This Project has received funding from European Commission by means of Horizon 2020,the EU Framework Programme for Research & Innovation, under Grant Agreement no.727348.

SOCRATCES

Introduction

- SOCRATCES project and CSP with energy storage
  - The **Ca-Looping** (CaL) process based upon the reversible carbonation/calcination of CaO is one of the most promising technologies for **thermochemical energy storage**.
  - SOCRATCES global **objectives** are:
    - To develop a prototype that will reduce the risks of scaling up the technology.
    - To solve challenges demonstrating the feasibility of the CSP-CaL integration.
  - **Basic Ca-looping in CSP applications**
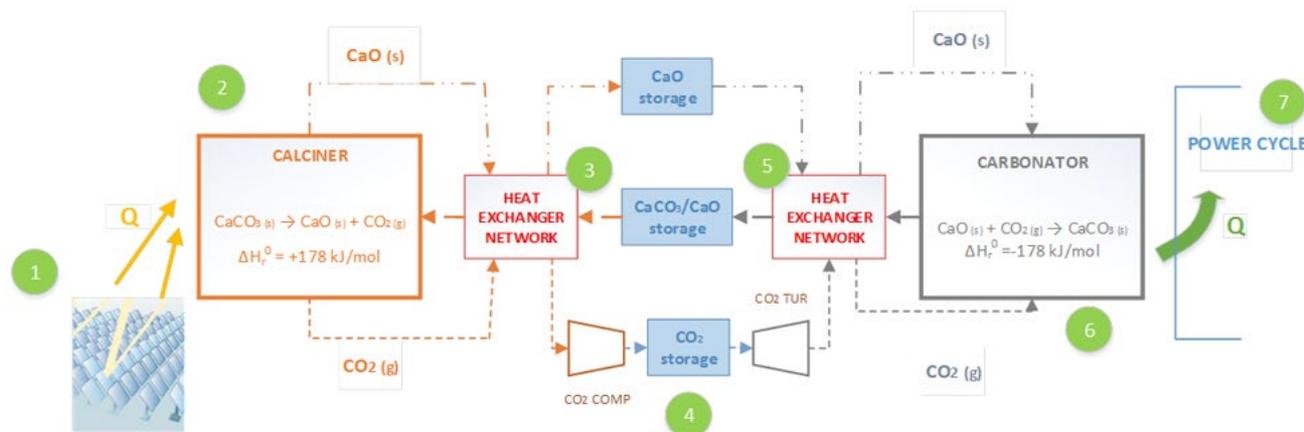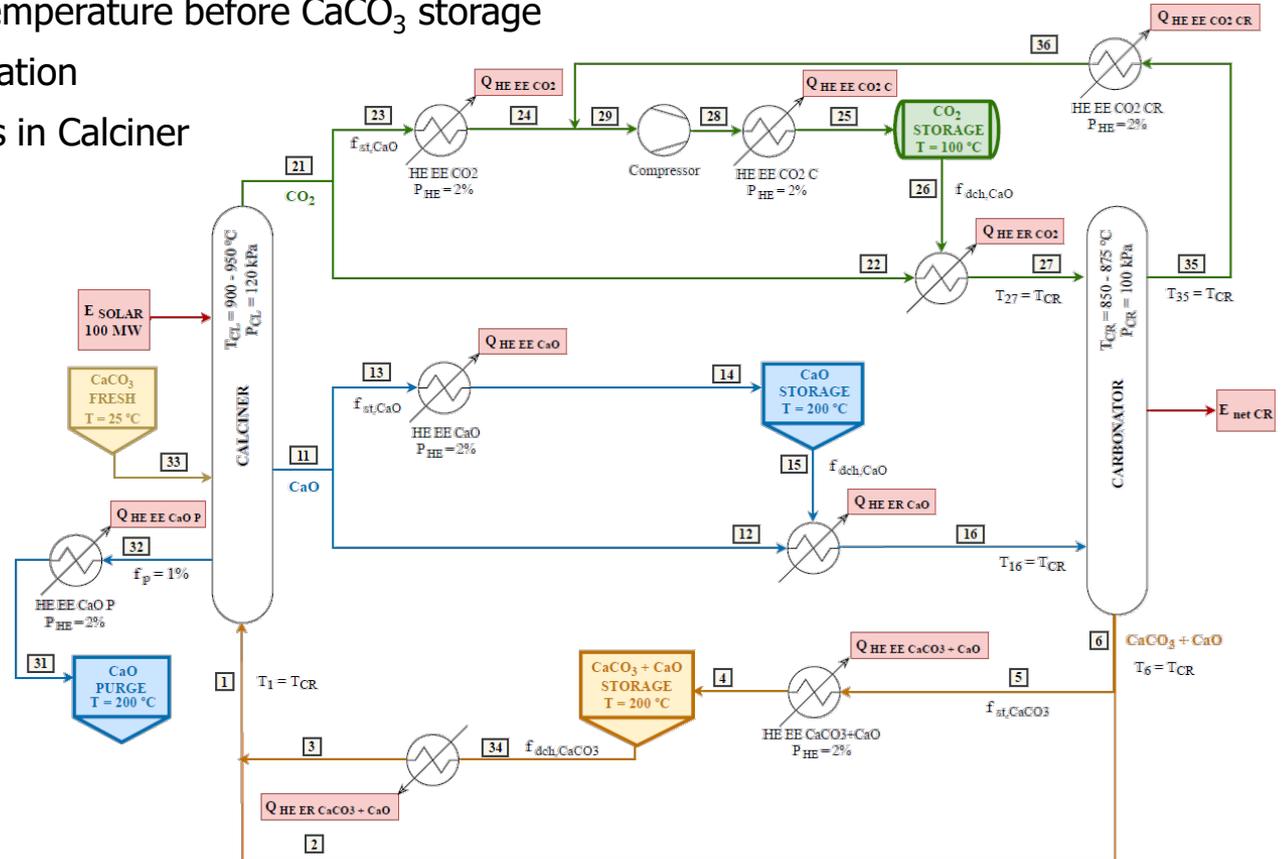
Main characteristics of the process

- **Main characteristics of the Ca-looping process in CSP applications**
  - High temperature Calcination, around 900ºC.
    - Heat exchanger to reduce temperature before CaO storage
    - Heat exchanger to reduce temperature before CO_2 storage
  - High temperature Carbonation, around 850ºC.
    - Heat exchanger to reduce temperature before $CaCO_3$ storage
    - Less critical due to energy is used in power block
  - Necessity of elevated temperature at Calciner (even at Carbonator) inlet
    - Reduce energy requirements in Calciner and take advantage of solar energy for calcination
  - Partial carbonation ($X_{ave} \sim 15\%$-20%)
    - CO_2 is cyclically used.
  - Sorbent deactivation
  - Storage at medium temperature
  - Simplicity and low cost
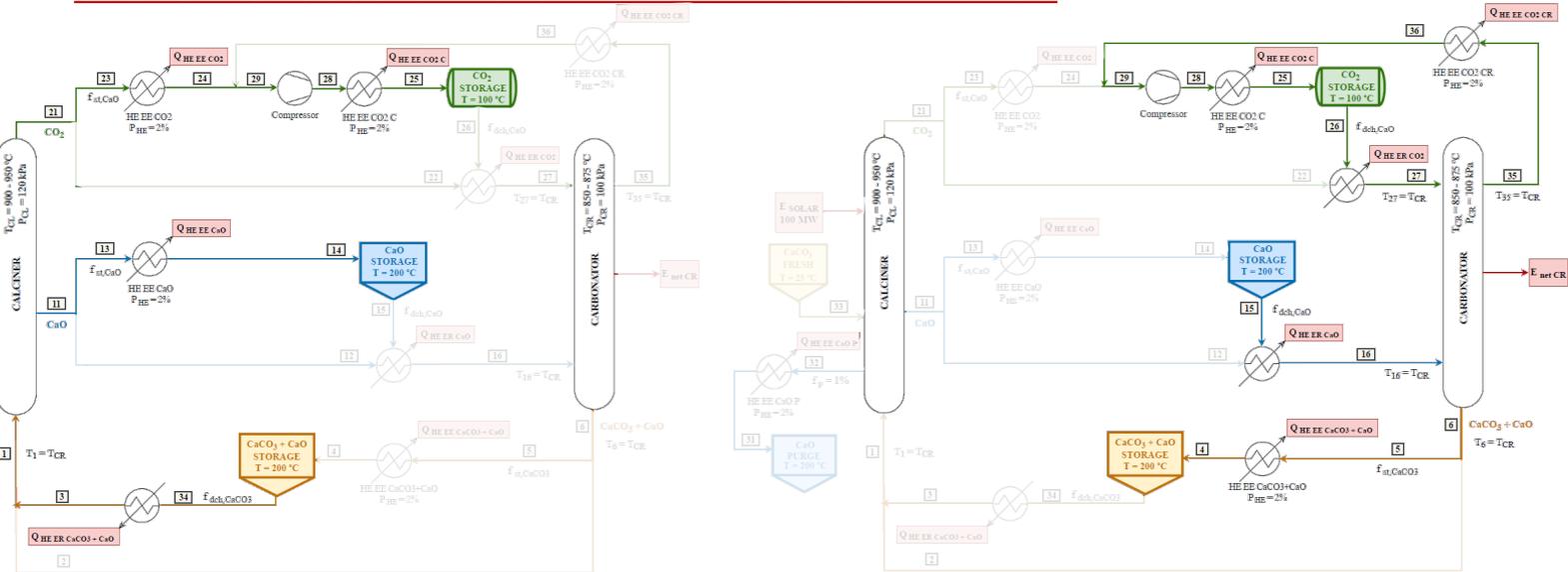
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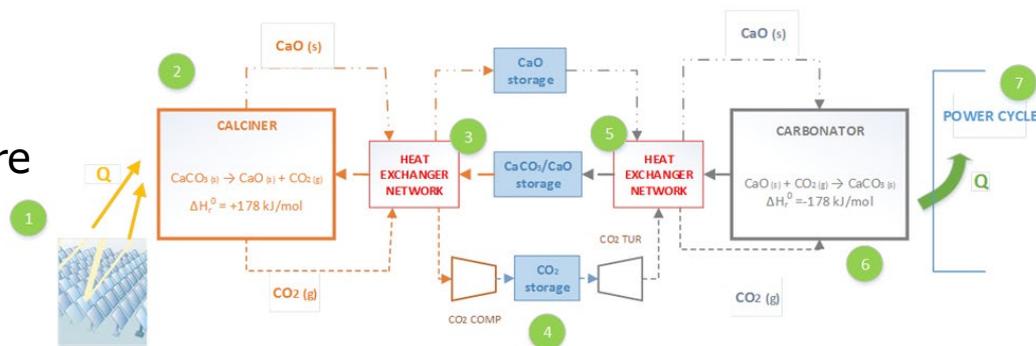
Scale-up layout

- Heat exchanger to reduce temperature before CaO storage
- Heat exchanger to reduce temperature before CO_2 storage
- Heat exchanger to reduce temperature before $CaCO_3$ storage
- CO_2 cyclically. Partial carbonation
- Reduce energy requirements in Calciner
- Sorbent deactivation

Main characteristic of the process

- What does happen if …?
  - Calciner works at 100% but …
    - Carbonator works at 0% → ENERGY STORAGE   • Carbonator works at 100% → DIRECT USE
    - Carbonator works at 0-100% → PARTIAL LOADS, different possibilities through storage/direct
  - Carbonator works at 100% but …
    - Calciner works at 0-100% → PARTIAL LOAD, different possibilities through storage/direct
    - Calciner works at 0% → STORAGED ENERGY UTILIZATION

SOCRATCES webminar
2021, June 10st

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Main characteristic of the process

- What does happen if there are PARTIAL LOADS at carbonator and calciner?
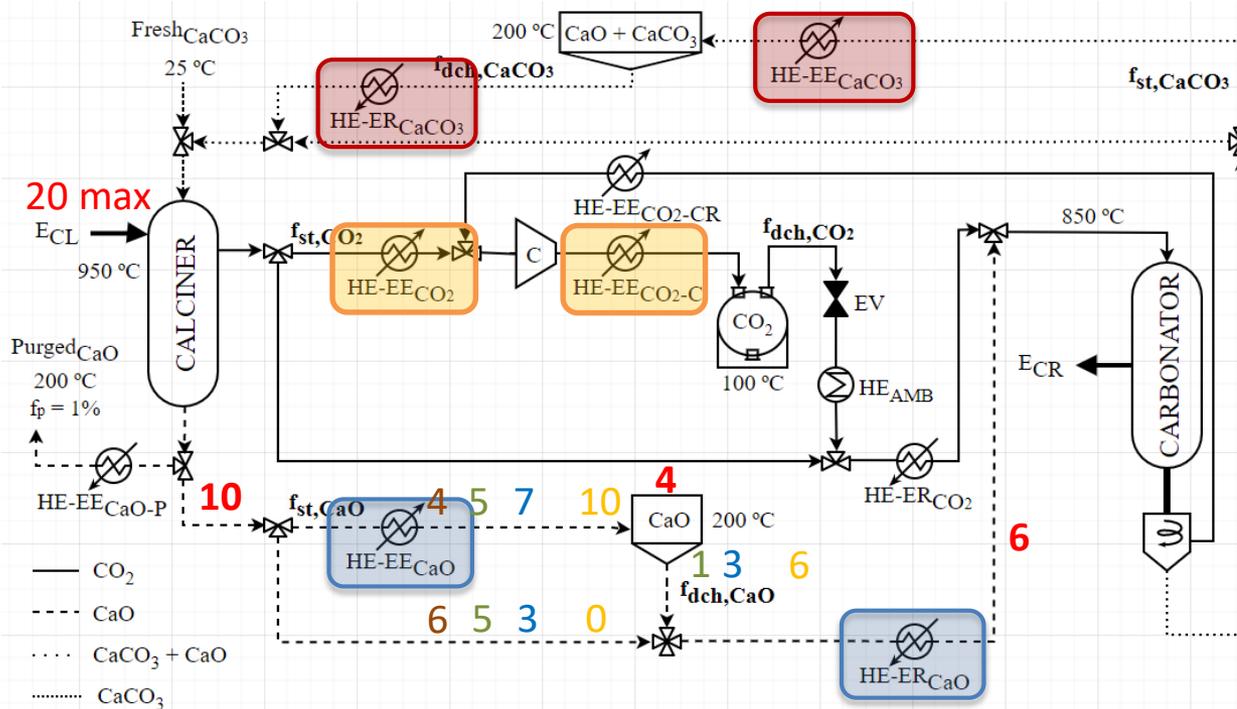
$$f_{st,CaCO3} = \frac{\dot{m}_{st,CaCO3}}{\dot{m}_{st,max,CaCO3}}$$

$$f_{dch,CaCO3} = \frac{\dot{m}_{dch,CaCO3}}{\dot{m}_{st,max,CaCO3}}$$

$$f_{st,CaO} = \frac{\dot{m}_{st,CaO}}{\dot{m}_{st,max,CaO}} = \frac{\dot{m}_{st,CO2}}{\dot{m}_{st,max,CO2}}$$

$$f_{dch,CaO} = \frac{\dot{m}_{dch,CaO}}{\dot{m}_{st,max,CaO}} = \frac{\dot{m}_{dch,CO2}}{\dot{m}_{st,max,CO2}}$$

STORAGE
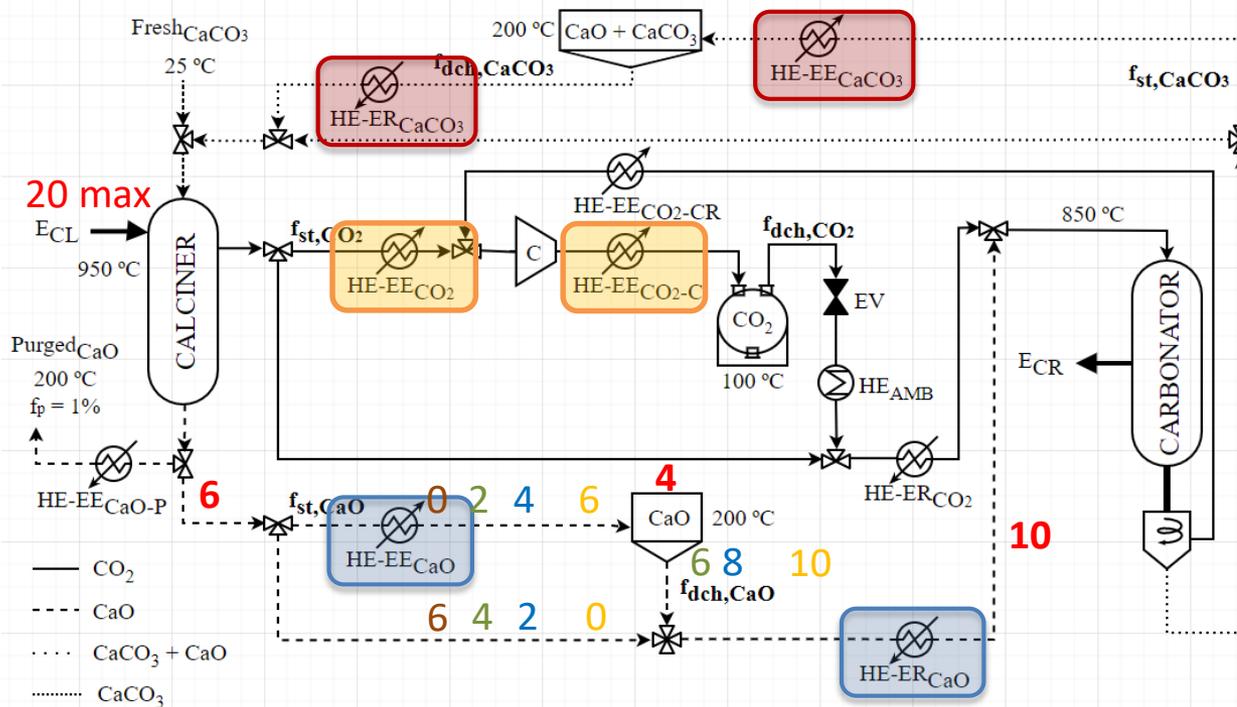
$f_{st,CaO}$	0.20	0.25	0.30	0.35	0.40	0.45	0.50
$f_{dch,CaO}$	0.00	0.05	0.10	0.15	0.20	0.25	0.30

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Main characteristic of the process

- What does happen if there are PARTIAL LOADS at carbonator and calciner?

$$f_{st,CaCO3} = \frac{\dot{m}_{st,CaCO3}}{\dot{m}_{st,max,CaCO3}}$$

$$f_{dch,CaCO3} = \frac{\dot{m}_{dch,CaCO3}}{\dot{m}_{st,max,CaCO3}}$$

$$f_{st,CaO} = \frac{\dot{m}_{st,CaO}}{\dot{m}_{st,max,CaO}} = \frac{\dot{m}_{st,CO2}}{\dot{m}_{st,max,CO2}}$$

$$f_{dch,CaO} = \frac{\dot{m}_{dch,CaO}}{\dot{m}_{st,max,CaO}} = \frac{\dot{m}_{dch,CO2}}{\dot{m}_{st,max,CO2}}$$

$f_{st,CaO}$	0.00	0.05	0.10	0.15	0.20	0.25	0.30
$f_{dch,CaO}$	0.20	0.25	0.30	0.35	0.40	0.45	0.50

UTILIZATION

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Main characteristic of the process

Energy flow description		T_{in} [°C]	T_{out} [°C]	$\dot{Q}$
CO_2	HE EE CO_2	950	25	AVAILABLE
	HE EE CO_2 C	455	100	AVAILABLE
	HE EE CO_2 CR	850	25	AVAILABLE
	HE ER CO_2	*950 - 100*	*850*	*AVAILABLE NECESSITY*
CaO	HE EE CaO	950	200	AVAILABLE
	HE EE CaO P	650	200	AVAILABLE
	HE ER CaO	*950 - 200*	*850*	*AVAILABLE NECESSITY*
$CaCO_3$ + CaO	HE EE $CaCO_3$+CaO	850	200	AVAILABLE
	HE ER $CaCO_3$+CaO	200	850	NECESSITY
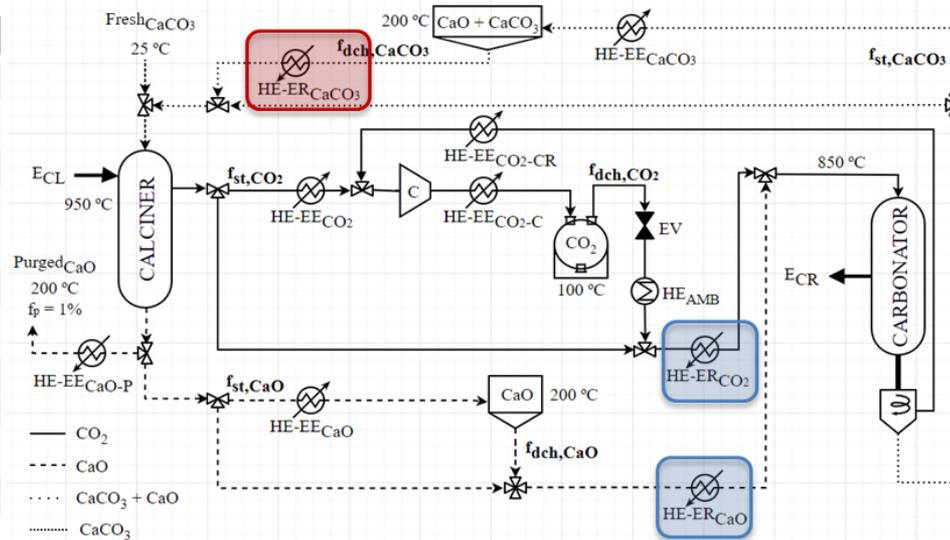
Table 1
Range size of heat exchangers.

Energy flow description	Heat Exchanger	T_{in} (°C)	T_{out} (°C)	Q (MW) ESOM	EROM
CO_2	EE-CO_2	950	50	0 to −24.22	0
	EE−CO_2−C	506.9	100	−0.39 to −10.62	−0.39
	EE−CO_2−CR	850	50	−0.82 to 0	−0.82
	ER-CO_2	950 100	850	−3.10 to 20.52	20.52 to −3.10
CaO	EE-CaO	950	200	0 to −20.50	0
	EE-CaO-P	950	200	−0.82	0 to −0.82
	ER-CaO	950 850 200	850	−2.91 to 18.02	18.02 to −2.91
$CaCO_3$	EE-$CaCO_3$	850	200	0	−40.55 to 0
	ER-$CaCO_3$	200	850	0 to 41.38	41.38 to 0

*Pascual et al.
Energy 220 (2021) 119715*

- release
+ necessity

Main characteristic of the process
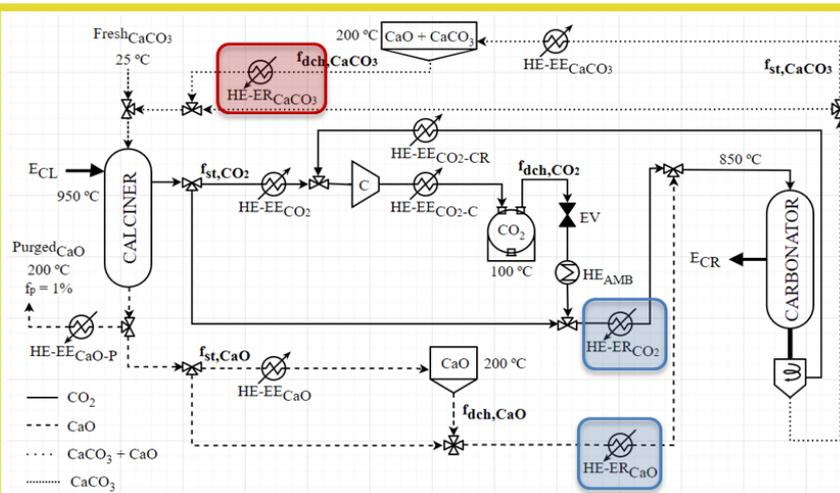
STORAGE

$f_{st,CaO}$	0.20	0.25	0.30	0.35	0.40	0.45	0.50
$f_{dch,CaO}$	0.00	0.05	0.10	0.15	0.20	0.25	0.30

UTILIZATION

$f_{st,CaO}$	0.00	0.05	0.10	0.15	0.20	0.25	0.30
$f_{dch,CaO}$	0.20	0.25	0.30	0.35	0.40	0.45	0.50
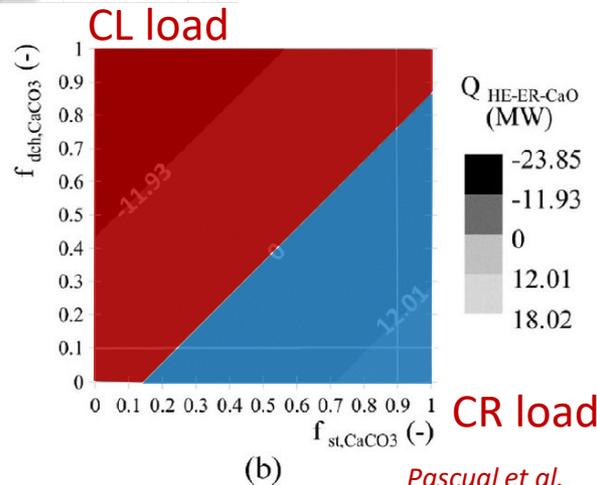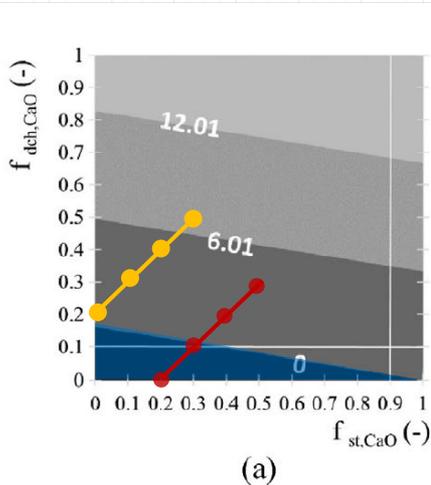
Fig. 6. ER-CaO heat exchanger operation map under ESOM (a) and EROM (b).

Pascual et al.
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Conclusions

- A large number of operating schemes for a CaL TCES system have to be evaluated to **determine the impact of storage and release operational modes in the sizing of heat exchangers and reactors**. Work in progress.

- A wide number of potential operational points coming from different combinations of charge/discharge fractions of the CaO, CO_2 and $CaCO_3$ storage tanks are **unavailable due to difficulties in HE sizing or because it works at different roles and/or at different loads (cost)**.

- **Operational maps** have to be created to clearly establish the available operational points in which energy is stored, the amount of stored and released energy and the **size range of heat exchangers**.