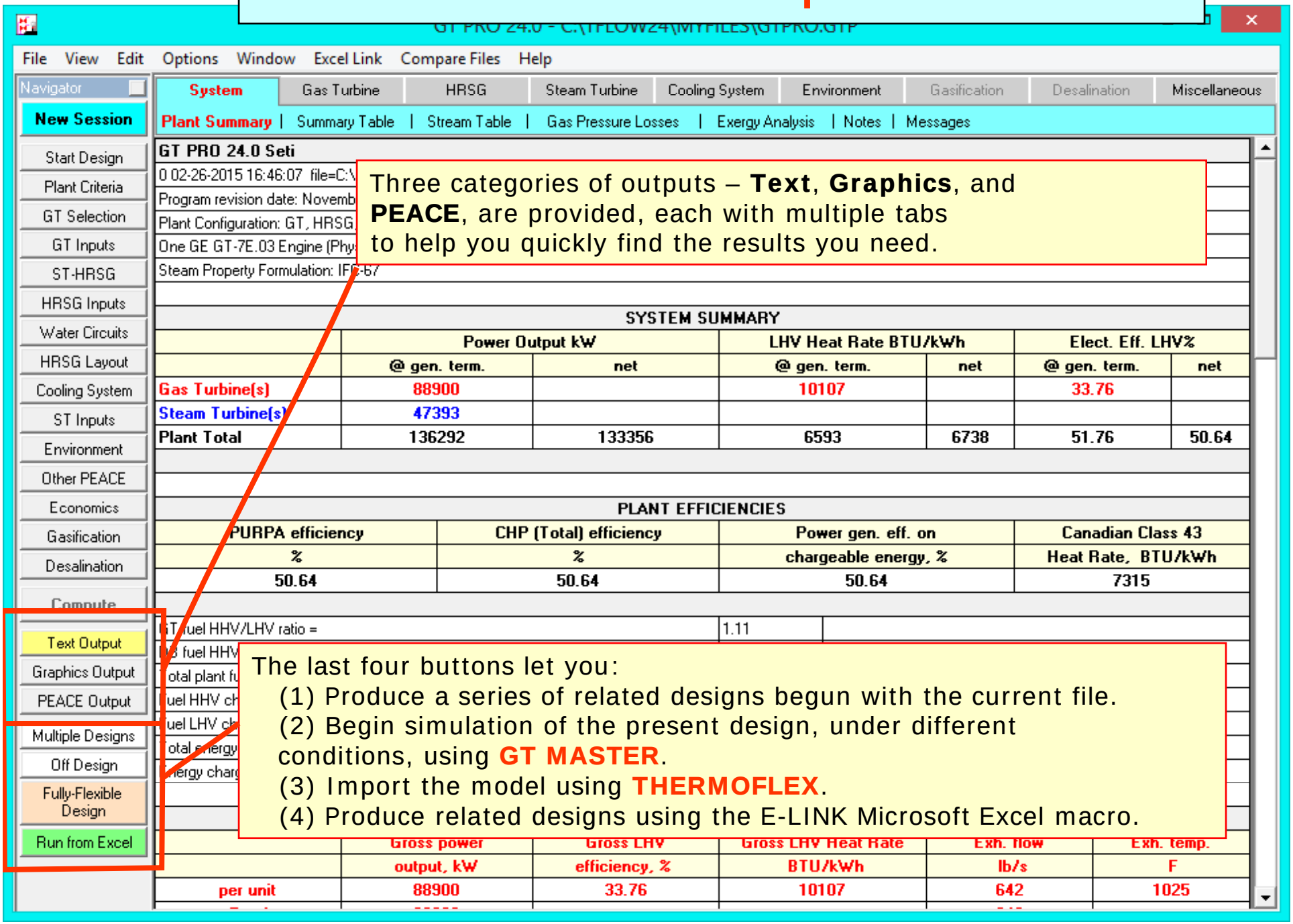
Looking at the ST Inputs topic...



Process streams supplied solely by extraction from the steam turbine are defined here. Other details of the turbine can be edited in the underlying tabs.

GT PRO

GT PRO Outputs



Three categories of outputs – **Text**, **Graphics**, and **PEACE**, are provided, each with multiple tabs to help you quickly find the results you need.

The last four buttons let you:

(1) Produce a series of related designs begun with the current file.

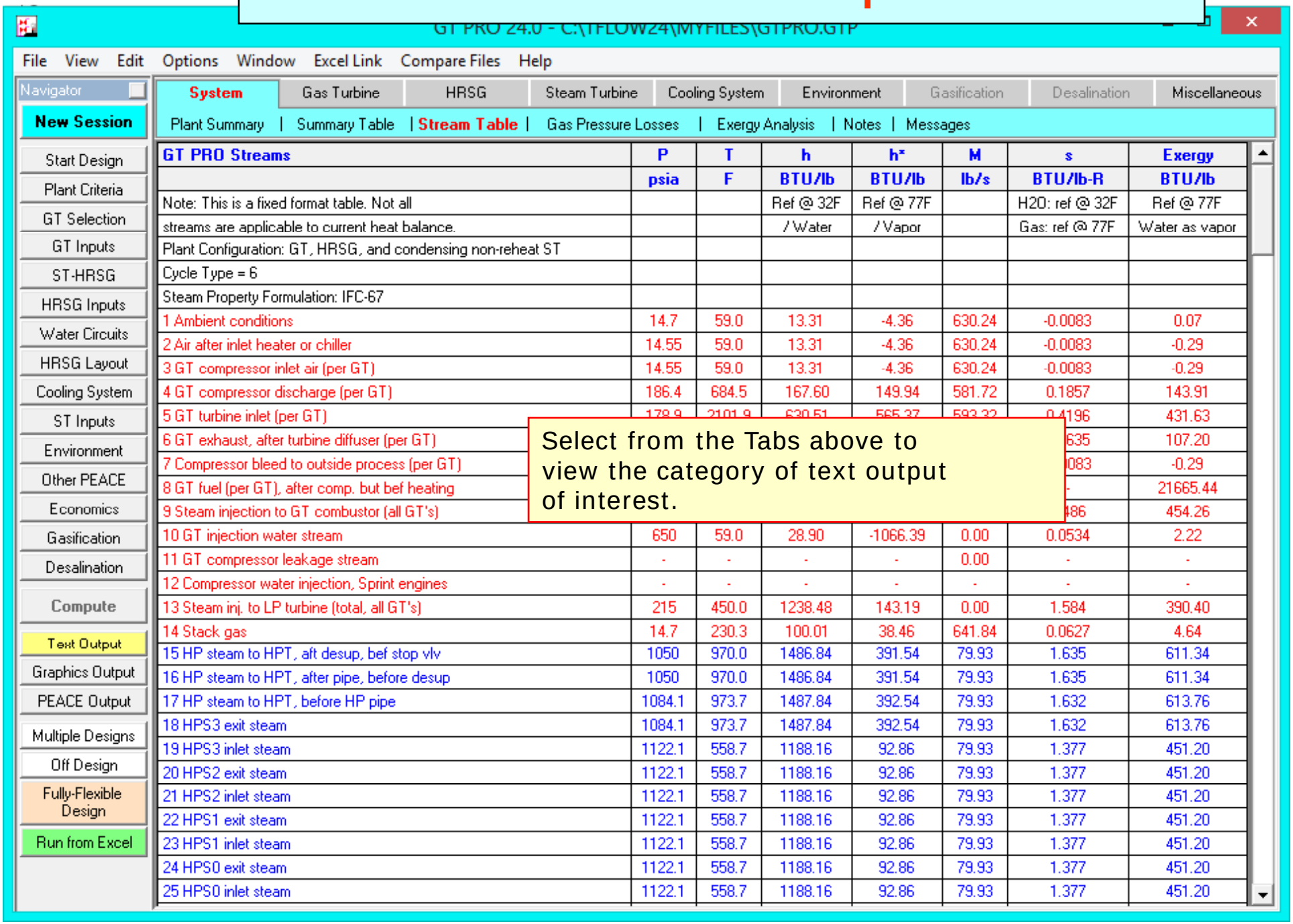
(2) Begin simulation of the present design, under different conditions, using **GT MASTER**.

(3) Import the model using **THERMOFLEX**.

(4) Produce related designs using the E-LINK Microsoft Excel macro.

GT PRO

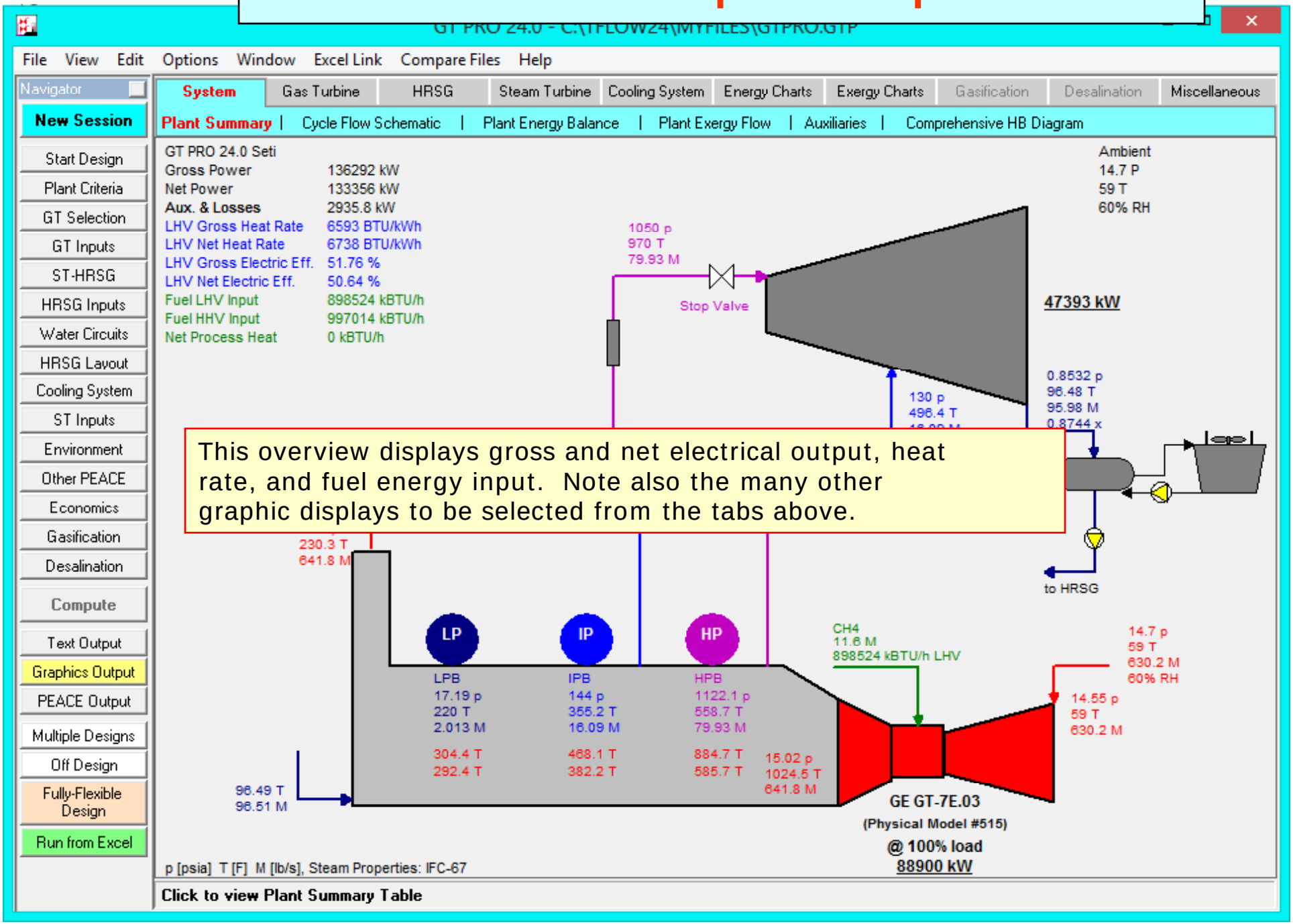
GT PRO Text Output



GT PRO Streams	P	T	h	h*	M	s	Exergy
	psia	F	BTU/lb	BTU/lb	lb/s	BTU/lb-R	BTU/lb
Note: This is a fixed format table. Not all			Ref @ 32F	Ref @ 77F		H2O: ref @ 32F	Ref @ 77F
streams are applicable to current heat balance.			/ Water	/ Vapor		Gas: ref @ 77F	Water as vapor
Plant Configuration: GT, HRSG, and condensing non-reheat ST							
Cycle Type = 6							
Steam Property Formulation: IFC-67							
1 Ambient conditions	14.7	59.0	13.31	-4.36	630.24	-0.0083	0.07
2 Air after inlet heater or chiller	14.55	59.0	13.31	-4.36	630.24	-0.0083	-0.29
3 GT compressor inlet air (per GT)	14.55	59.0	13.31	-4.36	630.24	-0.0083	-0.29
4 GT compressor discharge (per GT)	186.4	684.5	167.60	149.94	581.72	0.1857	143.91
5 GT turbine inlet (per GT)	178.9	2101.9	630.51	565.37	593.32	0.4196	431.63
6 GT exhaust, after turbine diffuser (per GT)						635	107.20
7 Compressor bleed to outside process (per GT)						083	-0.29
8 GT fuel (per GT), after comp. but bef heating						-	21665.44
9 Steam injection to GT combustor (all GT's)						486	454.26
10 GT injection water stream	650	59.0	28.90	-1066.39	0.00	0.0534	2.22
11 GT compressor leakage stream	-	-	-	-	0.00	-	-
12 Compressor water injection, Sprint engines	-	-	-	-	-	-	-
13 Steam inj. to LP turbine (total, all GT's)	215	450.0	1238.48	143.19	0.00	1.584	390.40
14 Stack gas	14.7	230.3	100.01	38.46	641.84	0.0627	4.64
15 HP steam to HPT, aft desup, bef stop vlv	1050	970.0	1486.84	391.54	79.93	1.635	611.34
16 HP steam to HPT, after pipe, before desup	1050	970.0	1486.84	391.54	79.93	1.635	611.34
17 HP steam to HPT, before HP pipe	1084.1	973.7	1487.84	392.54	79.93	1.632	613.76
18 HPS3 exit steam	1084.1	973.7	1487.84	392.54	79.93	1.632	613.76
19 HPS3 inlet steam	1122.1	558.7	1188.16	92.86	79.93	1.377	451.20
20 HPS2 exit steam	1122.1	558.7	1188.16	92.86	79.93	1.377	451.20
21 HPS2 inlet steam	1122.1	558.7	1188.16	92.86	79.93	1.377	451.20
22 HPS1 exit steam	1122.1	558.7	1188.16	92.86	79.93	1.377	451.20
23 HPS1 inlet steam	1122.1	558.7	1188.16	92.86	79.93	1.377	451.20
24 HPS0 exit steam	1122.1	558.7	1188.16	92.86	79.93	1.377	451.20
25 HPS0 inlet steam	1122.1	558.7	1188.16	92.86	79.93	1.377	451.20

GT PRO

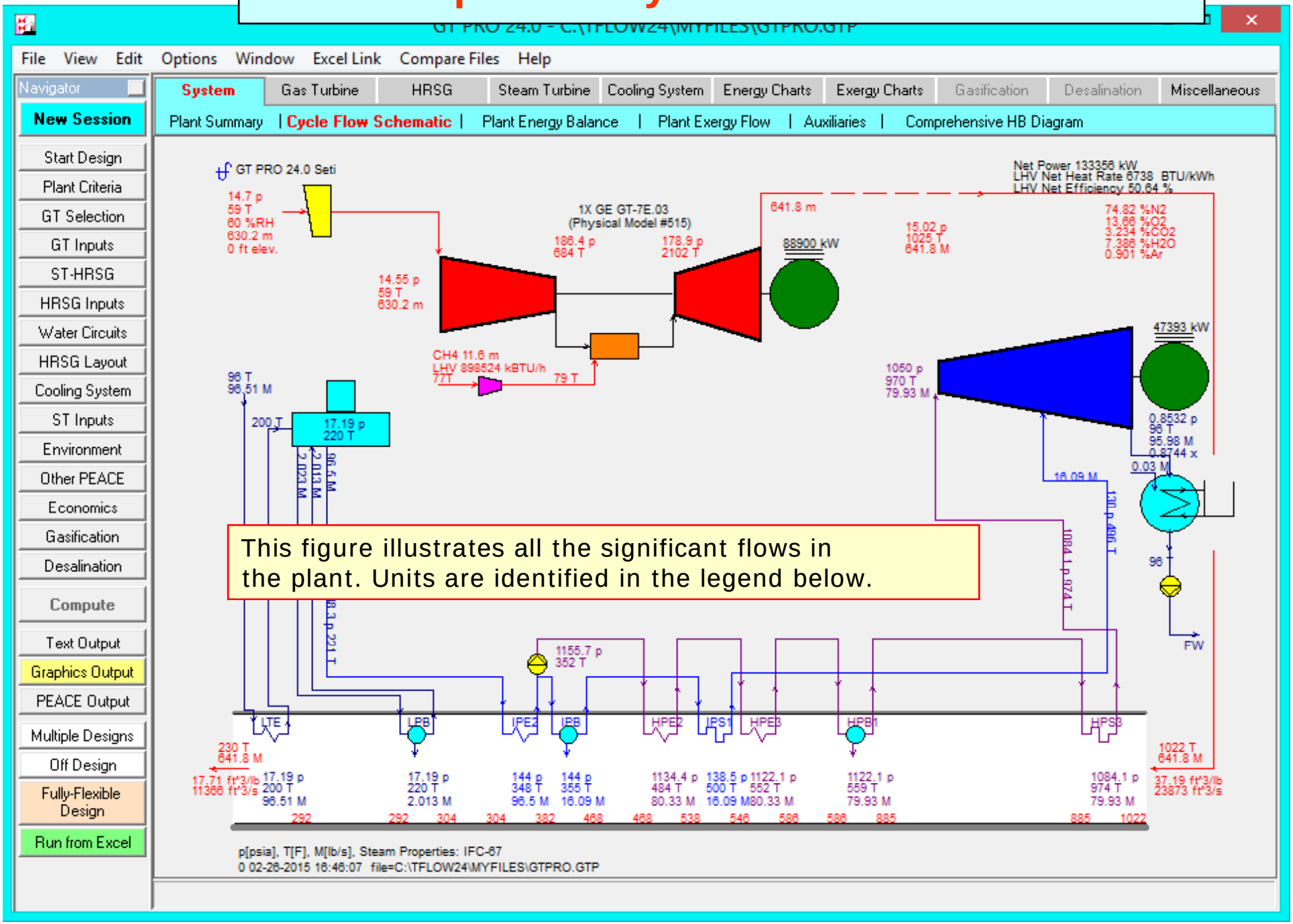
GT PRO Graphics Output



This overview displays gross and net electrical output, heat rate, and fuel energy input. Note also the many other graphic displays to be selected from the tabs above.

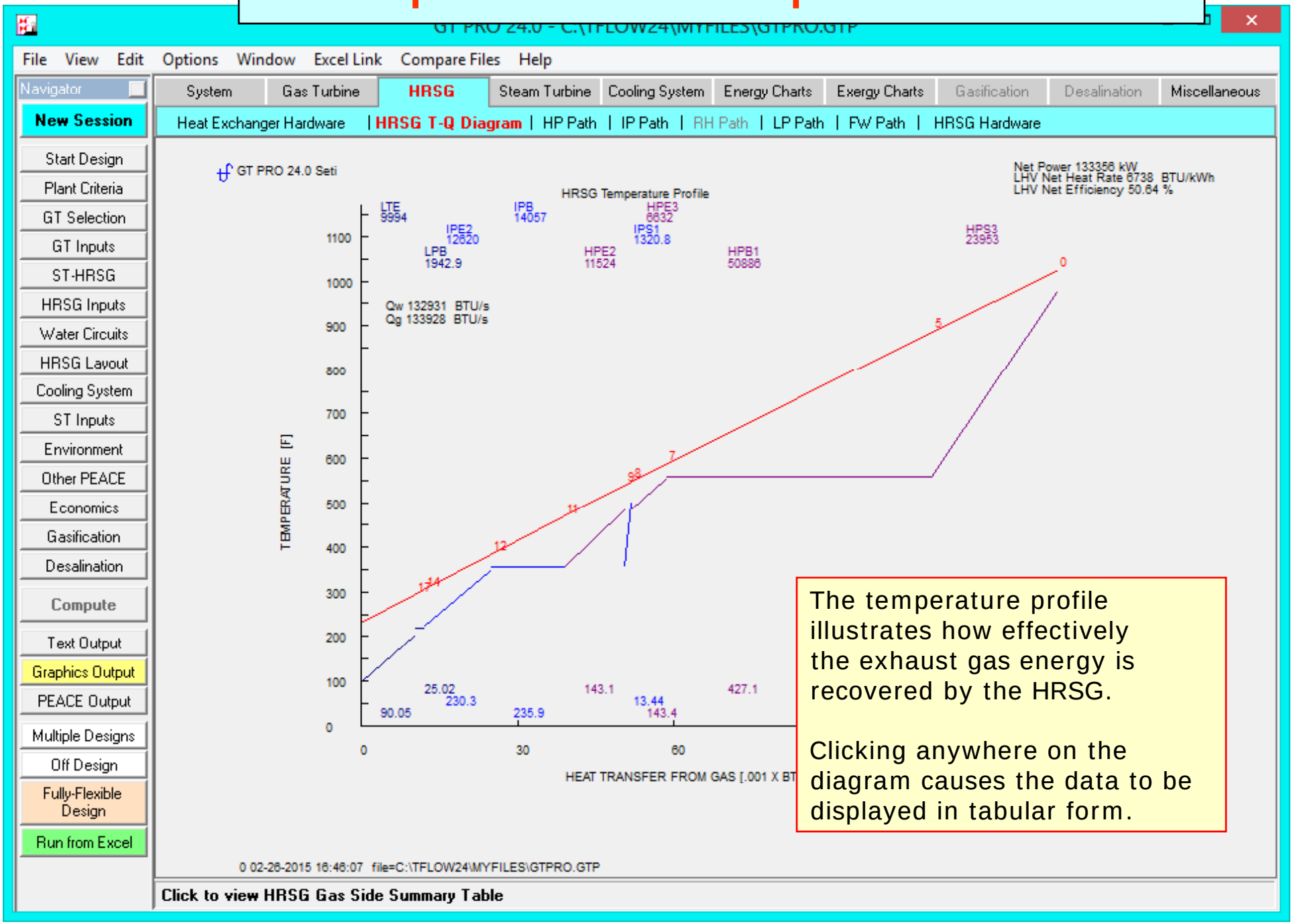
GT PRO

Graphics – Cycle Flow Schematic



GT PRO

Graphics – HRSG Temperature Profile

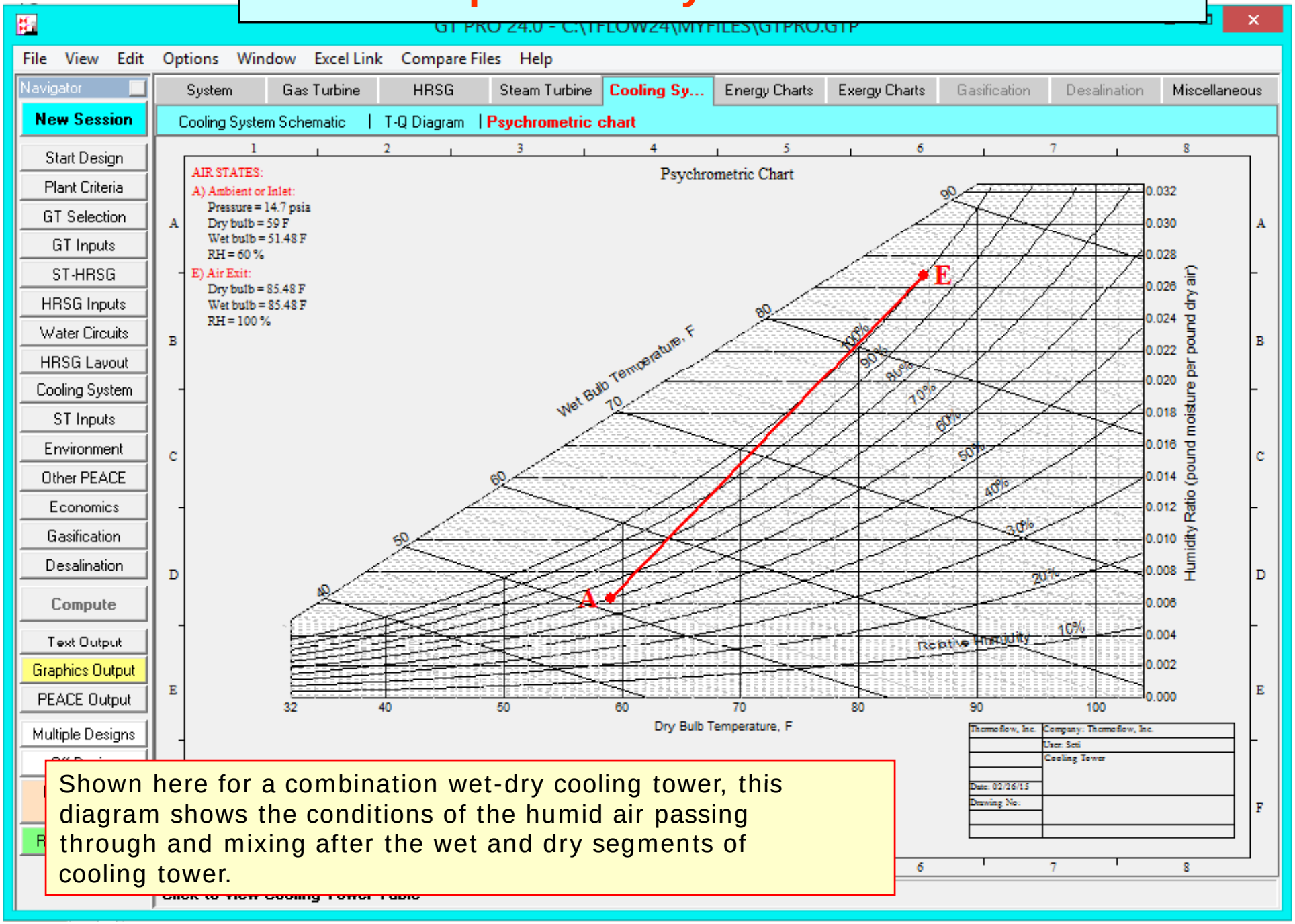


The temperature profile illustrates how effectively the exhaust gas energy is recovered by the HRSG.

Clicking anywhere on the diagram causes the data to be displayed in tabular form.

GT PRO

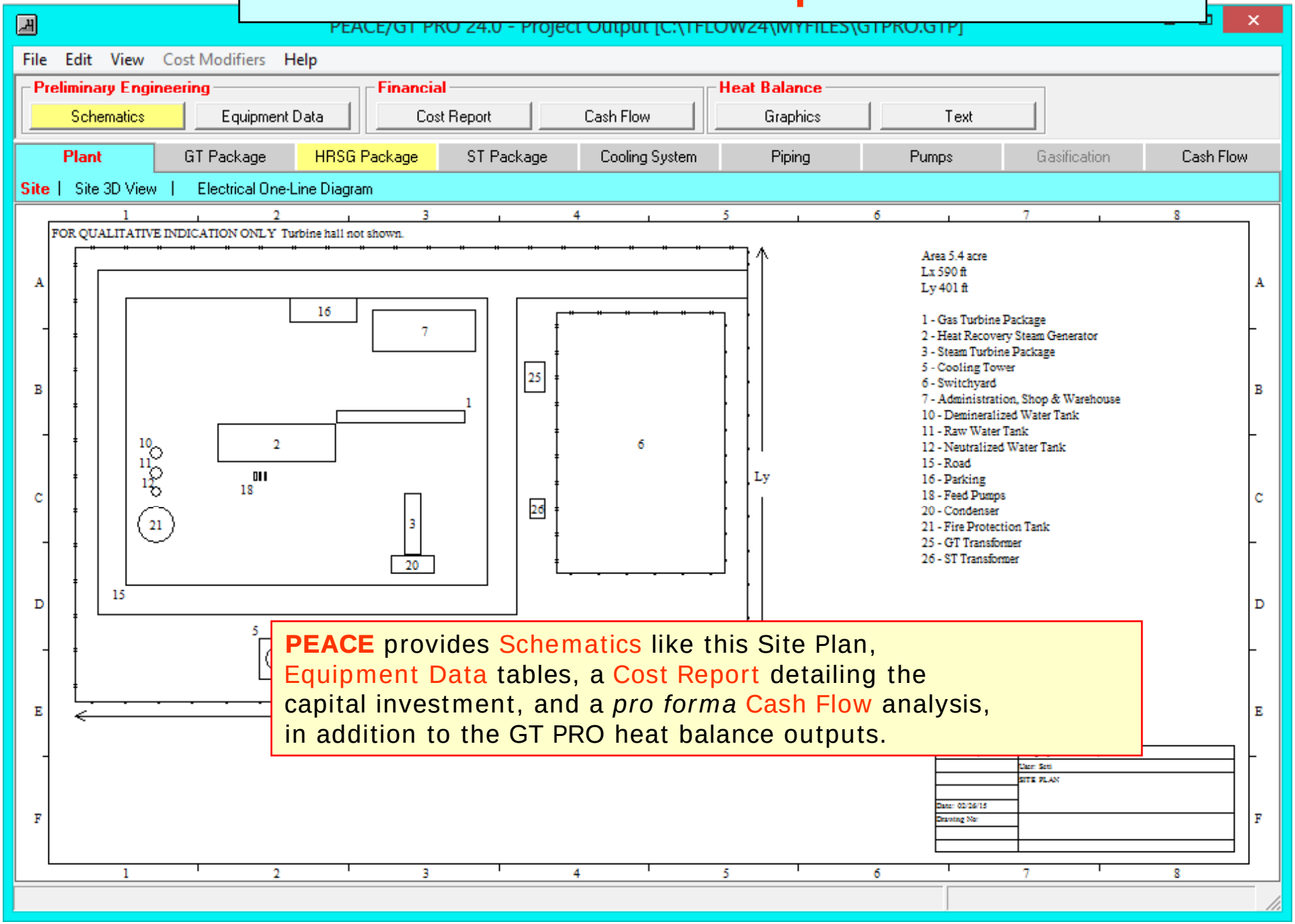
Graphics – Psychrometric Chart



Shown here for a combination wet-dry cooling tower, this diagram shows the conditions of the humid air passing through and mixing after the wet and dry segments of cooling tower.

GT PRO

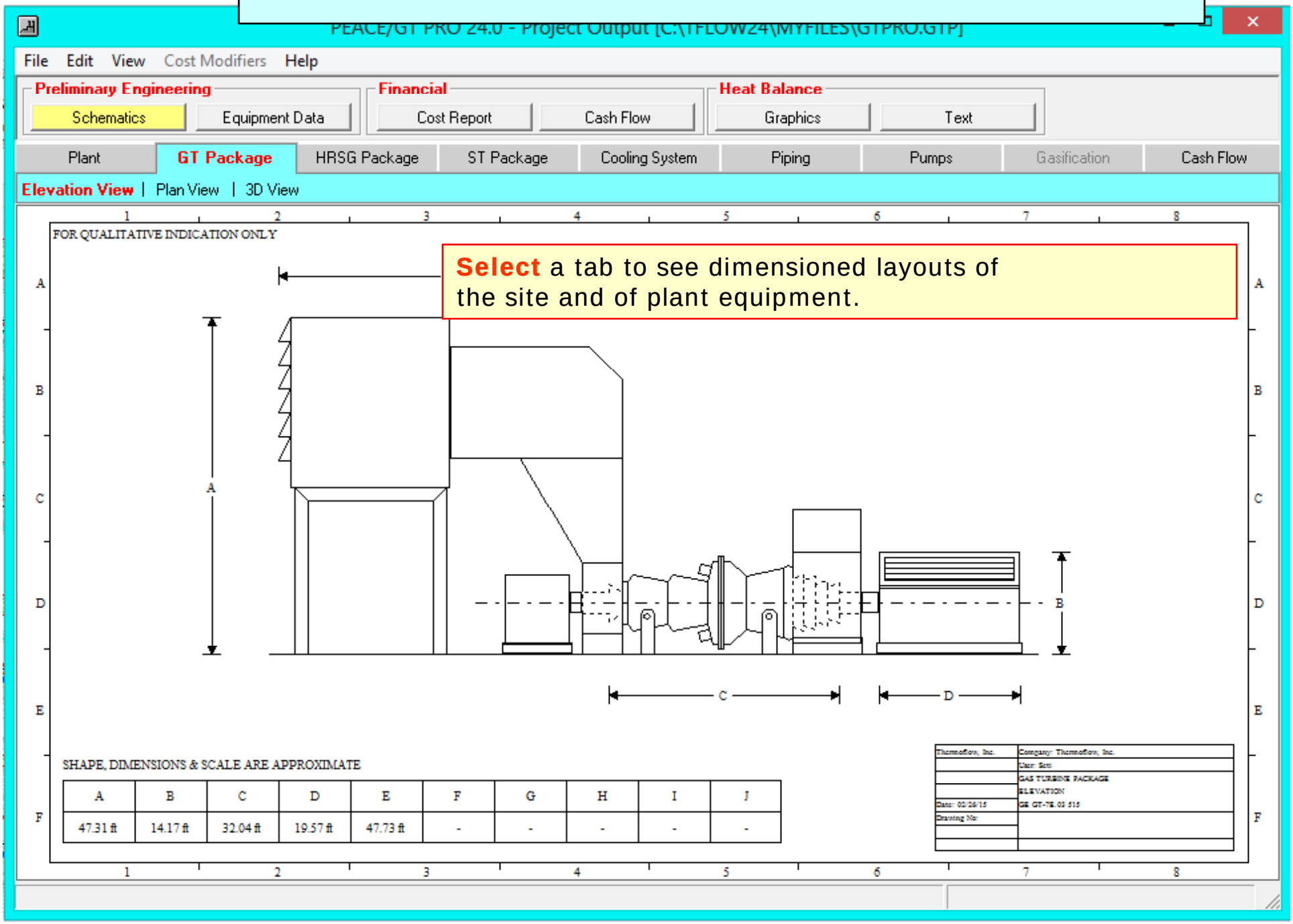
PEACE Outputs



PEACE provides Schematics like this Site Plan, Equipment Data tables, a Cost Report detailing the capital investment, and a *pro forma* Cash Flow analysis, in addition to the GT PRO heat balance outputs.

GT PRO

PEACE Schematics



http://www.Thermoflow.ir/

GT PRO

PEACE Equipment Data

PEACE/GT PRO 24.0 - Project Output [C:\TFLOW24\MYFILES\GTPRO.GTP]

File Edit View Cost Modifiers Help

Preliminary Engineering: Schematics | Equipment Data

Financial: Cost Report | Cash Flow

Heat Balance: Graphics | Text

Plant | **Gas Turbine** | HRSG | Steam Turbine | Cooling System | Gasification | Desalination | Miscellaneous

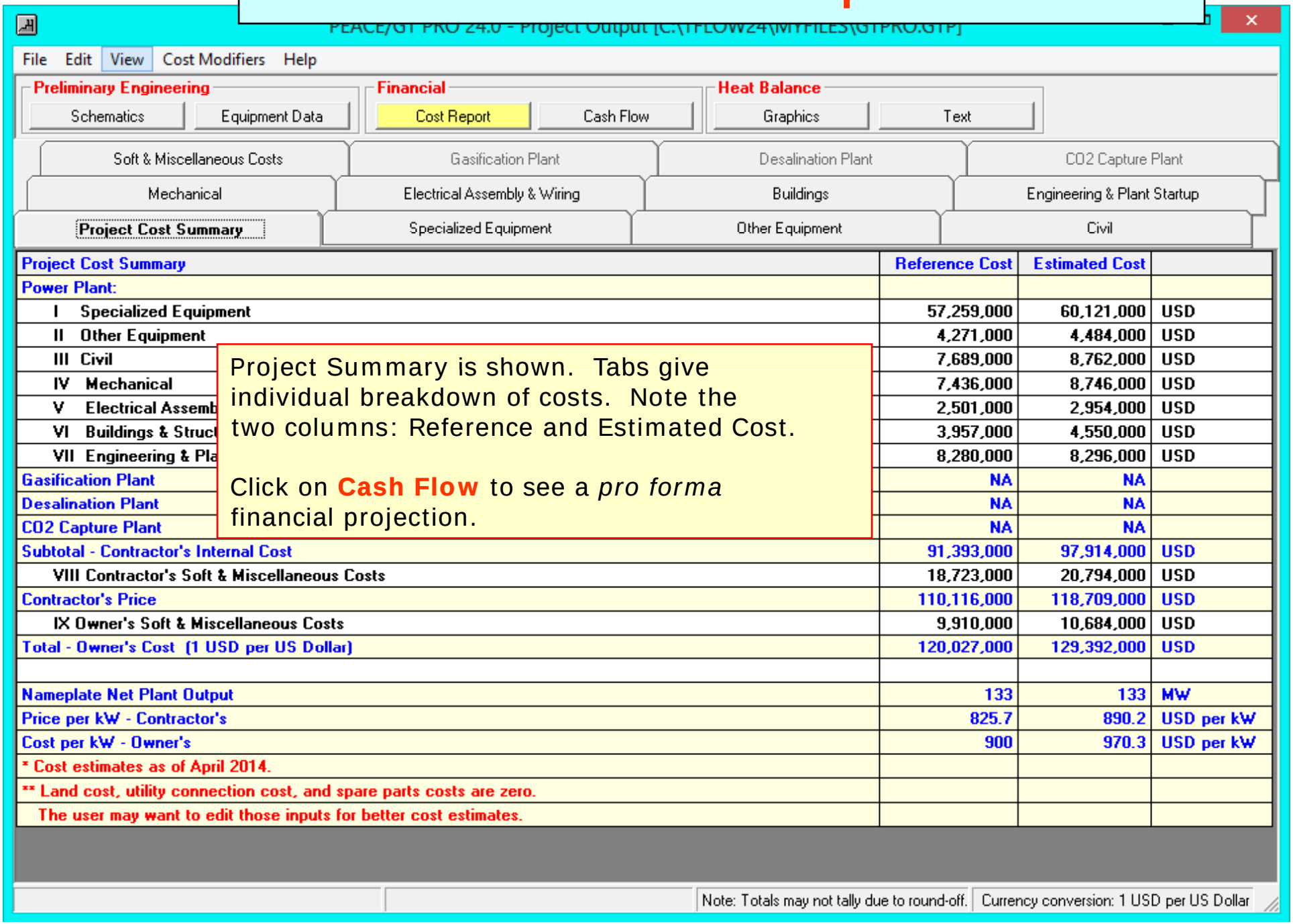
Gas Turbine | Chiller

Estimated Gas Turbine Data		
Number of units	1	
1. Nominal Gas Turbine Description & Performance Data (per unit)		
Model	GE GT-7E.03	
Dry Low NOx Combustion System is Available	Yes	
Engine Specification is Currently Offered New from Manufacturer	Yes	
Generator Output	90500	kW
LHV Heat Rate @ Generator Terminals	9985	BTU/kWh
LHV Efficiency @ Generator Terminals	34.17	%
Compressor Inlet Airflow	636.5	lb/s
Exhaust Temperature	1015	F
Firing Temperature	2100	F
Compressor Pressure Ratio	12.8	
Number of Shafts	1	
Engine Output Shaft Spe	3,600	RPM
Engine Output Shaft Driv	No	
Generator Efficiency	98.5	%
Gas Turbine Package Pr	29,532,000	USD
2. Site Specific Gas Turbine Performance Data (per unit)		
Generator Output	88900	kW
LHV Heat Rate @ Generator Terminals	10107	BTU/kWh
LHV Efficiency @ Generator Terminals	33.76	%
Compressor Inlet Airflow	630.2	lb/s
Exhaust Temperature	1024.5	F
Estimated Firing Temperature	2101.9	F
Compressor Pressure Ratio	12.81	

For each of the equipment categories, selectable by the tabs visible here, these tables indicate size, weight, and nameplate specifications.

GT PRO

PEACE Cost Report

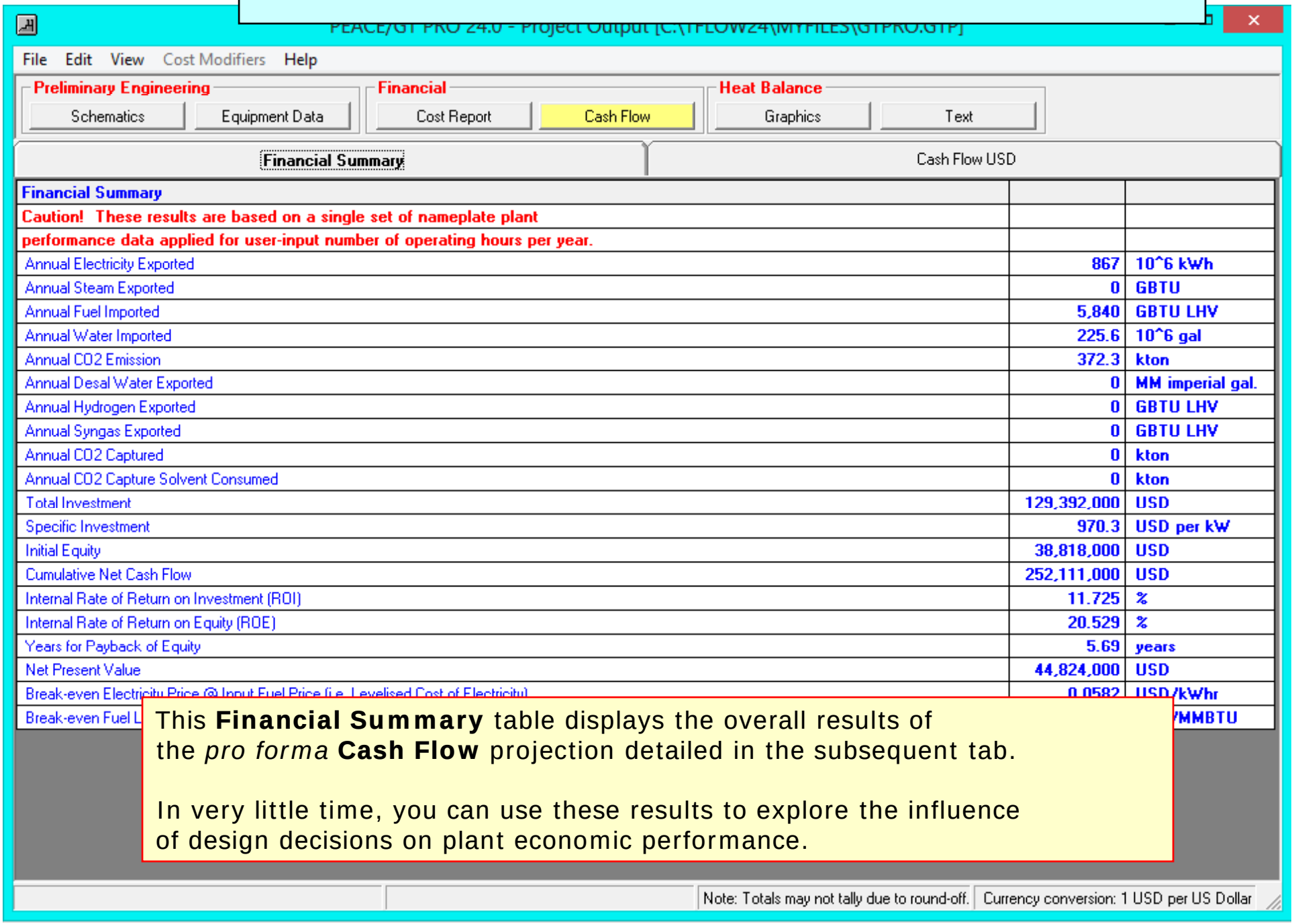


Project Summary is shown. Tabs give individual breakdown of costs. Note the two columns: Reference and Estimated Cost.

Click on **Cash Flow** to see a *pro forma* financial projection.

GT PRO

PEACE Cash Flow



This **Financial Summary** table displays the overall results of the *pro forma* **Cash Flow** projection detailed in the subsequent tab.

In very little time, you can use these results to explore the influence of design decisions on plant economic performance.