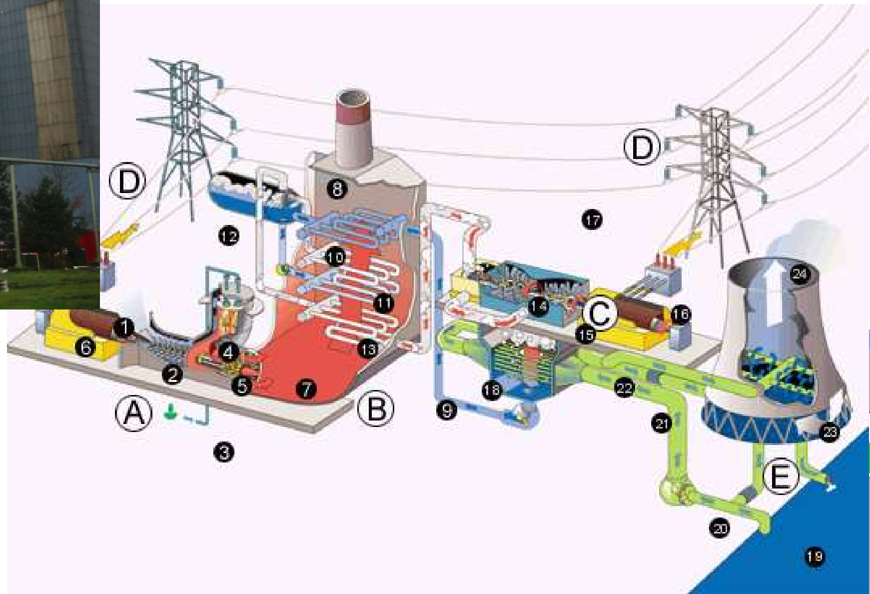
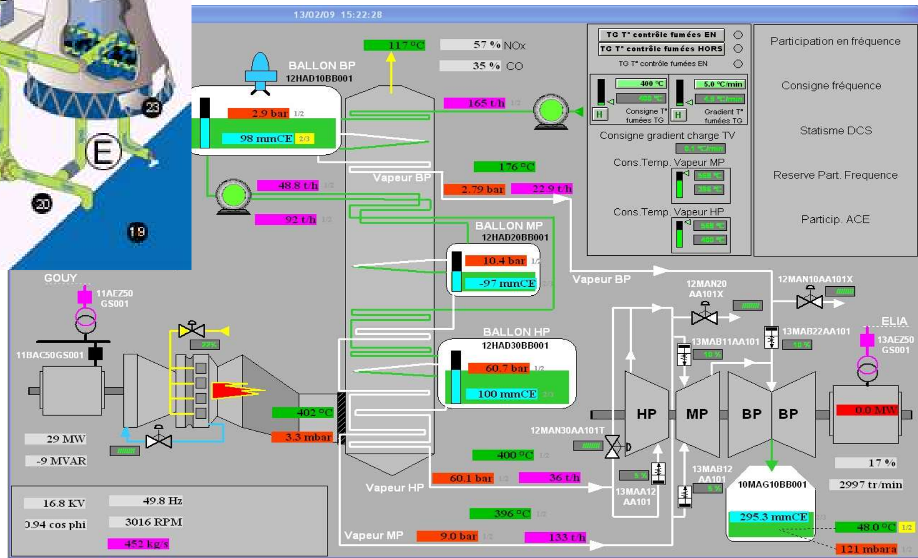
MECA 2150 : PROJECT

Modelisation of GT, ST, CCGT and cooling tower



Drogenbos (ENGIE)



25/09/2019

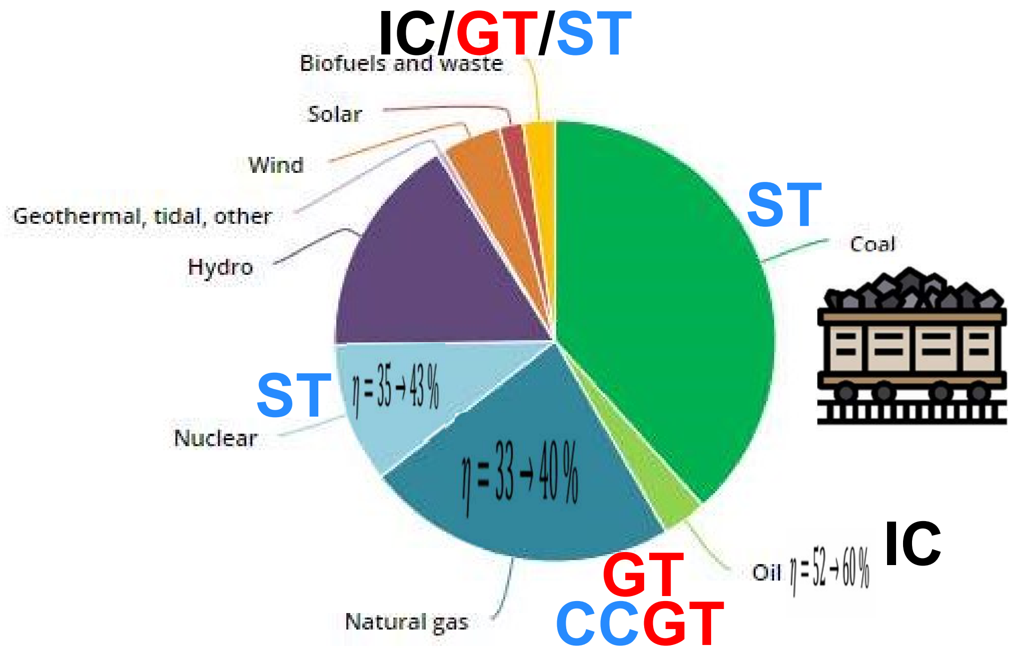
Gauthier LIMPENS

GL1

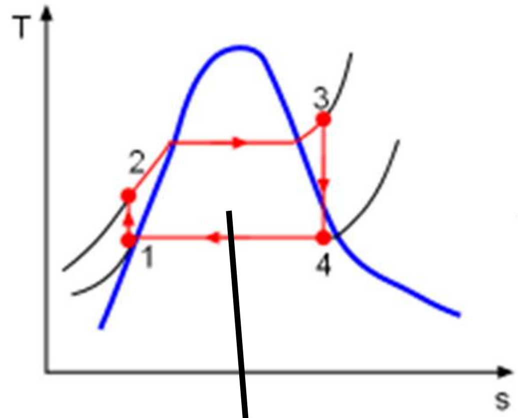
Introduction

➔ Context

World gross electricity production, by source, 2017

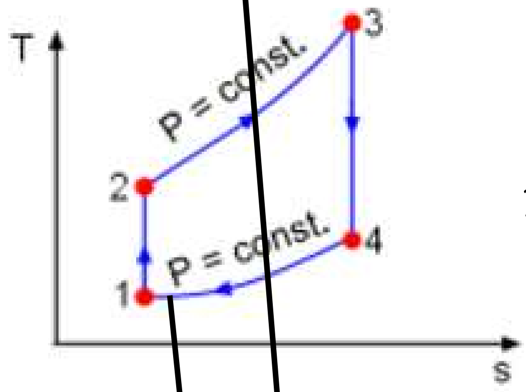


From : https://www.iea.org/statistics/electricity/



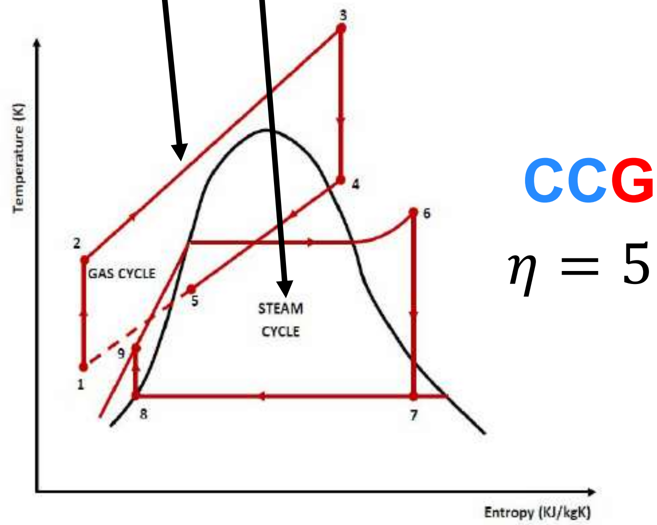
ST

$\eta = 33 \rightarrow 40\ \%$



GT

$\eta = 35 \rightarrow 43\ \%$



CCGT

$\eta = 52 \rightarrow 60\ \%$

≈**77%** world electricity production comes from **thermal cycles**

Diapositive 2

GL1 Gauthier Limpens; 25-09-19

Introduction

➔ Project goal :

- Perform an in-depth thermodynamic study of thermal cycles power plants, in order to :
  - Determine performances in the energy and exergy point of views of the different parts of the cycle
  - Draw T-s and h-s diagrams of the different cycles and heat exchangers
  - Study the impact of several parameters on the performances of the cycle

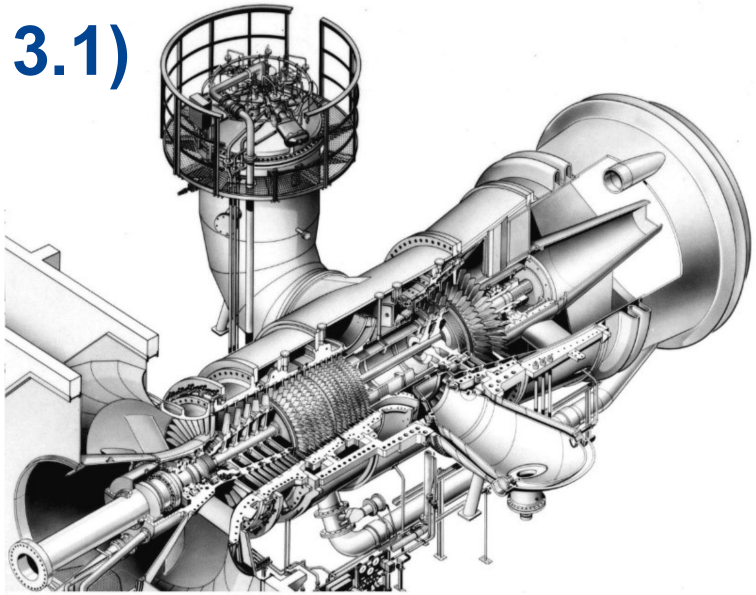
➔ Project structure :

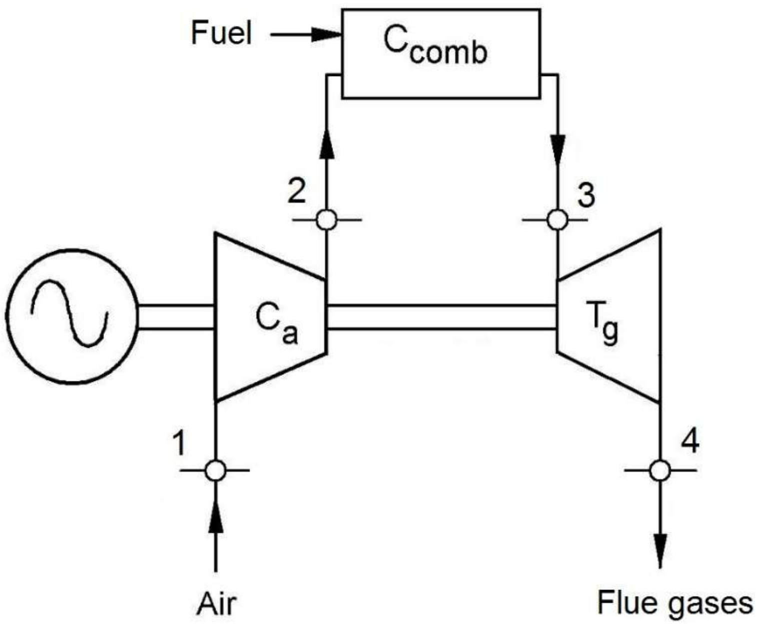
- The project is divided in four parts :
  - Gas turbine (**GT**) power plant cycle (including combustion)
  - Steam turbine (**ST**) power plant combining reheating and feed-heating for different fuels. It should be used in sub and super critical modes with a degazificator. It must include combustion (of the right fuel!)
  - Combine cycle gas turbine (**CCGT**) power plant with 3 pressure levels
  - Cooling tower for **ST** and **CCGT**
- The model will be developed with Matlab.

Thermal cycles : Gas turbine (Fig 3.1)

DATA	
Air temperature	15 [°C]
Max. temperature	1050 [°C]
Compression ratio	10 [-]

- Why are these data relevant?
- Which are the other relevant parameters, and their numerical values?
- Which assumptions can you do (and why?)

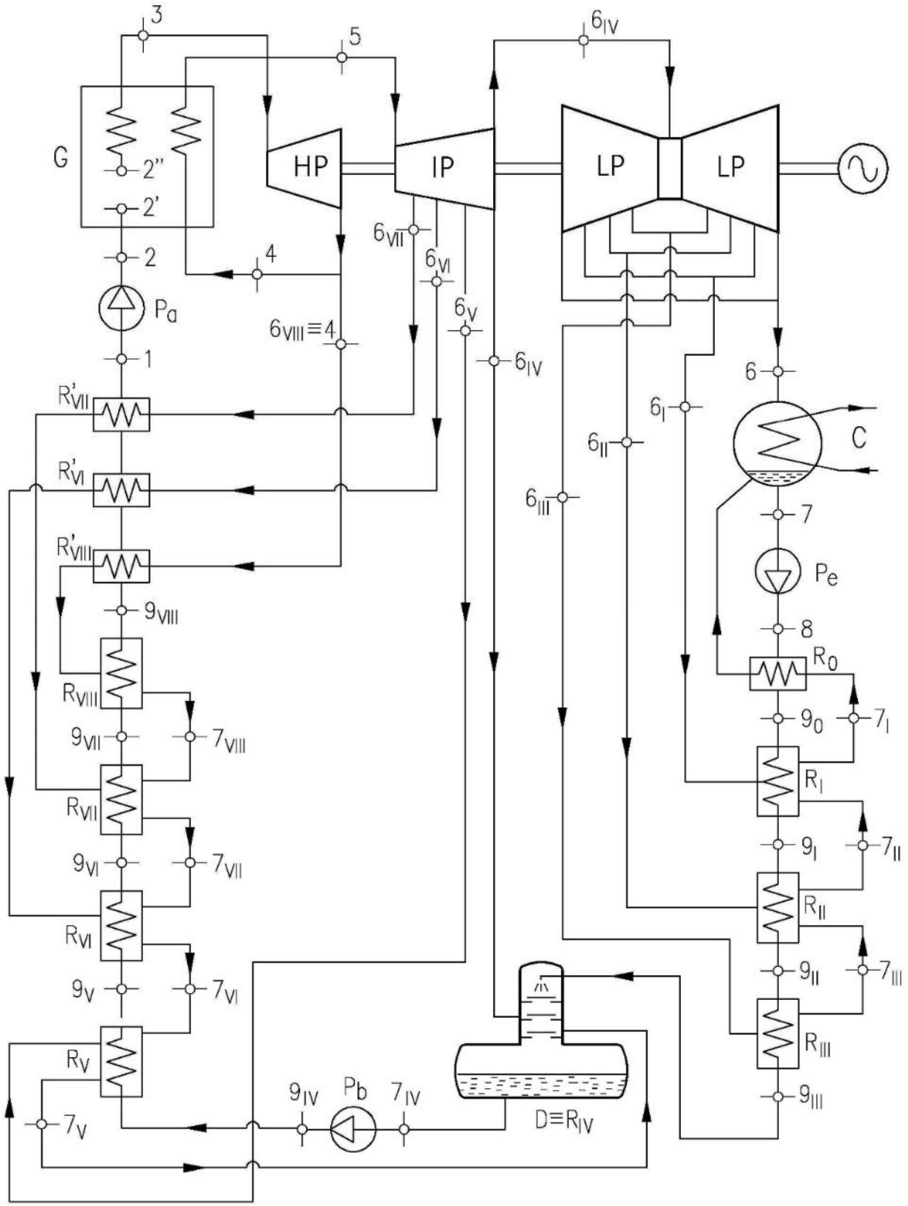




Thermal cycles : Steam turbine (see Fig 2.33)

DATA	
River temperature	15 [°C]
Max. temperature within the boiler	525 [°C]
Max. steam pressure	200 [bar]

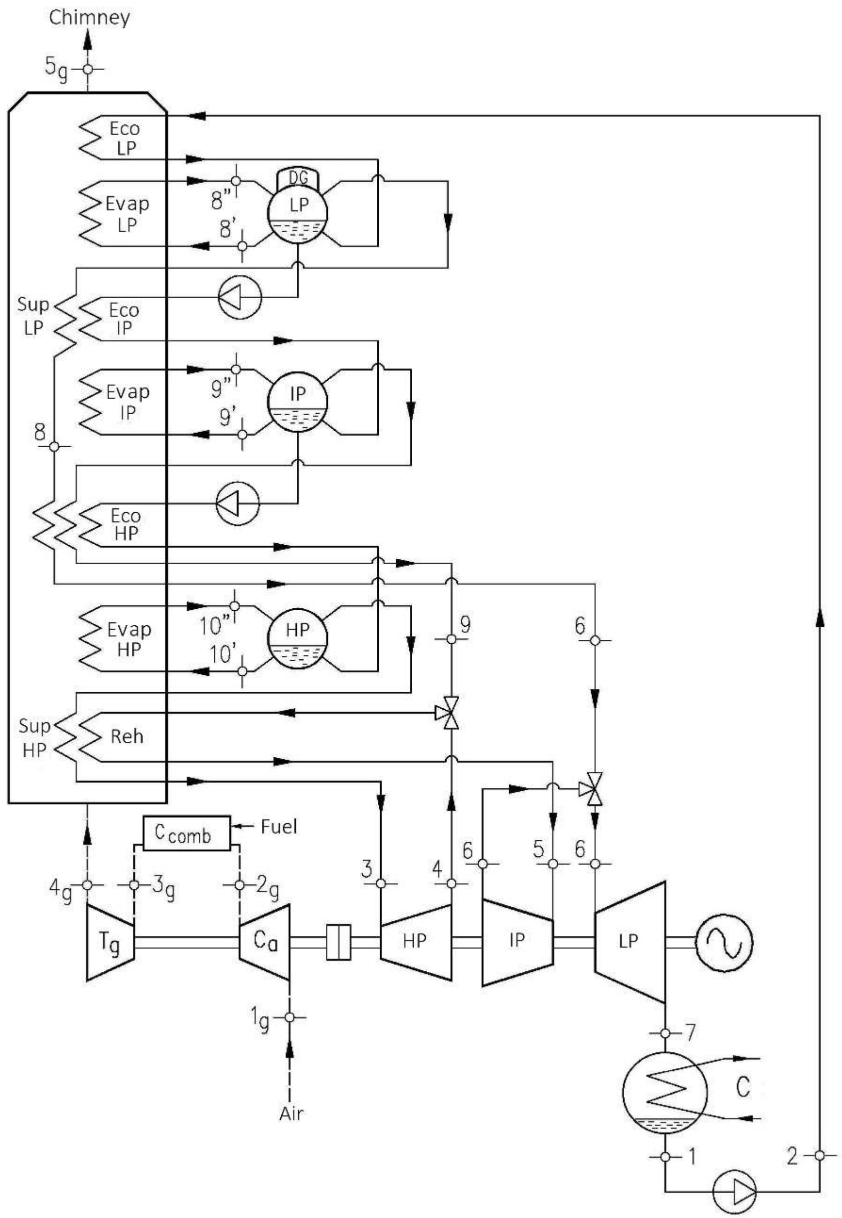
- Why are these data relevant?
- Which are the other relevant parameters, and their numerical values?
- Which assumptions can you do (and why?)



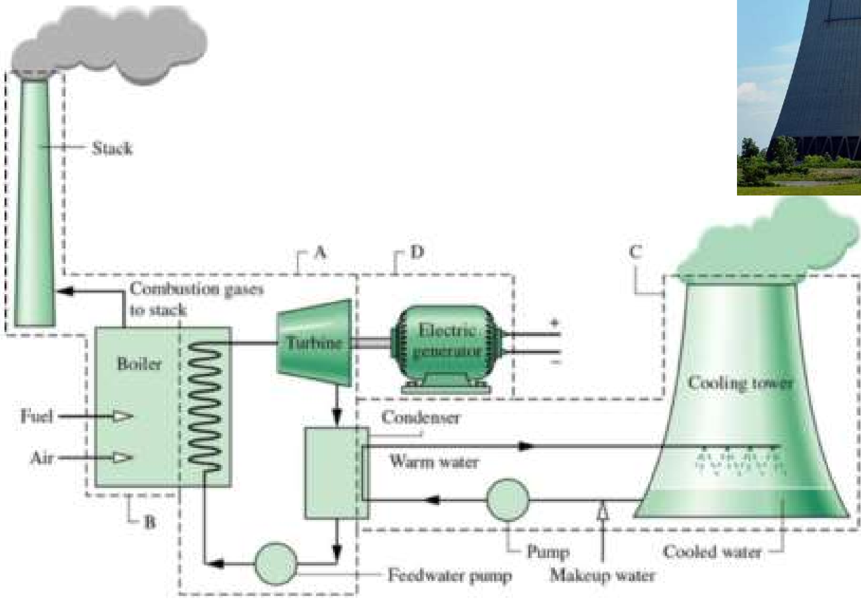
Thermal cycles : CCGT - three pressure level (see Fig 4.19)

DATA	
Steam pressure (HP)	122.8 [bar]
Steam pressure (HP)	27.3 [bar]
Steam pressure (LP)	3.6 [bar]
ST elec. power	153.8 [MW]
GT elec. power	283.7 [MW]

- Why are these data relevant?
- Which are the other relevant parameters, and their numerical values?
- Which assumptions can you do (and why?)



Tools to master:

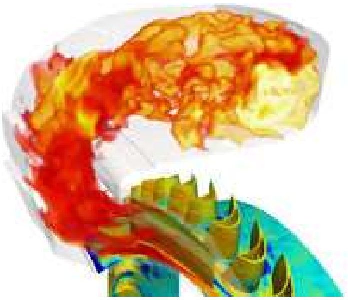


→ Design of a cooling tower :

- What are the required flows?
- What are the thermodynamic states?

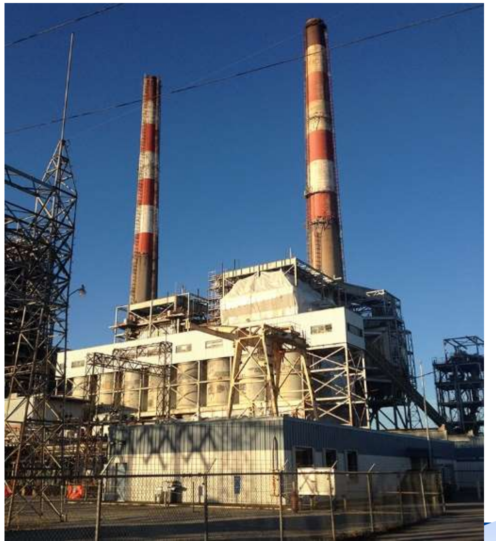
→ Combustion :

- What is the required amount of fluids?
- What is the exhaust gas composition?



→ Computation of the dew point at the chimney

- What is the value?
- What is the risk and what should be provided to avoid the risk?



Organisation

➔ Group :

- 2 students

➔ Input :

- Xsteam : thermodynamics state of liquid and gaseous water
- Janaf : heat capacity of various gas (CO_2, CO, O_2 N_2…)
- Psychrometrics : thermodynamics state of humid air (!!! $\Phi \in [0; 100]$)

➔ Support :

- Facultative exercices:
  - Moodle :
    - Cycles
    - Combustion
  - Class exercice about cycles and energy/exergy balance(to be organised).

- Consulting (see appendix 2):
  - Group forum (whenever) : Discussion between each group and me.
  - Consultation : Scheduled by myself based on questions on group forum. (During class hours)
- Informations :
  - Via moodle. Please check directly on moodle (not on your mails)

Evaluation

➔ Code (30%):

- The code must be done in matlab and respect a given structure (see appendix 3)
- Automatic computation of the code will occur (15%), I will check your graphs (15%).
- Exact signature and an example of computation code will be given later.
- Codes will be compared. Similarities will be sanctioned.

➔ Report (30%):

- Explain your assumptions, methodology to an expert with a synthetic 6 pages (3 sheets without cover & appendix) report. Add 1-2 pages per cycle with only graphes without comments (T-s, h-s, pie charts, steam generator and heat exchangers).

➔ Oral (40%):

- 10 minutes presentations on the strenght and the innovative part of your work
- 5-10 minutes Q-A.
- Previous group will attend actively the next one.

➔ Submissions

- S3 (03/10): Planning including milestones date, and estimated duration time + description (see appendix 1)
- S13 (13/12) : Code, report and updated planning will be given back on moodle
- S14 : Oral examination.

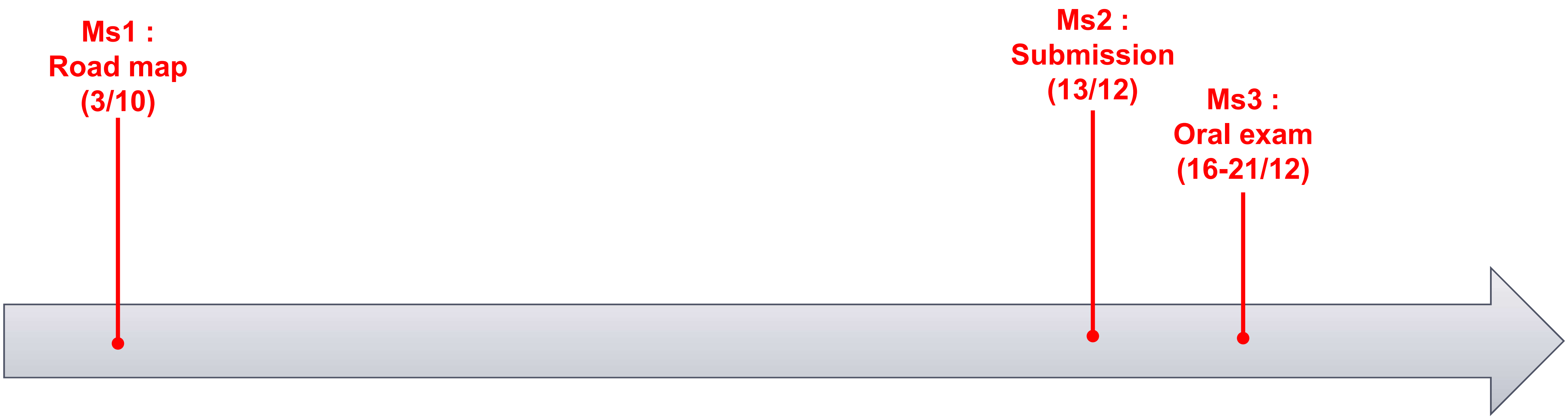
Why a planning :

- *'Failing to plan, is planning to fail'* (W. Churchill)
- I can give you a feedback at the very beginning!

Planning

→ Milestones (Ms) :

- Ms1 : Road map (1 page) see appendix 1
- Ms2 : Code + report (6 pages) submission
- Ms3 : Oral examination



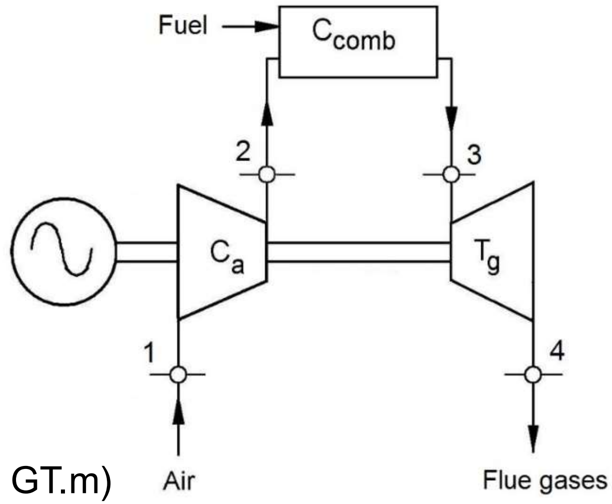
Let's start?

You want to start?

➔ Exercice :

- Solve a super simple exercice of GT as follow:
  - Turbine statment:
    - 1-2 : polytropic compression (compression ratio r, efficiency η_{PiC})
    - 2-3 : Heat increase (we neglect pressure drop, gases composition changes and mass flow increase).
    - 3-4 : polytropic expansion (efficiency η_{PiT})
  - Numerical data:
    - $\eta_{PiC} = \eta_{PiT} = 0{,}9\ [-]$
    - $T_3 = 1400°C$
    - $r = 12\ [-]$
    - Other numerical values to be find by yourself
- What if …
  - $\ldots\ \eta_{PiC} = 0.88$ and/or $\eta_{PiT} = 0.8$?
  - $\ldots\ T_3 = 1200\ or\ 600\ or\ 837.2\ \ldots\ [°C]$
  - $\ldots\ r = 11\ or\ 14\ or\ 4\ or \ldots [-]$

$\Rightarrow$ You need a model to compute results based on varying input parameters (start writting GT.m)



➔ What about improving the model?

- What happends in the combustion chamber?
- Which part of the energy is transformed into electricity?
- What if c_p is not constant?

➔ What about mastering this problem :

- Why T_3 can reach 1400°C whereas in ST it will be much more low?
- Which parameters have a critical change over the efficiency and what are the trends?

Examples of knowledge you have to master

➔ Questions:

- When can you use the 'perfect gas assumption'? Why using Janaf?
- How the losses are distributed in the cycles
- Energy/Exergy balance over a system
- Pros and cons of ST, GT and CCGT
- How does the design change if the power plant is built in Siberia instead of Sahara?
- What are the trends if… I increase the pressure? I lower that temperature ? Etc.
- Why this temperature cannot be above 700°C? Why this pressure is limited and by what?
- Which fuels are used in each power plants and why?

➔ Additional exercice:

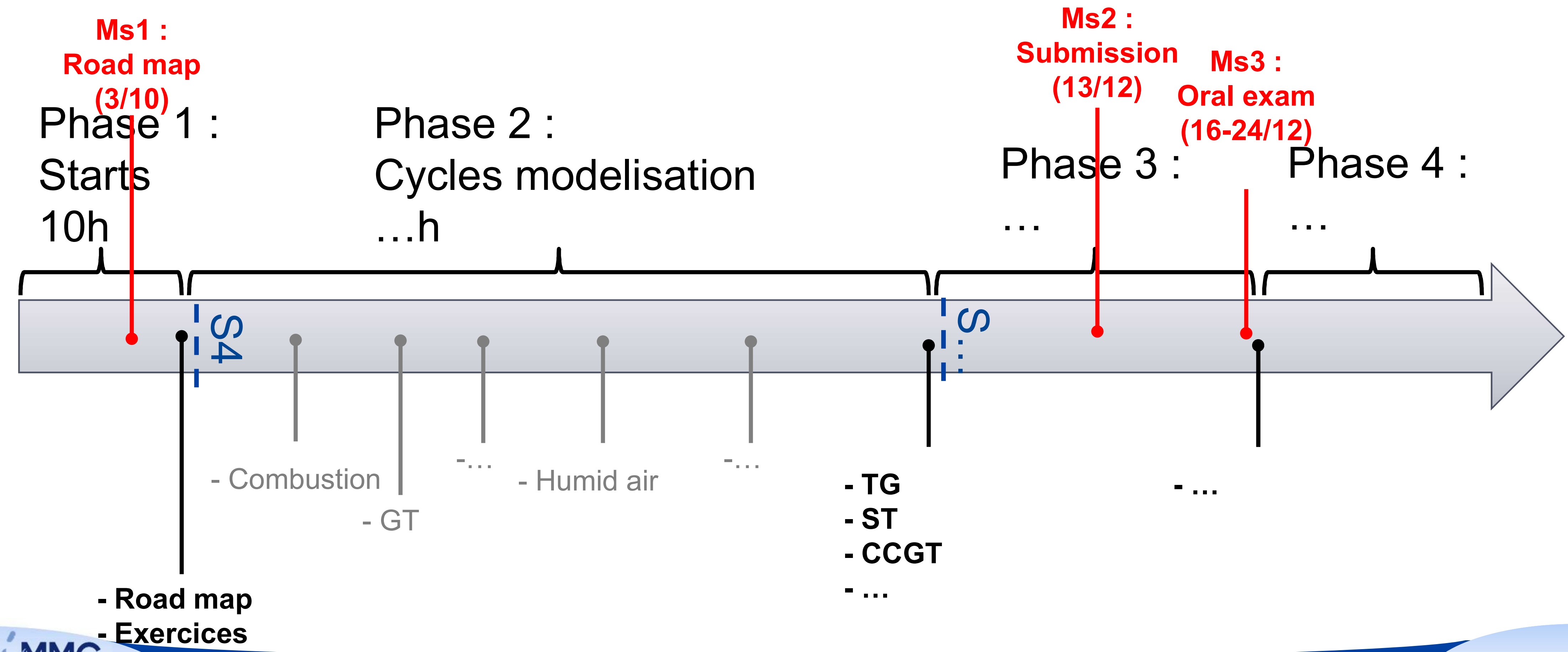
- What is the CO2 emissions of each cycle per MWh of electricity produced? (compare with the litterature

APPENDIX

APPENDIX 1 : Planning example

➔ Road map must include :

- Milestones description + date
- Approximal duration per milestone



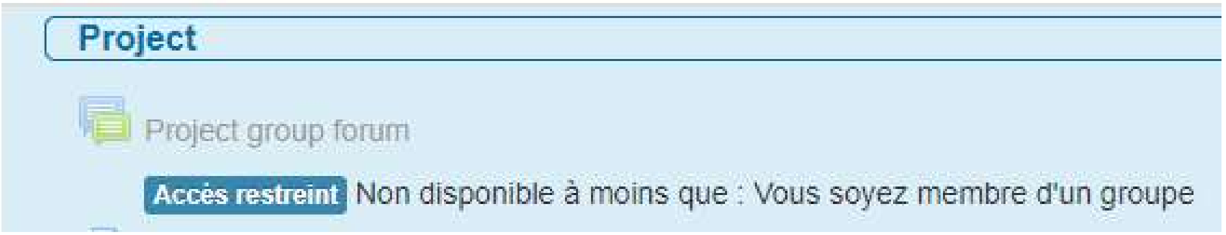
Why using this tool:

- You earn point by using it.
- It is the only way to have a consultancy.
- Fast support

APPENDIX 2 : Group forum and consultation

→ Use :

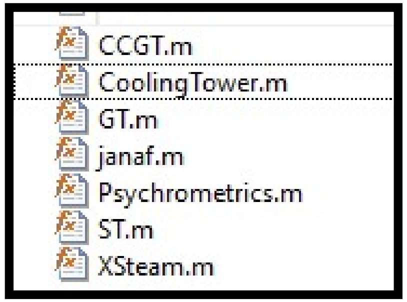
- I recommend to use this template for the forum :
  - 1 topic = 1 problem domain (exchanger/ heat feeders / combustion ...)
  - For each topic, make a short question (I know what is hard for you).
  - Use pictures/graphics that you can upload on the thread, it worths.
- Please be assertive, a question well asked will be faster to answer.
- I will answer your questions or I will schedule an appointment to help you during the consultation session.



APPENDIX 3 : Code structure

➔ Folder structure :

- Download it from Moodle and change its name (*LMECA2150_1718_Gr**X*** », where ***X*** is your group number).
- In this folder,
  - You must not change the location of the files.
  - You have to fill : CCGT.m GT.m ST.m CoolingTower.m
  - You can add other files (not mandatory).



APPENDIX 3 : Code structure

Functions will be provided in week 4 (S4)

➔ Signature :

- These are the minimum required. Your fonction can include more parameters (input/ouput).
- Use nargin to have default value of input. You may check input arguments and return a warning if a value seems unrelevant (ex : -300°C)

```
function [ETA DATEN DATEX DAT MASSFLOW COMBUSTION Cp_g FIG] = GT(P_e,options,display)
% GT Gas turbine modelisation
% GT(P_e,options,display) compute the thermodynamics states for a Gas
% turbine based on several inputs (given in OPTION) and based on a given
% electricity production P_e. It returns the main results. It can as well
% plots graphs if input argument DISPLAY = true (<=> DISPLAY=1)
%
% INPUTS (some inputs can be dependent o
%          be activated) Refer to Fig 3.1
% P_E = electrical power output target [
% OPTIONS is a structure containing :
%   -options.k mec [-] : Shaft losses
```

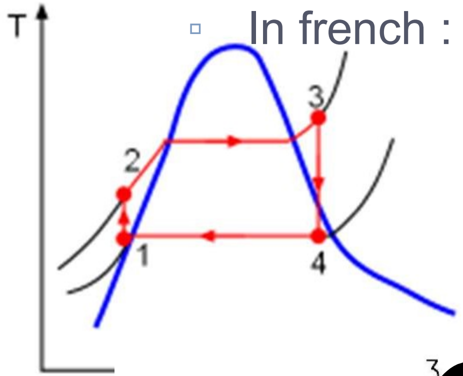
```
function [ETA XMASSFLOW DATEN DATEX DAT MASSFLOW COMBUSTION FIG] = ST(P_e,options,display)
% ST Steam power plants modelisation
% ST(P_e,options,display) compute the thermodynamics states for a Steam
% power plant (combustion, exchanger, cycle) turbine based on several
% inputs (given in OPTION) and based on a given electricity production P_e.
% It returns the main results. It can as well plots graphs if input
% argument DISPLAY = true (<=> DISPLAY=1)
%
% INPUTS (some inputs can be dependent on others => only one of these 2 can
%          be activated). Refer to Fig 2.33 from reference book (in english)
% P_E = electrical power output target [kW]
% OPTIONS is a structure containing :
%   -options.nsout     [-] : Number of feed-heating
%   -options.reheat    [-] : Number of reheating
%   -options.T_max     [°C] : Maximum steam temperature
```

Steam cycle illustration

Thermal cycles : Steam turbine (see Fig 2.33)

→ Illustration

- Focus on the Steam cycle, such in a Coal Power plant:
  - https://www.youtube.com/watch?v=SeXG8K5_UvU (57s -> 1m54)
  - In french : https://www.youtube.com/watch?v=QqcIxYe_QgU



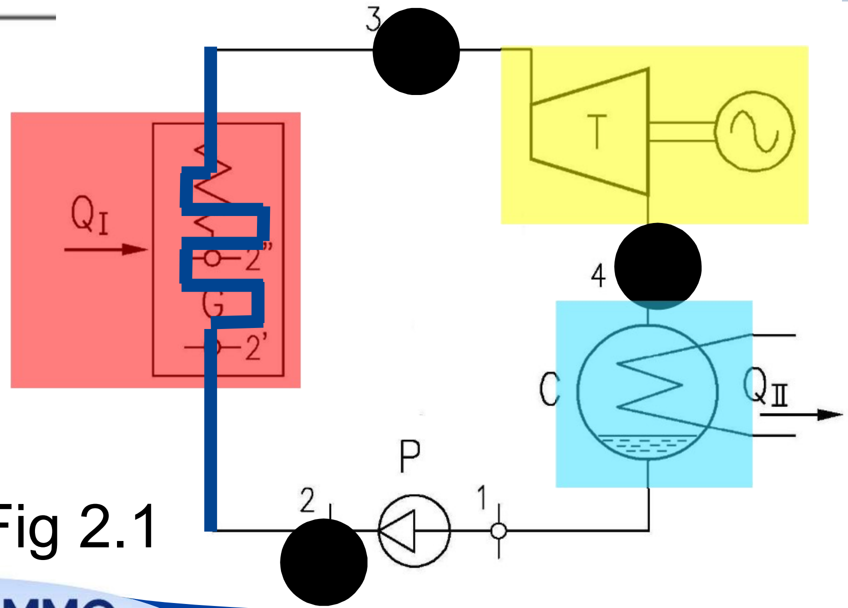


Fig 2.1