



PEGASUS FINAL WORKSHOP

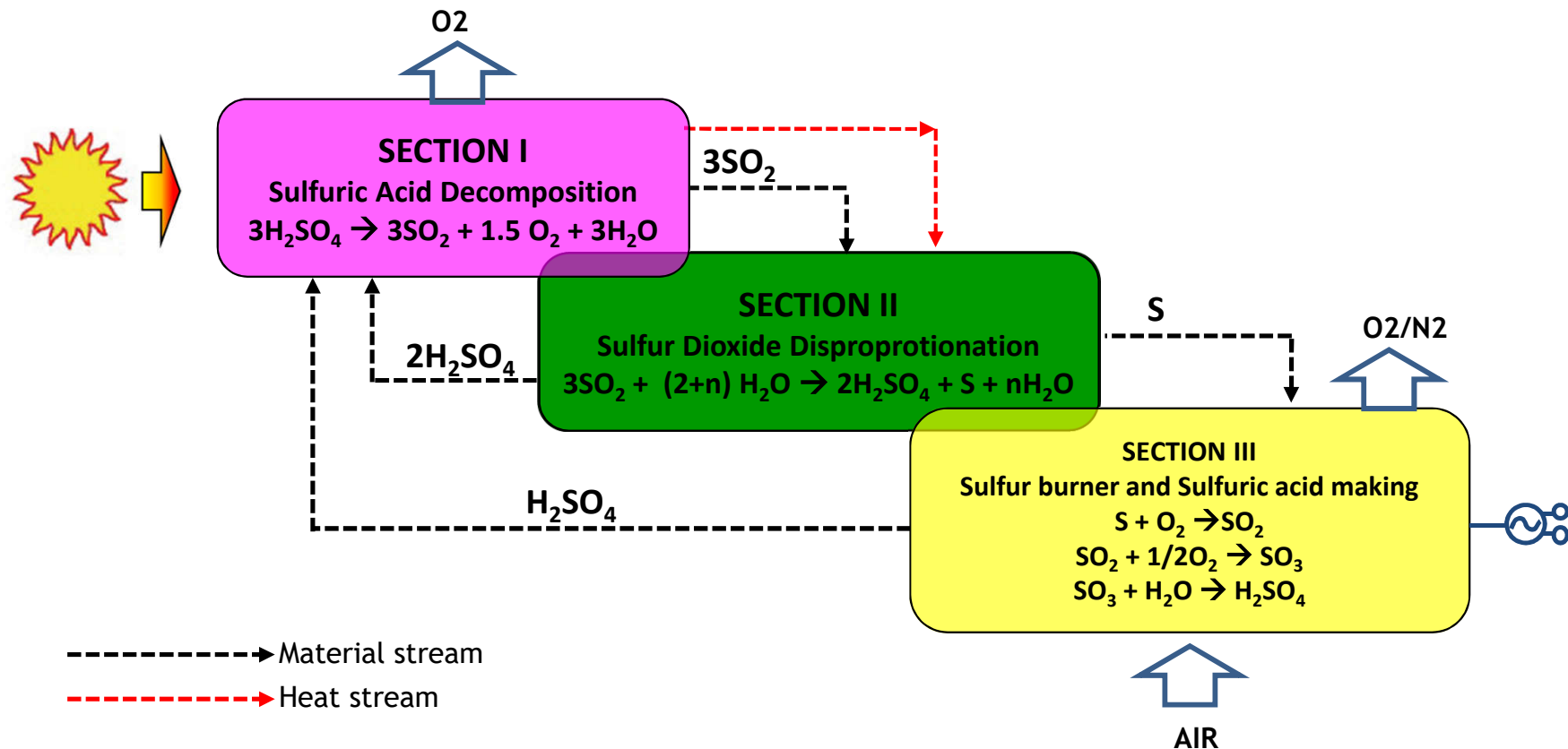




PROCESS FLOW SHEET

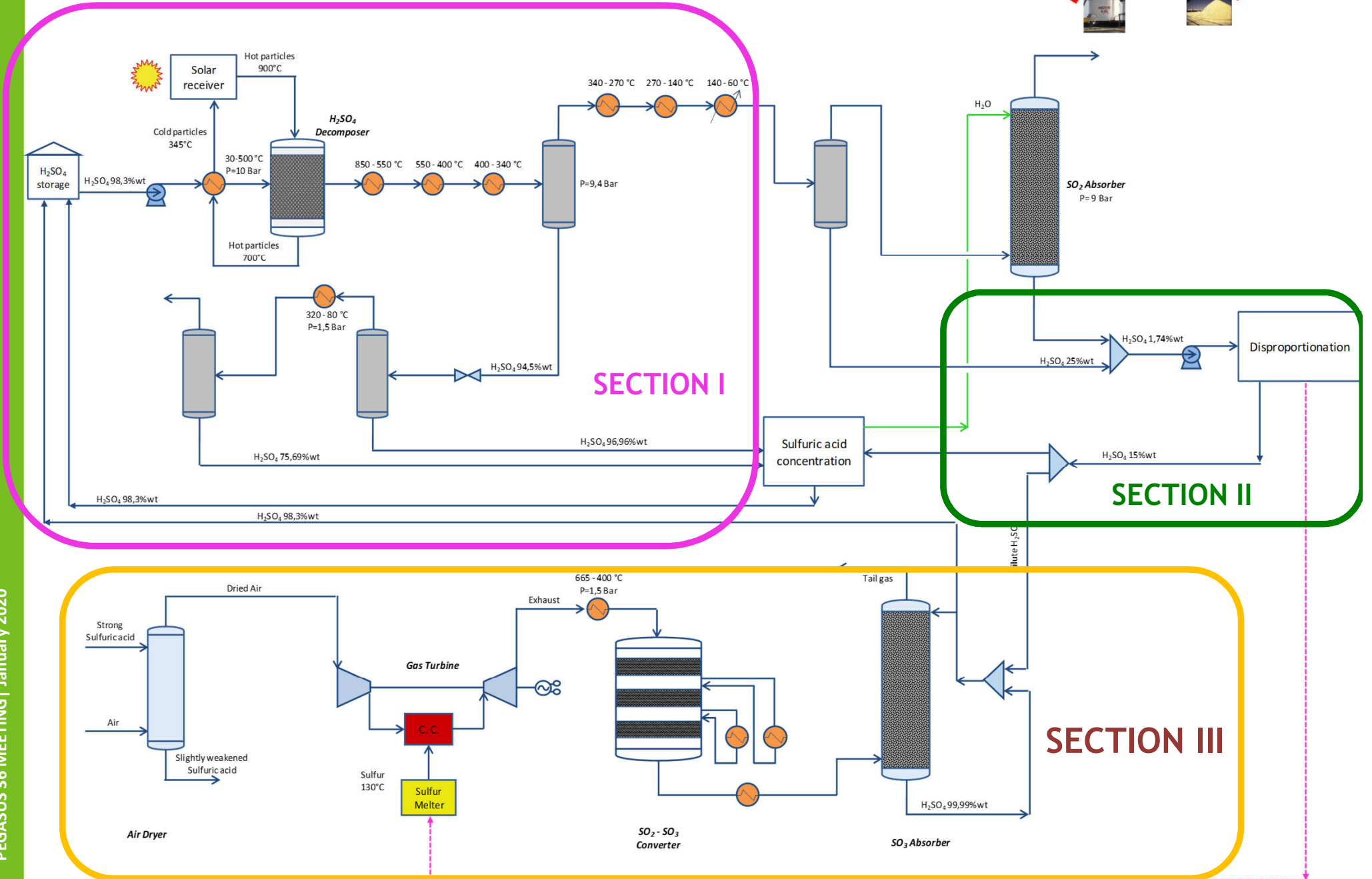
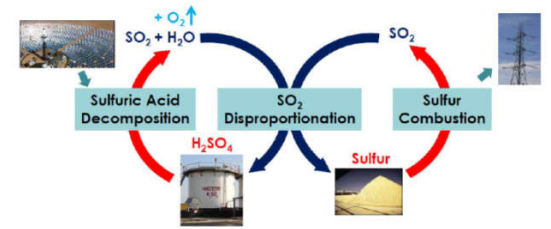
The overall flow sheet may be divided into three sub sections:

- SULFURIC ACID DECOMPOSITION;
- SULFUR DIOXIDE DISPROPORTIONATIO
- SULFUR COMBUSTION





OVERALL FLOWSHEET





TO BE ELABORATED.

FOCUS ON BUILT IN MODELING FOR SOLAR FIELD

AND Aspen plus model for the chemical plant including

- **the high non ideality of the system**
- **THE NON-CONVENTIONAL EQUIPMENT (receiver and reactor for SO₃ decomposition)**

RESUMING MAIN RESULTS OF D 6.5



COMPLETE FLOWSHEET

The below process description has to be read in conjunction with following Process Flow diagram:

- Process Flow diagram - Solar receiver, H₂SO₄/SO₃ decomposition and SO₂ separation;
- Process Flow diagram - Disproportionation and H₂SO₄ storage;
- Process Flow diagram -03 - H₂SO₄ concentration;
- Process Flow diagram -04 - Sulfur burner and SO₃ contact process;
- Process Flow diagram -05 - Steam cycle;

The drivers for process optimization are the:

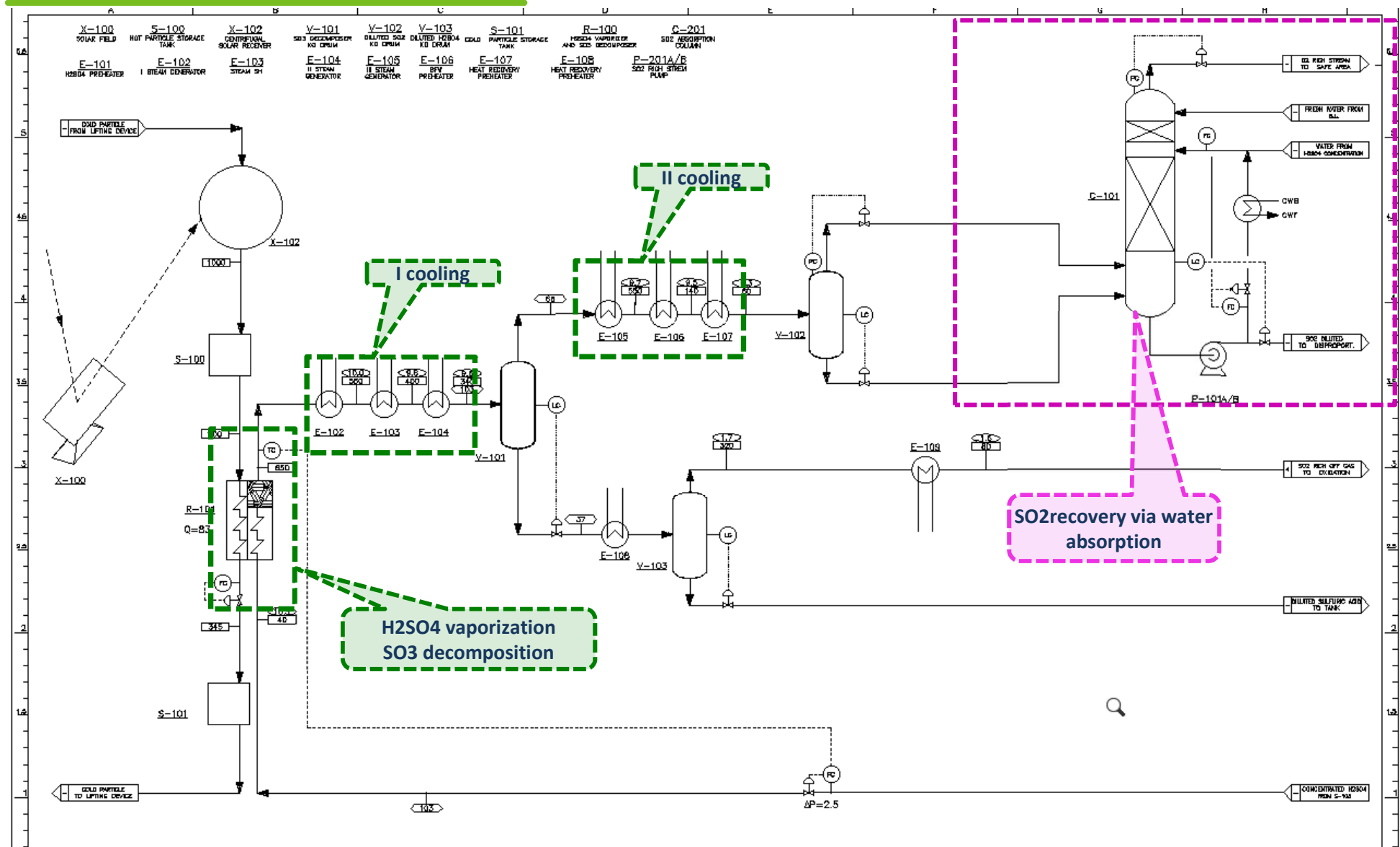
- Maximization of heat integration;
- Minimization of material loss through vent/off gas;
- Maximization of process efficiency

Reference capacity for the chemical plant was a base load thermal duty of 96MWht being the second one identified (12MWth) within D.6.1 too detrimental for the economy of scale for the chemical plant.



SOLAR RECEIVER, H₂SO₄/SO₃ DECOMPOSITION AND SO₂ SEPARATION

SECTION I Sulfuric Acid Decomposition $3\text{H}_2\text{SO}_4 \rightarrow 3\text{SO}_2 + 1.5\text{O}_2 + 3\text{H}_2\text{O}$



LEGEND		GENERAL NOTES		NOTES	
	Q [Mkcal/h]				
	AP [bar]				

WESTCHEM, AS REFERRED TO IN CONTRACT OR OTHERWISE, IS THE SOLE PROVIDER OF THE SERVICE OF THE DESIGN, ENGINEERING, CONSTRUCTION AND OPERATION OF THE SOLAR RECEIVER, H ₂ SO ₄ DECOMPOSITION AND SO ₂ SEPARATION.					
Sulfur based solar CSP plant					
PROCESS FLOW DIAGRAM					
SOLAR RECEIVER, H ₂ SO ₄ DECOMPOSITION AND SO ₂ SEPARATION					
REV	DATE	ISSUED	BY	CHKD	DATE
1		Issue for Feasibility study	US	ADD	01/10/10
2		Issue for Feasibility study	US	ADD	02/03/10
3		Issue for Feasibility study	US	ADD	03/03/10
4		Issue for Feasibility study	US	ADD	03/03/10
5		Issue for Feasibility study	US	ADD	03/03/10
6		Issue for Feasibility study	US	ADD	03/03/10
7		Issue for Feasibility study	US	ADD	03/03/10
8		Issue for Feasibility study	US	ADD	03/03/10
9		Issue for Feasibility study	US	ADD	03/03/10
10		Issue for Feasibility study	US	ADD	03/03/10
11		Issue for Feasibility study	US	ADD	03/03/10
12		Issue for Feasibility study	US	ADD	03/03/10
13		Issue for Feasibility study	US	ADD	03/03/10
14		Issue for Feasibility study	US	ADD	03/03/10
15		Issue for Feasibility study	US	ADD	03/03/10
16		Issue for Feasibility study	US	ADD	03/03/10
17		Issue for Feasibility study	US	ADD	03/03/10
18		Issue for Feasibility study	US	ADD	03/03/10
19		Issue for Feasibility study	US	ADD	03/03/10
20		Issue for Feasibility study	US	ADD	03/03/10
21		Issue for Feasibility study	US	ADD	03/03/10
22		Issue for Feasibility study	US	ADD	03/03/10
23		Issue for Feasibility study	US	ADD	03/03/10
24		Issue for Feasibility study	US	ADD	03/03/10
25		Issue for Feasibility study	US	ADD	03/03/10
26		Issue for Feasibility study	US	ADD	03/03/10
27		Issue for Feasibility study	US	ADD	03/03/10
28		Issue for Feasibility study	US	ADD	03/03/10
29		Issue for Feasibility study	US	ADD	03/03/10
30		Issue for Feasibility study	US	ADD	03/03/10
31		Issue for Feasibility study	US	ADD	03/03/10
32		Issue for Feasibility study	US	ADD	03/03/10
33		Issue for Feasibility study	US	ADD	03/03/10
34		Issue for Feasibility study	US	ADD	03/03/10
35		Issue for Feasibility study	US	ADD	03/03/10
36		Issue for Feasibility study	US	ADD	03/03/10
37		Issue for Feasibility study	US	ADD	03/03/10
38		Issue for Feasibility study	US	ADD	03/03/10
39		Issue for Feasibility study	US	ADD	03/03/10
40		Issue for Feasibility study	US	ADD	03/03/10
41		Issue for Feasibility study	US	ADD	03/03/10
42		Issue for Feasibility study	US	ADD	03/03/10
43		Issue for Feasibility study	US	ADD	03/03/10
44		Issue for Feasibility study	US	ADD	03/03/10
45		Issue for Feasibility study	US	ADD	03/03/10
46		Issue for Feasibility study	US	ADD	03/03/10
47		Issue for Feasibility study	US	ADD	03/03/10
48		Issue for Feasibility study	US	ADD	03/03/10
49		Issue for Feasibility study	US	ADD	03/03/10
50		Issue for Feasibility study	US	ADD	03/03/10
51		Issue for Feasibility study	US	ADD	03/03/10
52		Issue for Feasibility study	US	ADD	03/03/10
53		Issue for Feasibility study	US	ADD	03/03/10
54		Issue for Feasibility study	US	ADD	03/03/10
55		Issue for Feasibility study	US	ADD	03/03/10
56		Issue for Feasibility study	US	ADD	03/03/10
57		Issue for Feasibility study	US	ADD	03/03/10
58		Issue for Feasibility study	US	ADD	03/03/10
59		Issue for Feasibility study	US	ADD	03/03/10
60		Issue for Feasibility study	US	ADD	03/03/10
61		Issue for Feasibility study	US	ADD	03/03/10
62		Issue for Feasibility study	US	ADD	03/03/10
63		Issue for Feasibility study	US	ADD	03/03/10
64		Issue for Feasibility study	US	ADD	03/03/10
65		Issue for Feasibility study	US	ADD	03/03/10
66		Issue for Feasibility study	US	ADD	03/03/10
67		Issue for Feasibility study	US	ADD	03/03/10
68		Issue for Feasibility study	US	ADD	03/03/10
69		Issue for Feasibility study	US	ADD	03/03/10
70		Issue for Feasibility study	US	ADD	03/03/10
71		Issue for Feasibility study	US	ADD	03/03/10
72		Issue for Feasibility study	US	ADD	03/03/10
73		Issue for Feasibility study	US	ADD	03/03/10
74		Issue for Feasibility study	US	ADD	03/03/10
75		Issue for Feasibility study	US	ADD	03/03/10
76		Issue for Feasibility study	US	ADD	03/03/10
77		Issue for Feasibility study	US	ADD	03/03/10
78		Issue for Feasibility study	US	ADD	03/03/10
79		Issue for Feasibility study	US	ADD	03/03/10
80		Issue for Feasibility study	US	ADD	03/03/10
81		Issue for Feasibility study	US	ADD	03/03/10
82		Issue for Feasibility study	US	ADD	03/03/10
83		Issue for Feasibility study	US	ADD	03/03/10
84		Issue for Feasibility study	US	ADD	03/03/10
85		Issue for Feasibility study	US	ADD	03/03/10
86		Issue for Feasibility study	US	ADD	03/03/10
87		Issue for Feasibility study	US	ADD	03/03/10
88		Issue for Feasibility study	US	ADD	03/03/10
89		Issue for Feasibility study	US	ADD	03/03/10
90		Issue for Feasibility study	US	ADD	03/03/10
91		Issue for Feasibility study	US	ADD	03/03/10
92		Issue for Feasibility study	US	ADD	03/03/10
93		Issue for Feasibility study	US	ADD	03/03/10
94		Issue for Feasibility study	US	ADD	03/03/10
95		Issue for Feasibility study	US	ADD	03/03/10
96		Issue for Feasibility study	US	ADD	03/03/10
97		Issue for Feasibility study	US	ADD	03/03/10
98		Issue for Feasibility study	US	ADD	03/03/10
99		Issue for Feasibility study	US	ADD	03/03/10
100		Issue for Feasibility study	US	ADD	03/03/10

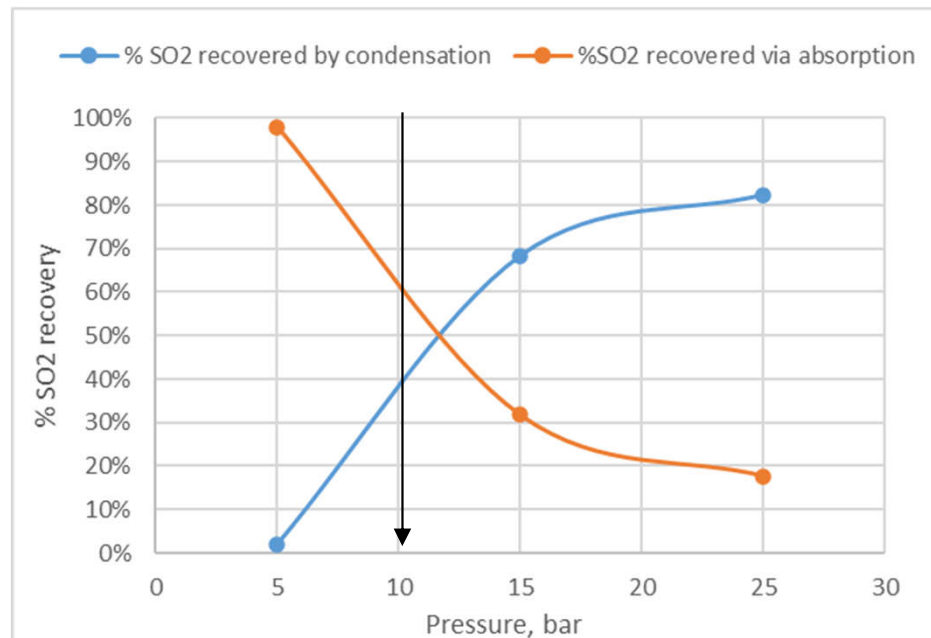


SOLAR RECEIVER, H₂SO₄/SO₃ DECOMPOSITION AND SO₂ SEPARATION

The SO₃ decomposition section is promoted by **High TEMPERATURE AND LOW PRESSURE.**

At increasing pressure SO₂ is mainly recovered via condensation reducing the load of the absorption column.

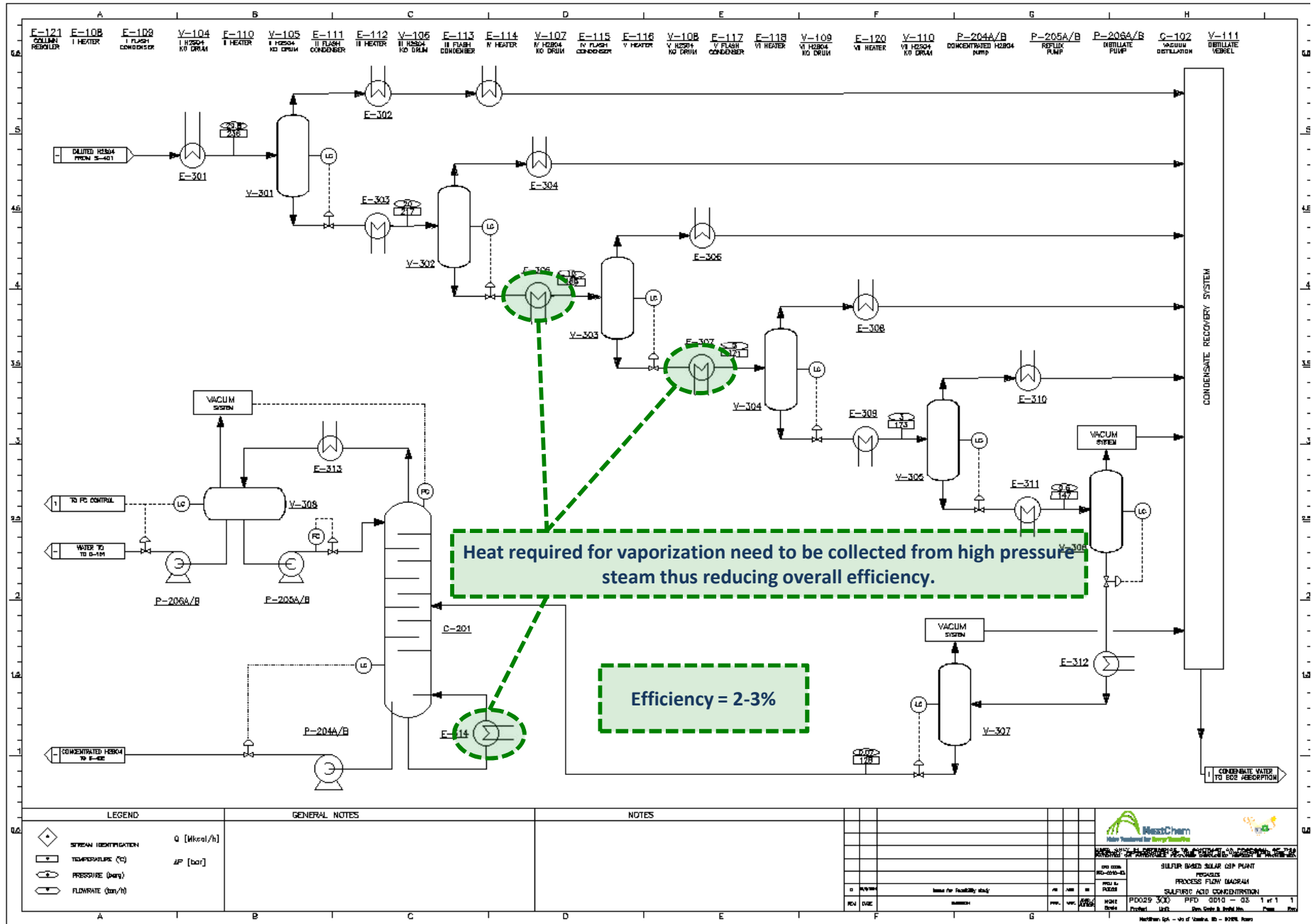
It derives that at increasing pressure a lower content of water is introduced into the downstream disproportionation and following H₂SO₄ concentration step.



Although increasing pressure at around 10 barg in order not to be too detrimental for the SO₃ decomposition, the amount of water is too high for the downstream section.



UNIT 300 - H2SO4 CONCENTRATION





SOLAR RECEIVER, H₂SO₄/SO₃ DECOMPOSITION AND SO₂ SEPARATION

To increase the efficiency of downstream H₂SO₄ concentration, as process optimization it has been decoupled pressure of the reaction section and pressure of the SO₂ absorption unit.

By introducing a compression step of the SO₂-O₂ mixture, the Water/SO₂ ratio of the absorption column may be consistently reduced.

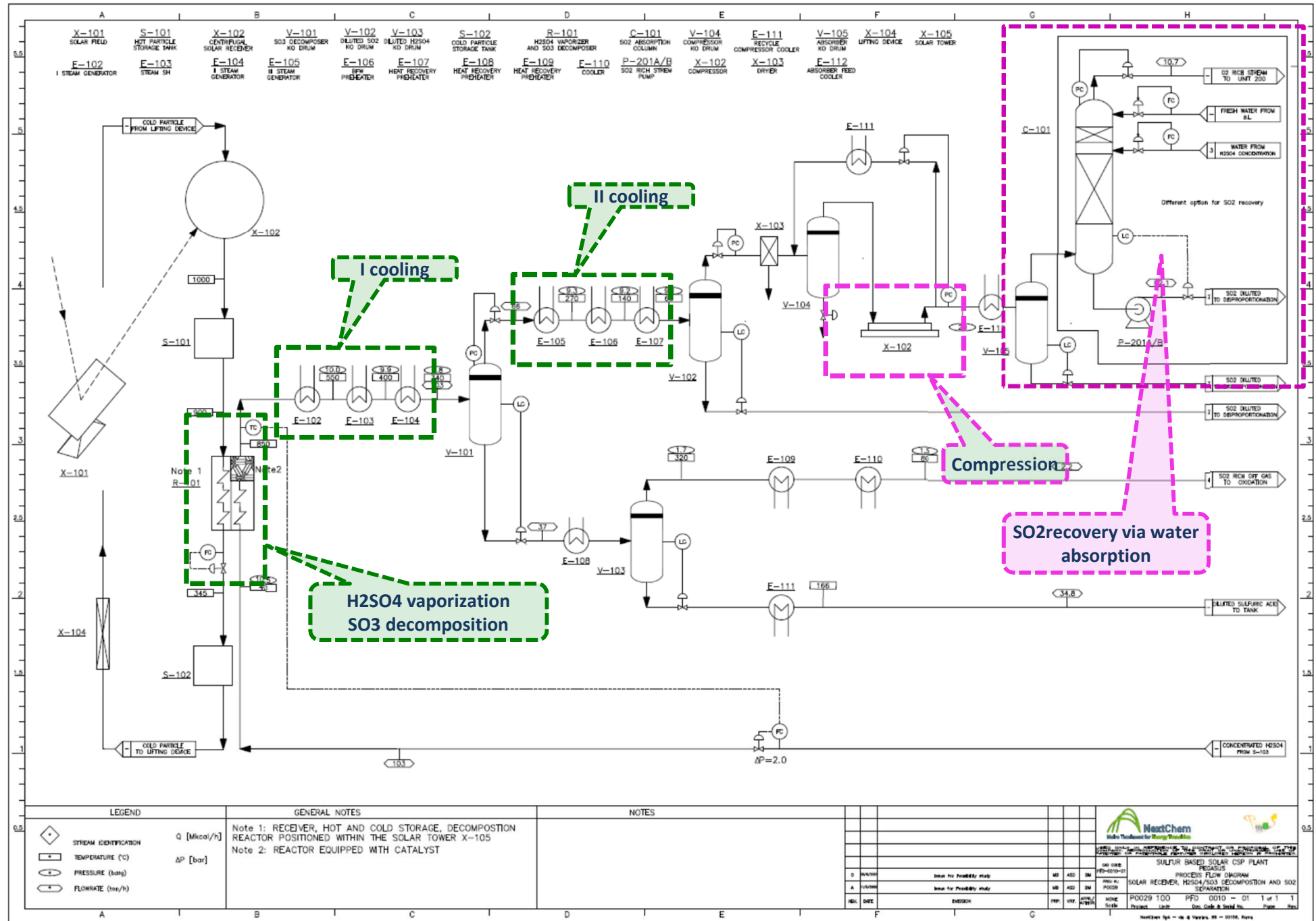
The resulting sulfuric acid solution is doubled moving from **16.5% to 36%w.**



Simplified plant architecture with lower energy requirements.



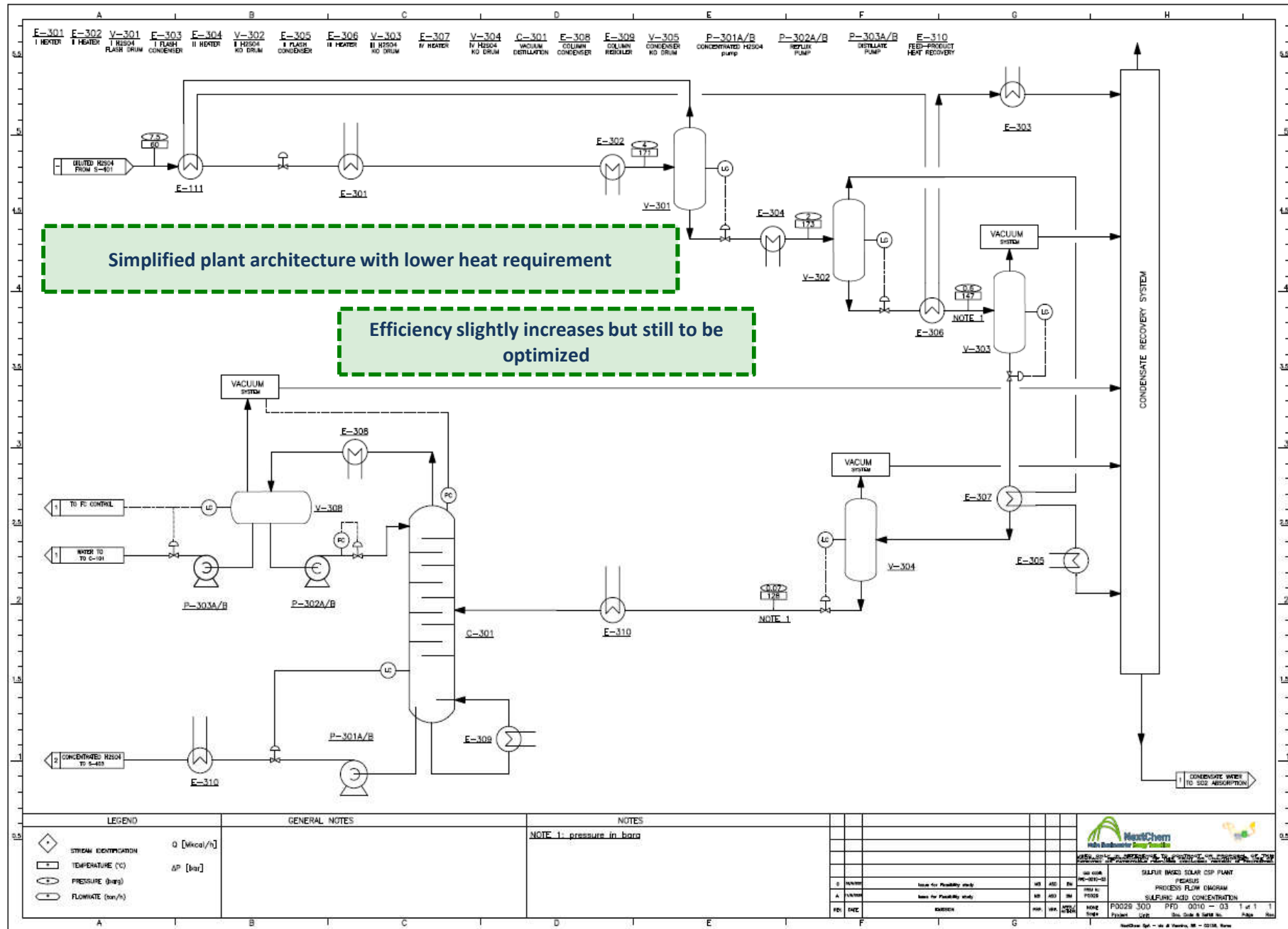
SOLAR RECEIVER, H₂SO₄/SO₃ DECOMPOSITION AND SO₂ SEPARATION





H2SO4 CONCENTRATION SECTION

From 7 stage towards
4 concentration stages





SOLAR RECEIVER, H₂SO₄/SO₃ DECOMPOSITION AND SO₂ SEPARATION

A further optimization of SO₂ recovery has to be carried out in order not to penalize the overall process efficiency:

Despite the reduction in steam consumption due to increased pressure, a solution based on absorption with pure water still accounts for the downstream disproportionation step an excessive amount of water that consumes too much steam for concentration via vaporization with a consequent penalty on global efficiency.

This suggests to move towards a **REGENERATIVE ABSORPTION** that means an architecture based on absorption and stripping column. Moving towards a regenerative scheme, SO₂ may be recovered without diluting SO₂. Several industrial applications are available on the market mainly for flue gas treatment application.

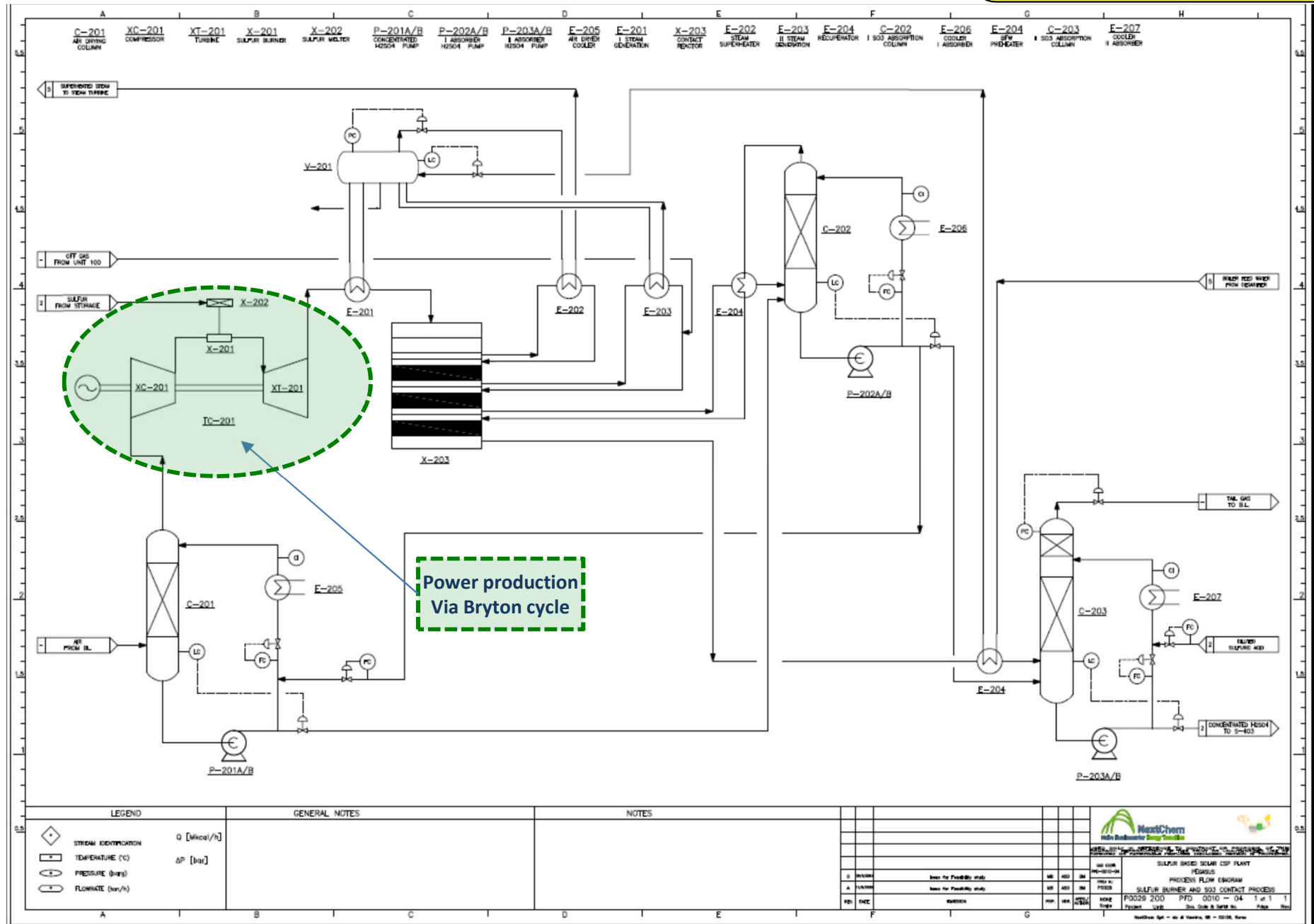
Estimated consumption available from literature is in order of 3,5 - 9 kg LPS/kg SO₂ recovered, depending on adopted conditions (DuPont. 2012). Although still using steam, the latter is a low-pressure steam that can be easily recovered as waste heat with a reduced impact on the overall power production.

Under this figure steam requested for SO₂ stripping is collected as spillage from turbine thus with a lower impact on process efficiency.



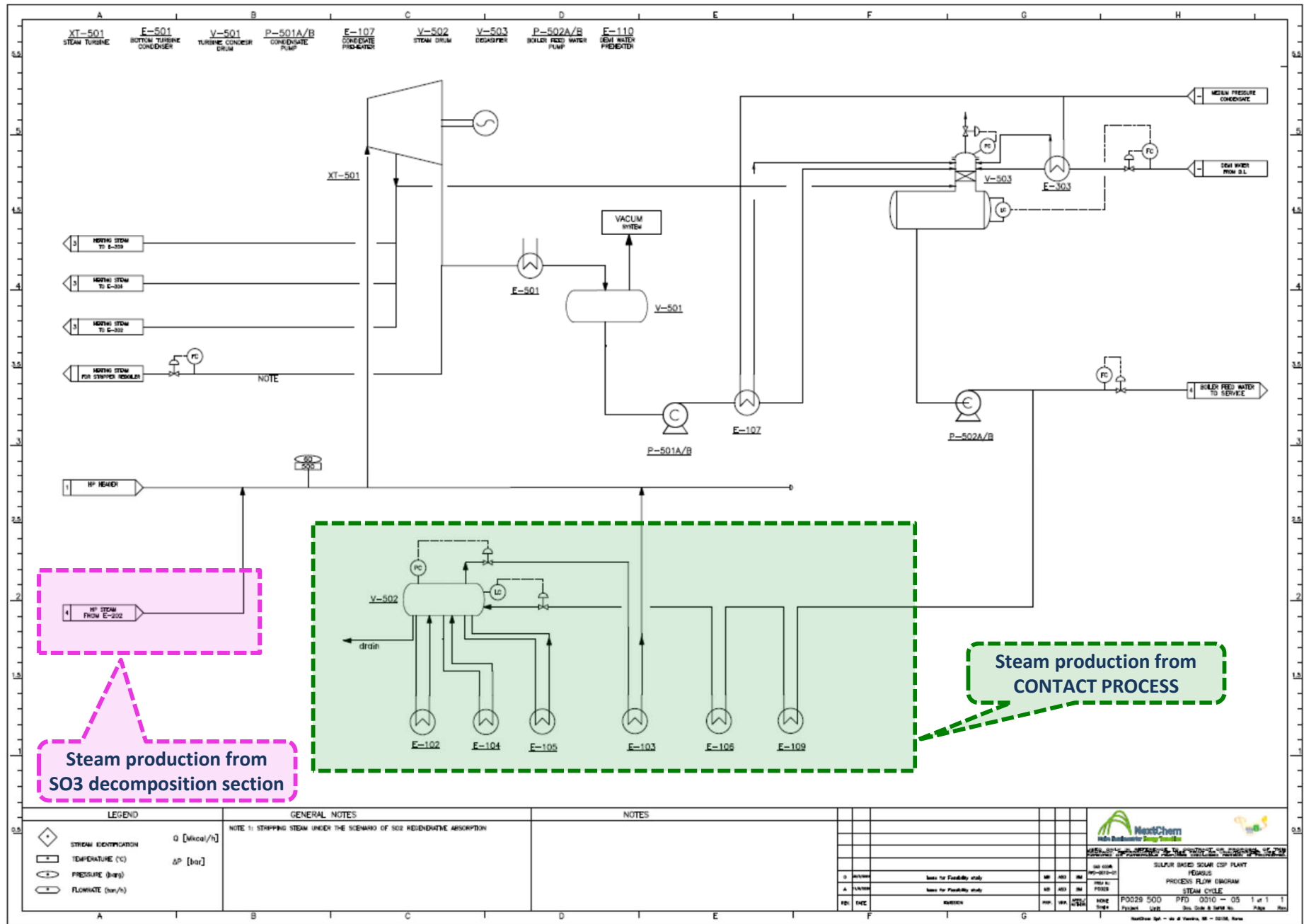
UNIT 200 - DOUBLE ABSORPTION PROCESS, SULFUR BURNER

SECTION III
Sulfur burner and Sulfuric acid making
 $S + O_2 \rightarrow SO_2$
 $SO_2 + 1/2O_2 \rightarrow SO_3$
 $SO_3 + H_2O \rightarrow H_2SO_4$





UNIT 500 - STEAM CYCLE





OVERALL PROCESS EFFICIENCY

OVERALL PROCESS EFFICIENCY

the achievable net overall power production resulting from Rankine cycle is around 15.1MWe. The spillage of LPS (3barg) from steam turbine is diverted to SO₂ regenerative reboiler. The low pressure at which spillage is carried out have a limited impact on power production lowering in the meantime the turbine condenser load. Under the above scenario adding the power production from Bryton Cycle and deducting around 1,1MWe for internal consumption, resulting overall net power production from combined cycle is in order **19.1 MWe**. Resulting efficiency in converting solar energy into power is thus around **19.9%**.

ROOM FOR PROCESS EFFICIENCY INCREASE

The latter is an interesting result once compared with target for CSP technology, also in relation to further improvement that can be achieved by the use of **novel solvent for SO₂ absorption**, such as ionic liquid, characterized by a high SO₂ loading combined to low regeneration heat. This figure can improve the overall power production from Rankine cycle thus increasing the overall efficiency.



NextChem S.r.l

Sede Legale:

via Guido Polidoro 1,
67100 L'Aquila, Italia

T +39 0862 763411

F +39 0862 763547

Sede Operativa:

Via di Vannina 88/94,
00156 Roma, Italia

T +39 06 9356771

www.mairetecnimont.com



NextChem

Maire Tecnimont for **Energy Transition**