

Process Systems Engineering
Prof. Davide Manca – Politecnico di Milano

Exercise 3

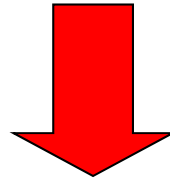
Assessing the economic potential of level-2 (EP2)

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Definitions

EP2 = (main products + by-products) – (cost of raw materials) [€/y]



$$EP_2 = \sum_{j=1}^{NP} \epsilon_{P,j} \cdot \dot{n}_j - \sum_{i=1}^{NR} \epsilon_{R,i} \cdot \dot{n}_i$$

$\epsilon_{P,j}$ = molar cost per product j – th

\dot{n}_j = molar flow per product j – th

$\epsilon_{R,i}$ = molar cost per reagent i – th

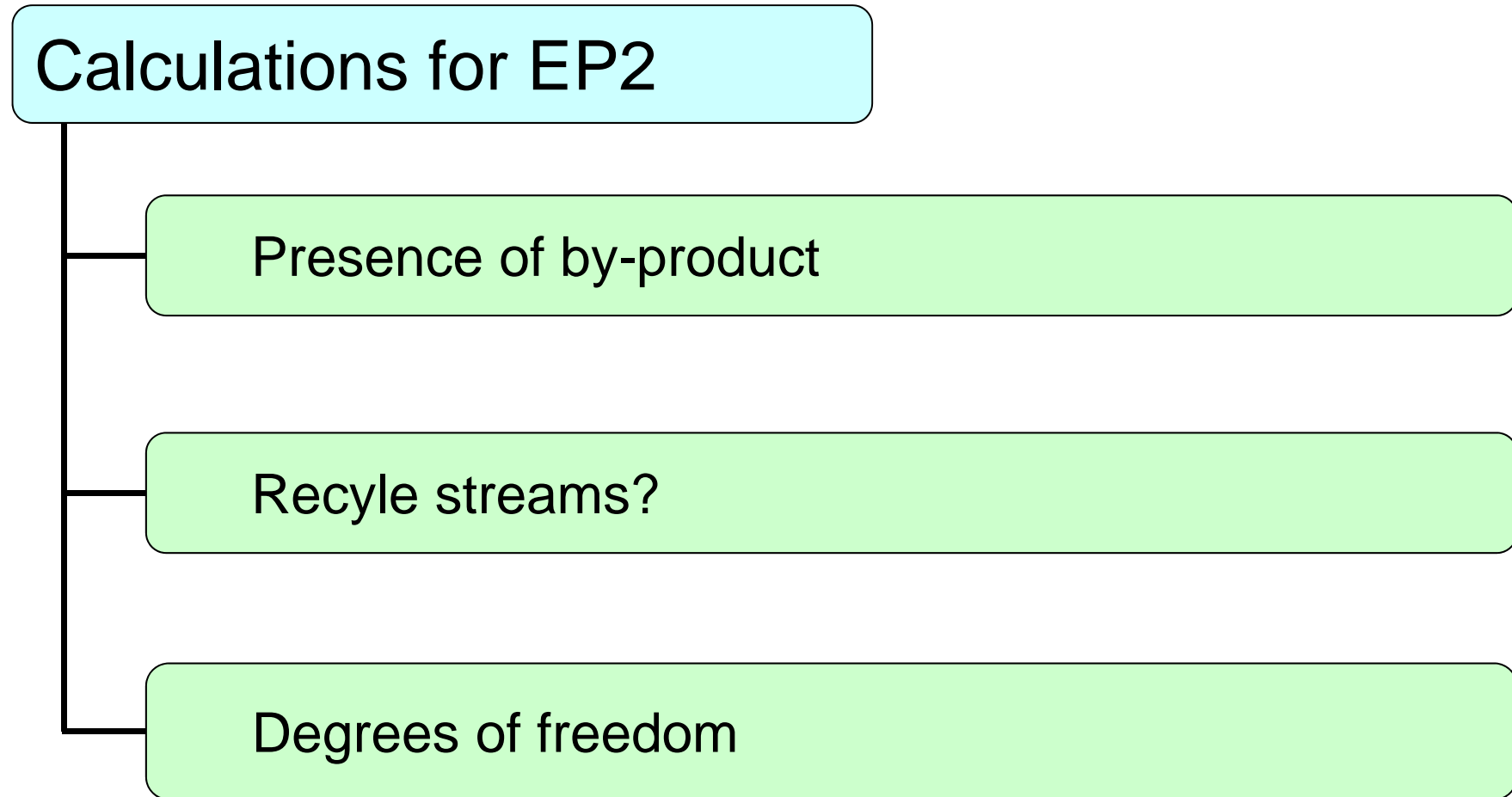
\dot{n}_i = molar flow per product i – th

NP = number of products

NR = number of reagents



Features

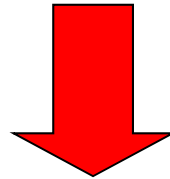


Features

Presence of by-products

The by-products can be analyzed from two different points of view:

- Can be considered as real products, and then sold at their market value;
- They can be used inside the process (e.g., as fuel for the utility system).



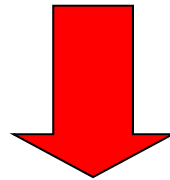
Need to investigate and find out which is the most convenient alternative!



Features

Recycle streams?

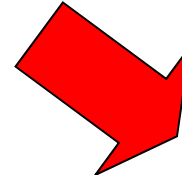
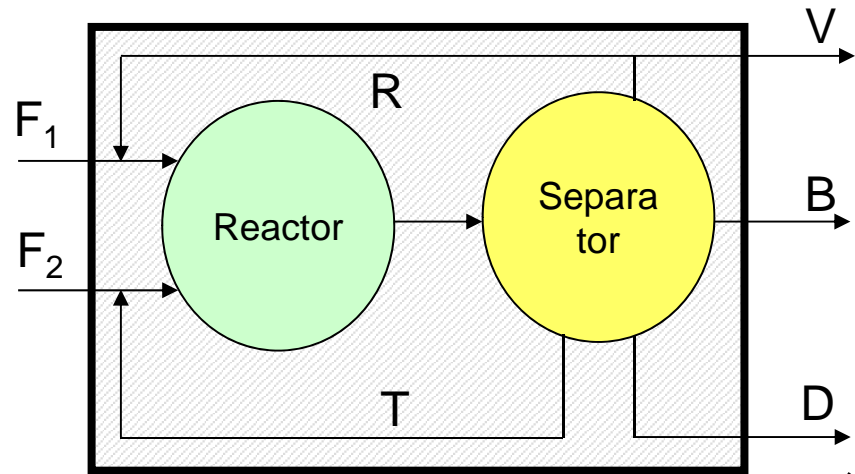
At this stage only the input and output streams are taken into account, meanwhile the recycling ones or the ones internal to the process are neglected.



The system can be figured as a black box, then considering only the streams entering and leaving the limits of the plant!



Features



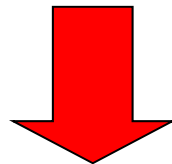
Features

Degrees of freedom

The degrees of freedom that influence EP2 are the same that influence the streams:

- **Conversion**: calculate as a function of temperature;
- **Splitting factor (i.e. $V / (R + V)$) or the molar fraction of hydrogen inside the recycle stream.**

NB. Selectivity: is a design specification, set equal to 96%;



Necessary to calculate EP2 by varying the degrees of freedom within their range of validity!



Costs of products and raw materials

Composition	Cost [€/kmol]
Benzene	12.5
Toluene	8.8
Hydrogen	2.1
Biphenyl	7.4

N.B.: the cost of hydrogen also includes a 5% methane as an impurity.

It is possible to assume 8000 working hours per year.



Heat of combustion

Composition	ΔH_c [MBtu/kmol]
Hydrogen	0.123
Methane	0.383
Benzene	1.41
Toluene	1.68
Biphenyl	2.688



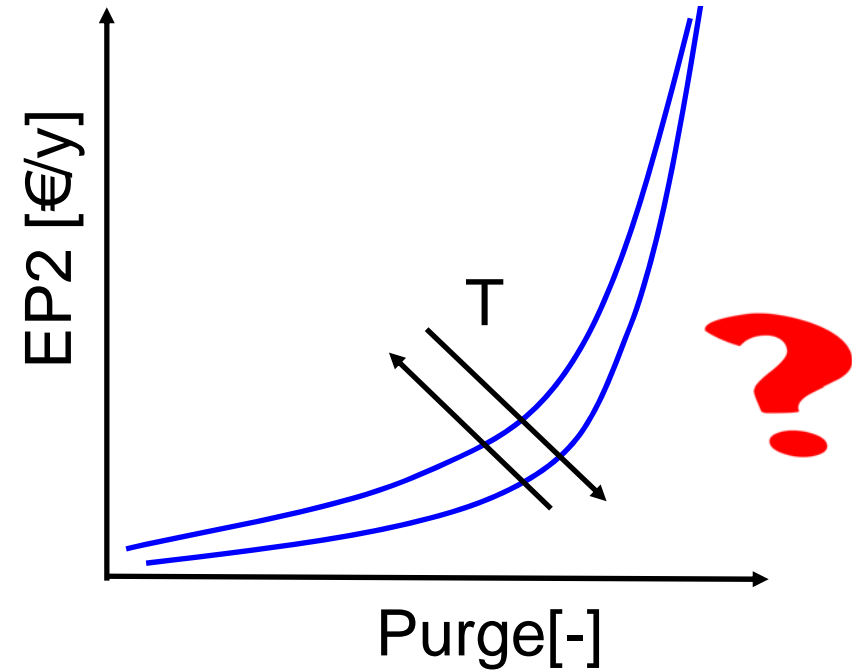
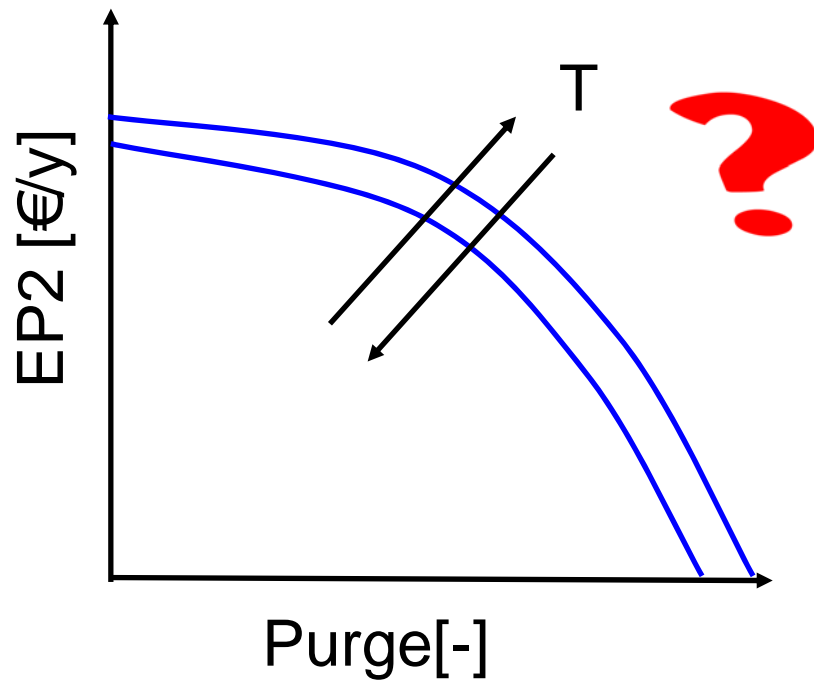
Assignment

- Determine the economic potential of level-2 related to the process conditions used in previous lessons.
- For EP2 evaluation, consider the possible convenience of burning by-products, whose economic value is 4 €/MBtu.
- Produce the following diagrams:
 - splitting factor/EP2, imposing minimum selectivity of 0.96
 - molar fraction of hydrogen in vent/EP2, imposing the minimum selectivity of 0.96
 - conversion/EP2 as a function of the molar fraction of hydrogen in the vent
 - temperature/EP2 as a function of the molar fraction of hydrogen in the vent



Analysis of results

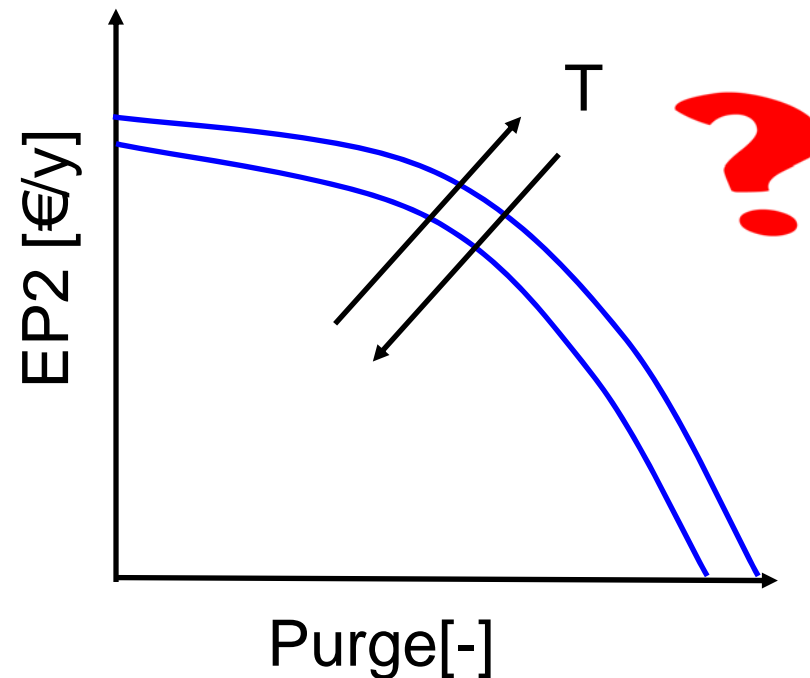
Splitting factor / EP2



Some considerations

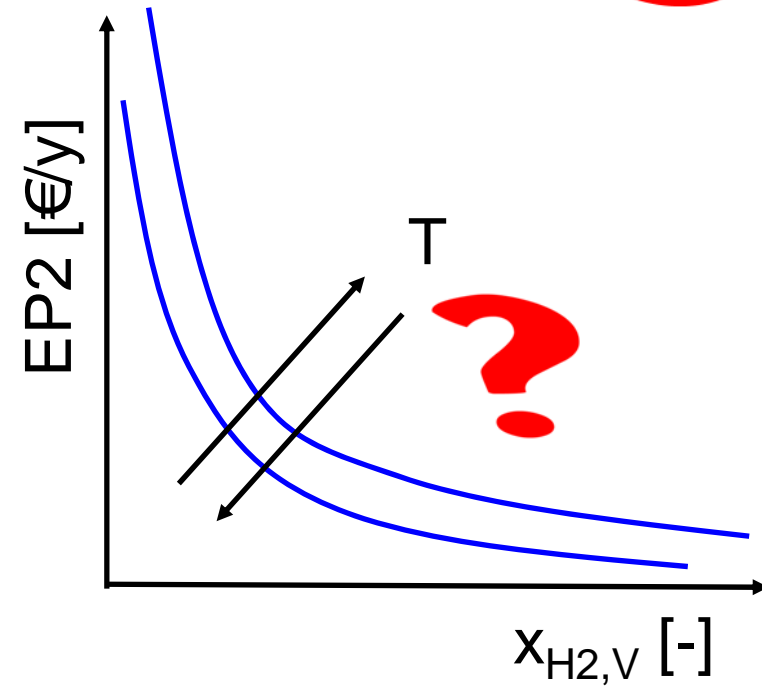
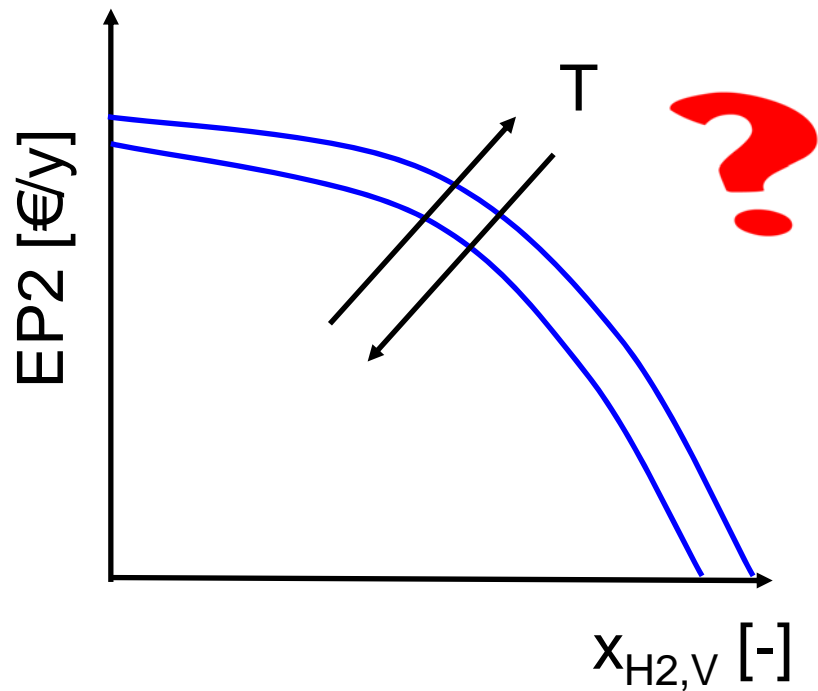
Splitting factor / EP2

With low purge ratios the concentration in the streams of the light raw materials (*i.e.* hydrogen) to be recycled is higher, then it will be necessary to provide fewer raw materials to obtain the same amount of benzene → higher EP2!



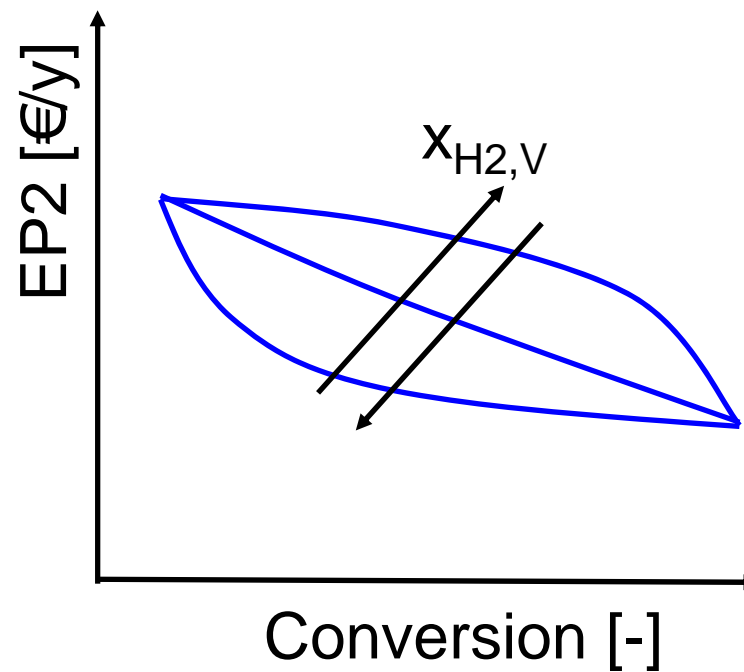
Analysis of results

$$X_{H2,V} / EP2$$



Analysis of results

Conversion / EP2



Analysis of results

Temperature / EP2

