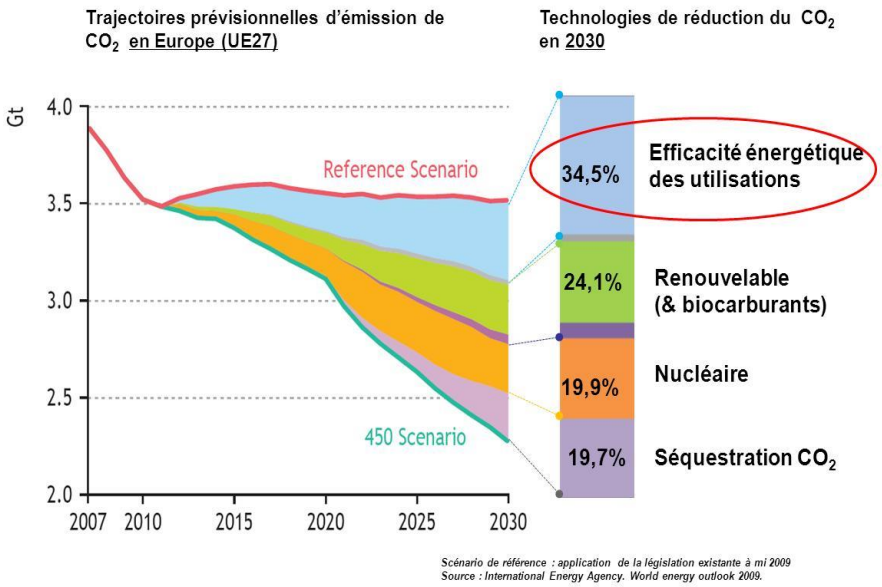
High temperature gas heat pumps to recover industrial waste heat

Julien DUCLOS, Philippe BUCHET
Dominique GOSSELIN

GDF SUEZ
ÊTRE UTILE AUX HOMMES

Industrial world Context: Main priorities focused on Energy efficiency & Heat recovery

- Energy and environmental context
  - ✓ Factor 4 – 450 ppm CO_2
  - ✓ European Energy- Climate targets: 3 x 20%
  - ✓ **Today's trend ➔ < 50 % of the EC 2020 target**
- Regulation Context
  - ✓ Energy management standards - ISO 50001
  - ✓ New operating permitting for industrial plants
  - ✓ National quotas CO_2 or White certificate allocations
  - ✓ New pollutants emissions values (NOx, SOx …cf EC BREF)
- Profitability of UE industries or ind. Plate-forms (Steel ind. Chemical ind. ….)
  - ✓ Energy prices ➔ Reduction of energy consumption
  - ✓ Sustainability of EC industries
  - ✓ Re-engineering of the energy master plans

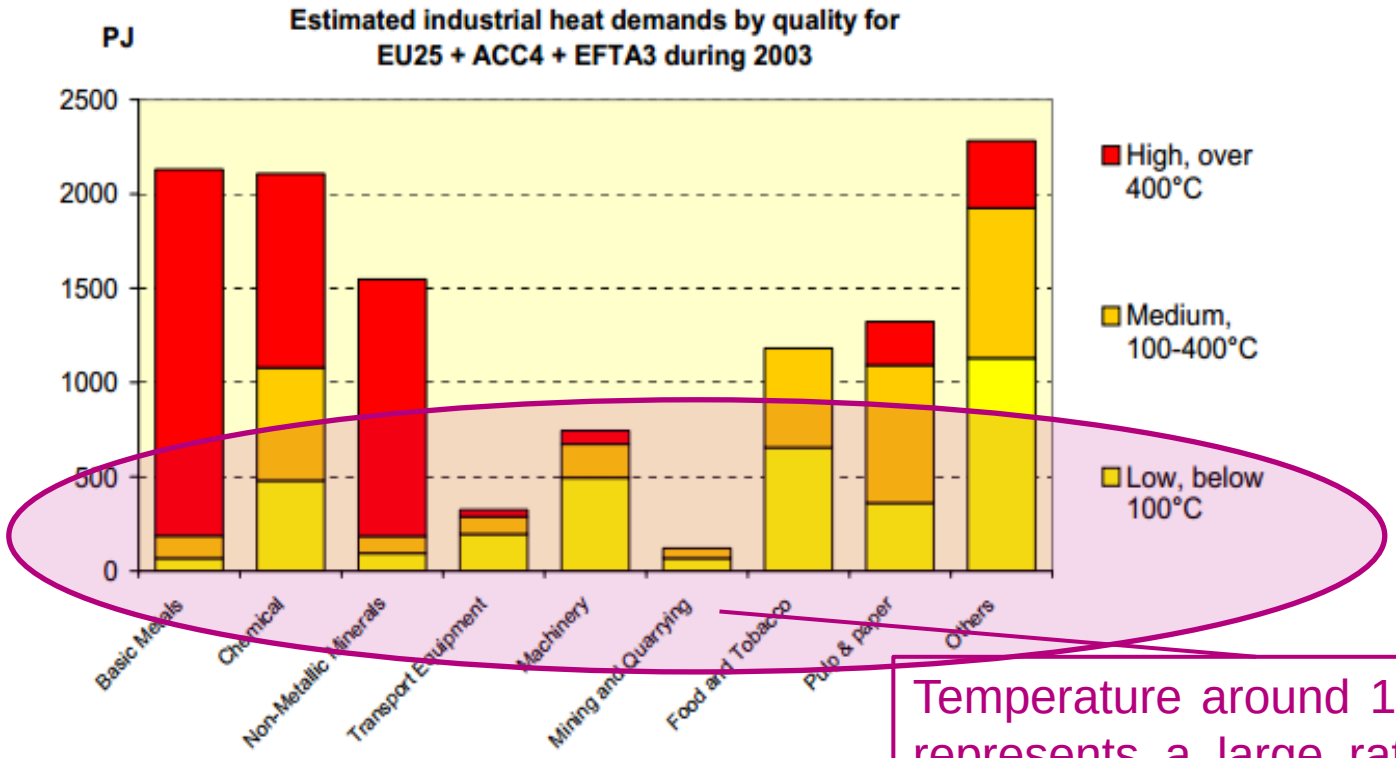


- **Average Energy efficiency of industrial System is ~60 - 65%**
- **Two types of Heat losses ~40% are :**
  - **High temperature Heat losses (>250°C) ~ 38% (*existing heat recovery solutions*)**
  - **Low Temp. Heat Losses (<250°C) ~12%**

- **Energy efficiency & heat recovery are main priorities and complementary**
- **Implementation high level of recovery needs specific Systems & territory approaches**

GDF SUEZ

Heat demand for the European industries



Source: EcoHeatCool project

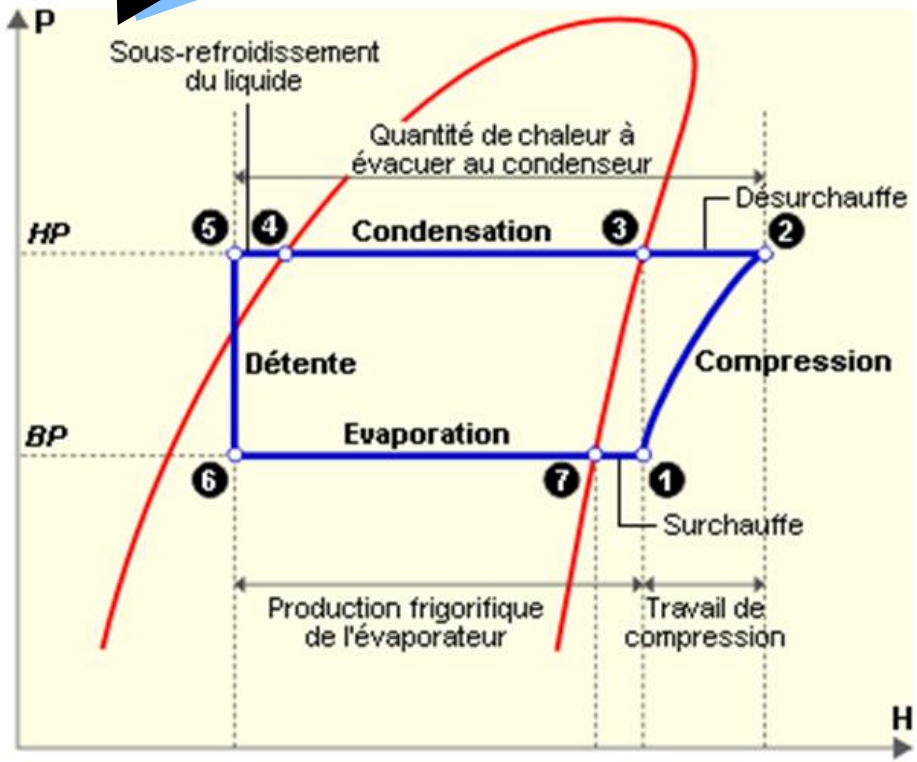
Temperature around 100-140°C represents a large ratio of the whole industry demand

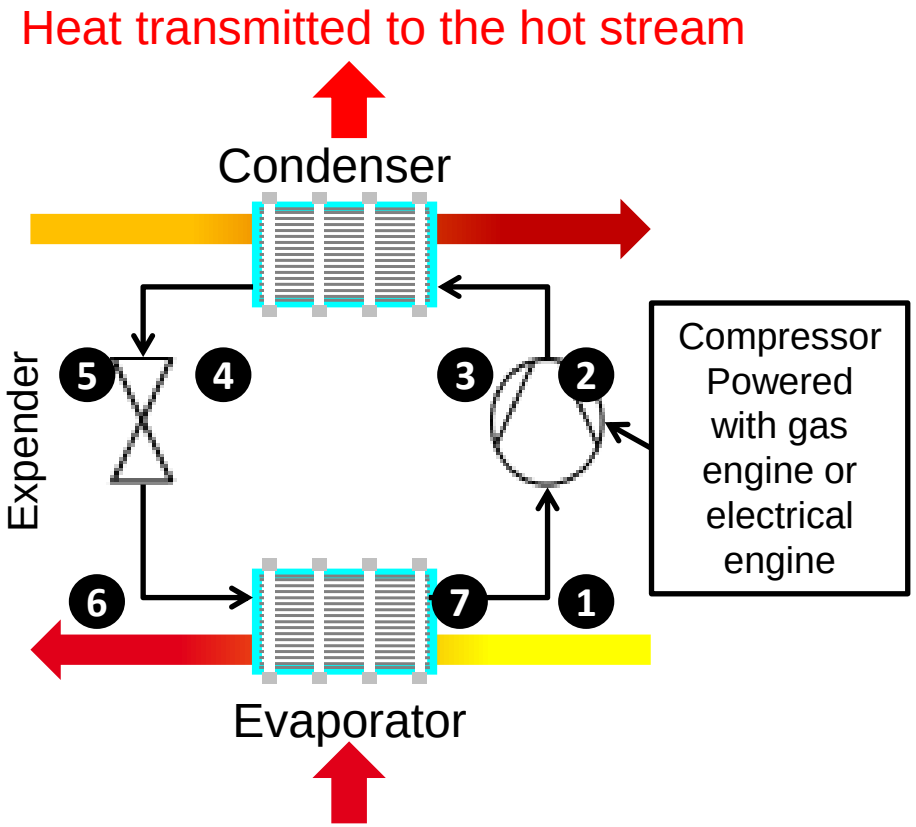
1MW< Power < 5 Mw

What technology to cover this energy demand through energy recovery on LTHL ?

~ No existing industrial solutions

Heat pump : One of the good candidate & basic principle



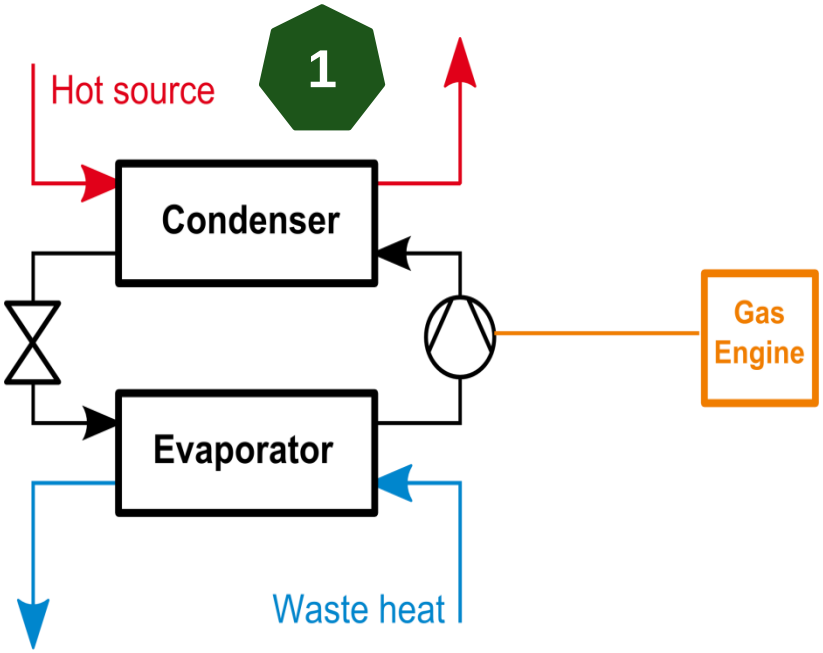


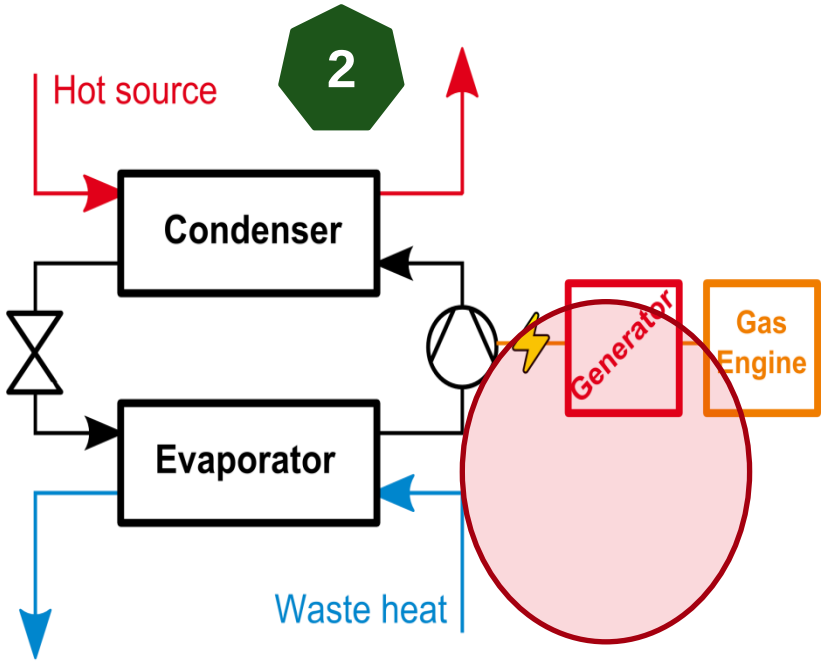
Mollier diagram (Heat pump cycle)

So Why not Gas Heat pumps ?

GDF Suez – natural gas heat pump design studied

Two configurations are under development





Direct (= mechanical) coupling

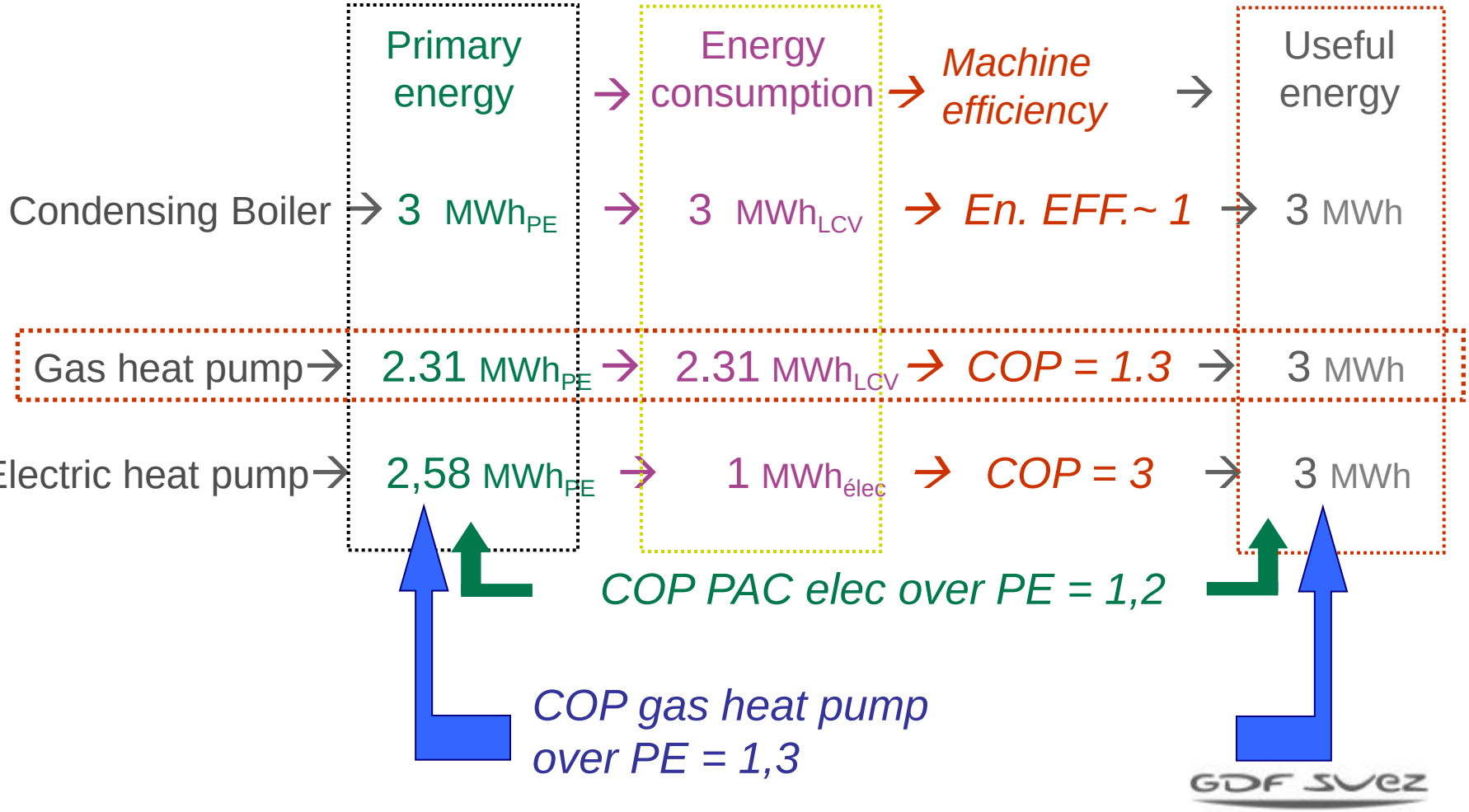
- Requires an open compressor
- Solution dedicated to NG
- Solution for large heat Pumps (P>3 MWth)

Generator system

- Half-open compressor, magnetic bearing elect. engine can also be used
- Mixte solution adapted to Smart managment of energy suplying
- Power Range ~ 1.5 MWth

GDF SUEZ

Interest of Gas heat pumps:
Primary energy consumption of gas heat pumps



Development of industrial Gas heat pump: First Setp: Which working fluid for high temperature gas heat pumps?

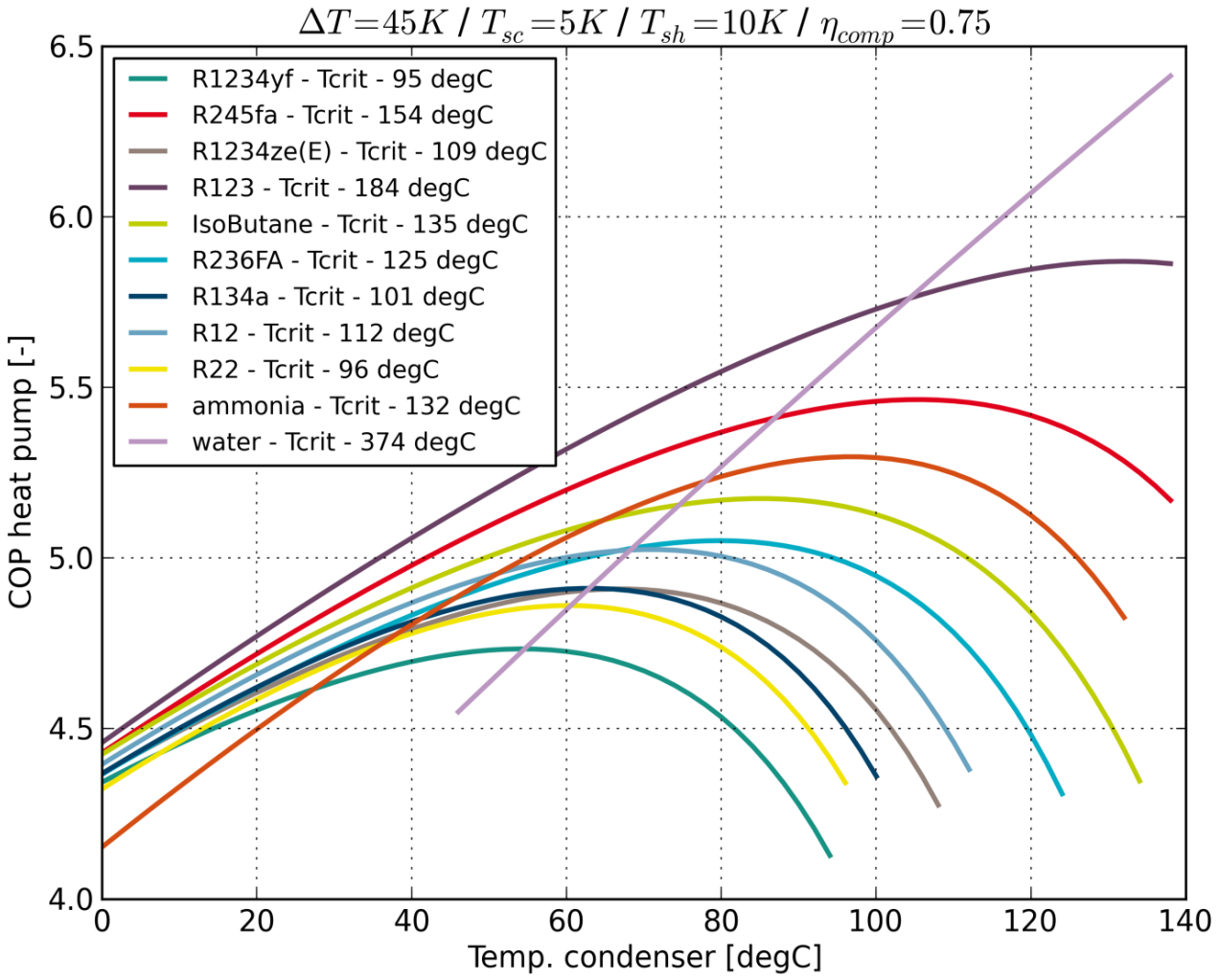
Type	ASHRAE number	Chemical Name	ODP	GWP	Critical temp. [°C]
HFC	R-134a	1,1,1,2-Tetrafluoroethane	0	1430	101.1
HFC	R-245fa	1,1,1,3,3-Pentafluoropropane	0	1030	154.1
HFO	R-1234yf	2,3,3,3-Tetrafluoropropene	0	4	94.7
HCFC	R-123	2,2-Dichloro-1,1,1-trifluoroethane	0.02	77	183.7
HC	R-600a	Isobutane	0	3	134.7
Natural	R-717	Ammonia	0	0	132.4

Calculation from the open source library Coolprop

- The refrigerant has to offer the best energy performance, the lowest cost, the lowest impact on environment and to guarantee the safety of the machines
- Optimal COP is obtained for a condensation temperature of the fluid lower than around 30°C of the critical temperature

GDF SUEZ

First step: Mechanical COP vs various fluids

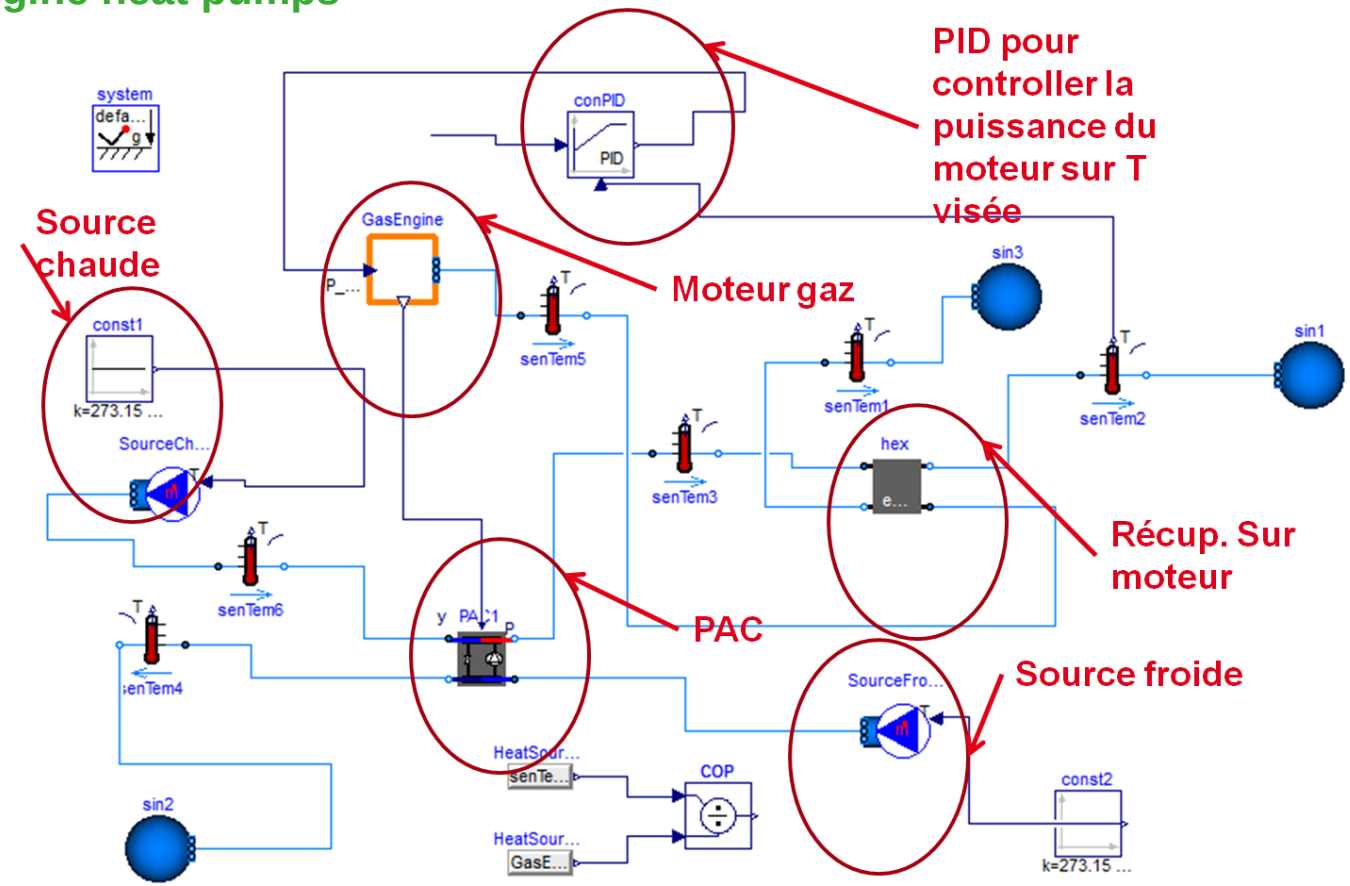


CRIGEN calculations

Second Step: Energy integration of a gas heat pump into industrial process

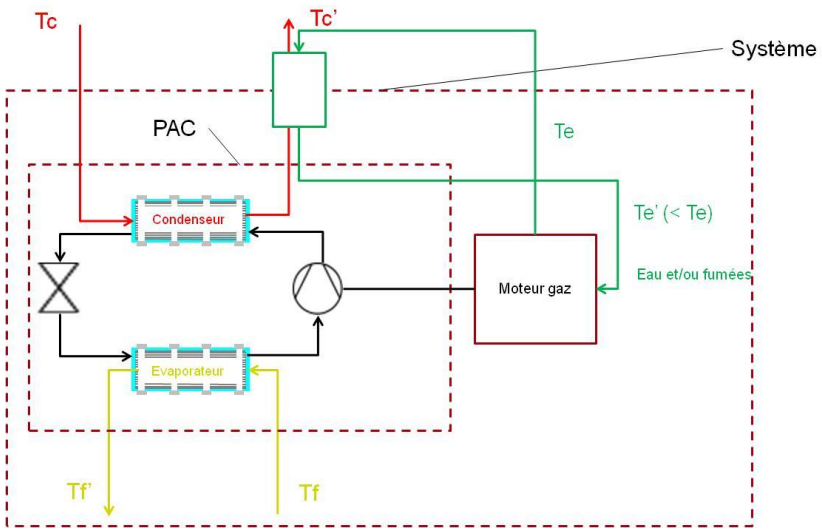
A new GDF Suez model to calculate performances

➔ **The model helps to determine the best configuration between various gas engine heat pumps**

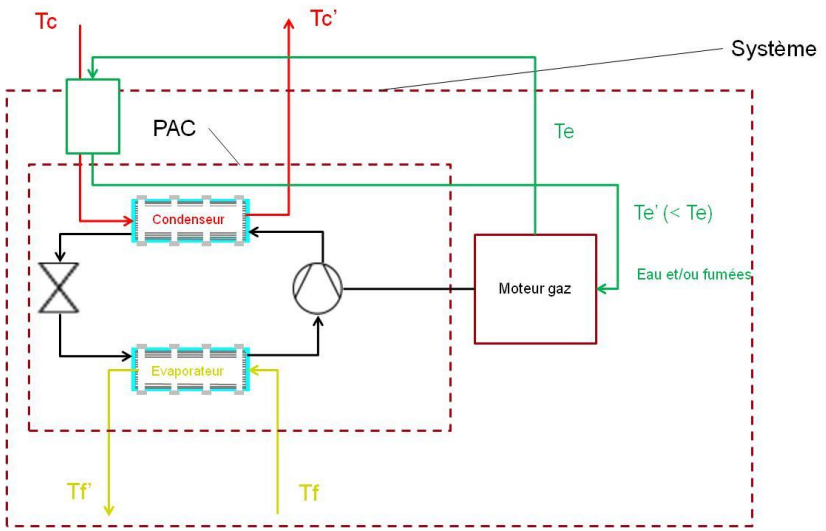


Examples of options to recover heat energy from the NG engine

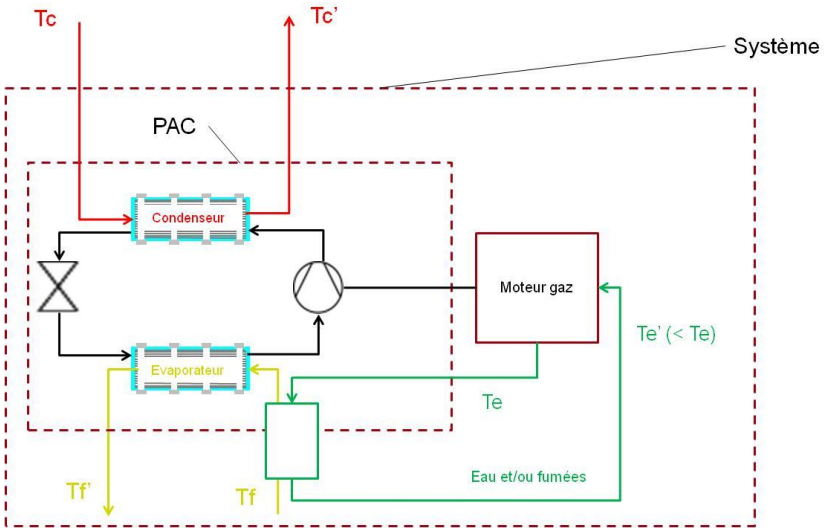
Config 2 (direct) – option 1



Config 2 (direct) – option 2

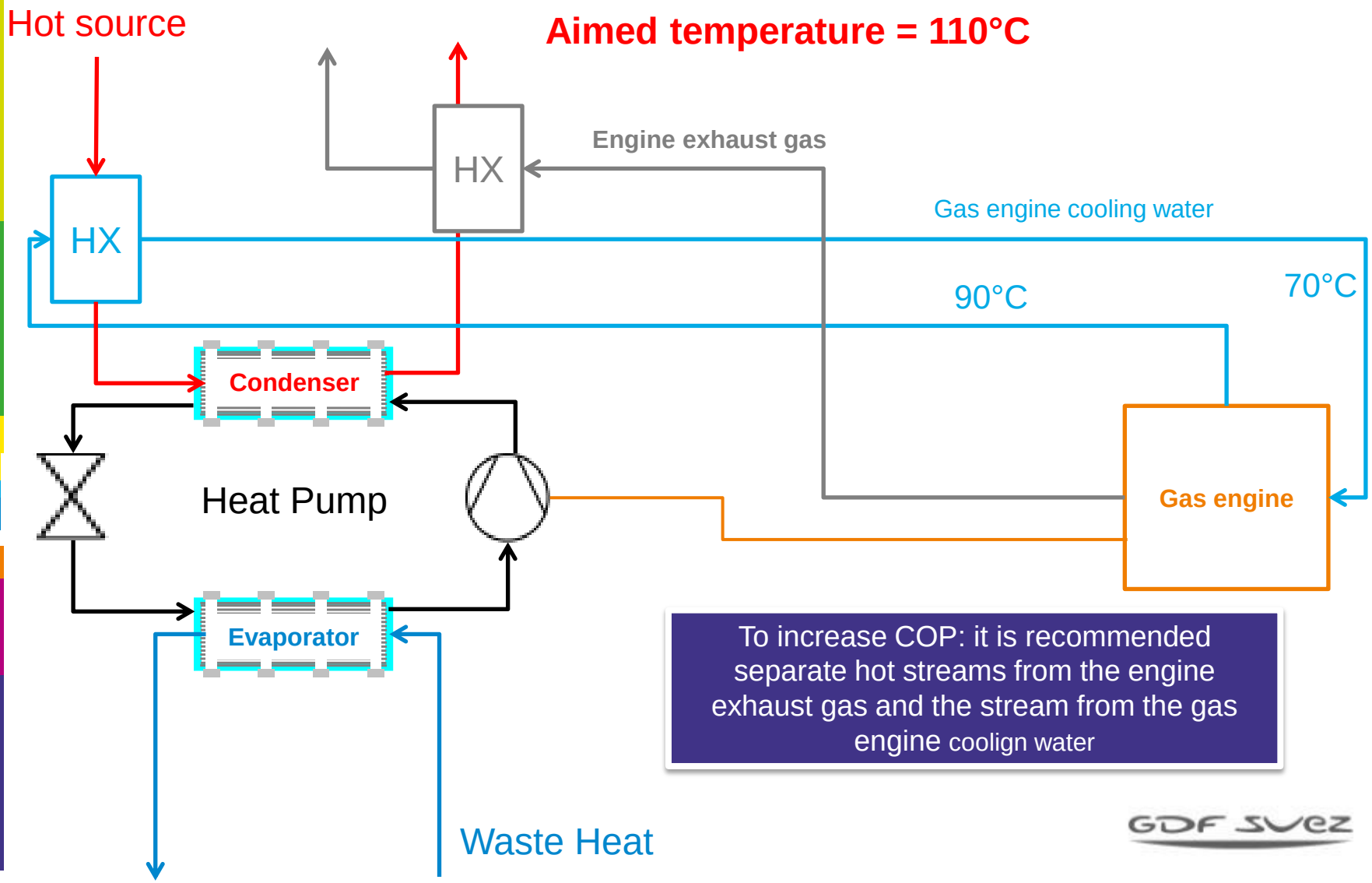


Config 2 (direct) – option 3



➔ The best option strongly depends on the process

Example of Integration of a gas heat pump into industrial process
Best configuration desined



To increase COP: it is recommended separate hot streams from the engine exhaust gas and the stream from the gas engine coolign water

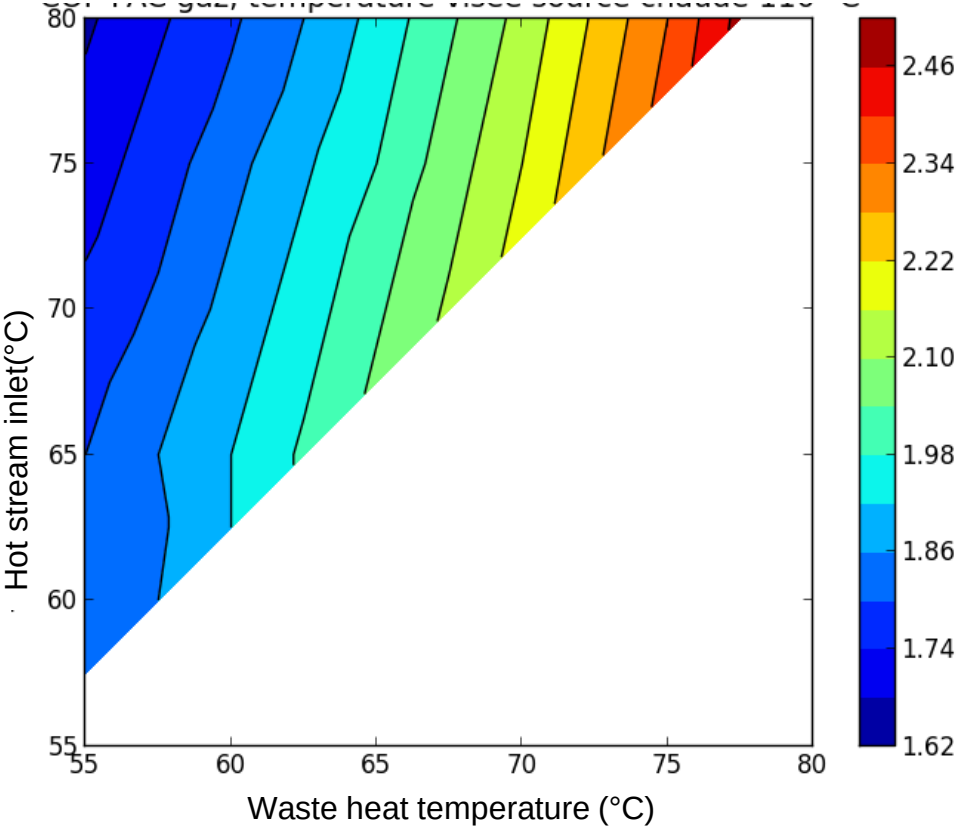
GDF SUEZ

Example of Integration of a gas heat pump into industrial process

Performance charts

$$COP = \frac{\Delta P_{hot\_source}}{P_{gas}} = \frac{(P_{condenser} + P_{water\_hx} + P_{fumes\_hx})}{P_{gas}}$$

COP obtained to reach 110°C temperature for hot stream outlet



➔ **Asumptions:**

➔ Aimed temeprature = 110°C

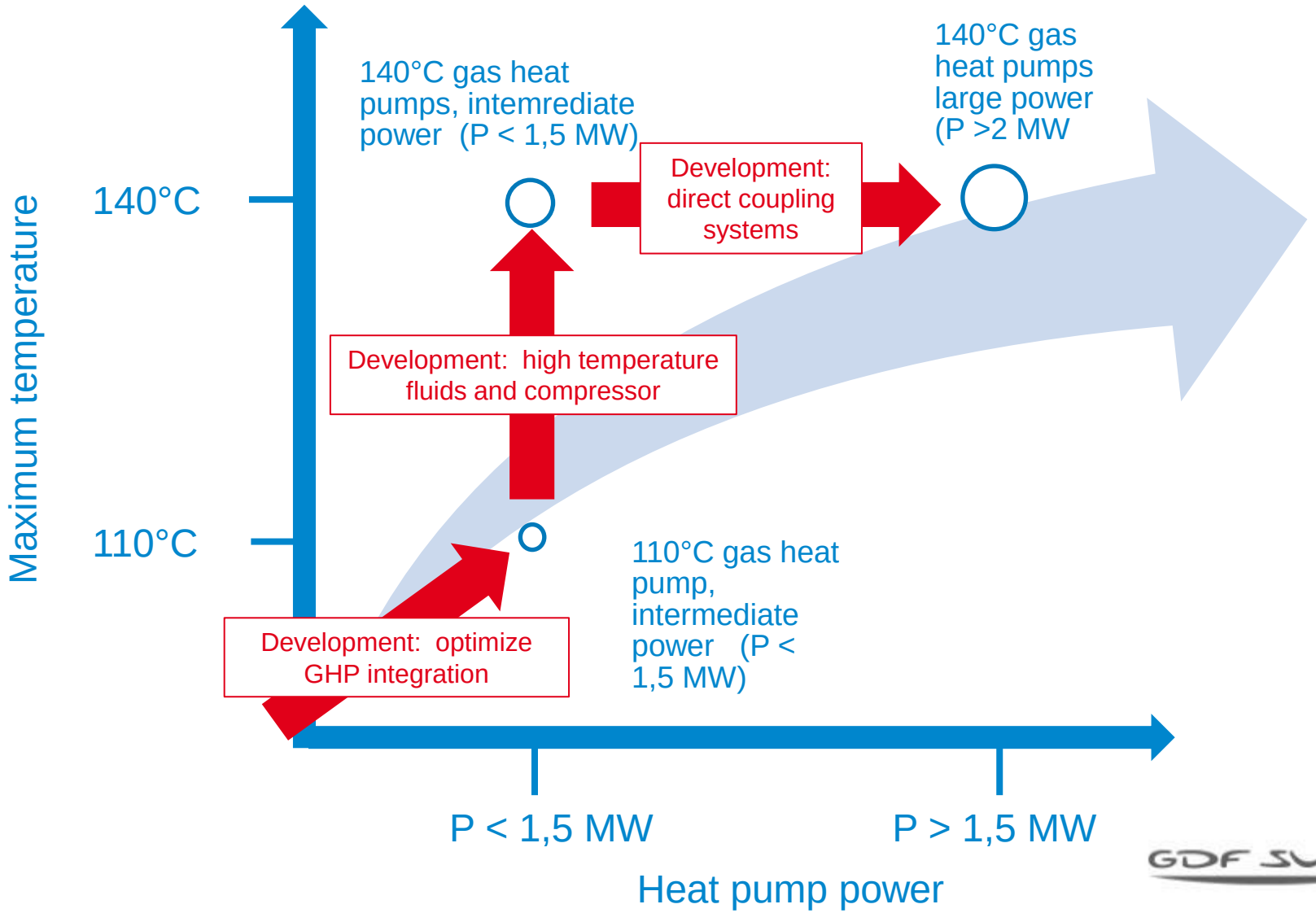
➔ Useful power = 1 MW

➔ cold stream flow rate / hot stream flow rate = 10

➔ Gas POWER ~ 400 kW LCV

➔ **It is possible to obtain a up to 2.4 COP with a gas heat pump**

GDF Suez Roadmap for the gas heat pump development



Valenthin project : Development of innovative solutions & New Businesses for the Energy valorization of Low Temp. Heat Losses (LTHL) in industries

Potential:
- 40 TWh/y France
- ~500 TWh/y Europe

Chemical

Paper industries

Glass industries ; Food industries, Steel industries

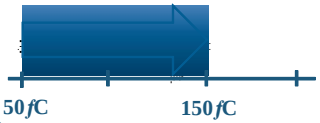
…

VALENTHIN
FILIERE DE VALORISATION ENERGETIQUE DES REJETS THERMIQUES INDUSTRIELS

1er application Case
VALLEE DE LA CHIMIE - LYON

Sources

Thermal Energies



Low grade heat losses Industries

Re Uses outside

Municipalities

Recovery on side

Others industries

ORC

Gas Heat PUMPs

Utilisations

Thermal Energies

0,5 à 1,5 MW

Electrical Ener

0,5 à 3 MW

4 topics for these developments :

- Indus. High Temp. Heat Pumps
- HP coupling with thermal Storages
- Conversion of heat losses to electricity (ORC)
- New engineering tools & operation Services

GDF SUEZ

"crigen

VALENTHIN project

➔ **We are building a new sector for energy recovery from industrial waste heat**

VALENTHIN
FILIERE DE VALORISATION ENERGETIQUE DES REJETS THERMIQUES INDUSTRIELS

enertime · GEA · GDF SUEZ · ARKEMA INNOVATIVE CHEMISTRY · ideel Inventer l'usine du futur

bertin TECHNOLOGIES

cea

Centre de Thermique de Lyon · CETHIL UMR 5008

cnrs · INSA LYON · Lyon 1

Johnson Controls · ctp centre technique du papier · Rio Tinto Alcan · BLUESTAR SILICONES · SOLVAY asking more from chemistry®

Supported by

bpifrance · UIC RHÔNE-ALPES · GRANDLYON communauté urbaine · GDF SUEZ

Thank you for your attention

Questions?