Améliorer le rendement des cycles thermodynamiques grâce à des fluides de travail réactifs

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Maîtresse de Conférences, Université de Lorraine

Congrès SFT

4 juin 2026, Nancy

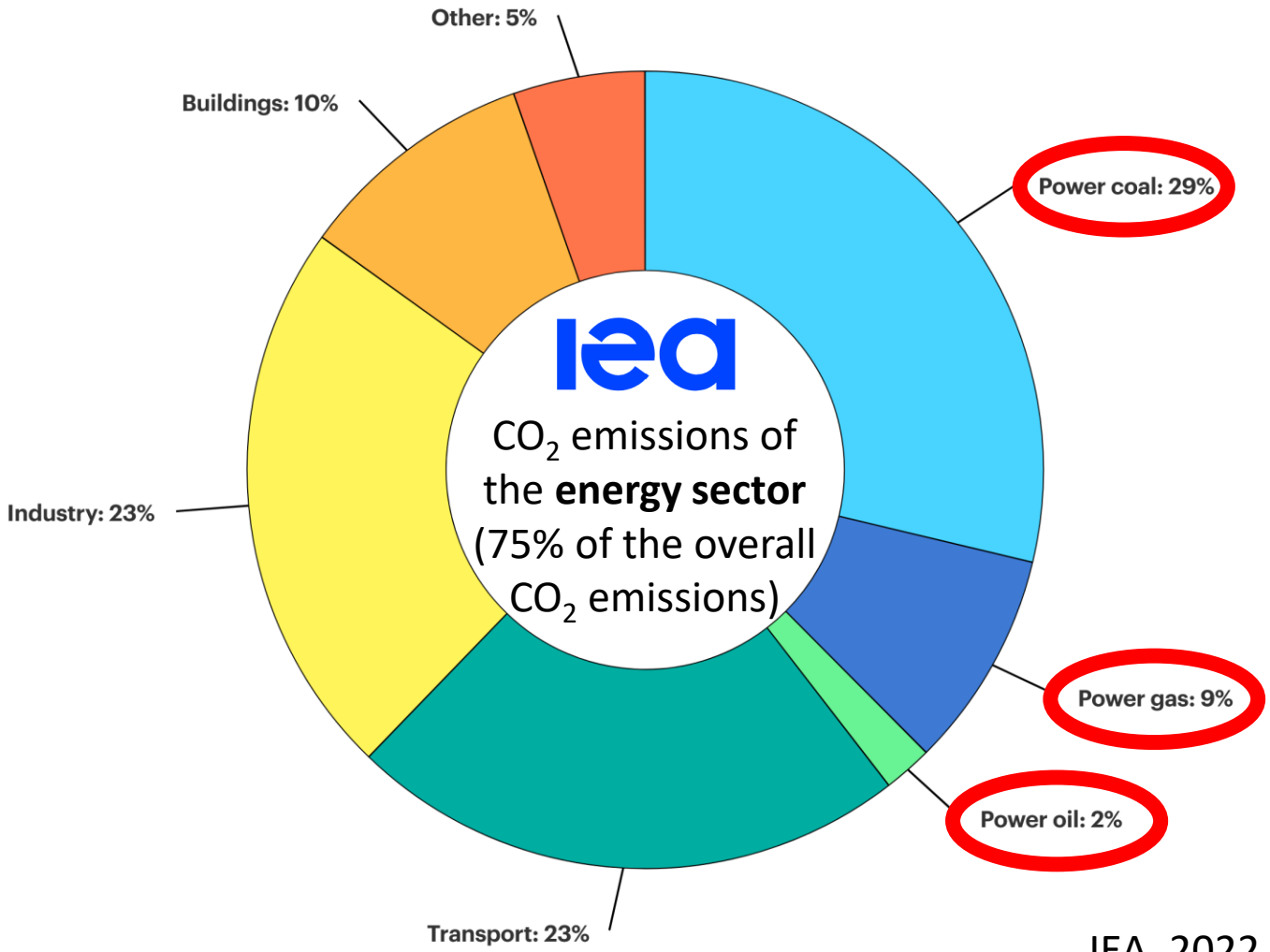
Outline

- Motivations
- A still unexplored energy conversion process
- Reactive working fluids: preliminary results
- From fictitious to real reactive fluids: the project REACHER
- Further projects: towards higher TRLs

Priority areas for rapid CO_2 emission reductions

- Increase **thermal power plants efficiency**

  → **40% of CO_2 emissions**



IEA, 2022

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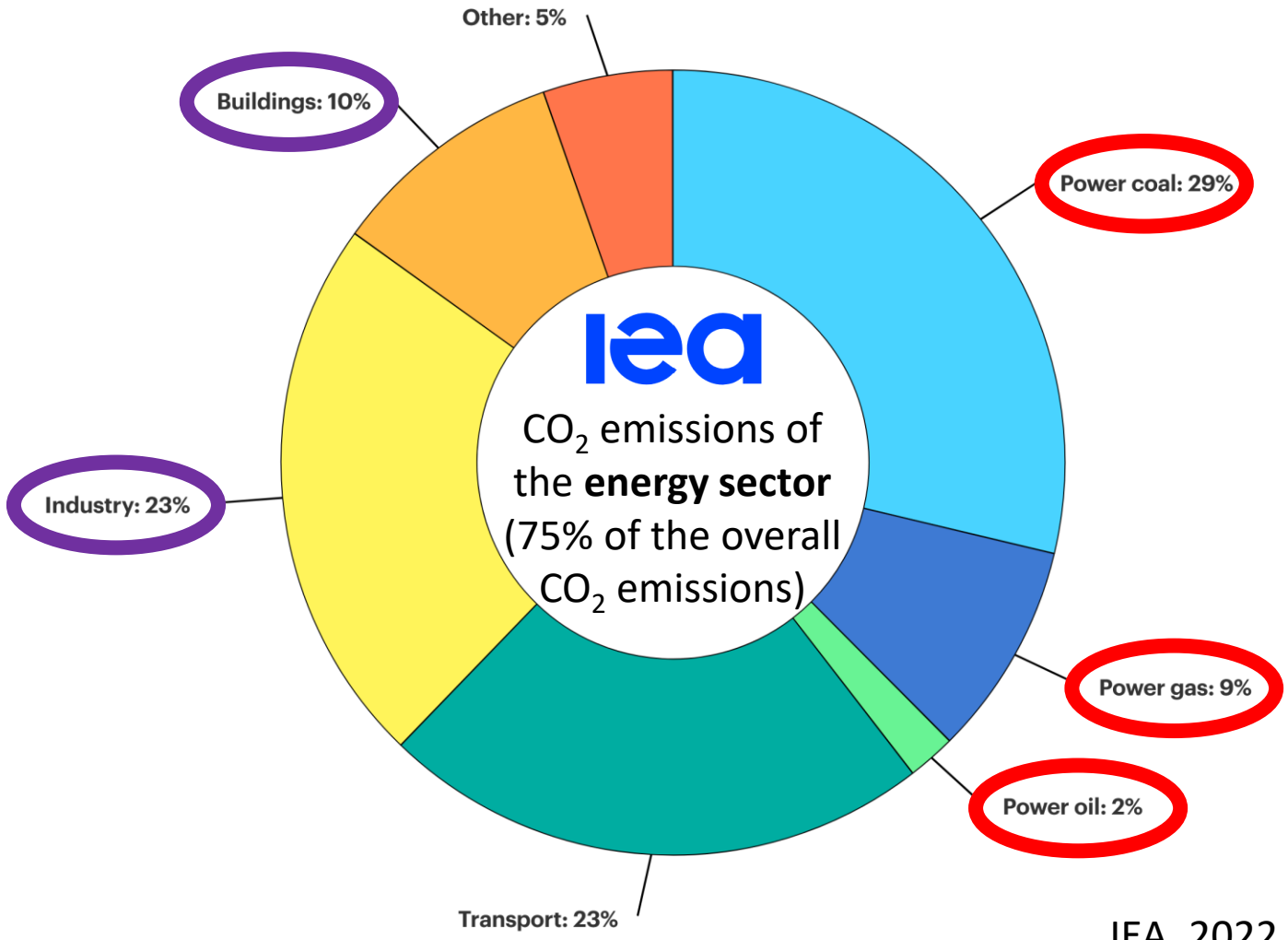

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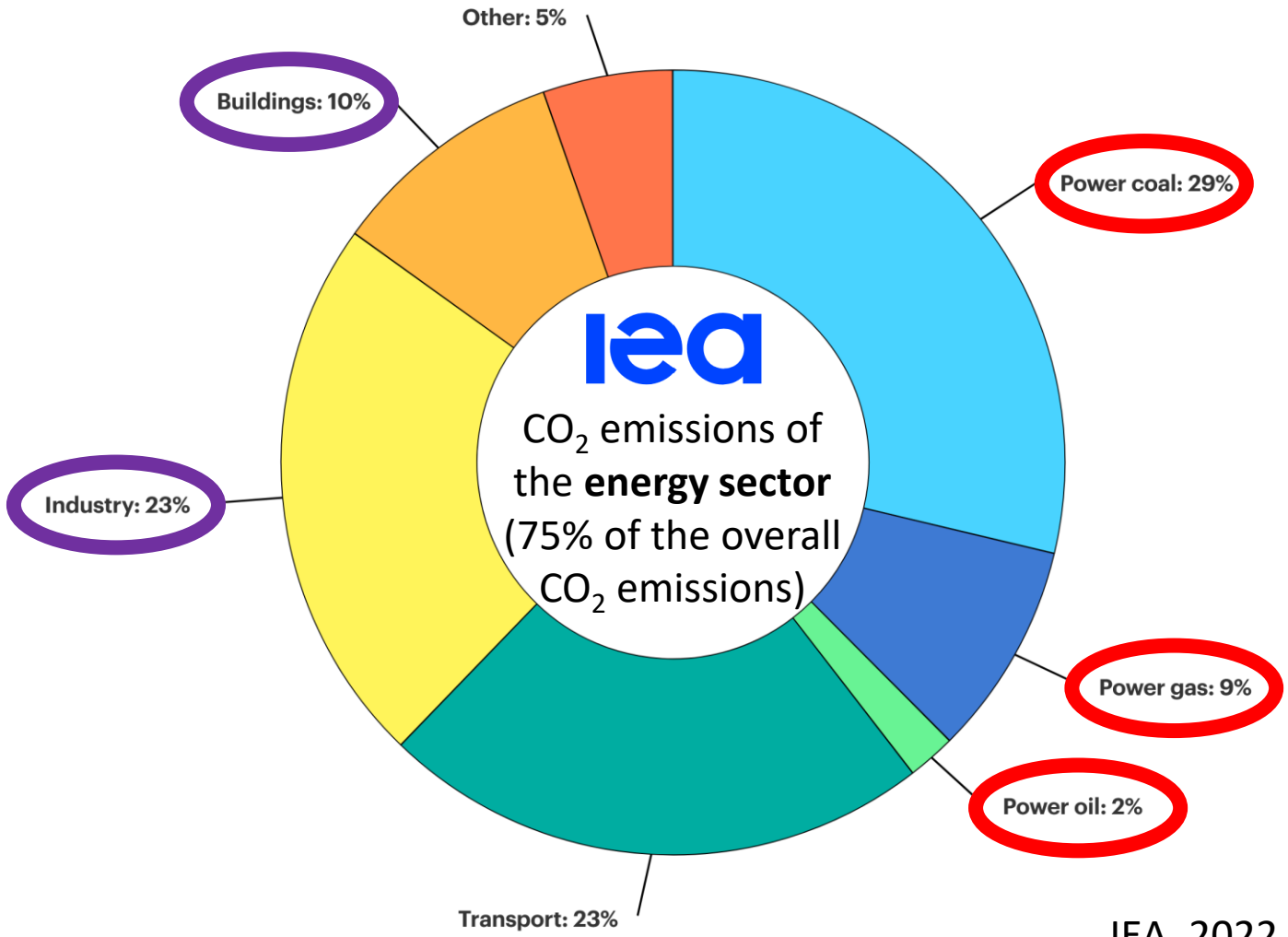

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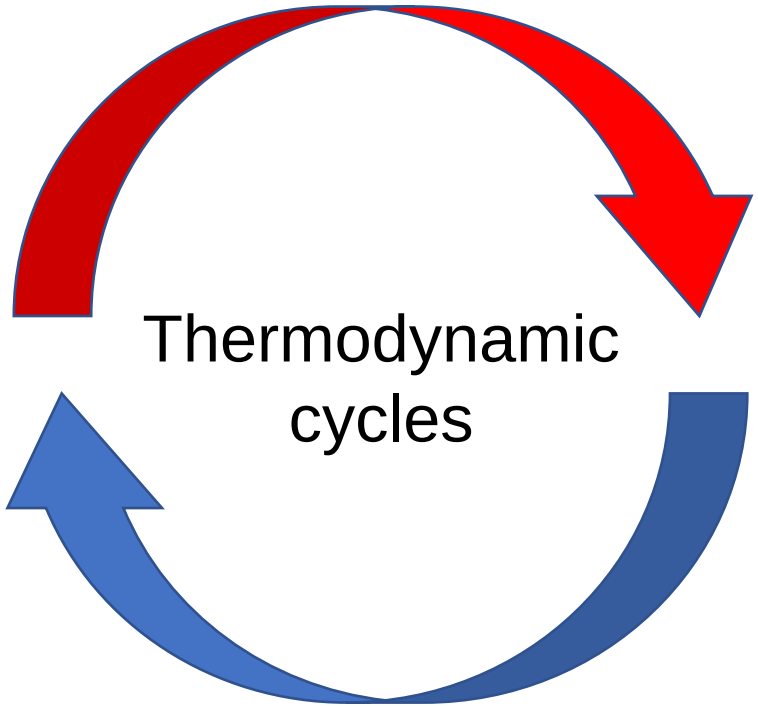
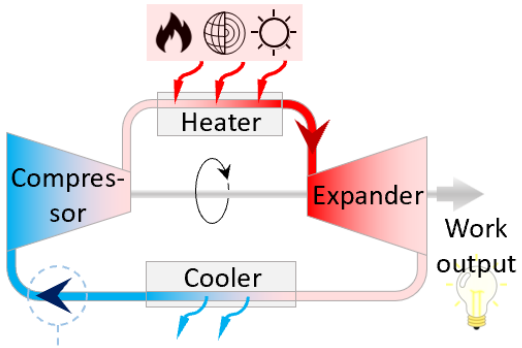


A still unexplored energy conversion process

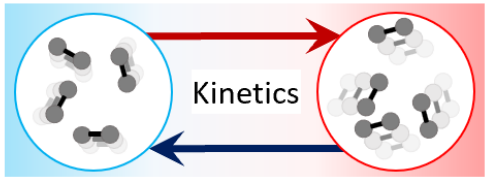
A new energy conversion system

State of the art

Thermal power cycles

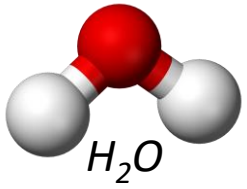


Inert working fluids



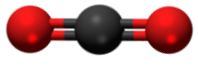
... the same in **heat pumps & refrigeration cycles !**

Thermal energy-based conversion processes

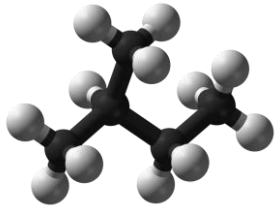


H_2O

N_2



CO_2



Iso-pentane

...

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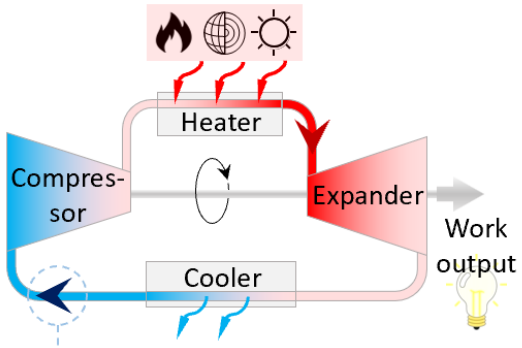

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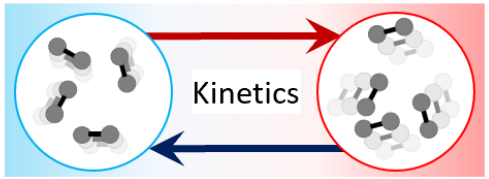

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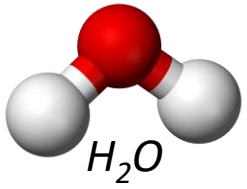

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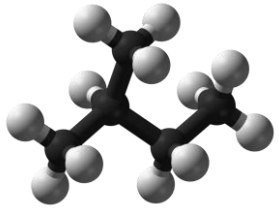

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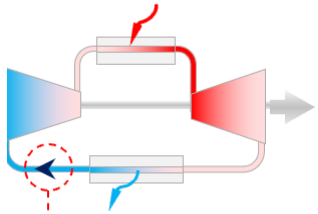
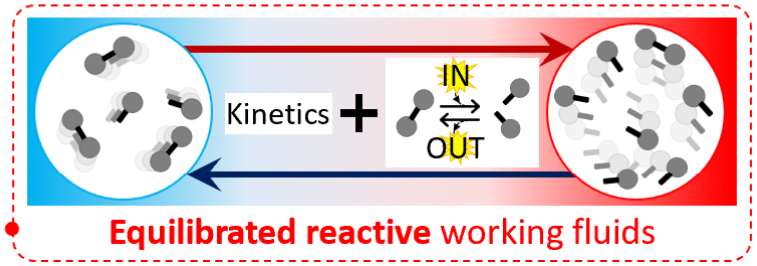
A still unexplored concept





Equilibrated reactive working fluids

Thermal AND Chemical energy-based conversion process

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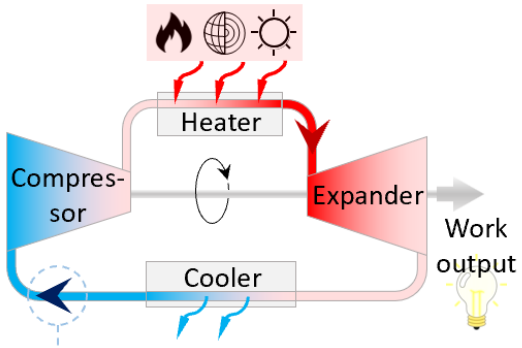

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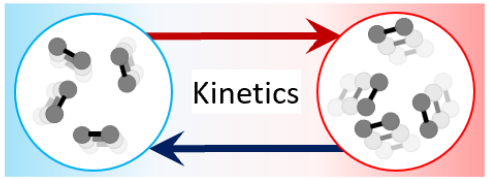

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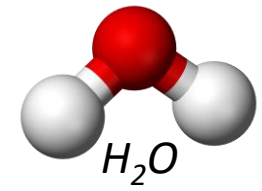

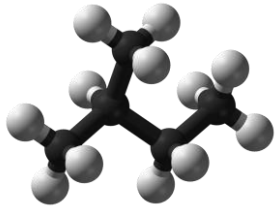

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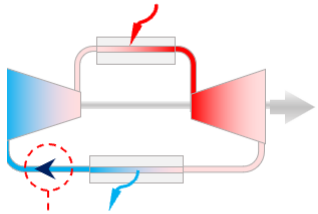

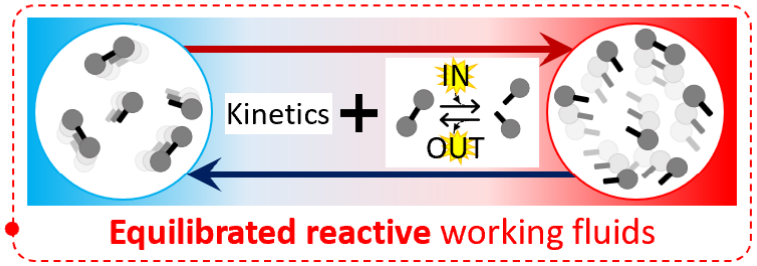

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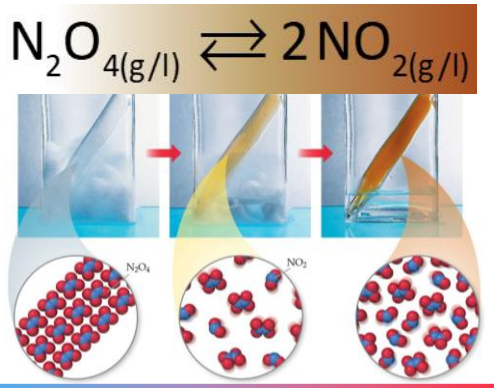
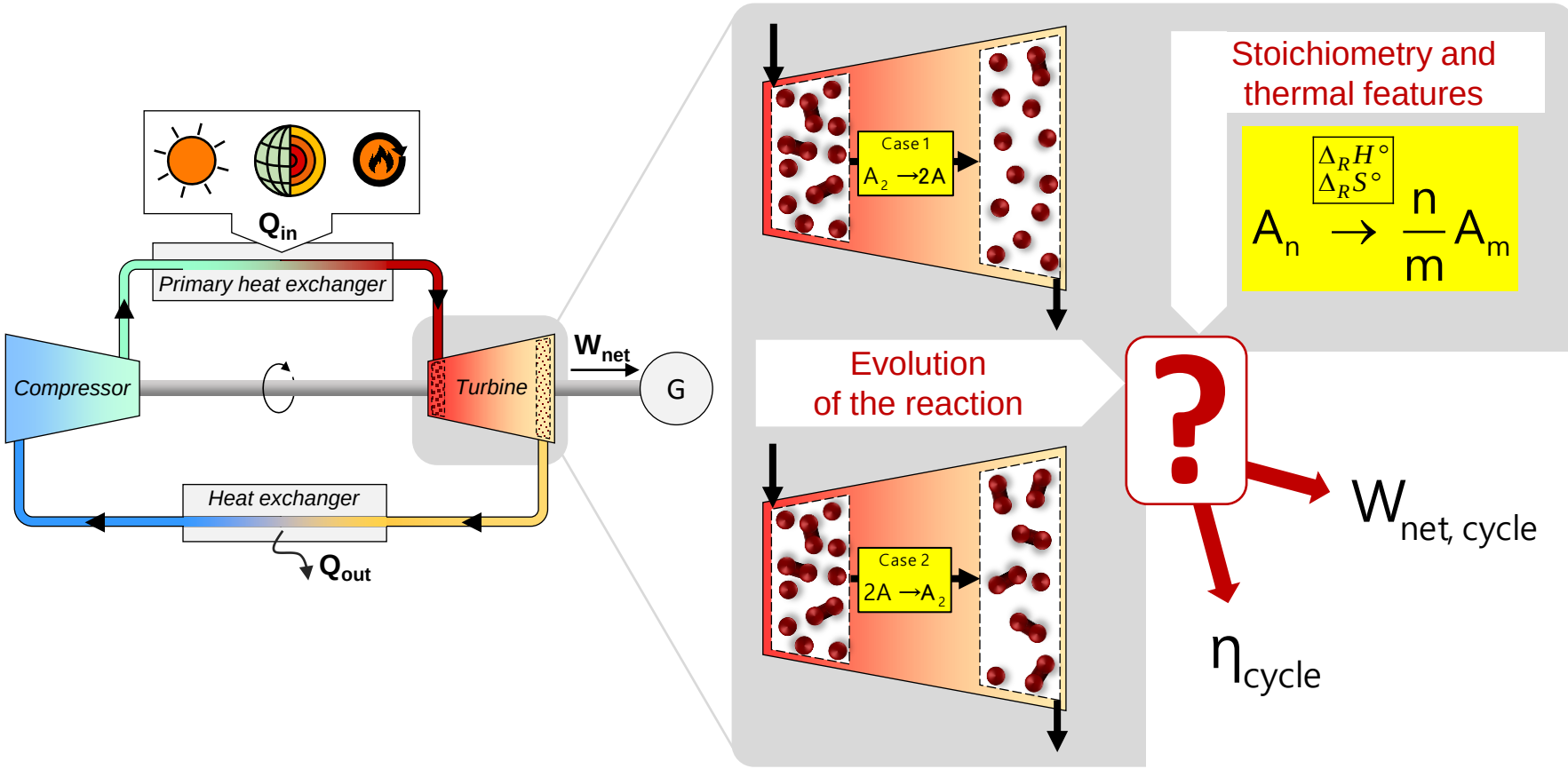


Temperature

Our questions



A preliminary study based on *fictitious* reactive working fluids

2017 - 2022

Contributors:
A. Barakat (UL),
J-N. Jaubert (UL),
R. Privat (UL),
P. Arpentinier (Air Liquide)
P. Tobaly (CNAM)
S. Lasala (UL)

Funded by: Air Liquide

A preliminary study: Fictitious reactive fluids

1) The structure of the reaction takes the following generalized form:

$$A_n \rightleftarrows \frac{n}{m} A_m$$

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4) The system is considered in chemical equilibrium:

$$\Delta_R G(T,P,\mathbf{n}) \overset{\text{chemical equilibrium}}{=} 0$$

$$K_{eq}(T) \overset{\text{chemical equilibrium}}{=} \left(\frac{P/P_0}{n_{tot}}\right)^{\sum_{i=1}^{nc}\nu_i} \prod_{i=1}^{nc}(n_i)^{\nu_i}$$

$$\ln K_{eq} \sim \frac{\Delta_R S^\circ(T^*)}{R} - \frac{\Delta_R H^\circ(T^*)}{R} \cdot \frac{1}{T}$$

A preliminary study: Fictitious reactive fluids $A_2 = 2A$

Power Brayton cycles

Heat pump Brayton cycles

Power Stirling cycle

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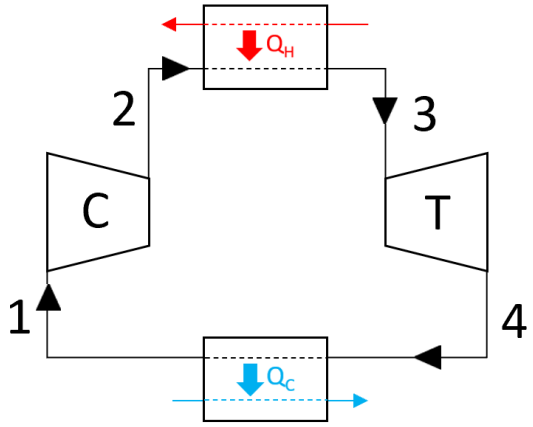

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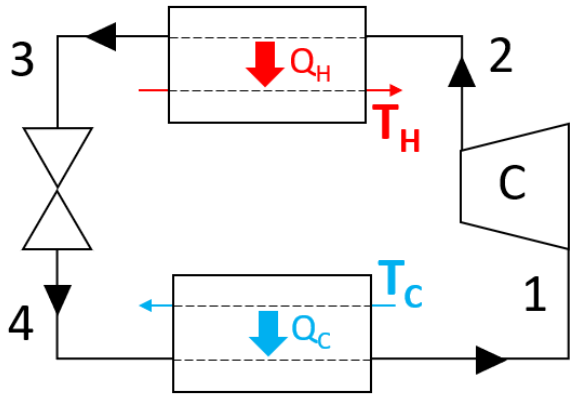

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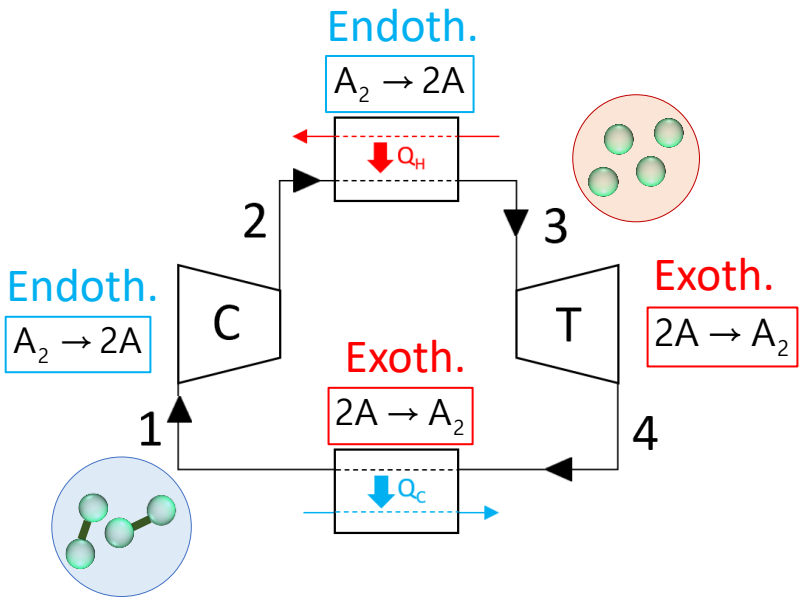

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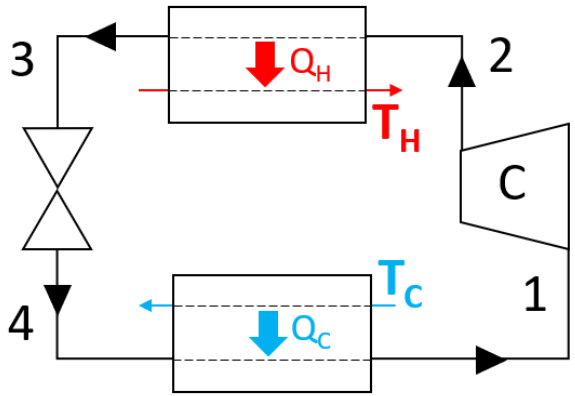

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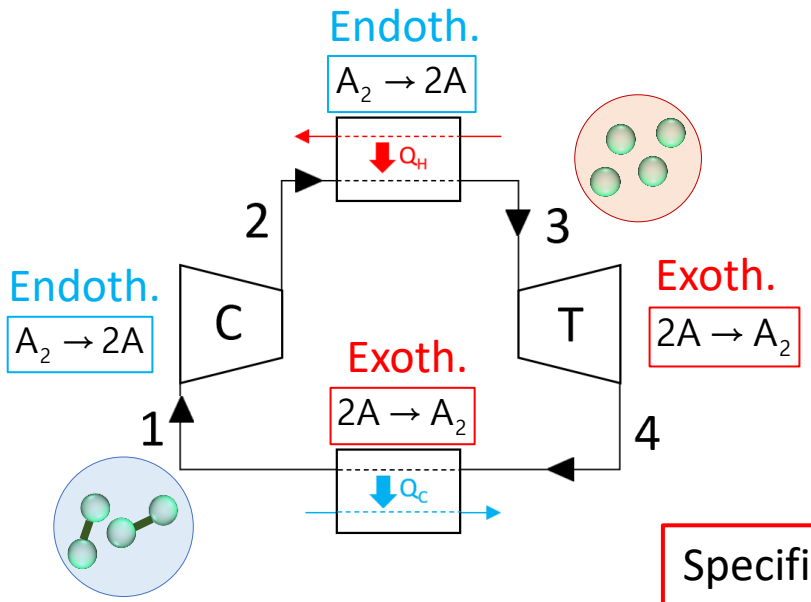

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Reactive vs. Inert working fluids

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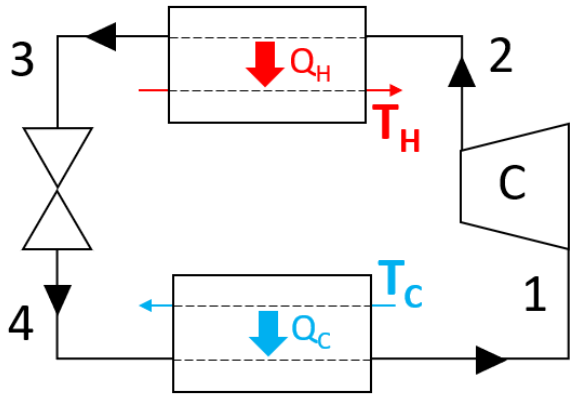

Lasala et al. 2021, 10.1016/j.enconman.2020.113685

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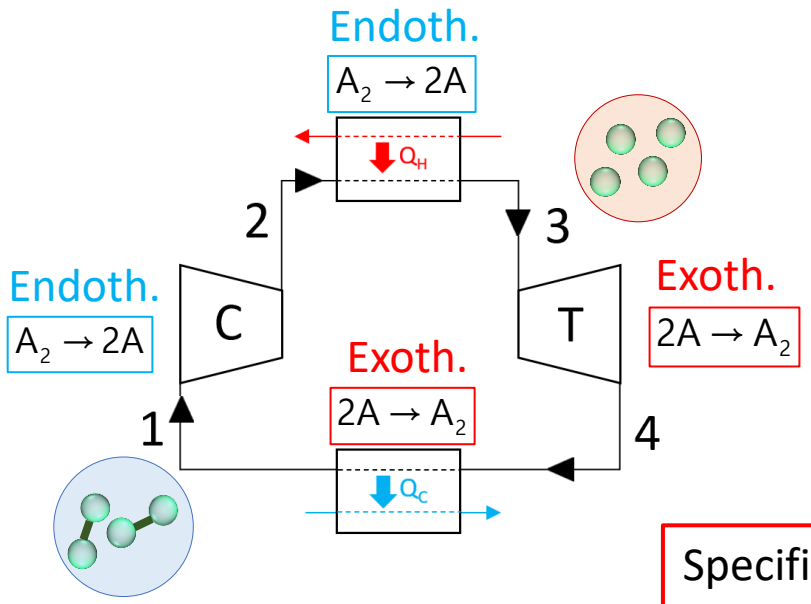

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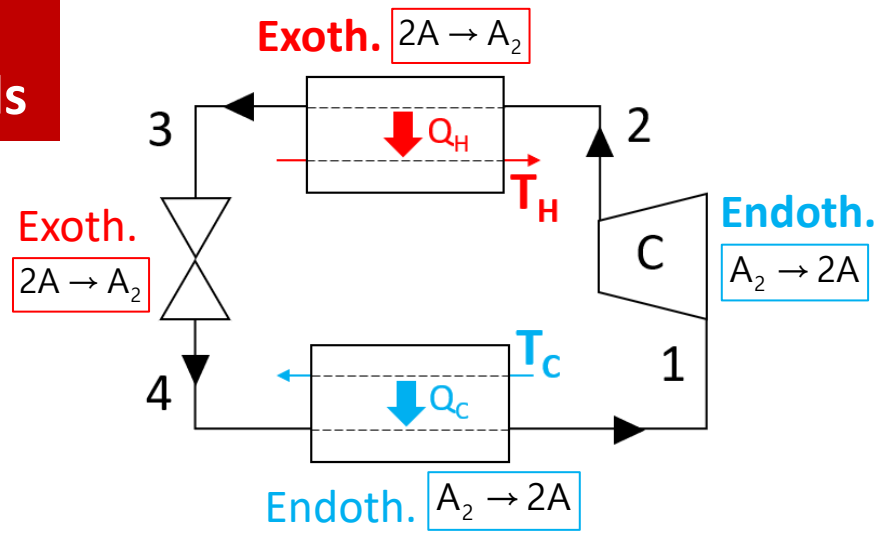

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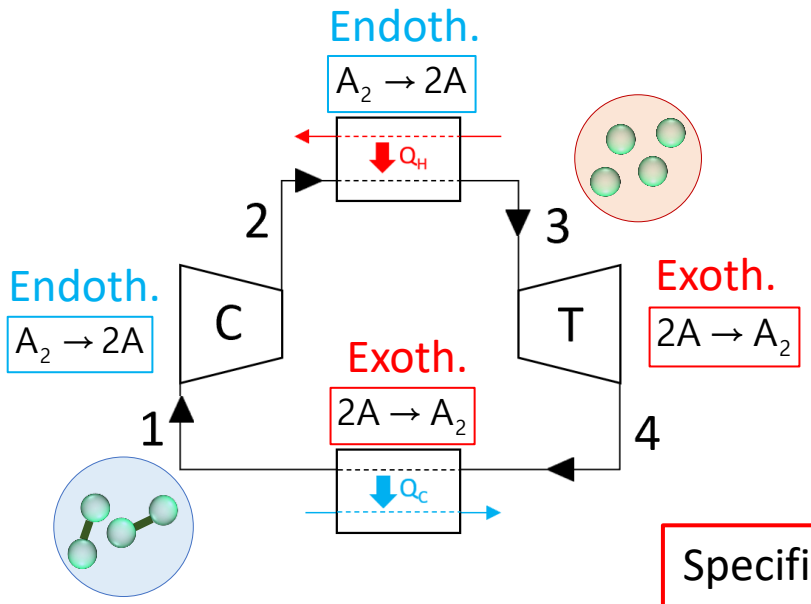

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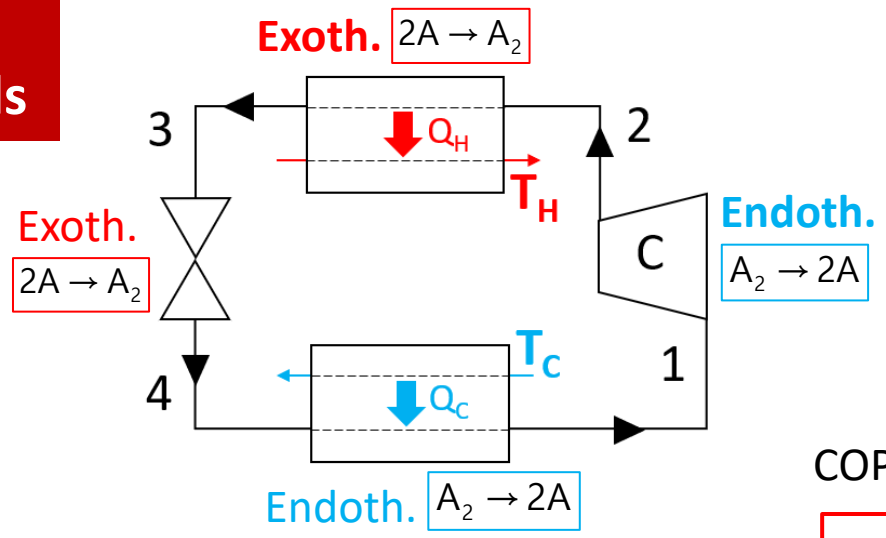

$COP = Q_H/W_C$

COP > **x2**

Barakat et al. 2022, 10.1016/j.ceja.2022.100400

Heat pump Stirling cycle

Barakat et al. 2024

REACHER

REACTIVE FLUIDS FOR ENERGY

From fictitious to *real* reactive working fluids

2022 –2027

ERC Starting Grant

www.univ-lorraine.fr/erc-reacher

Main contributors (UL):

J. Joliat, R. Hadjadj, S. Vilas-Boas, L. Pinilla-Monsalve, K. Samukov, I. Velazquez Palencia, J. N. Jaubert, R. Prinat, O. Herbinet, J.-F. Portha, P. Arnoux, LRGP services, Silvia Lasala

UNIVERSITÉ DE LORRAINE

Membre d'UNYS

REACHER: The methodology

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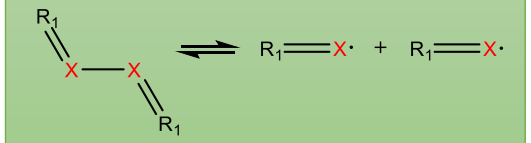
For power, heating and cooling applications

1. Discovery of suitable reactions and their characterization

Reaction search & design | Kinetics and thermochemistry assess. | Thermodynamic properties | Further characterization

Search of existing dimerization reactions

Design of new reactants (dimers) and relative products (monomers)



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Enthalpy and entropy of reaction
Ideal gas heat capacity

Quantum Mechanics

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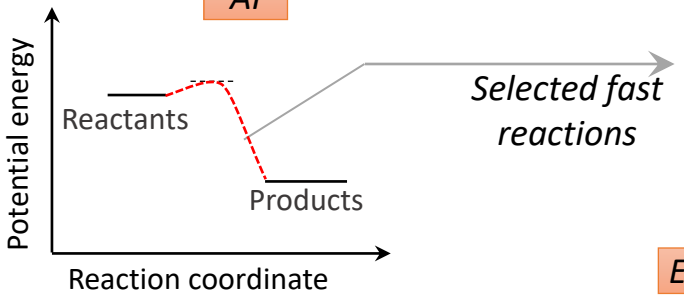

Thermodynamic basic properties of pure components (Tc, Pc, ω)

Monte Carlo *AI*

Full thermodynamic characterisation of the reactive mixture (ρ, VLE, h, s, ...)

Equations of state *Monte Carlo*

Safety Features

Environmental properties

WP 2

WP 3

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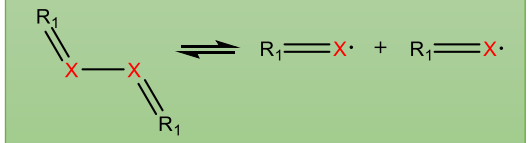

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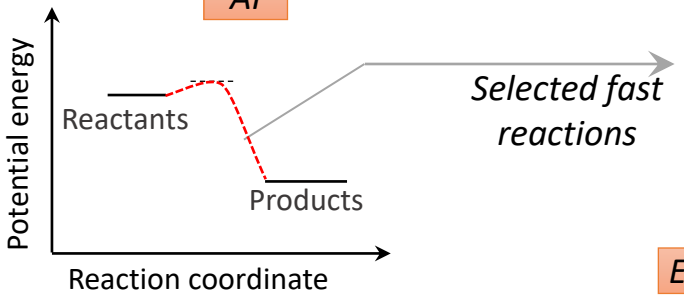

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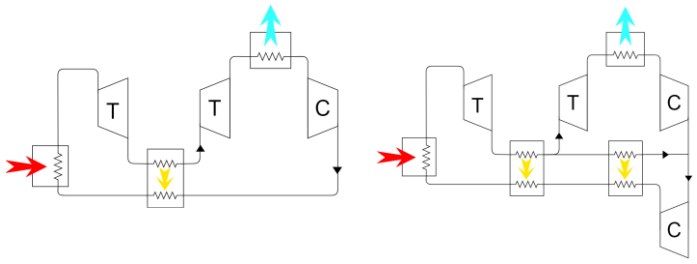
i-th reaction → Optimal efficiency → ***i-th* optimal cycle architecture**



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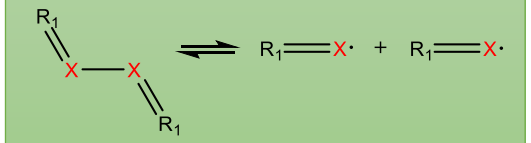

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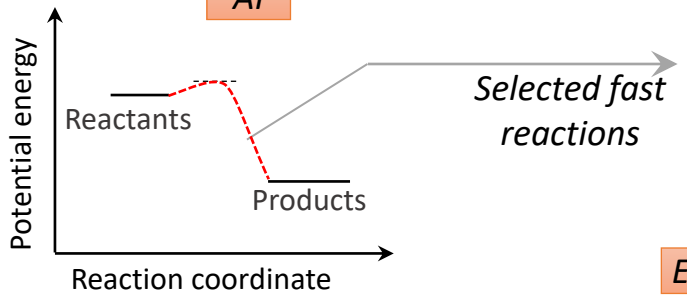

Selected fast reactions

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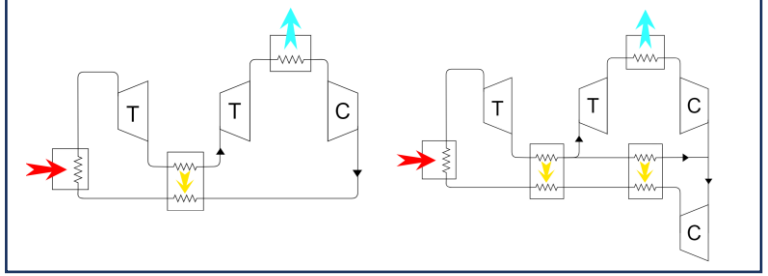
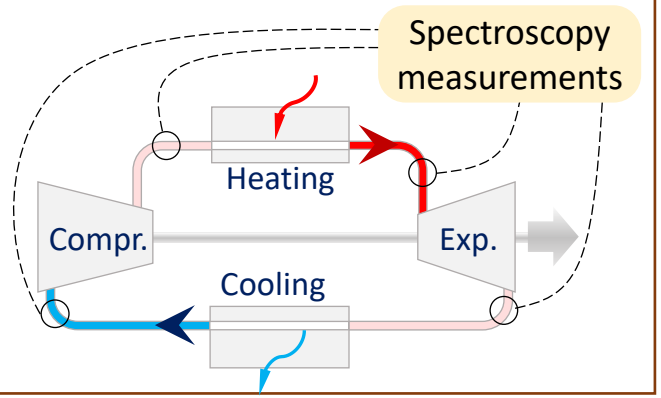


3. Experimental validation

Power plant

CO_2 + reactive fluid



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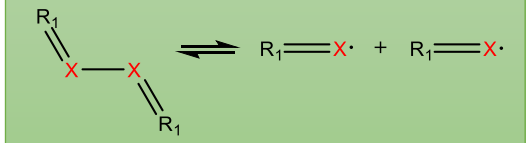
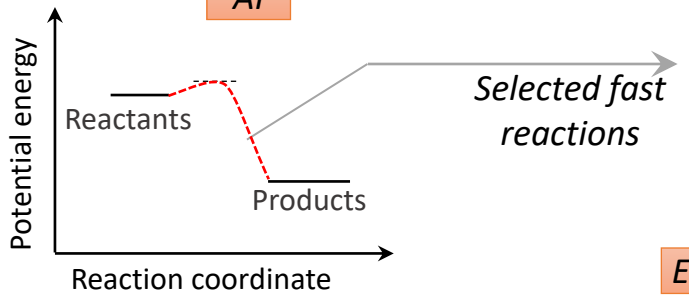


...

Enthalpy and entropy of reaction
Ideal gas heat capacity

Quantum Mechanics

AI



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Monte Carlo *AI*

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Equations of state *Monte Carlo*

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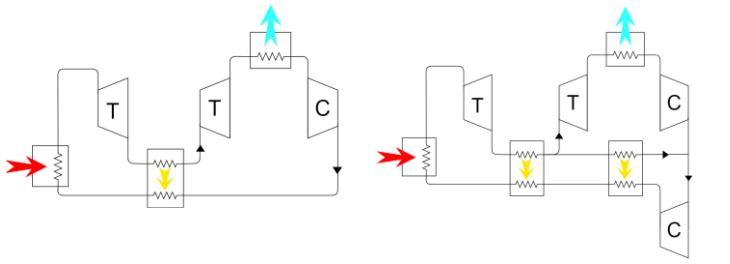
i-th reaction → Optimal efficiency → ***i-th* optimal cycle architecture**



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Themodynamic transformations

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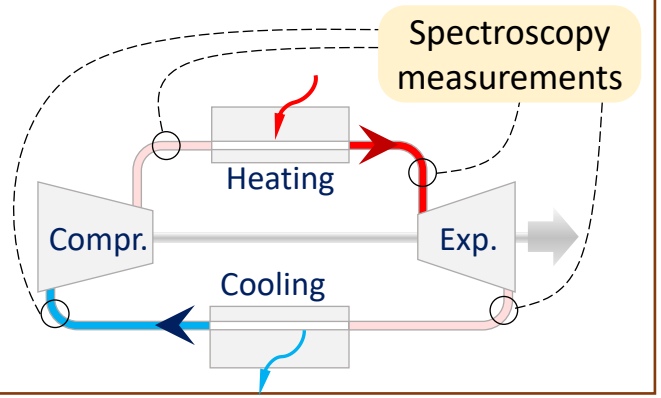
CO_2 + reactive fluid



REACHER: The methodology

1. Discovery of suitable reactions and their characterization

For power, heating and cooling applications

Reaction search & design → Kinetics and thermochemistry assess. → Thermodynamic properties → Further characterization

Search of existing dimerization reactions

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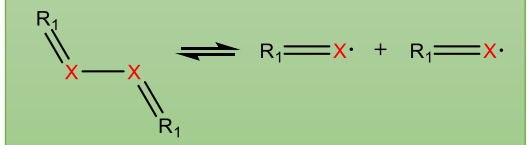

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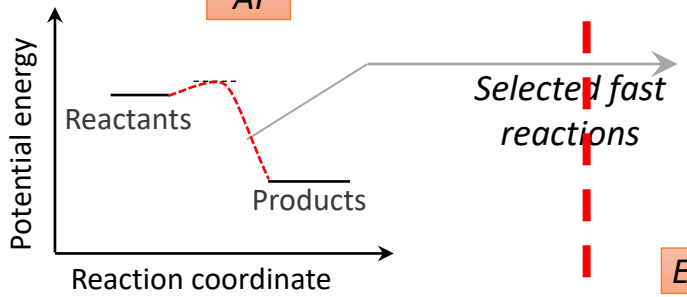

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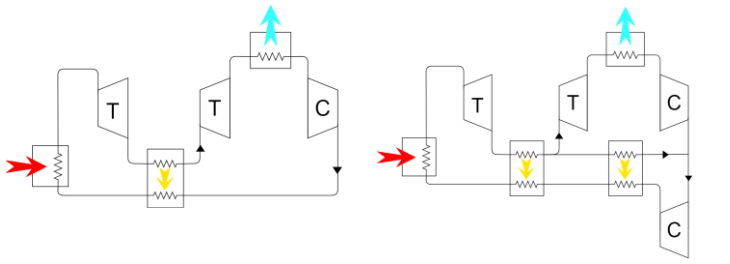

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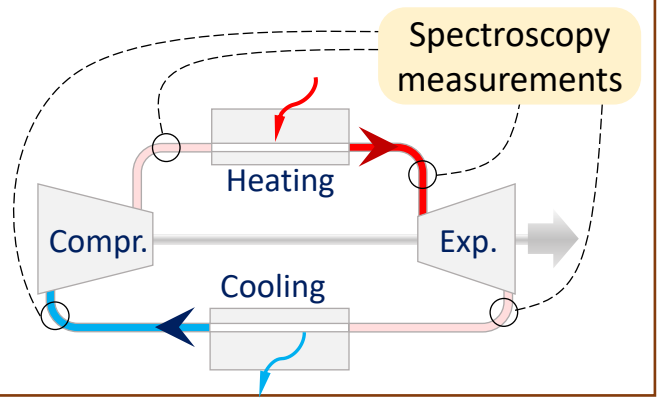


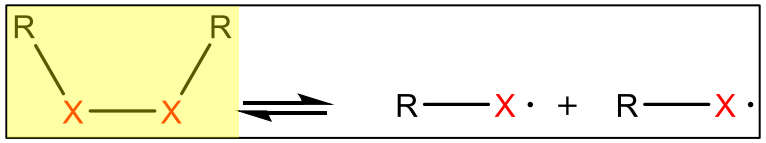
1. Discovery of suitable reactions and their characterization

DIMERGEN

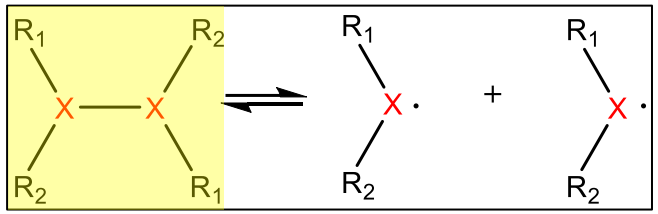
- Generation of dimers (the monomer is straightforward)

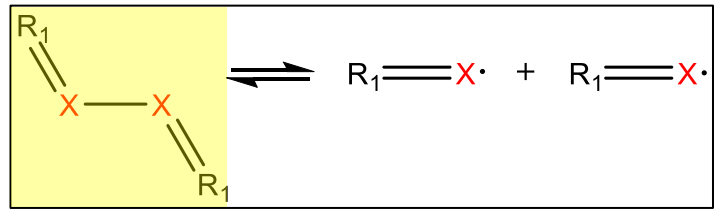
  For example:

Valence of X = 2

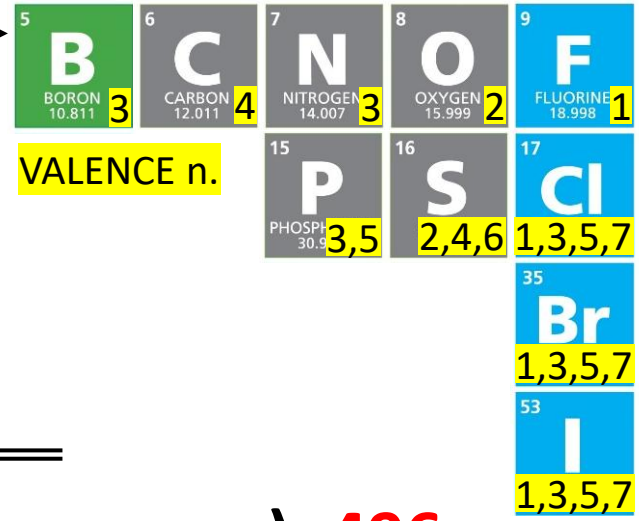


Valence of X = 3



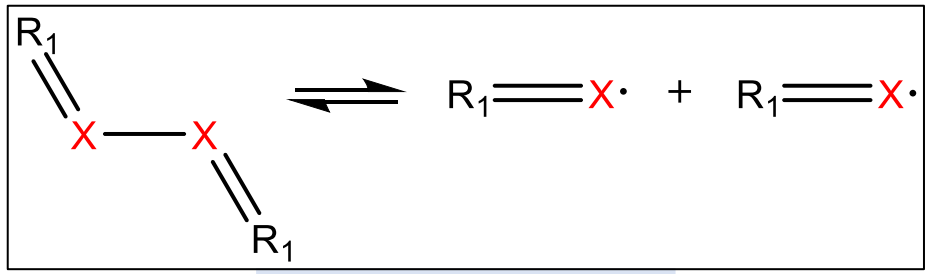


- Selected atoms:
- Dimers are covalent bonded
- No more than 3 different atomic species in each dimer
- Peripherical atoms (R1 and R2) are different than central atoms (X)
- Peripheral positions are occupied by atoms at their lowest valence



Number or resulting dimers (and relative monomers): 496

1. Discovery of suitable reactions and their characterization



DIMERGEN

496 generated dimers

GAUSSIAN 09

STABILITY ANALYSIS & GEOMETRY OPTIMISATION

151 stable dimers

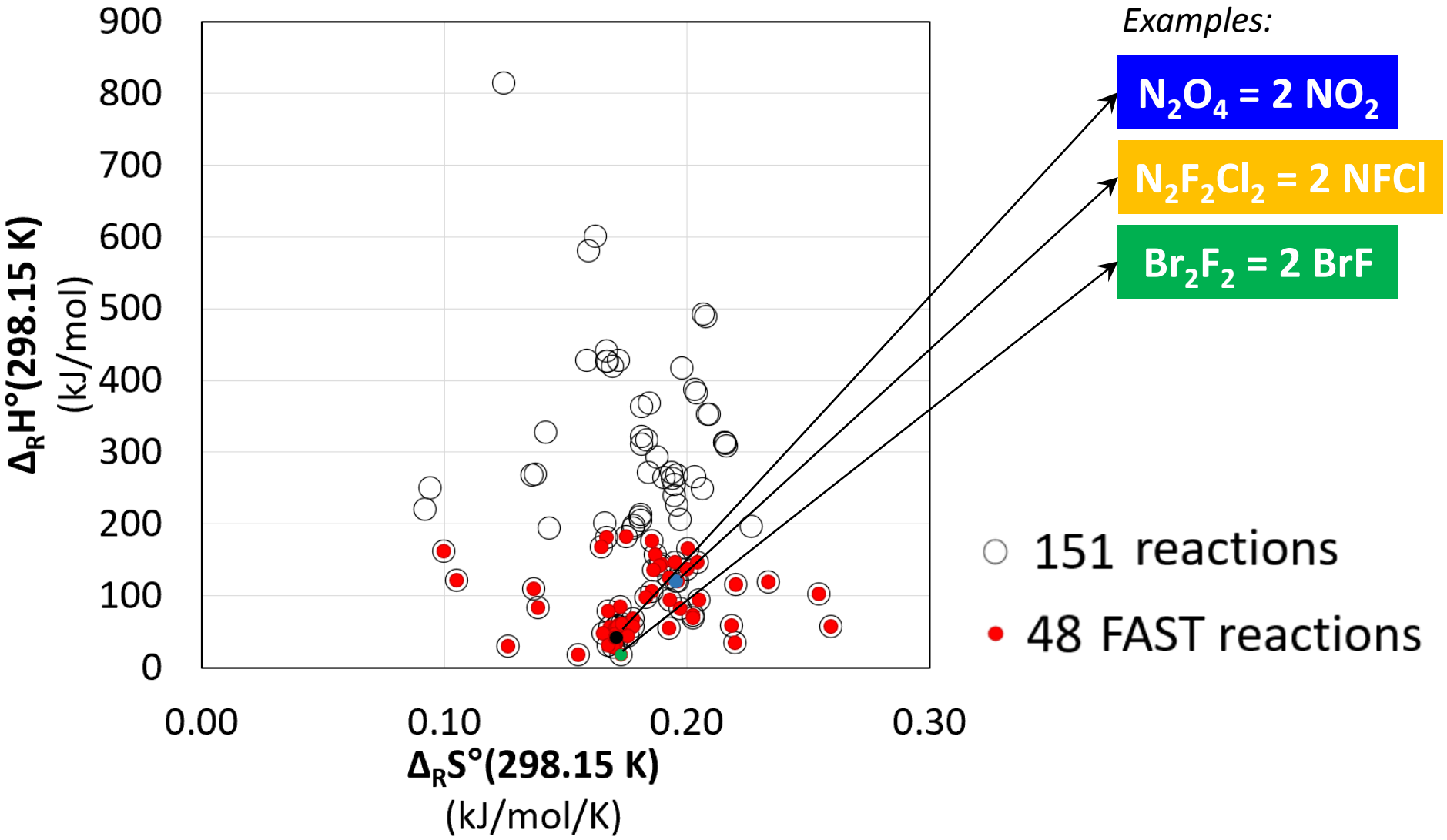
GAUSSIAN 09

GEOMETRY OPTIMISATION of 151 monomers

Calculation of:

- $\Delta_R G°_{298K}$
- $\Delta_R H°_{298K}$
- $\Delta_R S°_{298K}$
- $c_{p,ig,i}(T)$
- preliminary kinetics for each reaction

1. Discovery of suitable reactions and their characterization

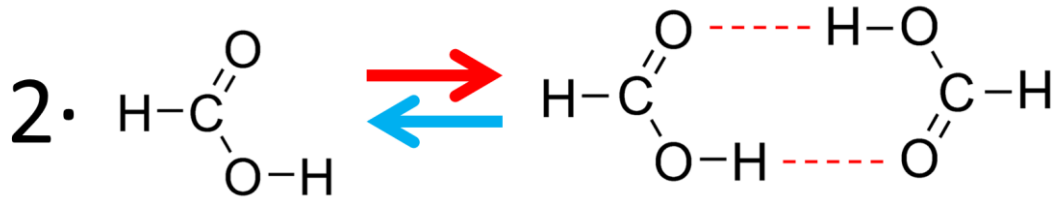


1. Discovery of suitable reactions and their characterization

2 families of reactive fluids:

Hydrogen-bond breaking/forming (carboxylic acids)

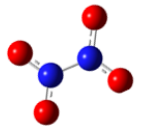
Example: formic acid



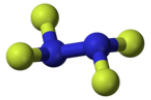
Wasik et al., 2025, doi.org/10.1016/j.fluid.2025.114356

Covalent-bond breaking/forming

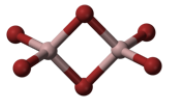
Examples:



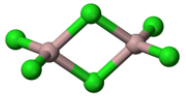
$N_2O_{4(g/l)} \rightleftarrows 2\,NO_{2(g)}$



$N_2F_{4(g)} \rightleftarrows 2\,NF_{2(g)}$



$Al_2Br_{6(g/l)} \rightleftarrows 2\,AlBr_{3(g)}$



$Al_2Cl_{6(g/l)} \rightleftarrows 2\,AlCl_{3(g)}$

+ new designed reactions

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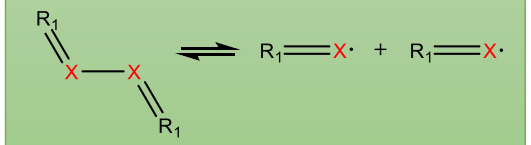

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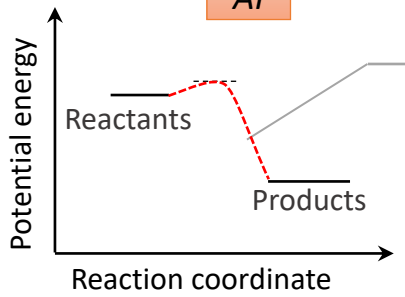

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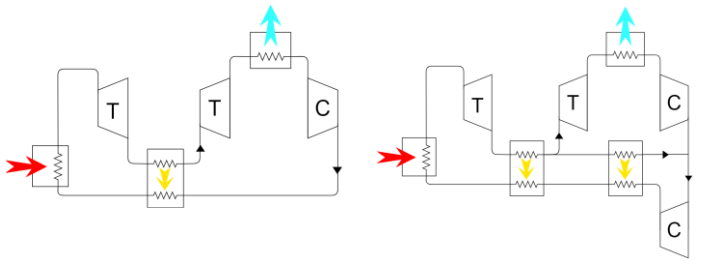

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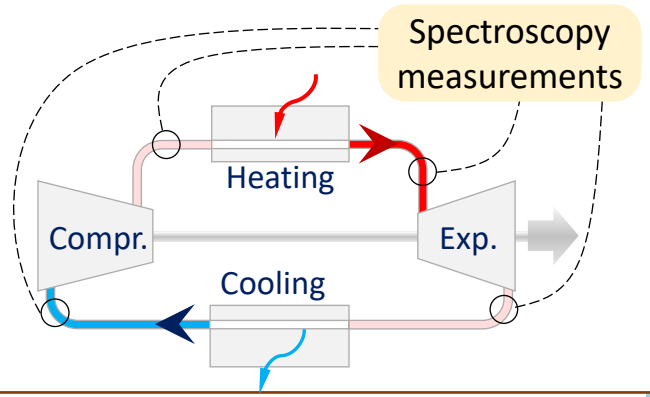

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$N_2F_2Cl_2 = 2\ NFCl$

$Br_2F_2 = 2\ BrF$

$N_2O_4 = 2\ NO_2$

...

? $h(T,P,\boldsymbol{z})$ $s(T,P,\boldsymbol{z})$

$$h(T,v,\boldsymbol{z}) = \sum_{i=1}^{2} z_i \left(h_i^{ig}(T_{ref}) + \int_{T_{ref}}^{T} c_{P,i}^{ig}(T)\,dT \right) + h^{res-TV}(T,v,\boldsymbol{z})$$

Ideal gas properties

$\Delta_f H_i^{\circ}$ S_i° $c_{p,i}^{ig}(T)$

Equation of state

$P(T,v,\boldsymbol{z})$

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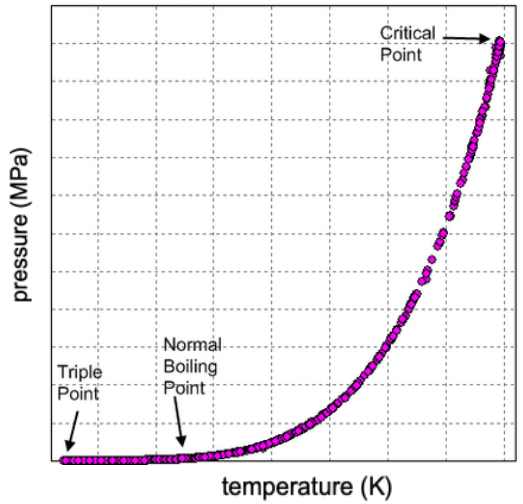
EoS inputs:

Pure components critical properties

Ex. N_2O_4 & NO_2

1. Discovery of suitable reactions and their characterization

PURE COMPONENT
Sat-P



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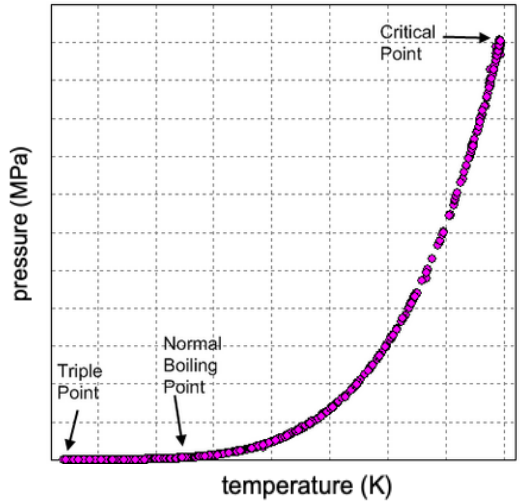
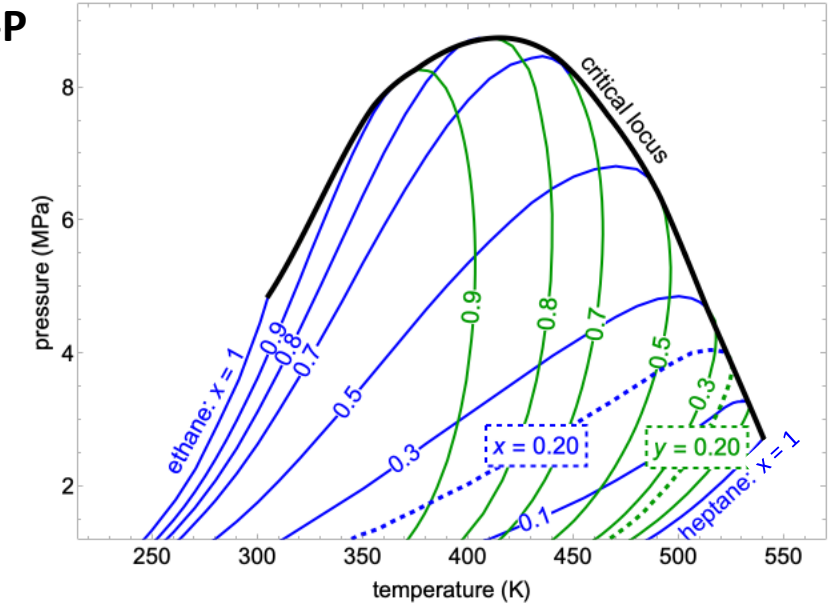


BINARY INERT MIXTURE
VLE-P



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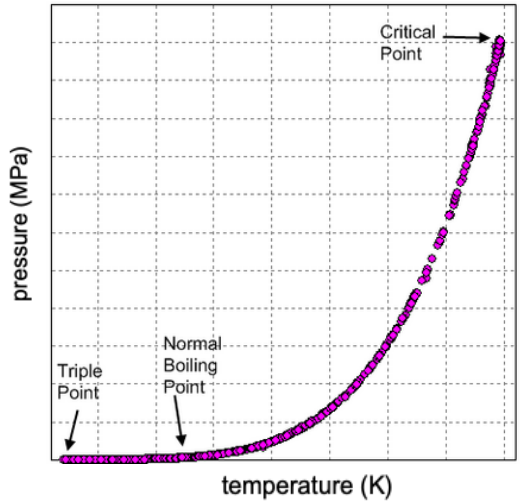

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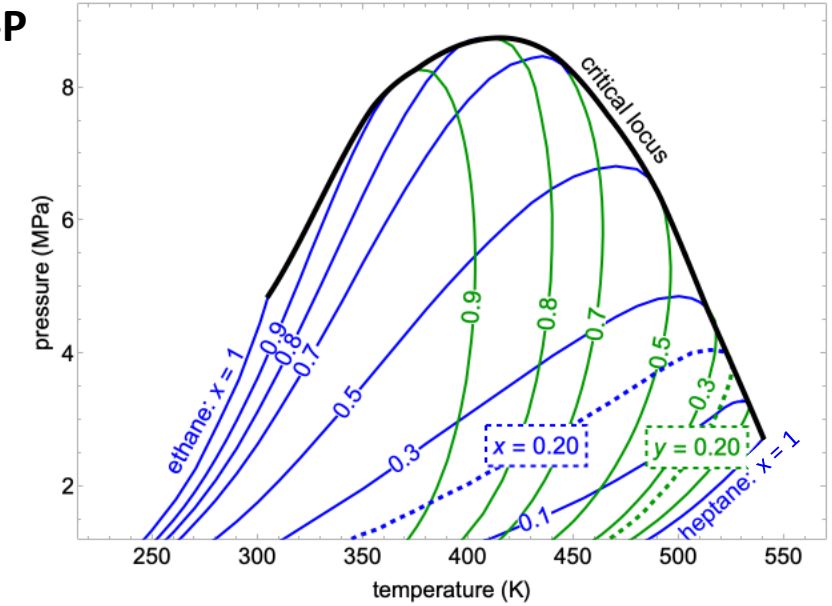
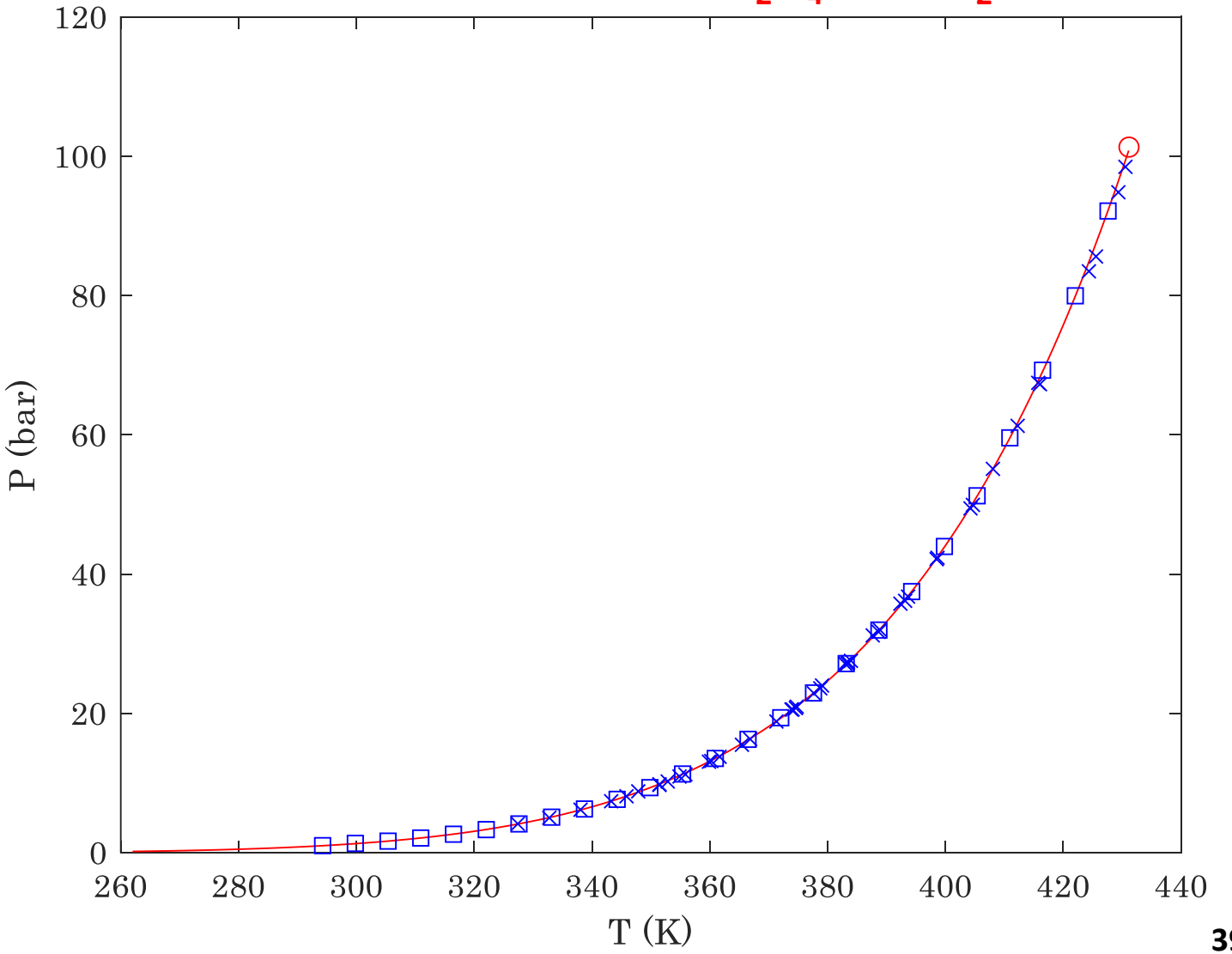


BINARY REACTIVE MIXTURE: N_2O_4 = 2 NO_2



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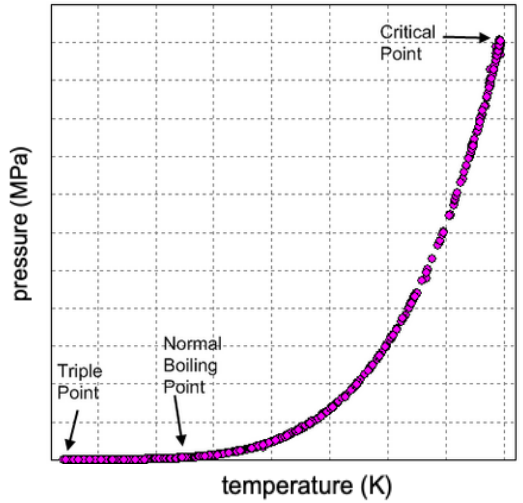

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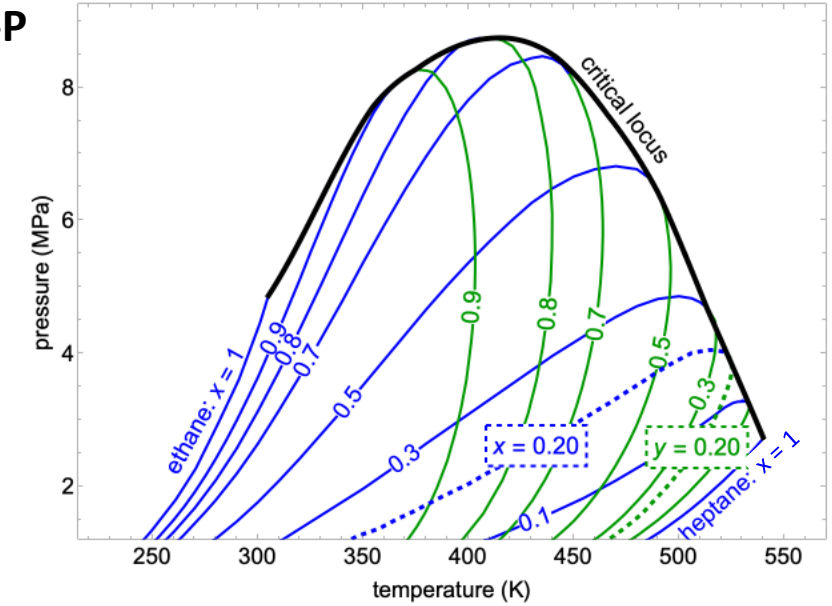
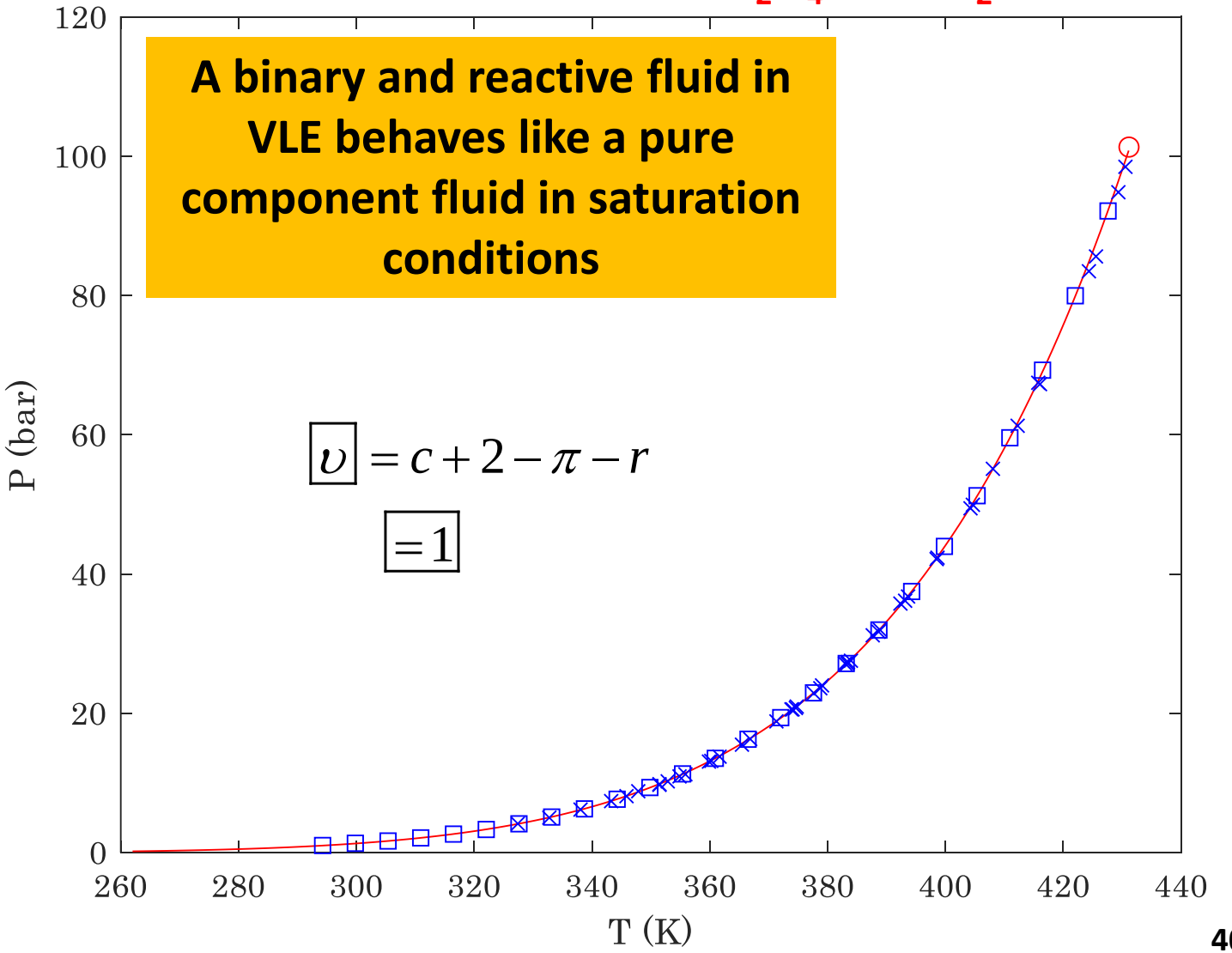


BINARY REACTIVE MIXTURE: $N_2O_4 = 2\ NO_2$

A binary and reactive fluid in VLE behaves like a pure component fluid in saturation conditions

$$\boxed{\upsilon} = c + 2 - \pi - r$$

$$\boxed{=1}$$



1. Discovery of suitable reactions and their characterization

Monte Carlo simulations to determine the critical coordinates of NO_2 and N_2O_4

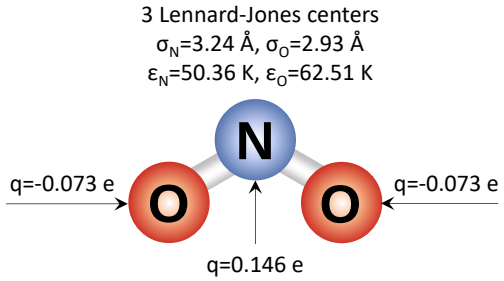
INPUT

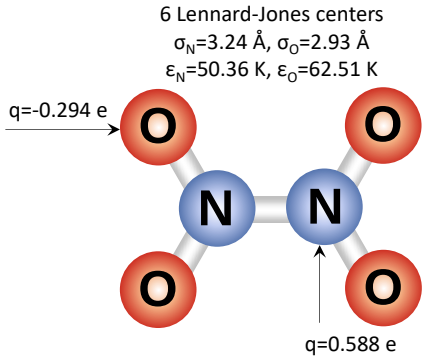
Optimal geometry, Partition function

Calculated by ab-initio Quantum Mechanics

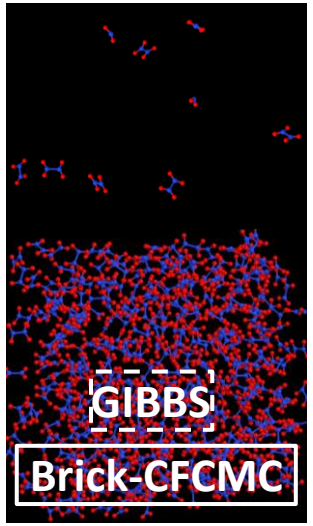
Lennard Jones potential parameters for O-O and N-N

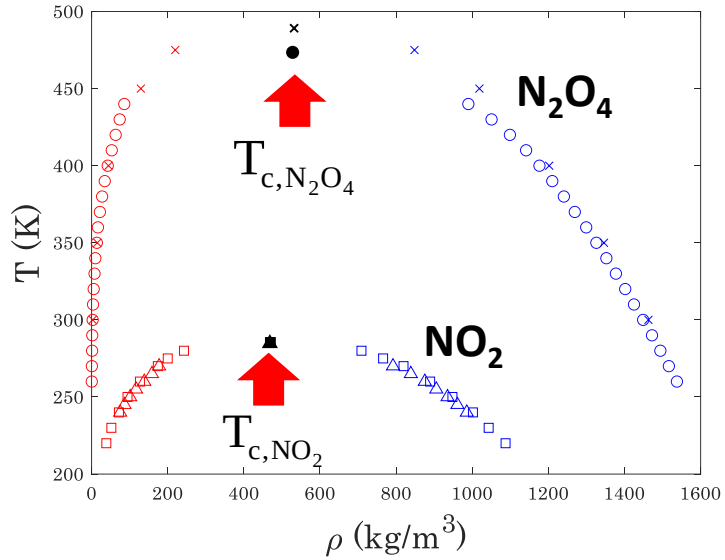
Optimised on experimental data

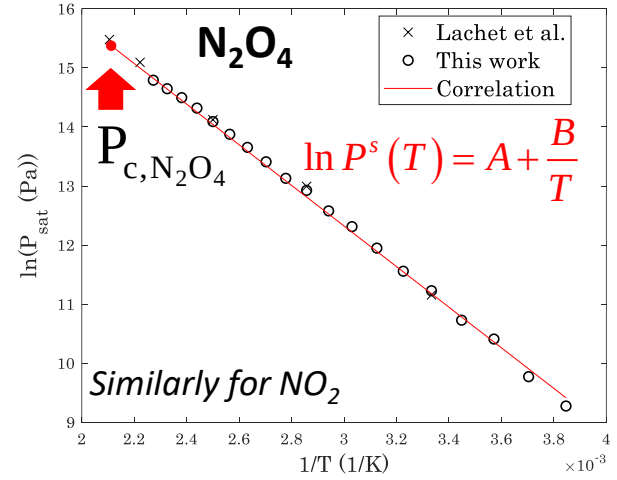




Results







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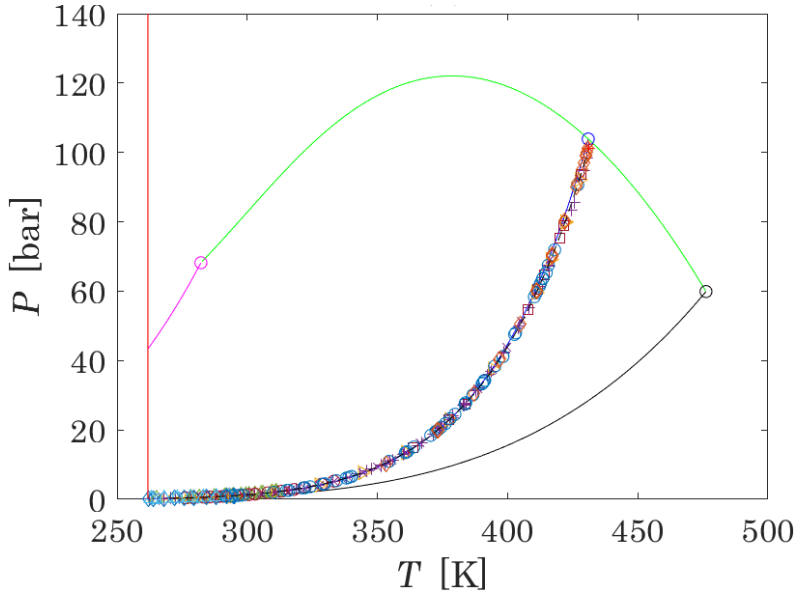
Equation of state

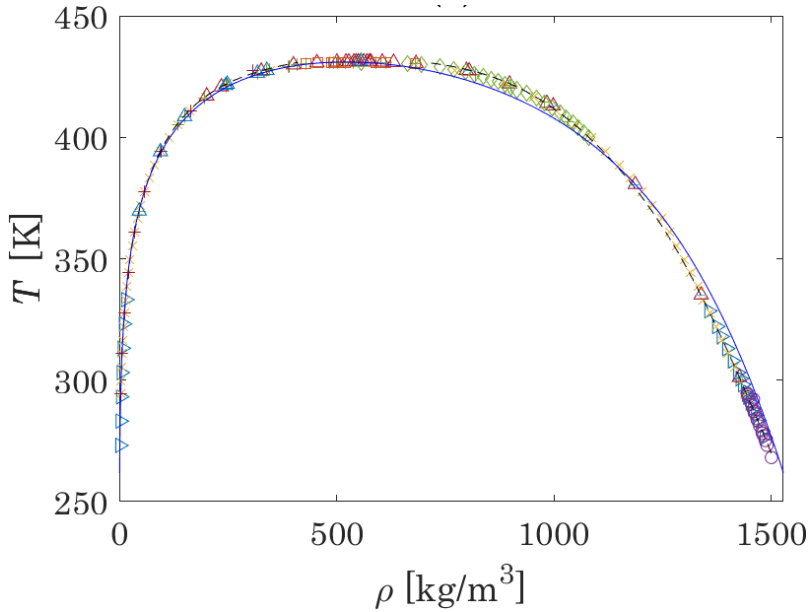
$P(T,v,\boldsymbol{z})$

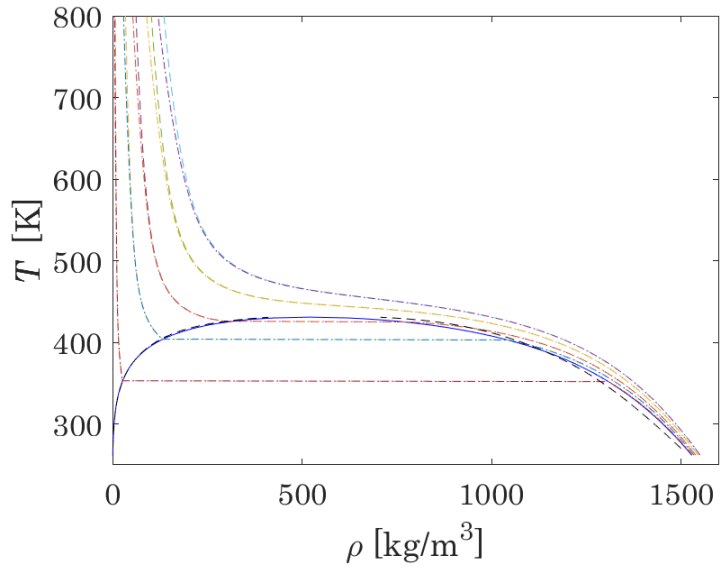
1. Discovery of suitable reactions and their characterization

Validation of the predictive thermodynamic model

$N_2O_4 \rightleftarrows 2\ NO_2$







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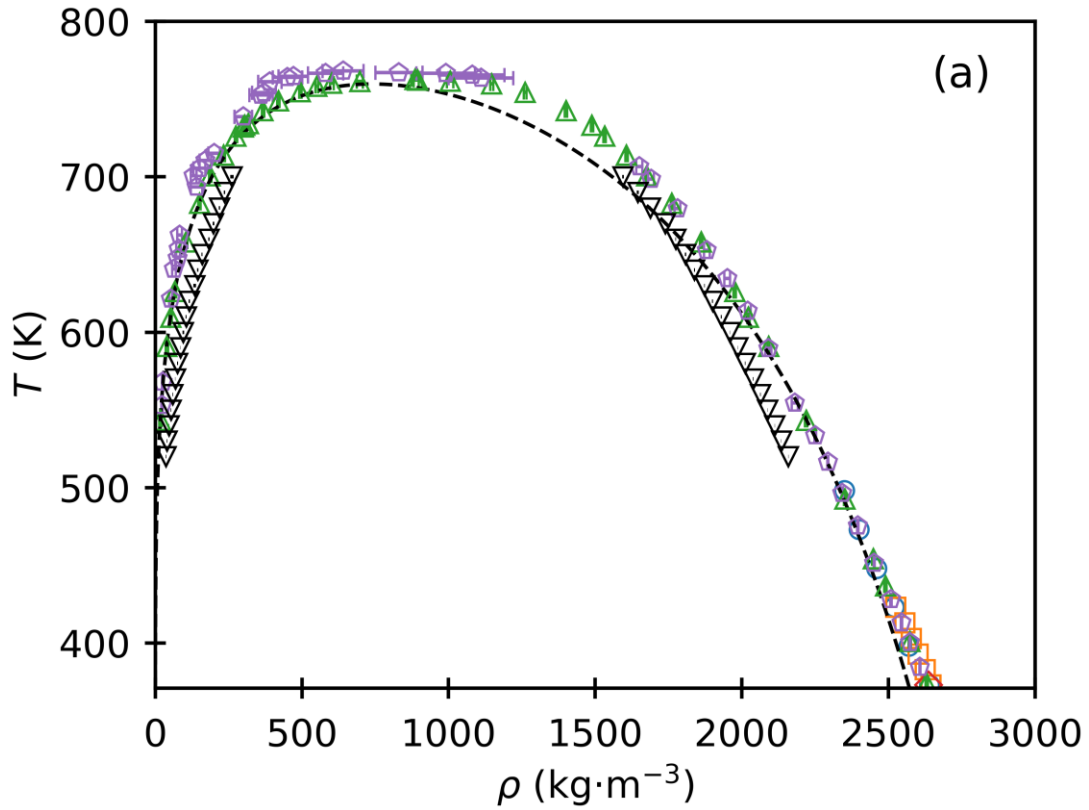
Validation of the predictive thermodynamic model

(a) $Al_2Br_6 \leftrightharpoons 2AlBr_3$



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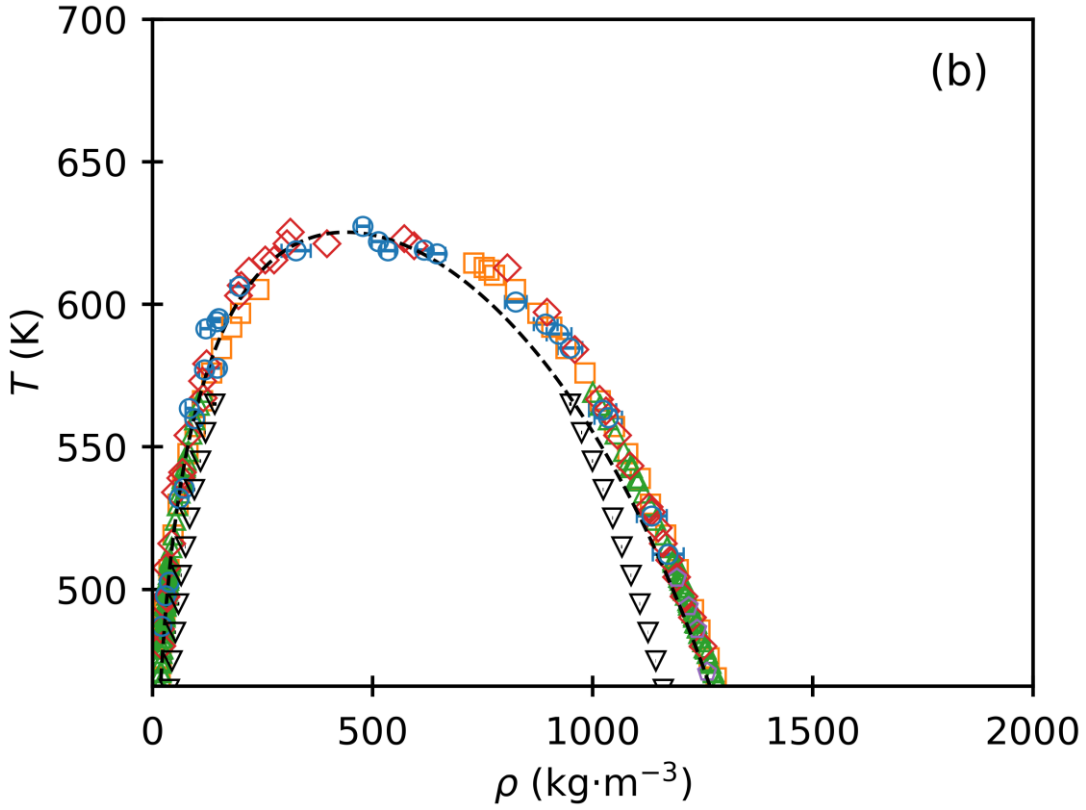

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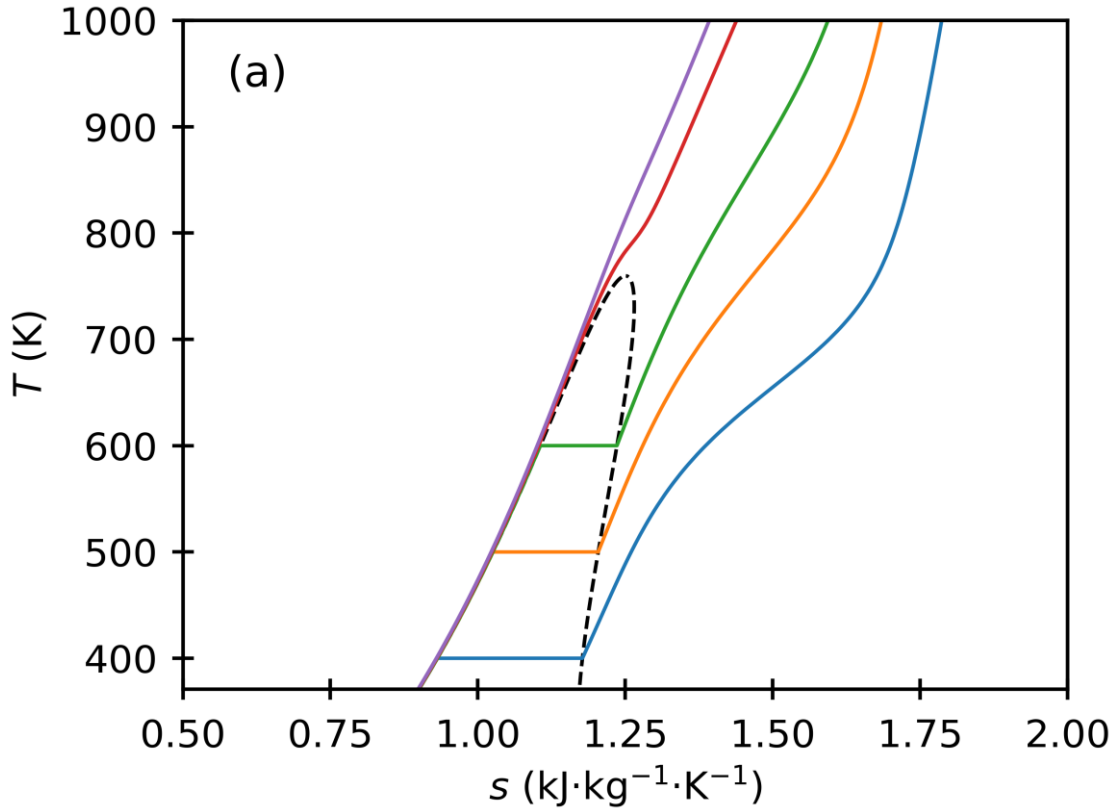
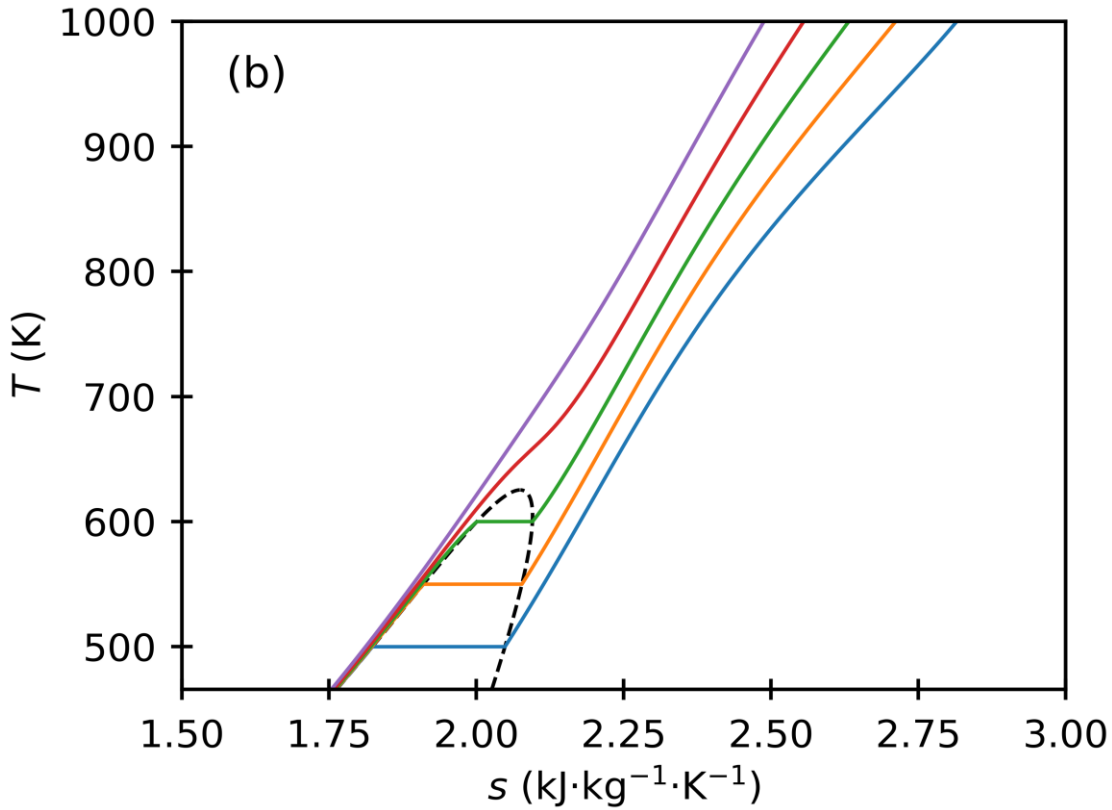
Application of the predictive thermodynamic model

(a) $Al_2Br_6 \leftrightharpoons 2AlBr_3$



(b) $Al_2Cl_6 \leftrightharpoons 2AlCl_3$



1. Discovery of suitable reactions and their characterization

Chemical Engineering Journal 483 (2024) 148961

Contents lists available at ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Application of thermodynamics at different scales to describe the behaviour of fast reacting binary mixtures in vapour-liquid equilibrium

Silvia Lasala [a,*], Konstantin Samukov [a], H. Mert Polat [b], Véronique Lachet [c], Olivier Herbinet [a], Romain Privat [a], Jean-Noël Jaubert [a], Othonas A. Moultos [b], Kevin De Ras [d], Thijs J. H. Vlugt [b,*]

[a] Université de Lorraine, CNRS, LRGP, F-54000 Nancy, France
[b] Engineering Thermodynamics, Process & Energy Department, Faculty of Mechanical Engineering, Delft University of Technology, Leeghwaterstraat 39, Delft 2628CB, The Netherlands
[c] IFP Energies nouvelles, 1 et 4 avenue de Bois-Préau, 92852 Rueil-Malmaison, France
[d] Ghent University, Laboratory for Chemical Technology (LCT), Technologiepark 125, B-9052 Ghent, Belgium

International Journal of Thermophysics (2025) 46:95
https://doi.org/10.1007/s10765-025-03565-x

An Accurate Thermodynamic Model to Characterise Dissociating N_2O_4 at Vapour–Liquid Equilibrium States

Konstantin Samukov[1] · David Vega-Maza[2] · Eric W. Lemmon[3] · Vladimir Diky[3] · Silvia Lasala[1]

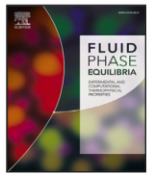
Received: 26 March 2025 / Accepted: 19 April 2025 / Published online: 10 May 2025

Fluid Phase Equilibria 594 (2025) 114356

Contents lists available at ScienceDirect

Fluid Phase Equilibria

journal homepage: www.sciencedirect.com/journal/fluid-phase-equilibria



Multiscale modeling of dimerization thermodynamics of formic acid

Dominika O. Wasik [a,b], Silvia Lasala [c,*], Olivier Herbinet [c], Konstantin Samukov [c], Sofía Calero [a,b], Thijs J.H. Vlugt [d,*]

[a] Materials Simulation and Modelling, Department of Applied Physics, Eindhoven University of Technology, 5600MB Eindhoven, The Netherlands
[b] Eindhoven Institute for Renewable Energy Systems, Eindhoven University of Technology, PO Box 513, Eindhoven 5600 MB, The Netherlands
[c] Université de Lorraine, CNRS, LRGP, F-54000 Nancy, France
[d] Engineering Thermodynamics, Process & Energy Department, Faculty of Mechanical, Maritime and Materials Engineering, Delft University of Technology, Leeghwaterstraat 39, Delft 2628CB, The Netherlands

Fluid Phase Equilibria 582 (2024) 114084

Contents lists available at ScienceDirect

Fluid Phase Equilibria

journal homepage: www.sciencedirect.com/journal/fluid-phase-equilibria

Scaling towards the critical point in the combined reaction/Gibbs ensemble

H. Mert Polat [a], Silvia Lasala [b], Frédérick de Meyer [c,d], Céline Houriez [d], Othonas A. Moultos [a], Thijs J.H. Vlugt [a,*]

[a] Engineering Thermodynamics, Process & Energy Department, Faculty of Mechanical Engineering, Delft University of Technology, Leeghwaterstraat 39, Delft 2628CB, The Netherlands
[b] Université de Lorraine, Laboratoire Réactions et Génie des Procédés, 54000 Nancy, France
[c] CO_2 and Sustainability R&D Program, Gas & Low Carbon Entity, OneTech, TotalEnergies S.E., 92078 Paris, France
[d] Mines Paris, PSL University, Center for Thermodynamics of Processes (CTP), 77300 Fontainebleau, France

REACHER: The methodology

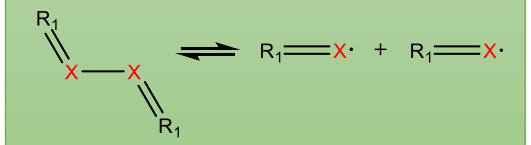
1. Discovery of suitable reactions and their characterization

For power, heating and cooling applications

Reaction search & design → Kinetics and thermochemistry assess. → Thermodynamic properties → Further characterization

Search of existing dimerization reactions

Design of new reactants (dimers) and relative products (monomers)



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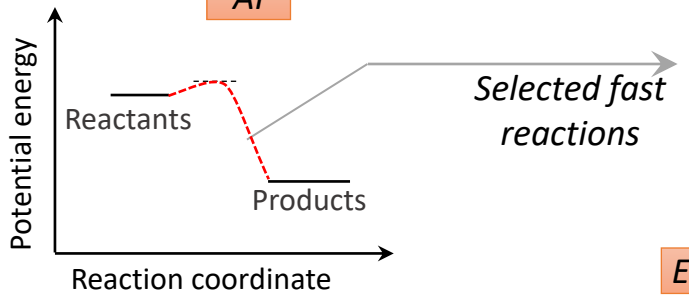
Enthalpy and entropy of reaction
Ideal gas heat capacity

Quantum Mechanics

AI



Selected fast reactions

Thermodynamic basic properties of pure components (Tc, Pc, ω)

Monte Carlo *AI*

Full thermodynamic characterisation of the reactive mixture (ρ, VLE, h, s, ...)

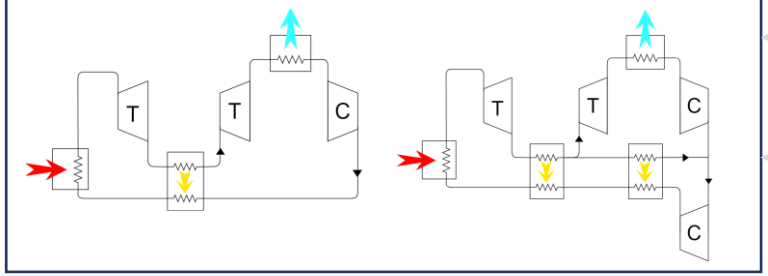
Equations of state *Monte Carlo*

Safety Features

Environmental properties

2. Cycle's architecture design

i-th reaction → Optimal efficiency → ***i-th* optimal cycle architecture**



Predictive thermodynamic calculation tool

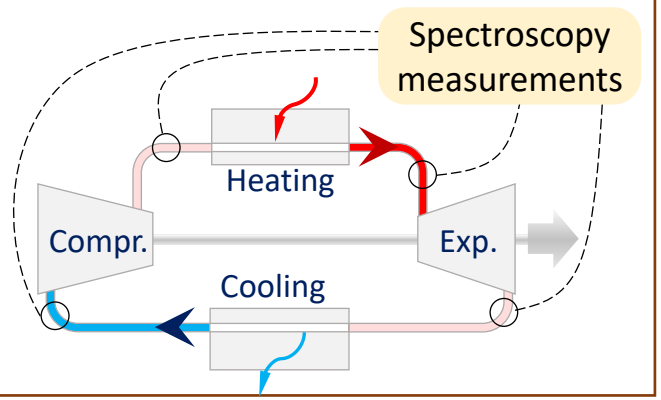
Reactive fluids equilibrium properties

Themodynamic transformations

3. Experimental validation

Power plant

CO_2 + reactive fluid



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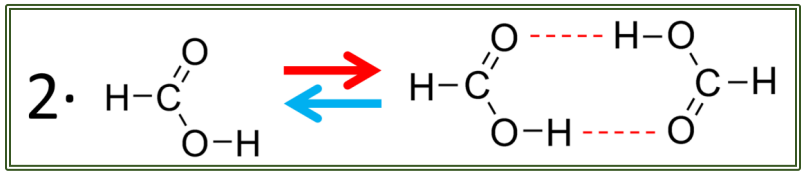

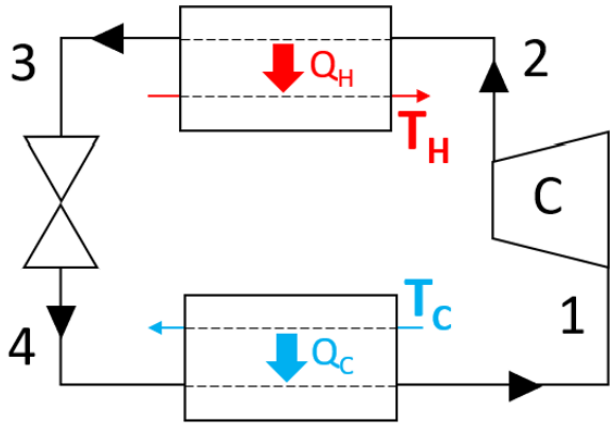

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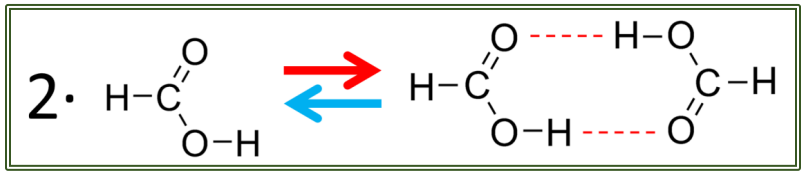
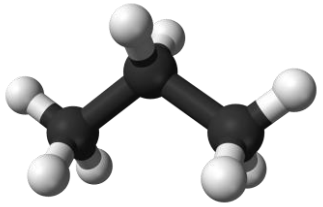
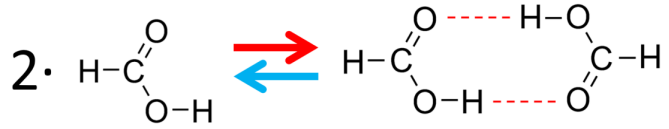


Domestic HP

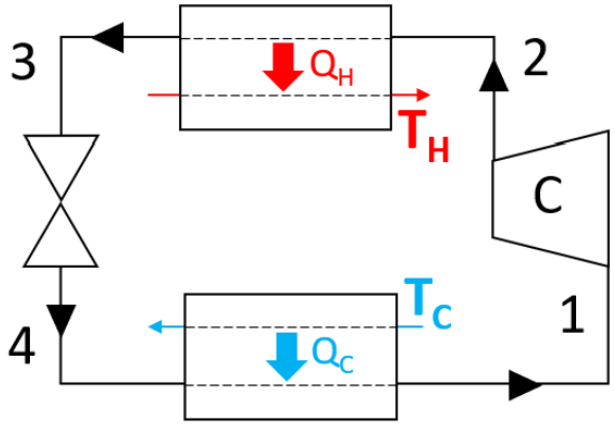
Propane



Formic acid



Industrial HP



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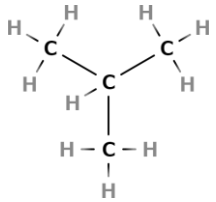
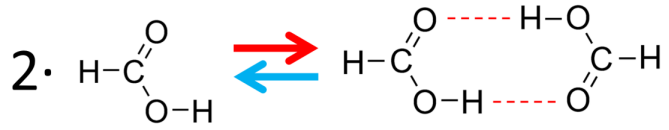


Formic acid



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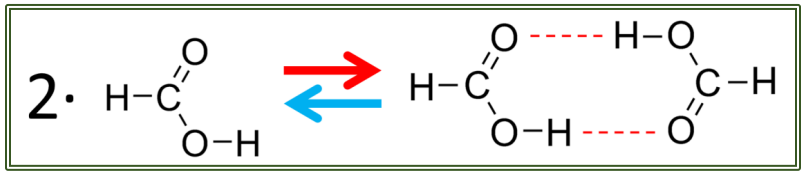
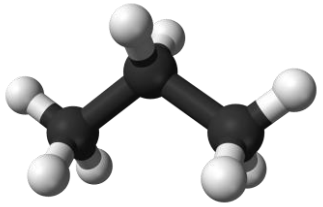
Formic acid:



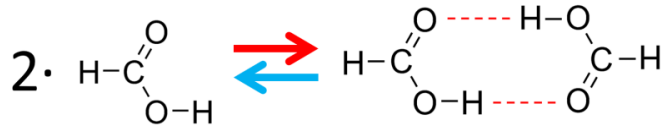
Domestic HP

Propane

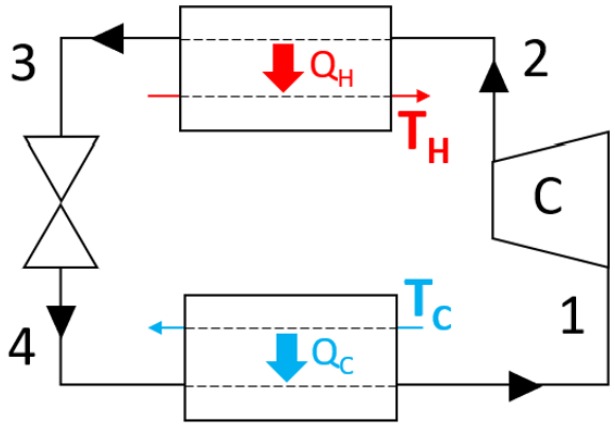


$$\frac{COP}{COP_{max}} = 41\%$$

Formic acid

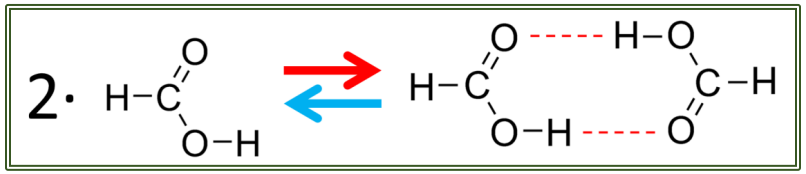


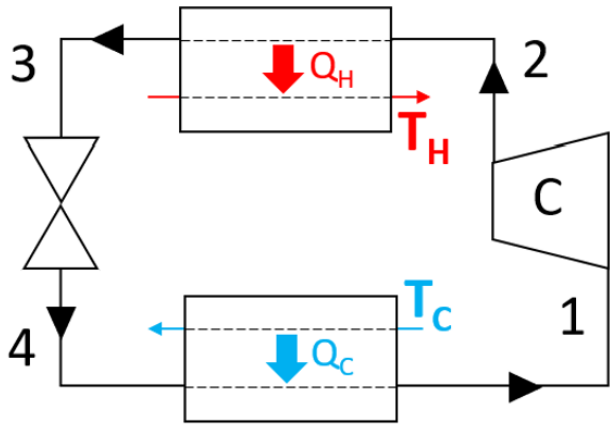
$$\frac{COP}{COP_{max}} = 52\%$$



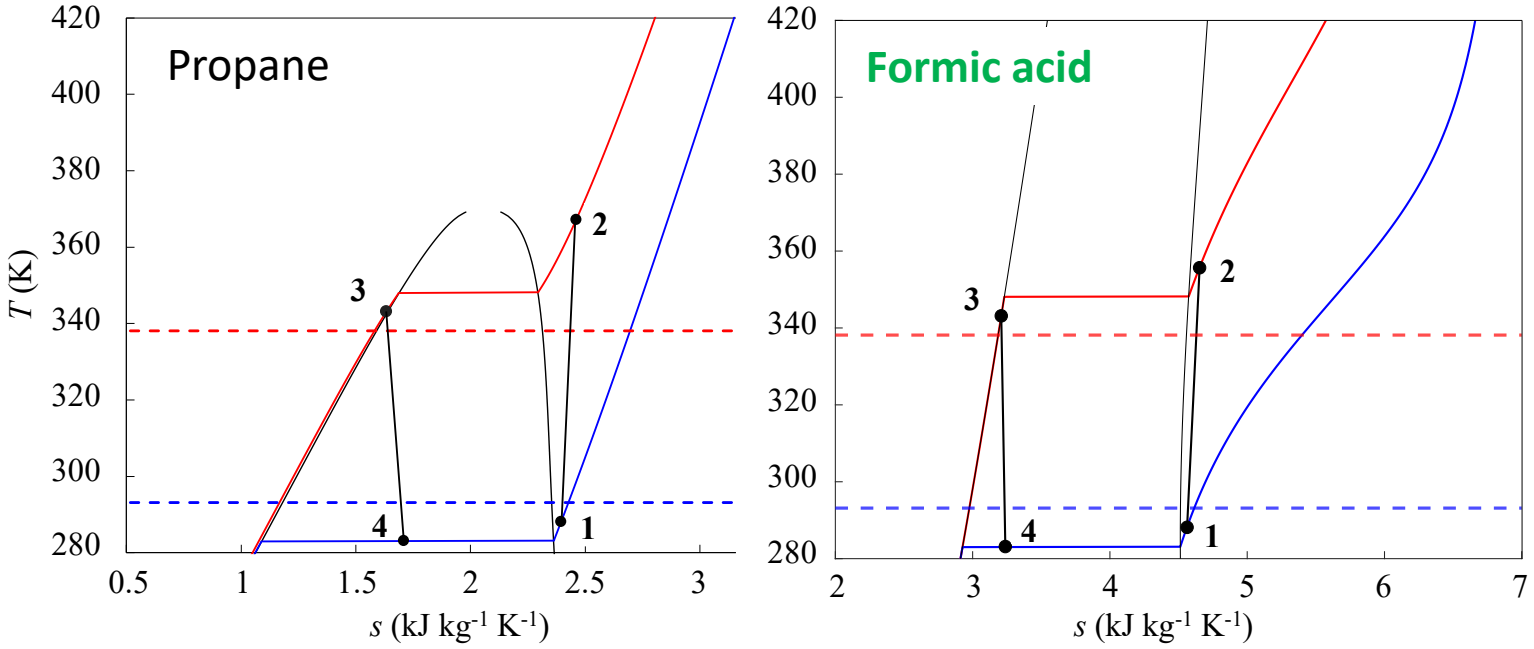
2. Heat Pump modelling

Formic acid:





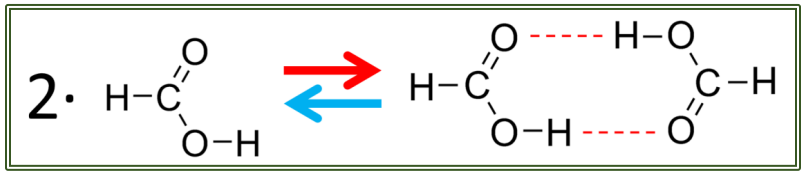
Domestic HP

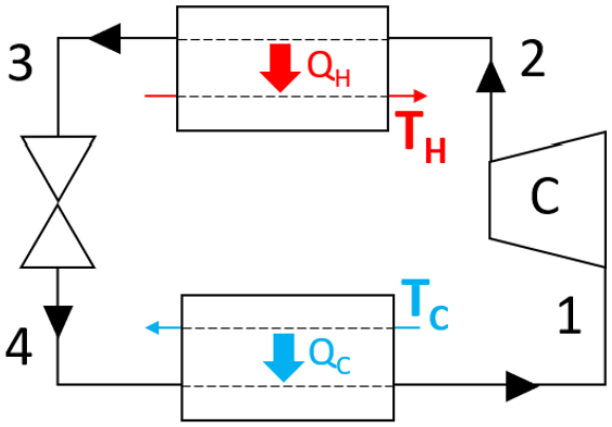


$$\frac{COP}{COP_{max}} = 41\% \quad \Rightarrow \quad \frac{COP}{COP_{max}} = 52\%$$

2. Heat Pump modelling

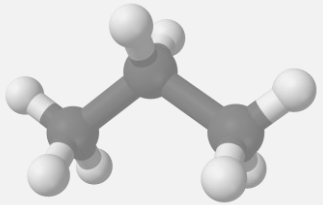
Formic acid:





Domestic HP

Propane



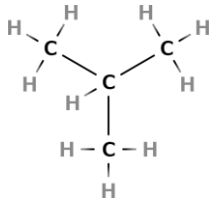
$$\frac{COP}{COP_{max}} = 41\%$$

Formic acid

$$\frac{COP}{COP_{max}} = 52\%$$

Industrial HP

R1233zd(E)



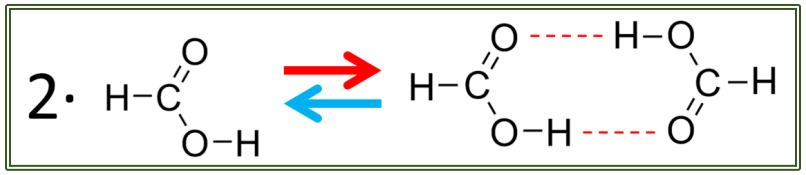
$$\frac{COP}{COP_{max}} = 34\%$$

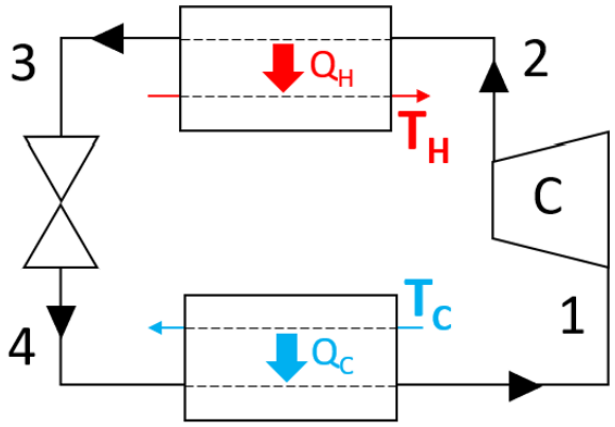
Formic acid

$$\frac{COP}{COP_{max}} = 50\%$$

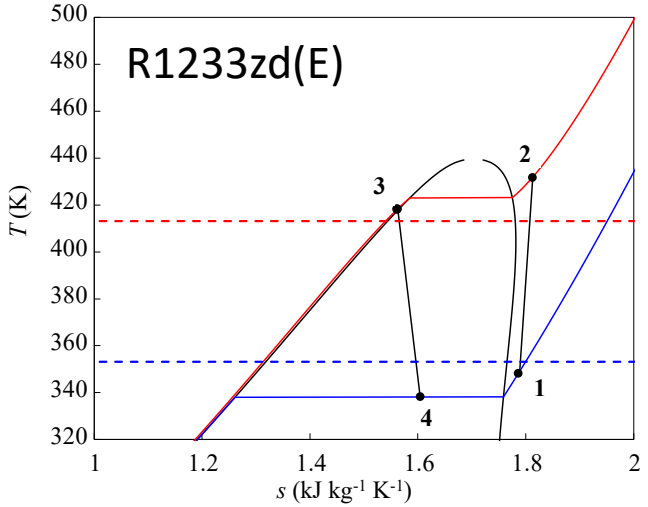
2. Heat Pump modelling

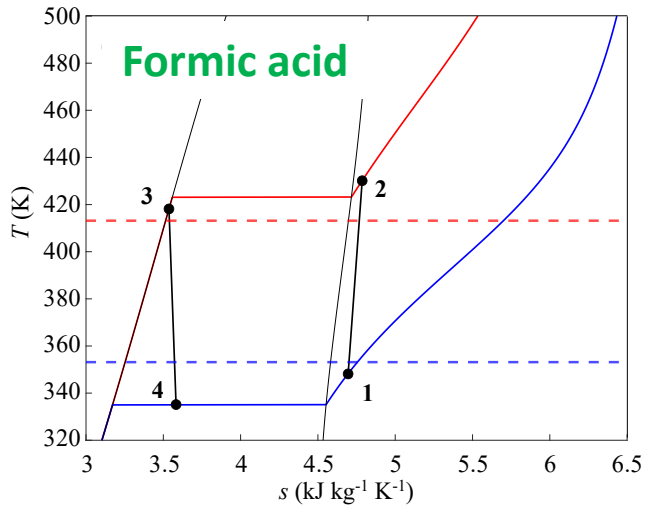
Formic acid:

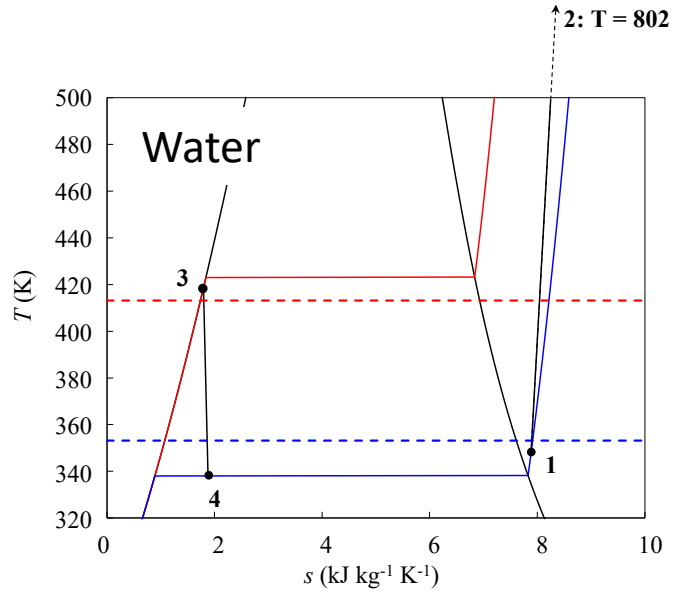




Industrial HP







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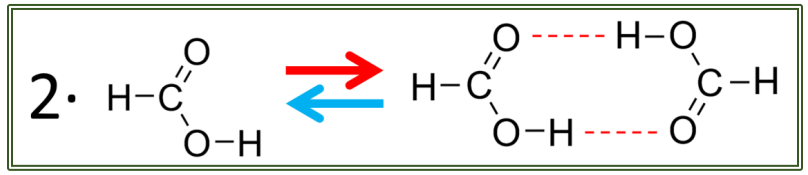
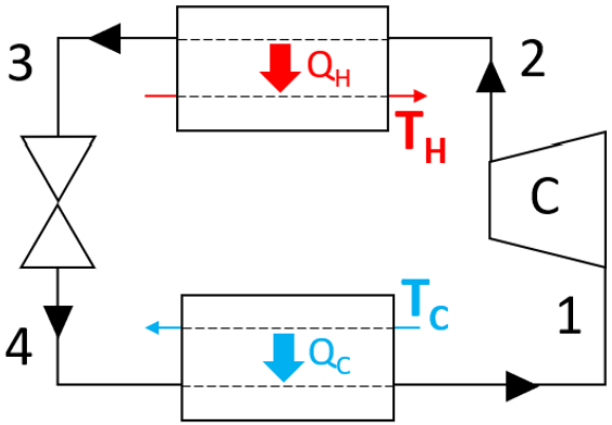
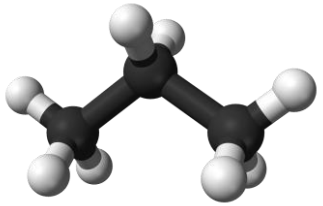




Domestic HP

Propane



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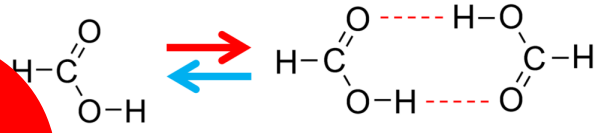
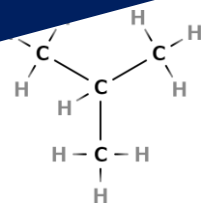


$$\frac{COP}{COP_{max}} = 52\%$$

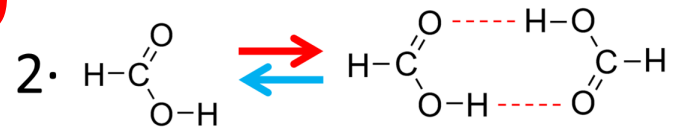
Why so efficient?

Industrial HP



$$\frac{COP}{COP_{max}} = 34\%$$

Formic acid



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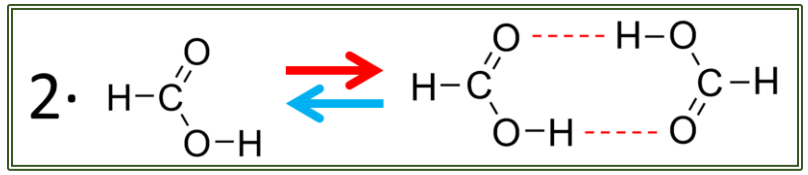
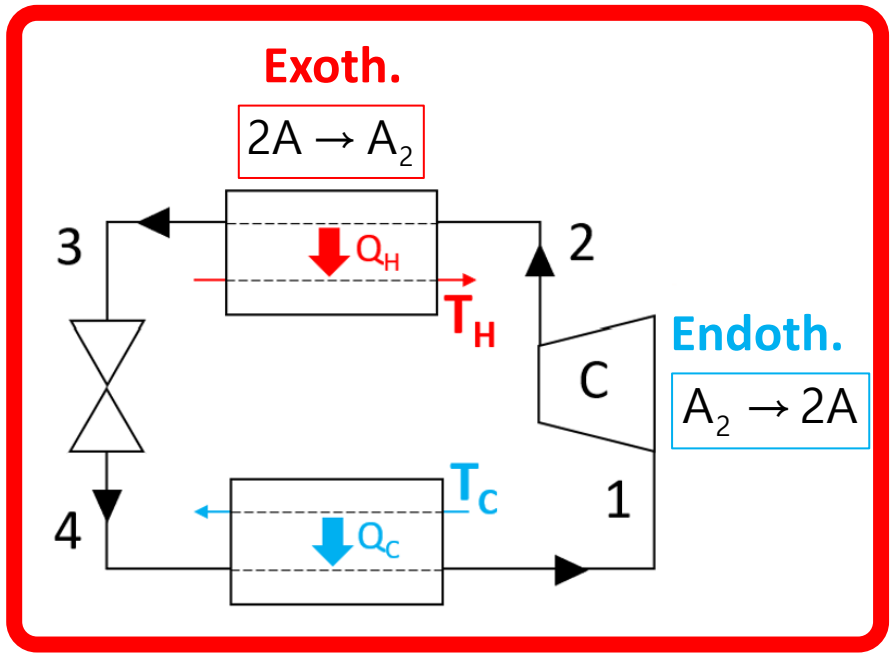
2. Heat Pump modelling

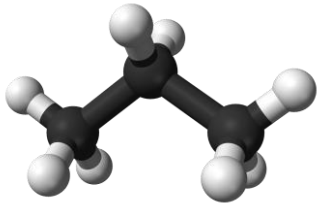
Formic acid:





Domestic HP

Propane



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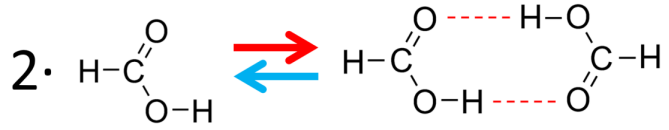

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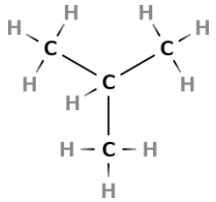
Industrial HP

R1233zd(E)



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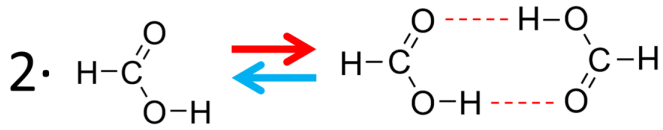

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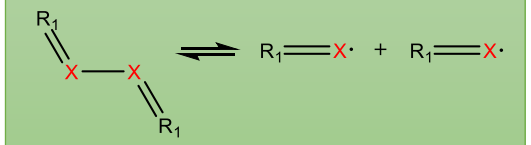

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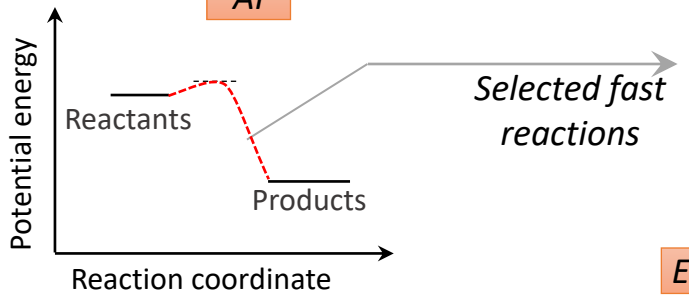

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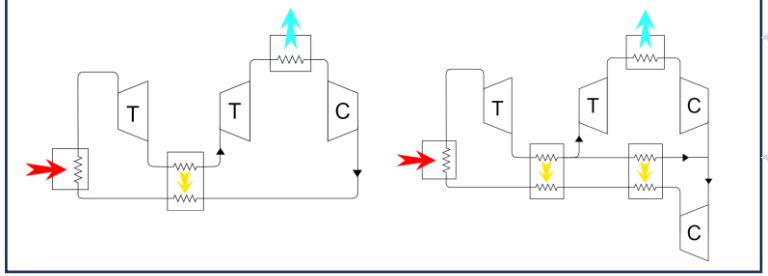

Predictive thermodynamic calculation tool

Reactive fluids equilibrium properties

Themodynamic transformations

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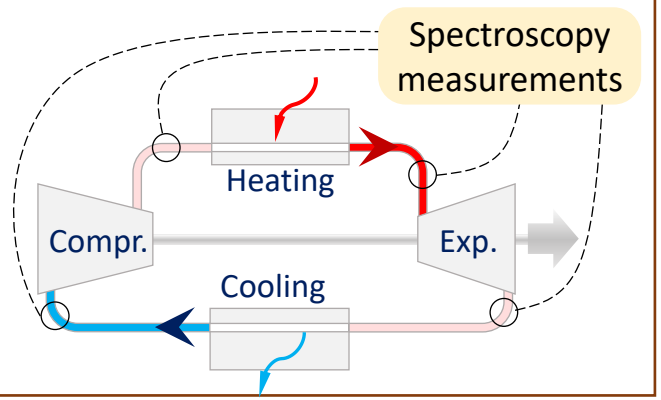
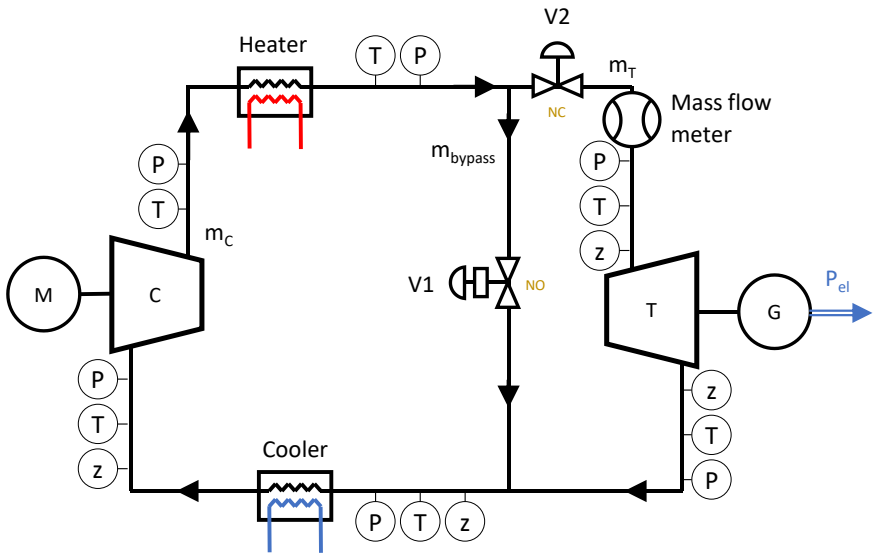
Power plant

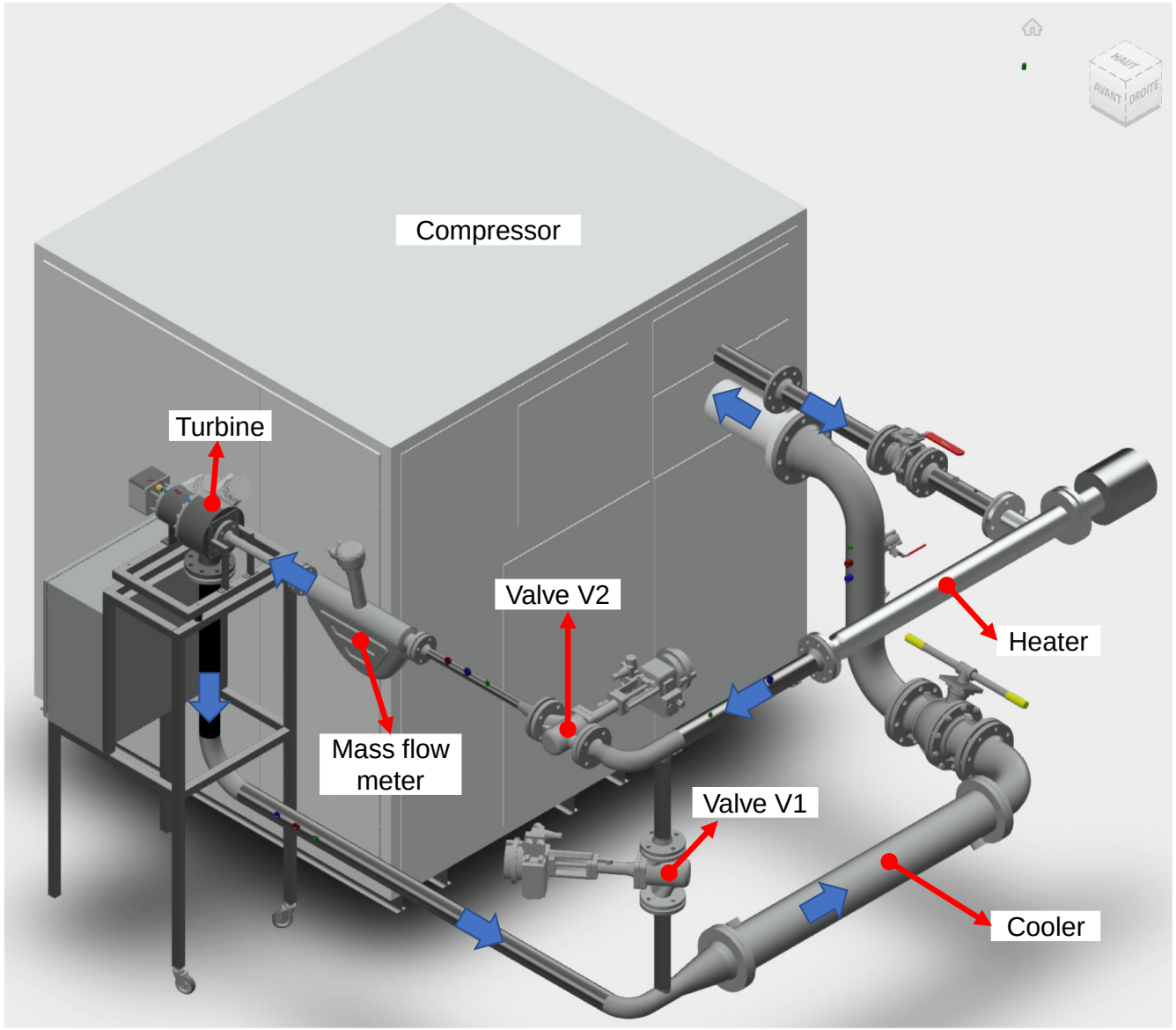
CO_2 + reactive fluid



3. Experimental validation

Pel, turbine = 3.5 kW
Tmax = 180 °C
Pmax = 4.5 bar
Pmin = 1.5 bar



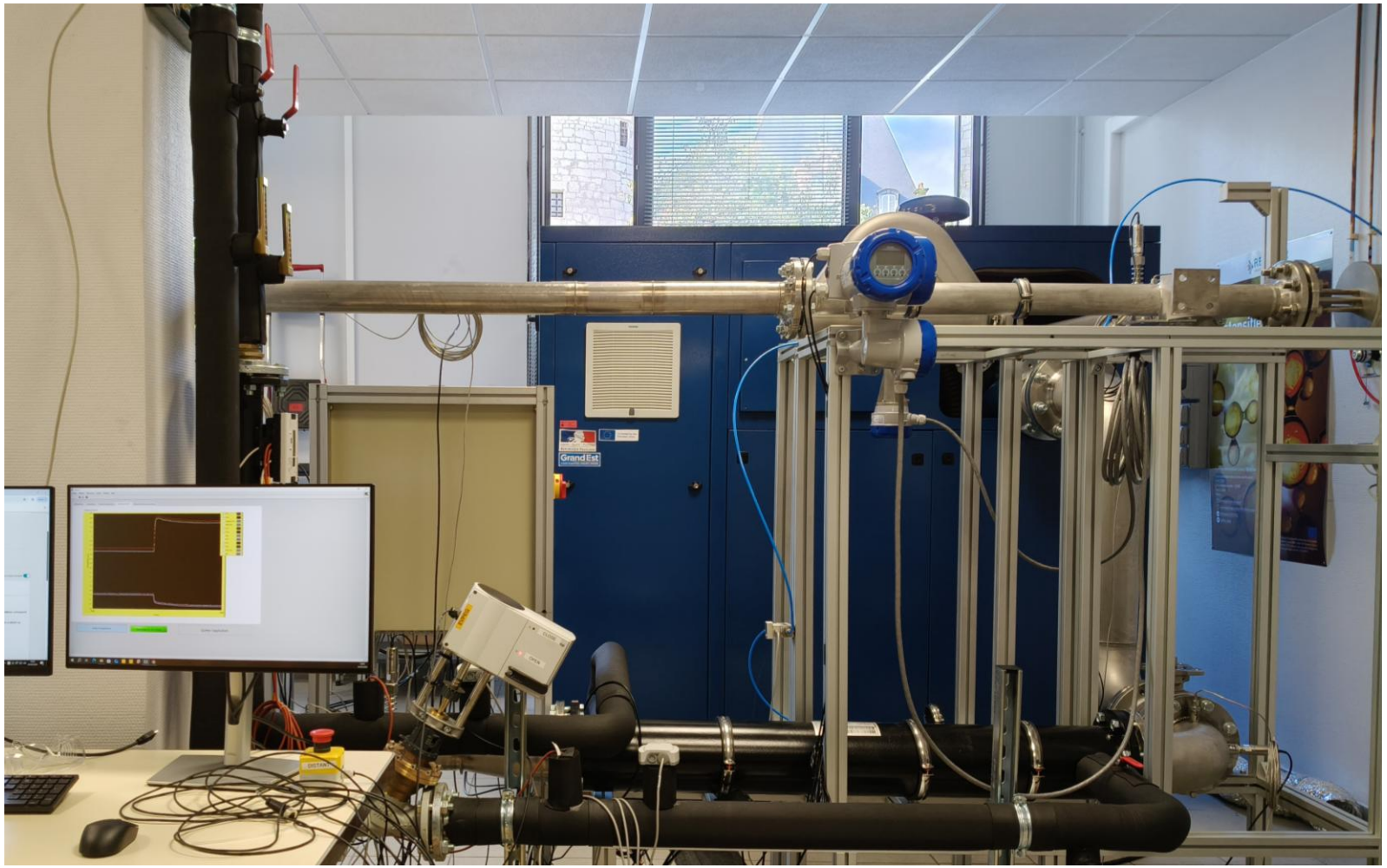


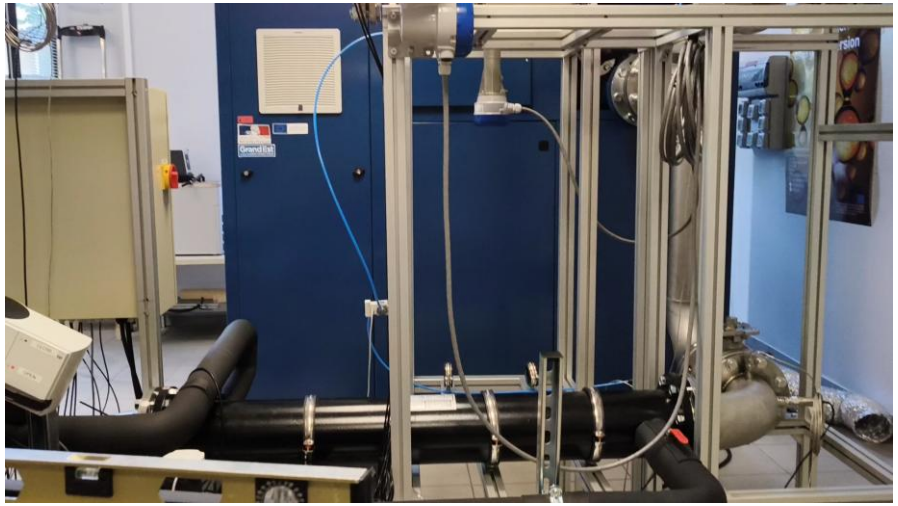
Not so easy …

- Compressor selection
- Handle with compressor leakages
- Design of the injection system (to re-integrate leakages)
- Turbine start-up
- …

But it works!

3. Experimental validation





Towards higher TRLs
2024 - 2029

This work has received funding from the **European Research Council** (ERC) under the European Union's Horizon Europe research and innovation program (grant agreements No. 101040994 -REACHER- and No. 101213389 -CREATIVE), and from the **Agence Nationale de la Recherche**, within the framework of the French 2030 national research strategy, within the research project REHEAT - ANR-24-PESP-0009.

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L. Cruz, N. Hossaini,
O. Herbinet, R. Bounaceur,
LRGP services,
S. Lasala

Collaborations or regular presentations to the industry

BDR THERMEA GROUP

NEXT engineering

arabelle solutions EDF GROUP

Air Liquide

TotalEnergies

AlliA IWF GROUP COMPANY

ENGIE

NUCLEAR Valley
FEDERER LES ENERGIES

CERTIFICAT DE LABELLISATION
LABELLING CERTIFICATE

SPARTA | Utilisation de fluides réactifs au secondaire

Date de délivrance : 12/07/2023
Date of issue : 07/12/2023

Numéro de certificat : CL252NV12072023
Certificate number : CL252NV12072023

Le Comité de Labellisation de NUCLEAR VALLEY délivre son LABEL au projet « SPARTA | Utilisation de fluides réactifs au secondaire » sur la base du contenu technique mis à disposition et de la soutenance effectuée devant le Conseil Scientifique, qui s'est réuni le 12 juillet 2023.
Based on the technical content provided and on the presentation made to the Scientific Advisory Board, during its meeting held on July, 12th, 2023, the NUCLEAR VALLEY Labelling Committee grants its LABEL to the "SPARTA | Utilisation de fluides réactifs au secondaire" project.

Label NUCLEAR Valley

Pour le Comité de Labellisation,
For and on behalf of the NUCLEAR VALLEY Labelling Committee,

Colacicco

Myriam COLACICCO
Présidente du Conseil Scientifique

Marianne SECHERESSE
Présidente du Comité de Labellisation

Towards higher TRLs

Reactive fluids for industrial heat pumps

Reactive fluids for residential heat pumps

Reactive fluids for power plants

Towards higher TRLs

Reactive fluids for industrial heat pumps

FRANCE 2030 – PROGRAMME DE RECHERCHE – DÉCARBONATION DE L'INDUSTRIE

PEPR SPLEEN

REHEAT

2025 - 2029

TRL1 → **TRL4**

1.5 M€

Reactive fluids for residential heat pumps

Reactive fluids for power plants

cnrs – UNIVERSITÉ DE LORRAINE – Université Gustave Eiffel – UCA Université Clermont Auvergne – MINES PARIS | PSL

Towards higher TRLs

Reactive fluids for industrial heat pumps

PROGRAMME DE RECHERCHE FRANCE 2030 DÉCARBONATION DE L'INDUSTRIE

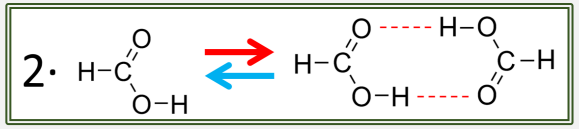
PEPR SPLEEN

REHEAT

2025 - 2029

TRL1 → **TRL4**

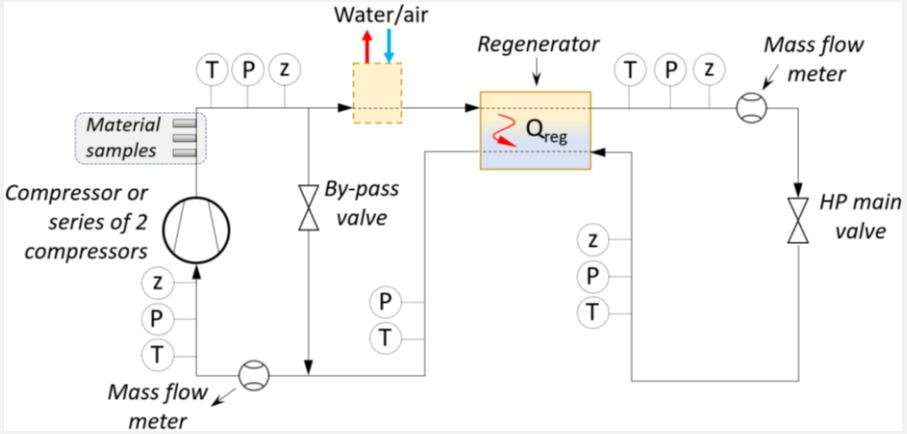
1.5 M€



Corrosion

Thermophysical properties measurement

Development of a high temperature HP prototype



T_H = 120 °C
COP = 50% COP_{max}

→

T_H = 140 °C
COP = 70% COP_{max}

Reactive fluids for residential heat pumps

Reactive fluids for power plants

cnrs · UNIVERSITÉ DE LORRAINE · Université Gustave Eiffel · UNIVERSITÉ Clermont Auvergne · MINES PARIS | PSL

Towards higher TRLs

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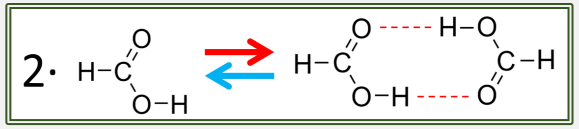

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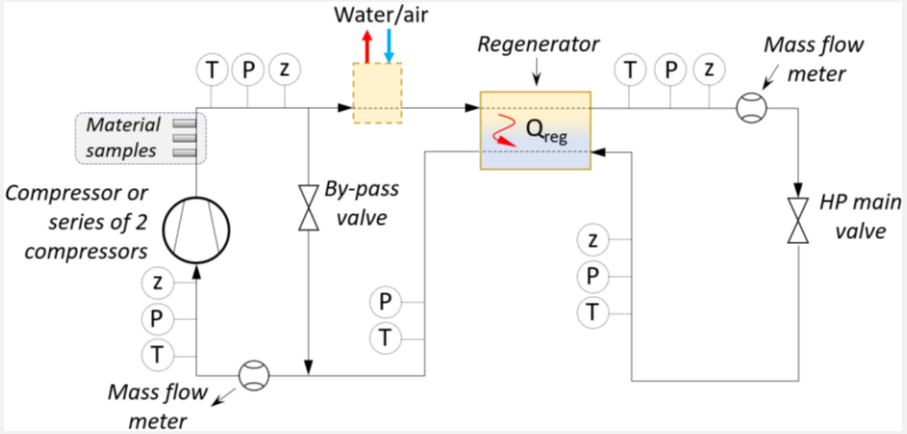

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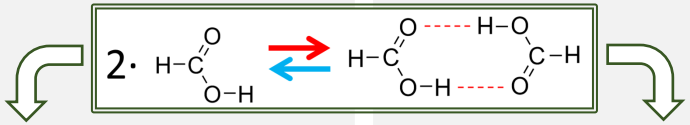

Reactive fluids for power plants

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Towards higher TRLs

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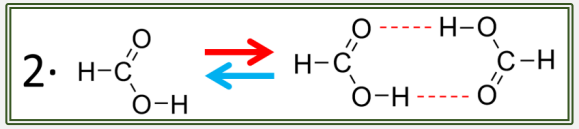

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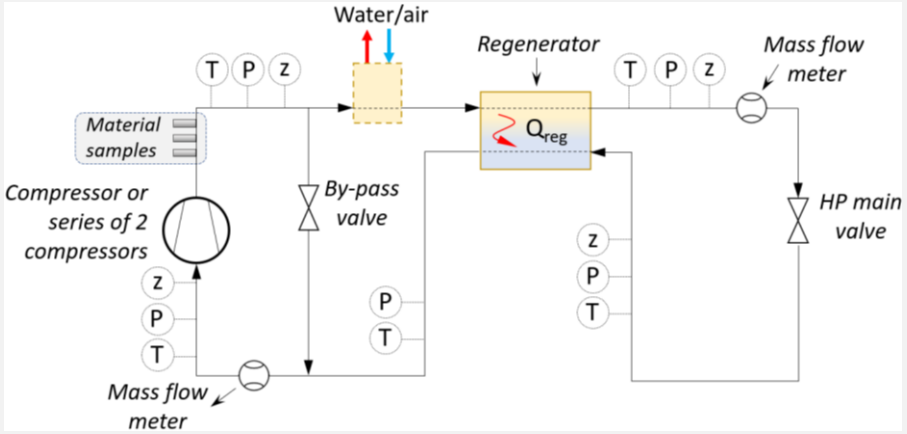

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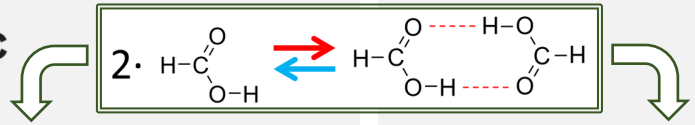
Reactive fluids for residential heat pumps

Proof-of-Concept



CREATIVE

2025 - 2026

TRL1 → **TRL3**

150 k€

Development of a compressor train for a formic acid heat pump

SAYENS SATT CATALYSEUR D'INNOVATIONS

Reactive fluids for power plants

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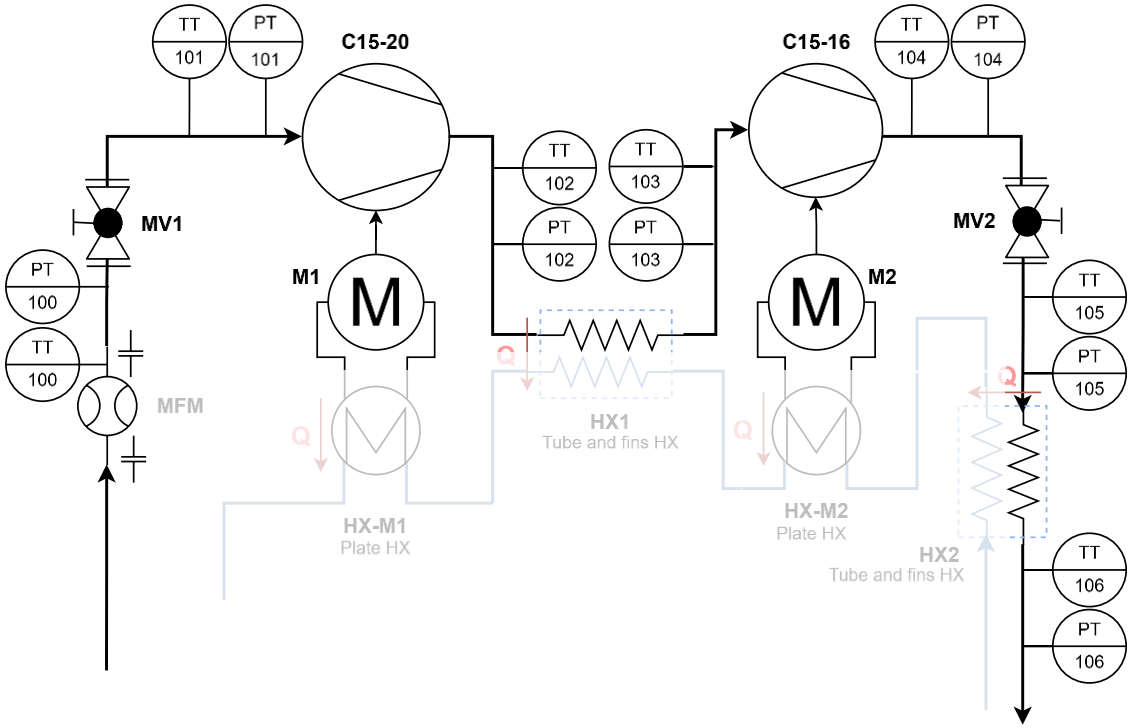
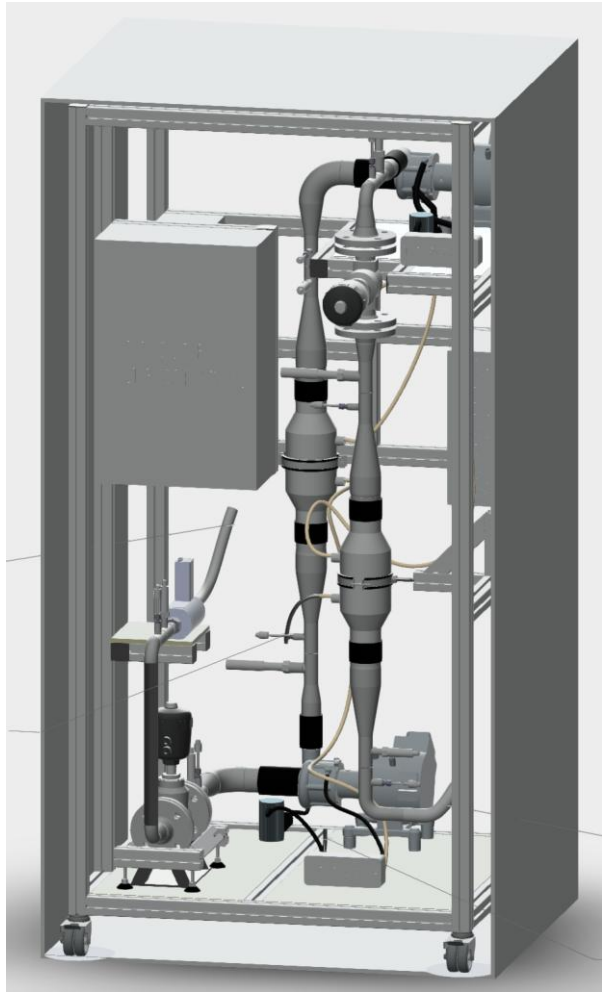
CREATIVE

2025-2026
ERC Proof of Concept

Development of a **compressor train** for a formic acid residential heat pump





SolvHeat

Towards higher TRLs (2024-2029)

Reactive fluids for industrial heat pumps

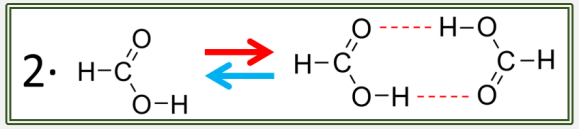
PEPR SPLEEN

REHEAT

2025 - 2029

TRL1 → **TRL4**

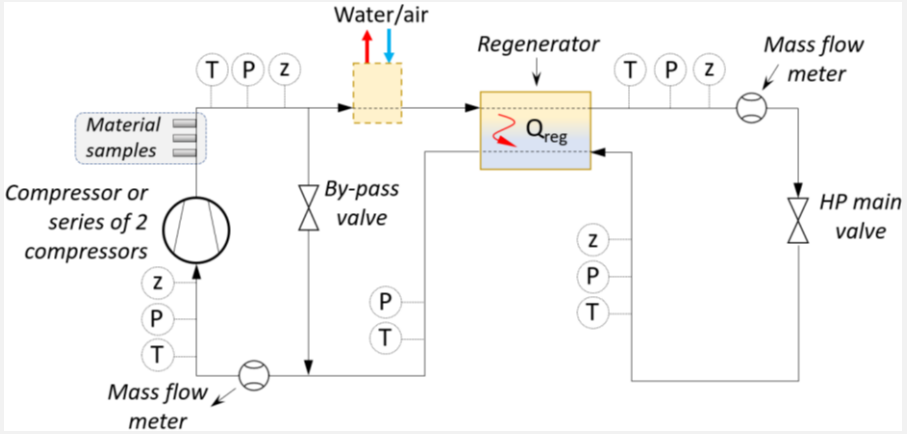
1.5 M€



Corrosion

Thermophysical properties measurement

Development of a high temperature HP prototype



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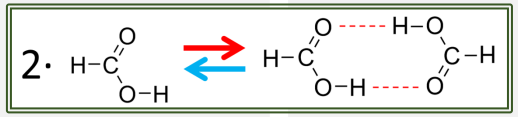
Reactive fluids for residential heat pumps

Proof-of-Concept

CREATIVE



2025 - 2026

TRL1 → **TRL3**

150 k€

Development of a compressor for reactive fluids

SmartFluids

2025 - 2029

TRL2 → **TRL6**

2 M€

Development of a residential HP prototype

BDR THERMEA GROUP

Reactive fluids for power plants

Towards higher TRLs (2024-2029)

Reactive fluids for industrial heat pumps

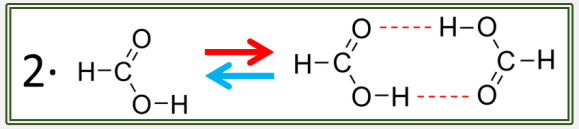
PEPR SPLEEN

REHEAT

2025 - 2029

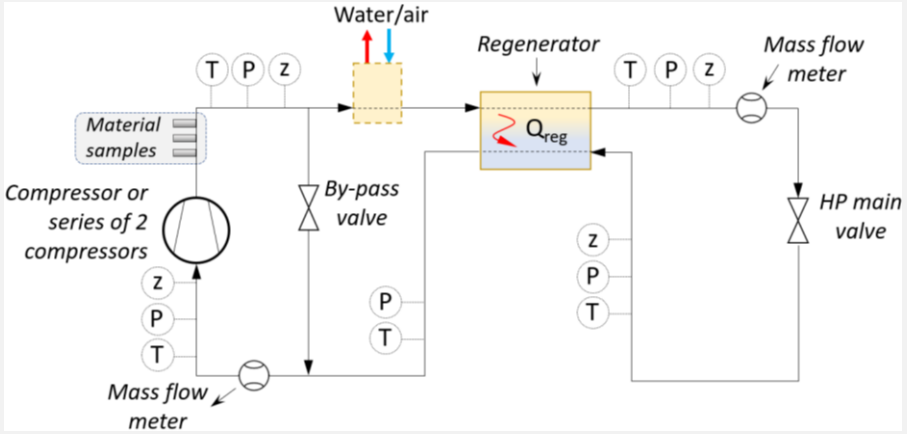
TRL1 → **TRL4**

1.5 M€



Corrosion | **Thermophysical properties measurement**

Development of a high temperature HP prototype



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Reactive fluids for residential heat pumps

Proof-of-Concept

CREATIVE

2025 - 2026

TRL1 → **TRL3**

150 k€

Development of a compressor for reactive fluids

SmartFluids

2025 - 2029

TRL2 → **TRL6**

2 M€

Development of a residential HP prototype

Reactive fluids for power plants

SPARTA

2024 - 2029

TRL4 → **TRL6**

10 M€

Development of a test bench and a demonstrator for a multi-use production plant operating with reactive fluids

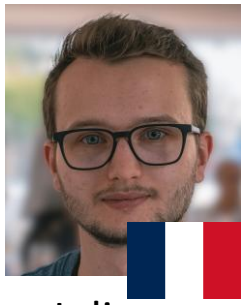
Luis Pinilla

Aya Barakat

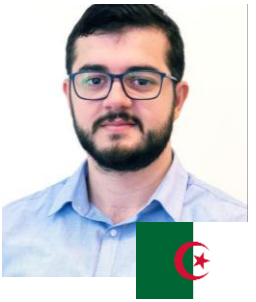
Konstantin Samukov

Marivone Kebou

Soufiane Khaddadi



Julien Joliat



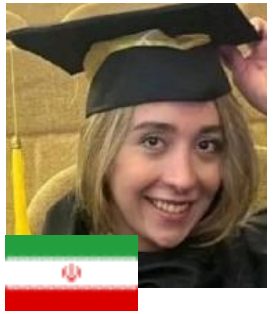
Rachid Hadjadj

Sérgio Vilas Boas

The team

Andrea Negrotto Cambiaso

Ivan Velazquez



Niayesh Hosseini Farahani

Lisseth Milena Cruz Ruiz

Thank you!

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Membre d'UNYS

LRGP cnrs

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