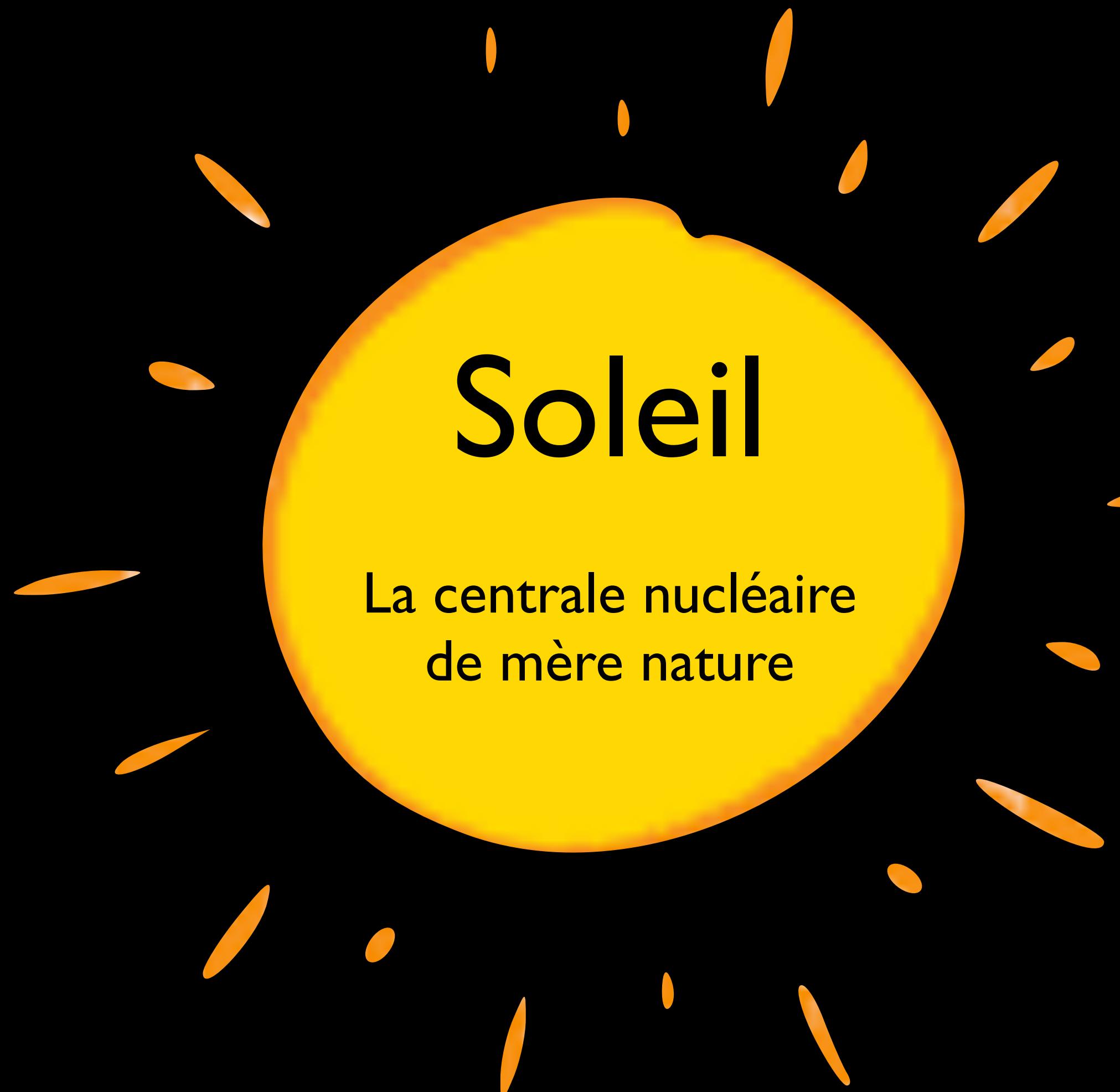


LE PARC BÂTIT DANS UNE SUISSE INDÉPENDANTE ET NEUTRE

**Prof. François Marechal @fmarech
Industrial Process and Energy Systems Engineering, EPFL, Switzerland**

EST CE QUE NOUS AVONS UN PROBLÈME D'ÉNERGIE ?



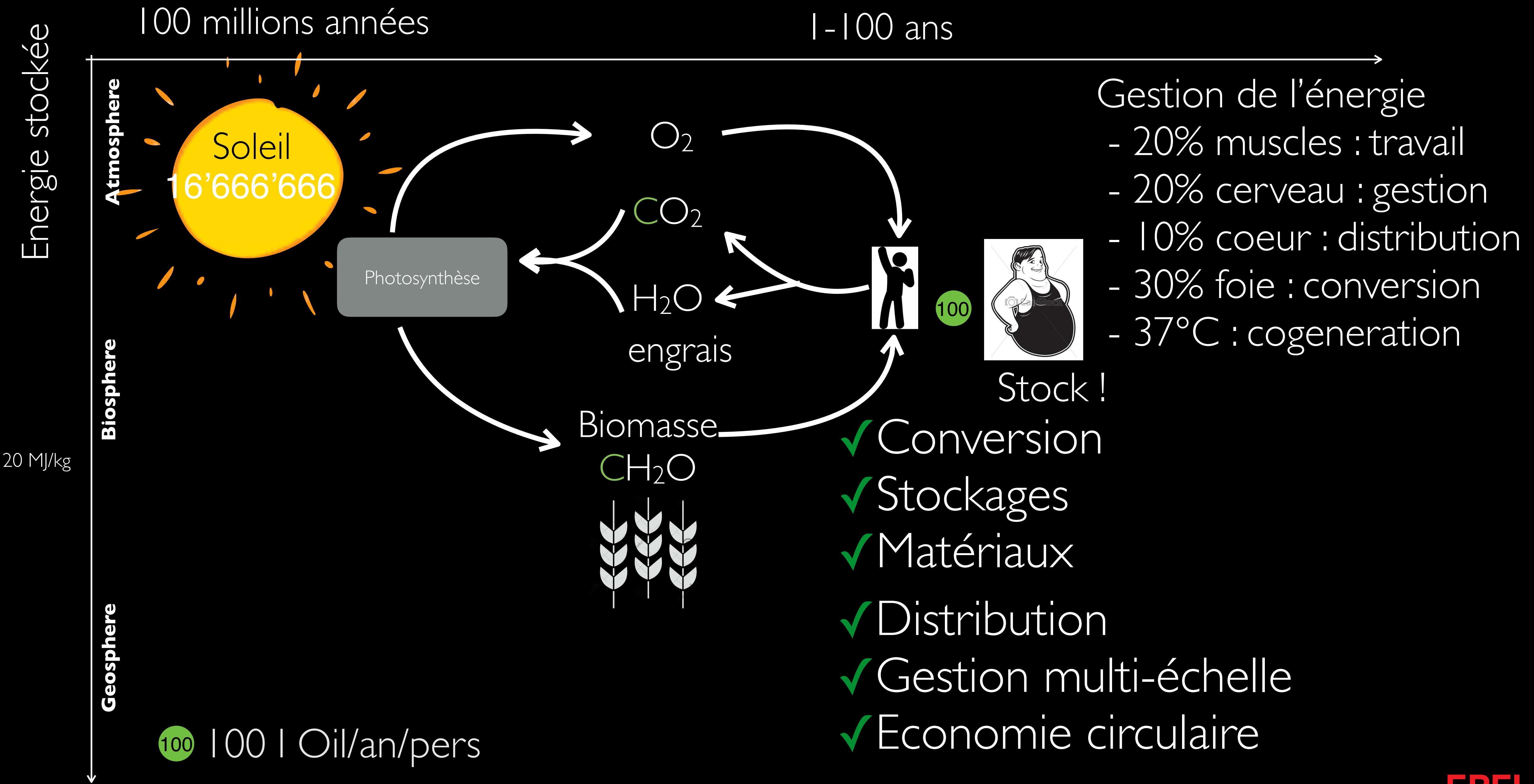
1.5 heures

temps nécessaire pour fournir nos besoins annuels

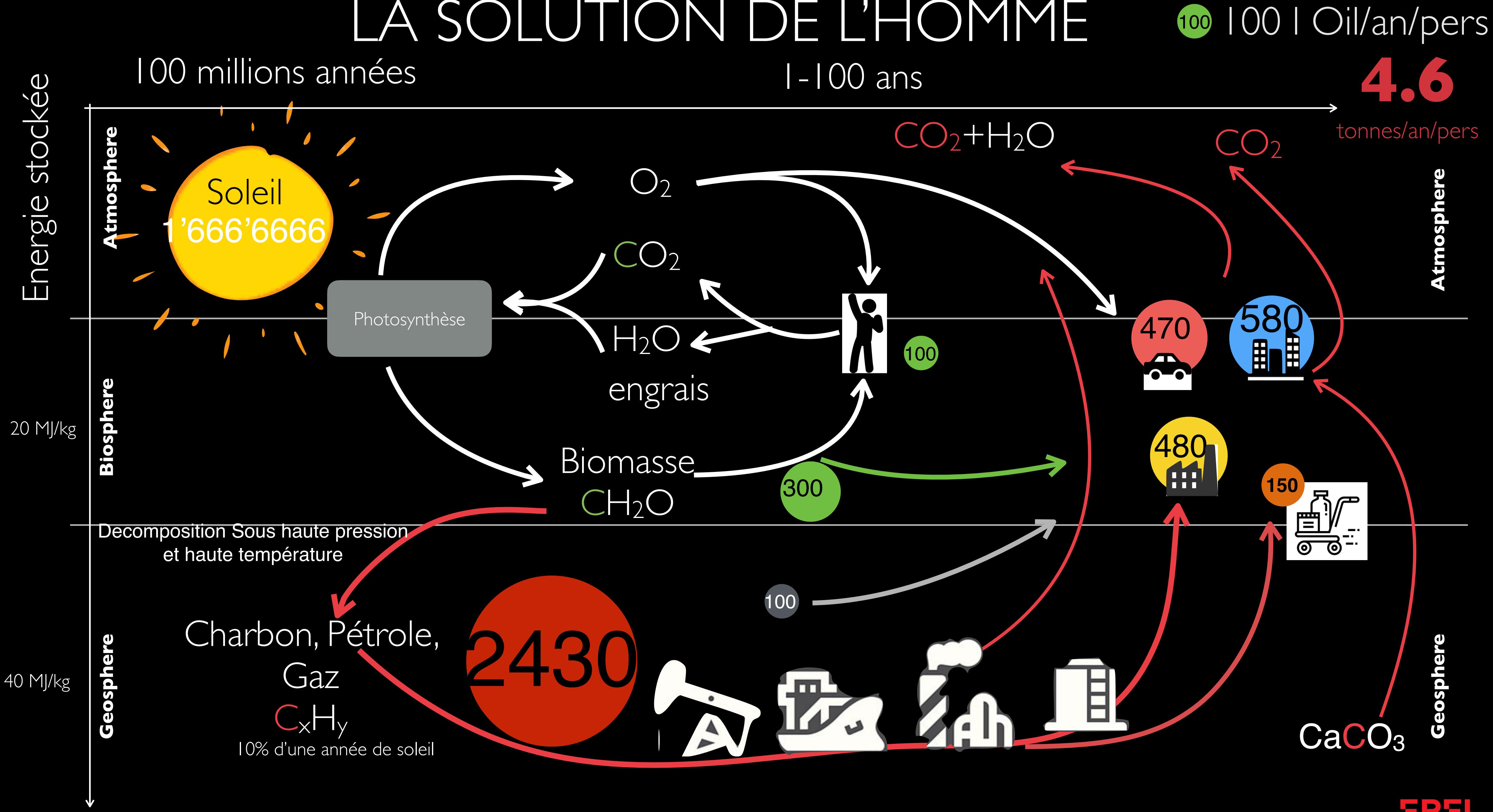
6500 ans

Notre survie si nous utilisons 1 an d'énergie solaire

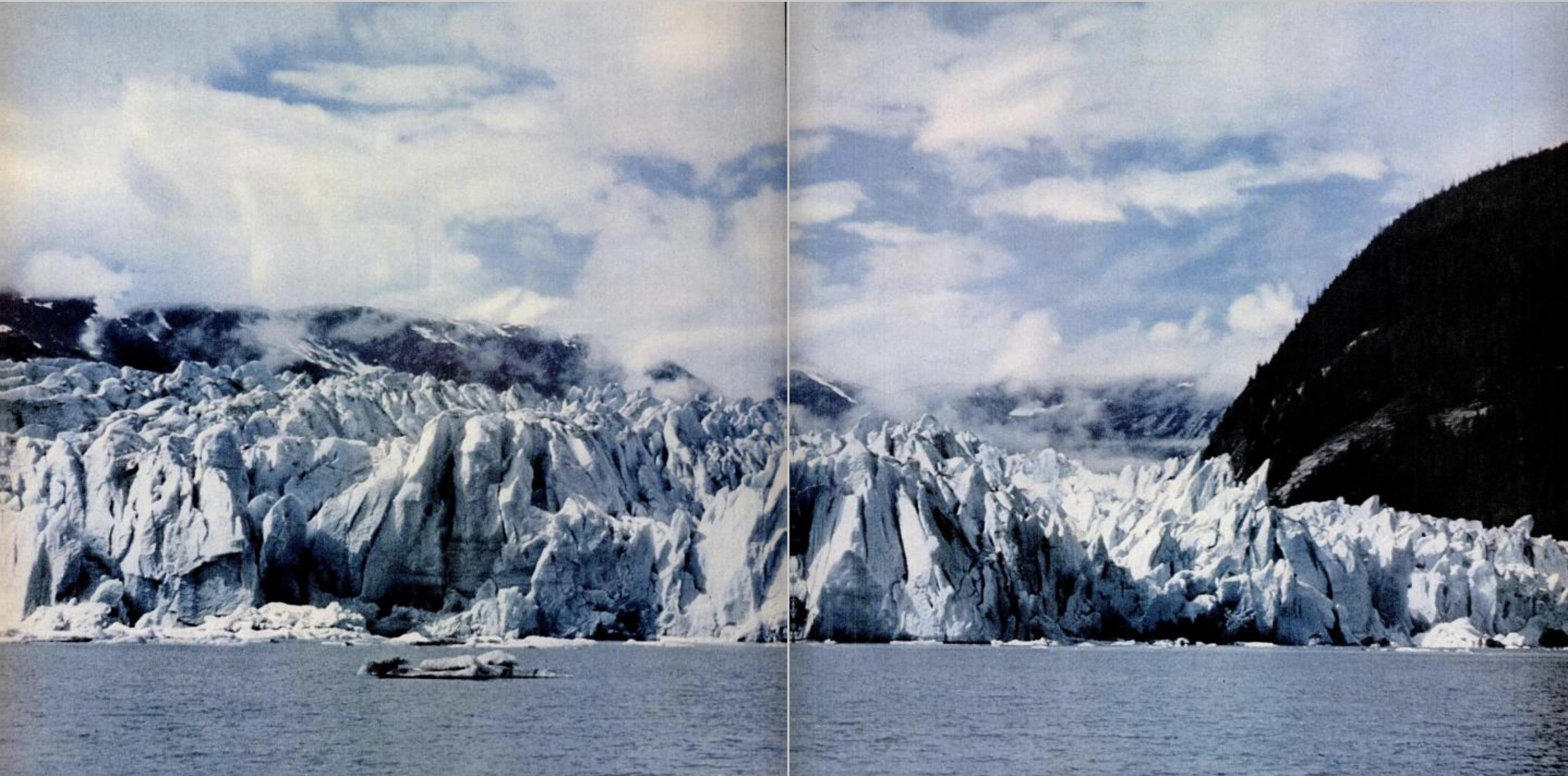
PEUT-ON APPRENDRE DE MÈRE NATURE ?



LA SOLUTION DE L'HOMME



1962 : L'homme est fier de sa découverte



EACH DAY HUMBLE SUPPLIES ENOUGH ENERGY TO MELT 7 MILLION TONS OF GLACIER!

This giant glacier has remained unmelted for centuries. Yet, the petroleum energy Humble supplies—if converted into heat—could melt it at the rate of 80 tons each second! To meet the nation's growing needs for energy, Humble has applied science to nature's resources to become America's Leading Energy Company. Working wonders with oil through research, Humble provides energy in many forms—to help heat our homes, power our transportation, and to furnish industry with a great variety of versatile chemicals. Stop at a Humble station for new Enco Extra gasoline, and see why the "Happy Motoring" Sign is the World's First Choice!

TAKU GLACIER, ALASKA, IS A RIVER OF ICE STRETCHING 270 SQUARE MILES. YET THE PETROLEUM ENERGY HUMBLE SUPPLIES AMERICA COULD MELT IT AT THE RATE OF 7 MILLION TONS A DAY!



(1)
Inc, T. LIFE; Time Inc, 1962.

Les scientifiques savaient depuis 125 ans

Prof. S. Arrhenius *on the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.*

Philosophical Magazine and Journal of Science
Series 5, Volume 41, April 1896, pages 237-276.

THE
LONDON, EDINBURGH, AND DUBLIN
PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon
the Temperature of the Ground.* By Prof. SVANTE
ARREHENIUS *.

I. *Introduction : Observations of Langley on
Atmospherical Absorption.*

A GREAT deal has been written on the influence of the absorption of the atmosphere upon the climate. Tyndall † in particular has pointed out the enormous importance of this question. To him it was chiefly the diurnal and annual variations of the temperature that were lessened by this circumstance. Another side of the question, that has long attracted the attention of physicists, is this : Is the mean temperature of the ground in any way influenced by the presence of heat-absorbing gases in the atmosphere? Fourier‡ maintained that the atmosphere acts like the glass of a hot-house, because it lets through the light rays of the sun but retains the dark rays from the ground. This idea was elaborated by Pouillet § ; and Langley was by some of his researches led to the view, that "the temperature of the earth under direct sunshine, even though our atmosphere were present as now, would probably fall to -200° C., if that atmosphere did not possess the quality of selective

* Extract from a paper presented to the Royal Swedish Academy of Sciences, 11th December, 1895. Communicated by the Author.

† 'Heat a Mode of Motion,' 2nd ed. p. 405 (London, 1865).

‡ *Mém. de l'Ac. R. d. Sci. de l'Instit. de France*, t. vii. 1827.

§ *Couppes rendus*, t. vii. p. 41 (1838).

Phil. Mag. S. 5. Vol. 41. No. 251. April 1896.

S



2x CO₂ in the atmosphere,
T goes up by 5° C
Later refined his calculation
to include *feedbacks* to get 2.1° C

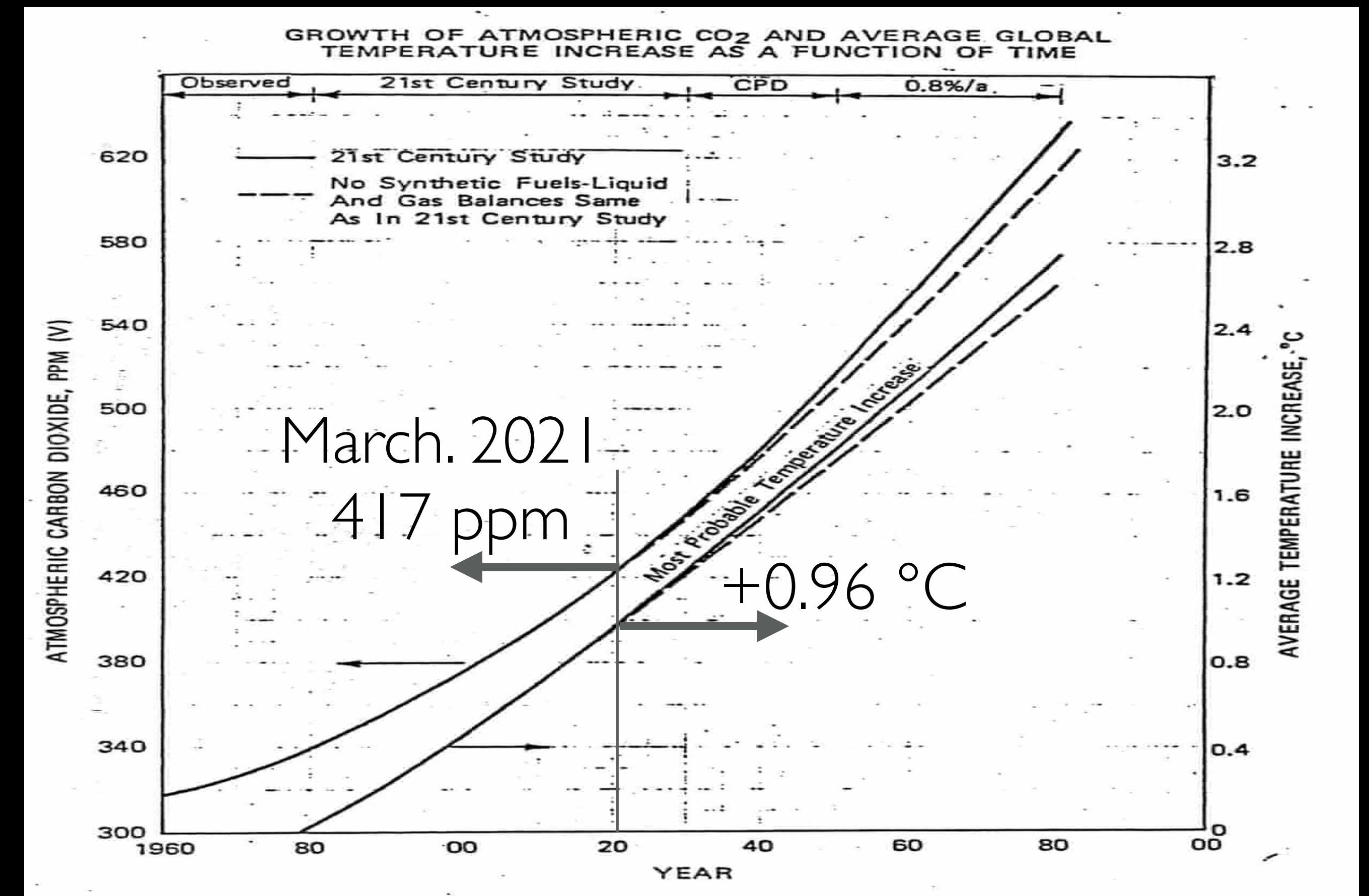
LES PÉTROLIERS SAVAIENT DEPUIS 40 ANS

■ Exxon study (1982)

Exxon's private prediction of the future growth of carbon dioxide levels (left axis) and global temperature relative to 1982 (right axis).

Elsewhere in its report, Exxon noted that the most widely accepted science at the time indicated that doubling carbon dioxide levels would cause a global warming of 3°C.

Illustration: 1982 Exxon internal briefing document



LE CO₂ EST UNE MENACE !

Floodings



+ 2°C

In Switzerland

Heat waves



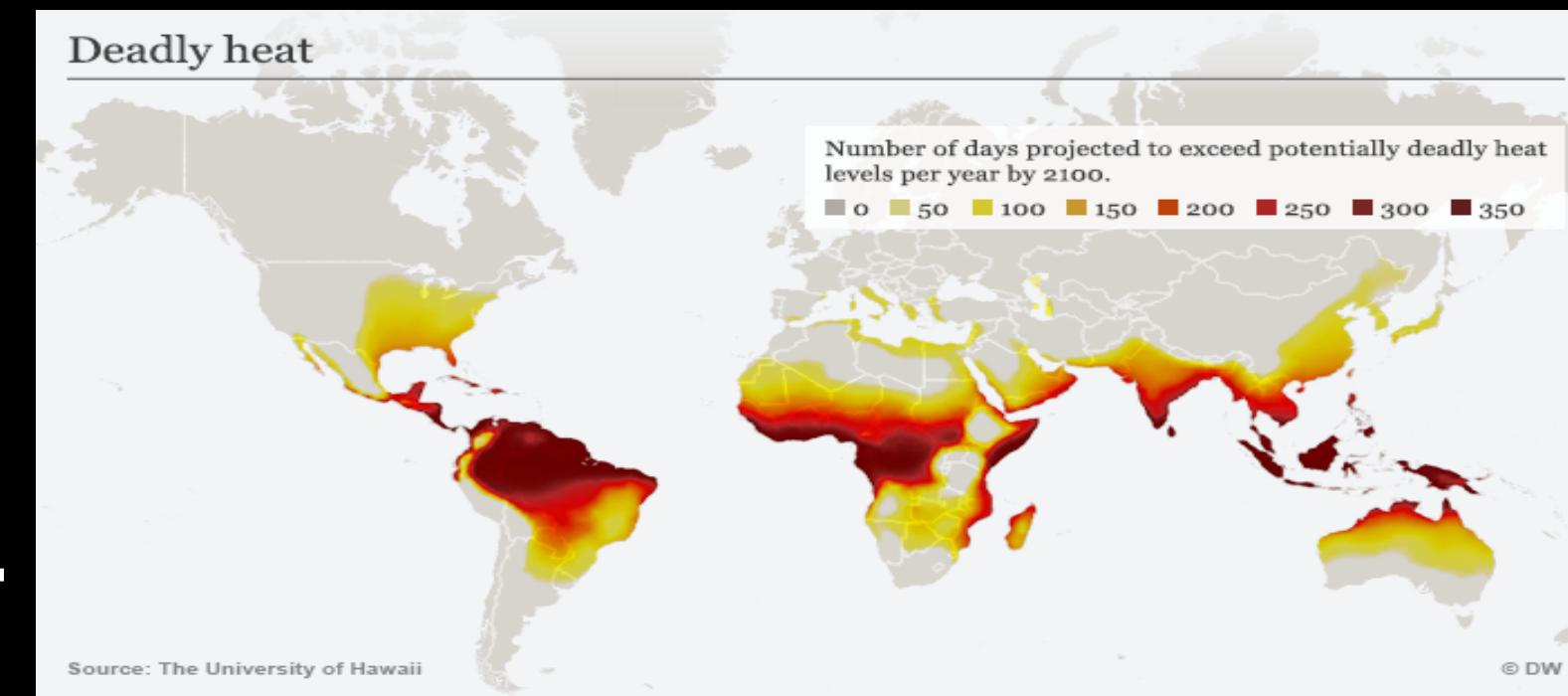
Fires and Droughts



Youth Revolution



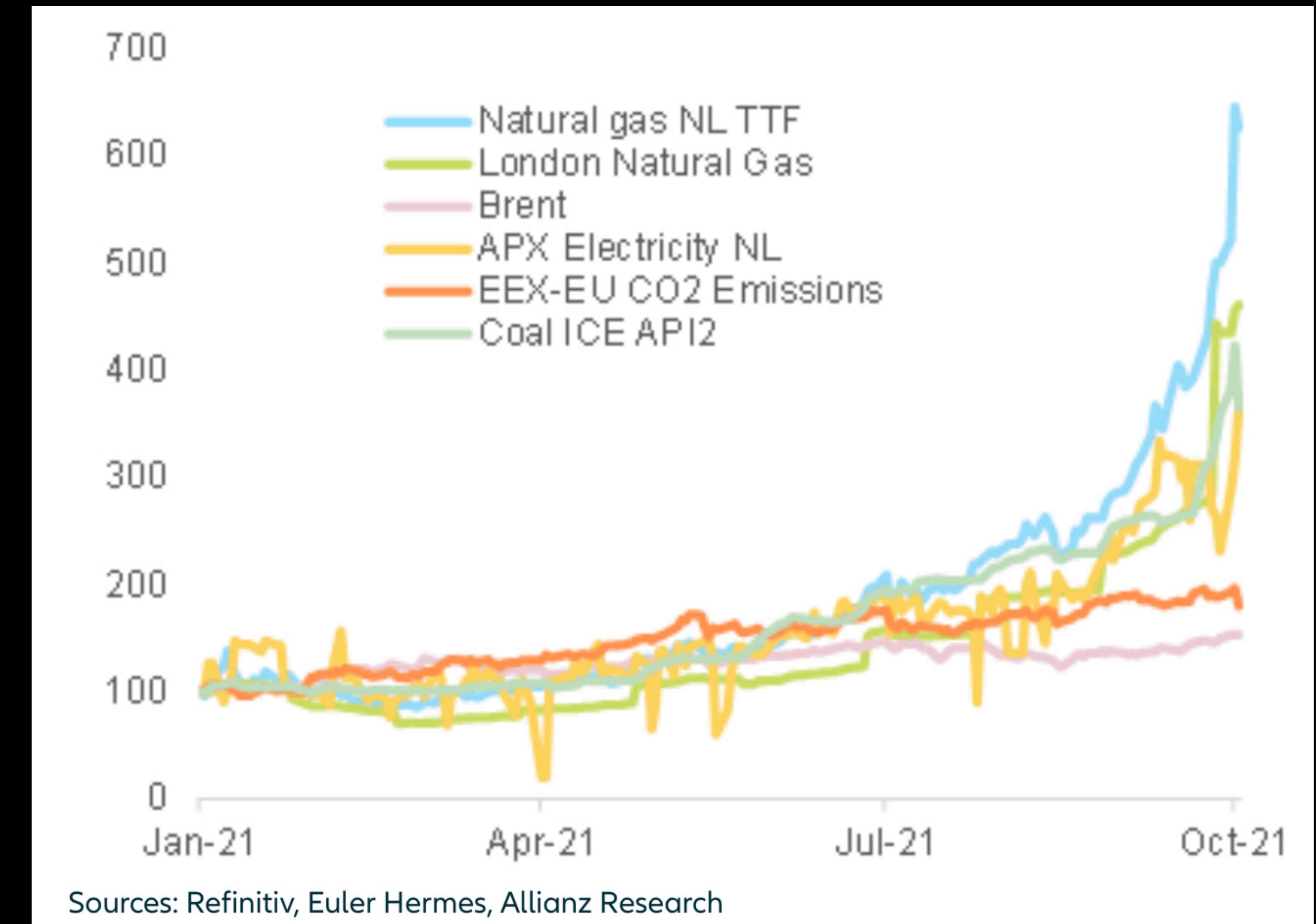
and scientists...



Zone is world where the temperature is higher than the cooling temperature of the body

LA PEUR DE LA PÉNURIE

- Echanges avec l'EU
- Marché de l'énergie
- Marché du carbone



Une Suisse
indépendante et neutre
en 2050

Oui, on l'a fait ...

URGENCE CLIMATIQUE COMBIEN DE CO₂ PEUT-ON ENCORE ÉMETTRE ?

have we released
to date?

1010 GtCO₂

added
1850-1999

55%

500

added
2000-2015

27%

more can we
“safely” release*?

335

our
‘carbon
budget’

18%

are left to release?

710

in fossil fuel
reserves
of all energy
companies

780

remaining
company
reserves that
could be
developed

1,265

other reserves
(including state-owned)

what's in the ground: 2755

CURRENT ANNUAL
FOSSIL FUEL EMISSIONS

36

gigatons

TIME BEFORE WE BREAK
OUR ‘CARBON BUDGET’

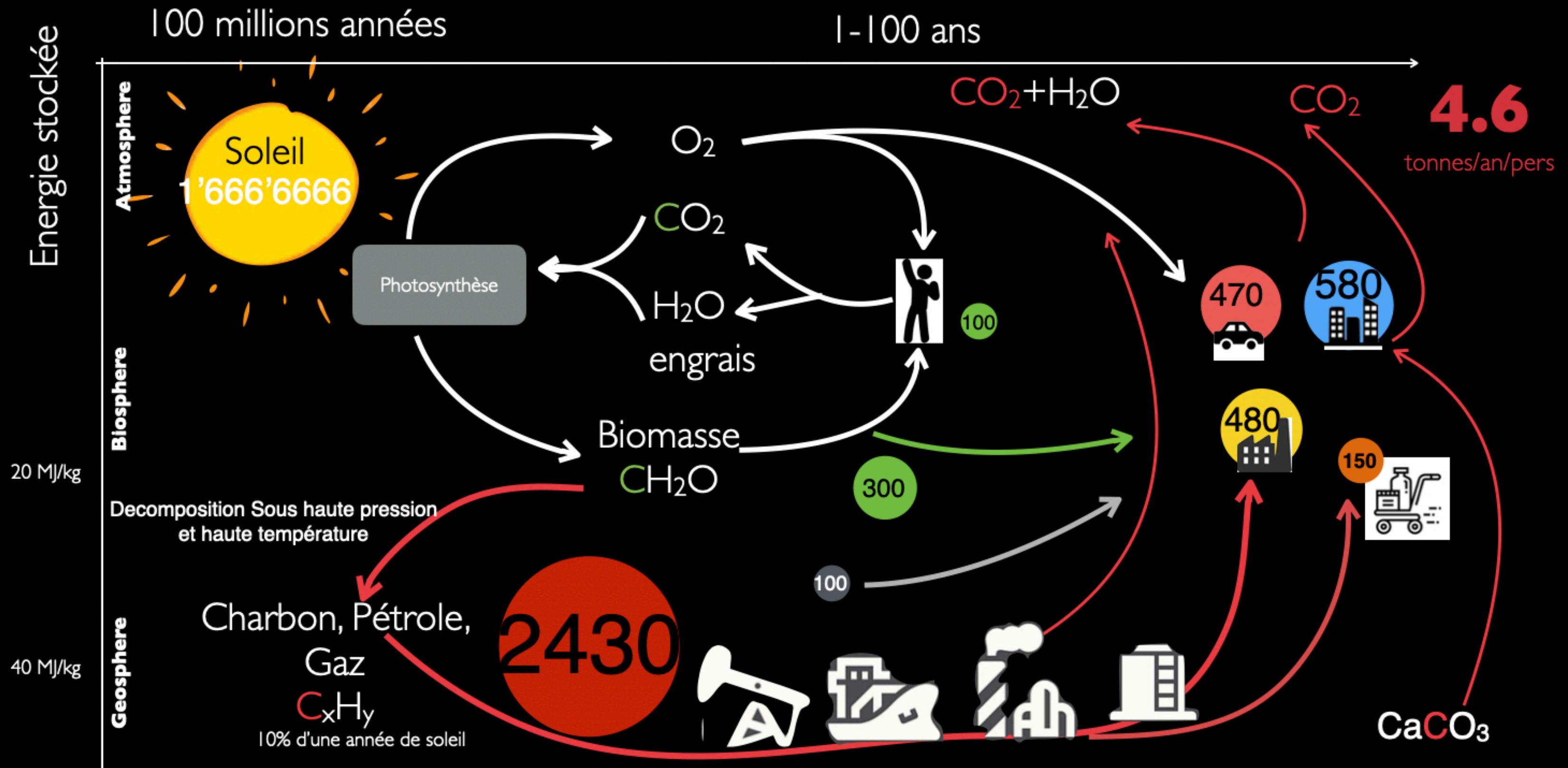


8 YEARS

if emissions continue to increase at 2.5% per year

* before 2050 and still have an 80% chance
of staying below 2°C warming

QU'EST CE QU'ON AVAIT RATÉ ?



- ✓ Conversion
- ✓ Stockage
- ✓ Matériaux
- ✓ Distribution
- ✓ Gestion

Renouvelable et Economie circulaire

ENERGY NEEDS

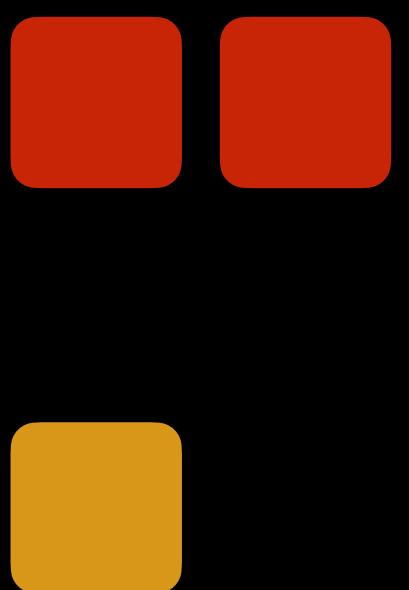
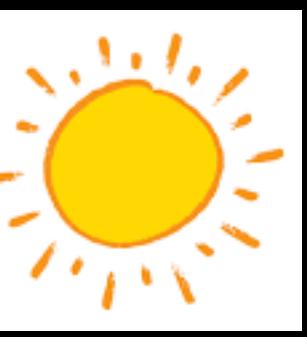
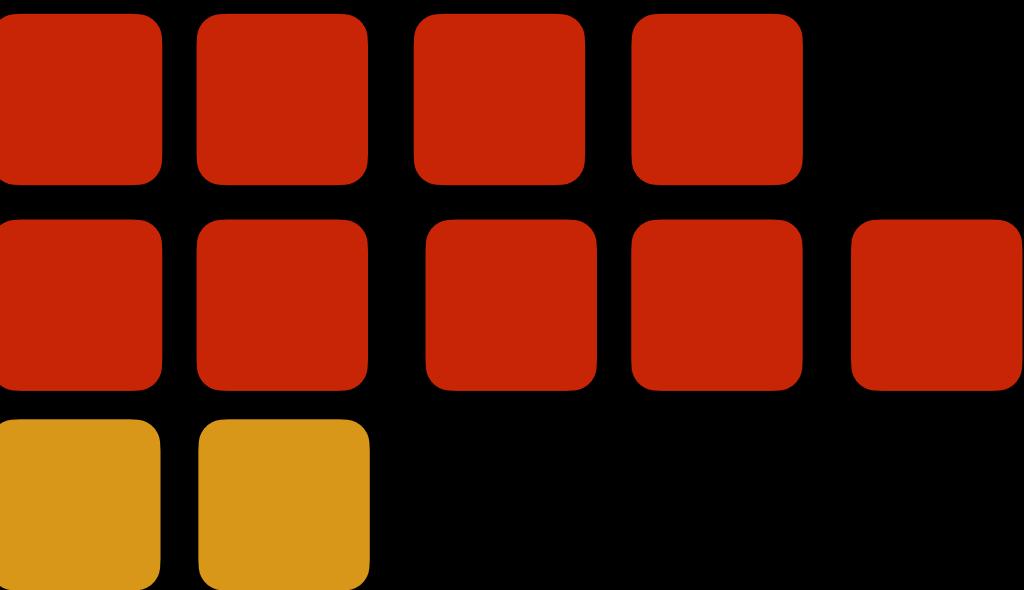


36%



products

17%
2%



100 l gasoline/hab/year



Electricity

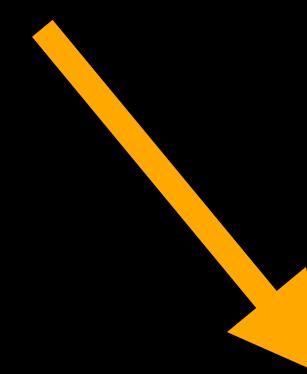
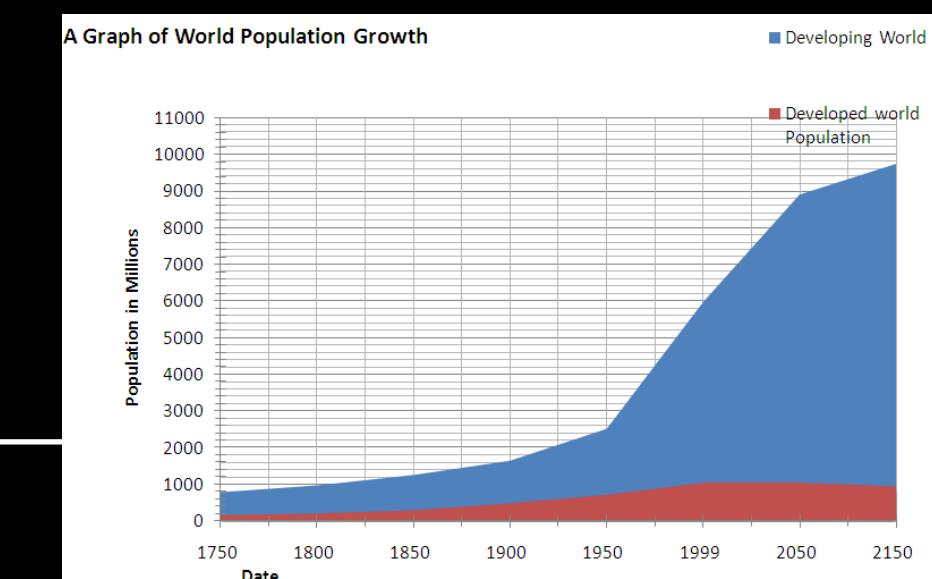
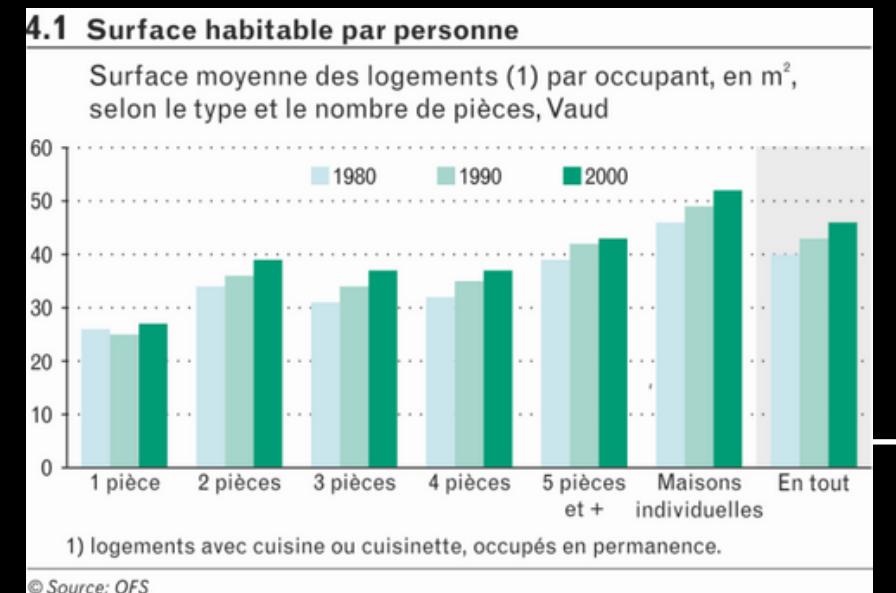
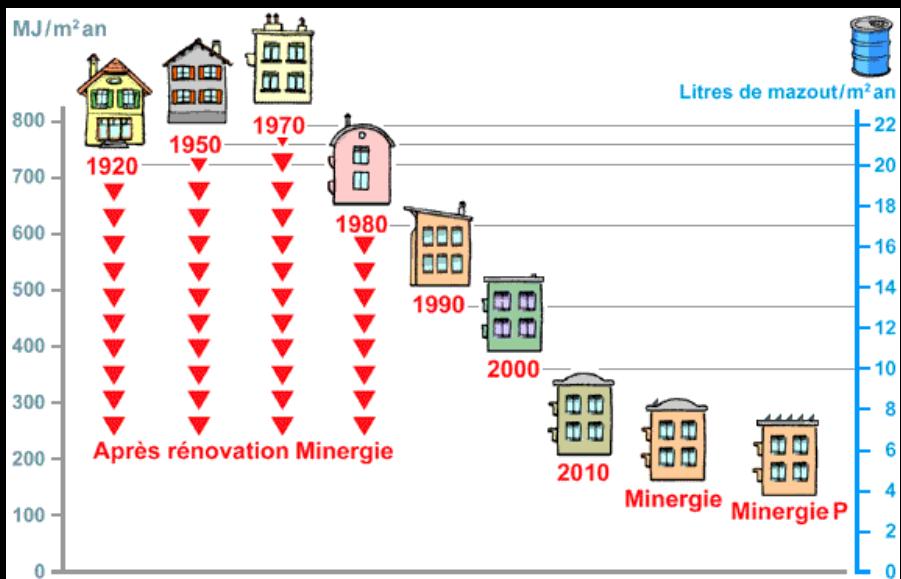
L'ÉNERGIE POUR LE BÂTIT [MJ_{th}/hab]

Soberty
MJ->m² heated

Comfort
m²->hab

Population
hab

= Service
MJ/hab



Renovation

2020

2050

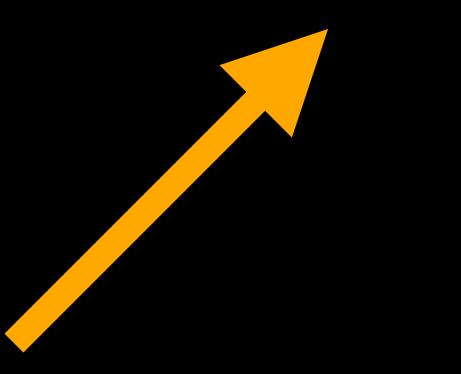
-

30 %



New buildinds

+56 %



Population

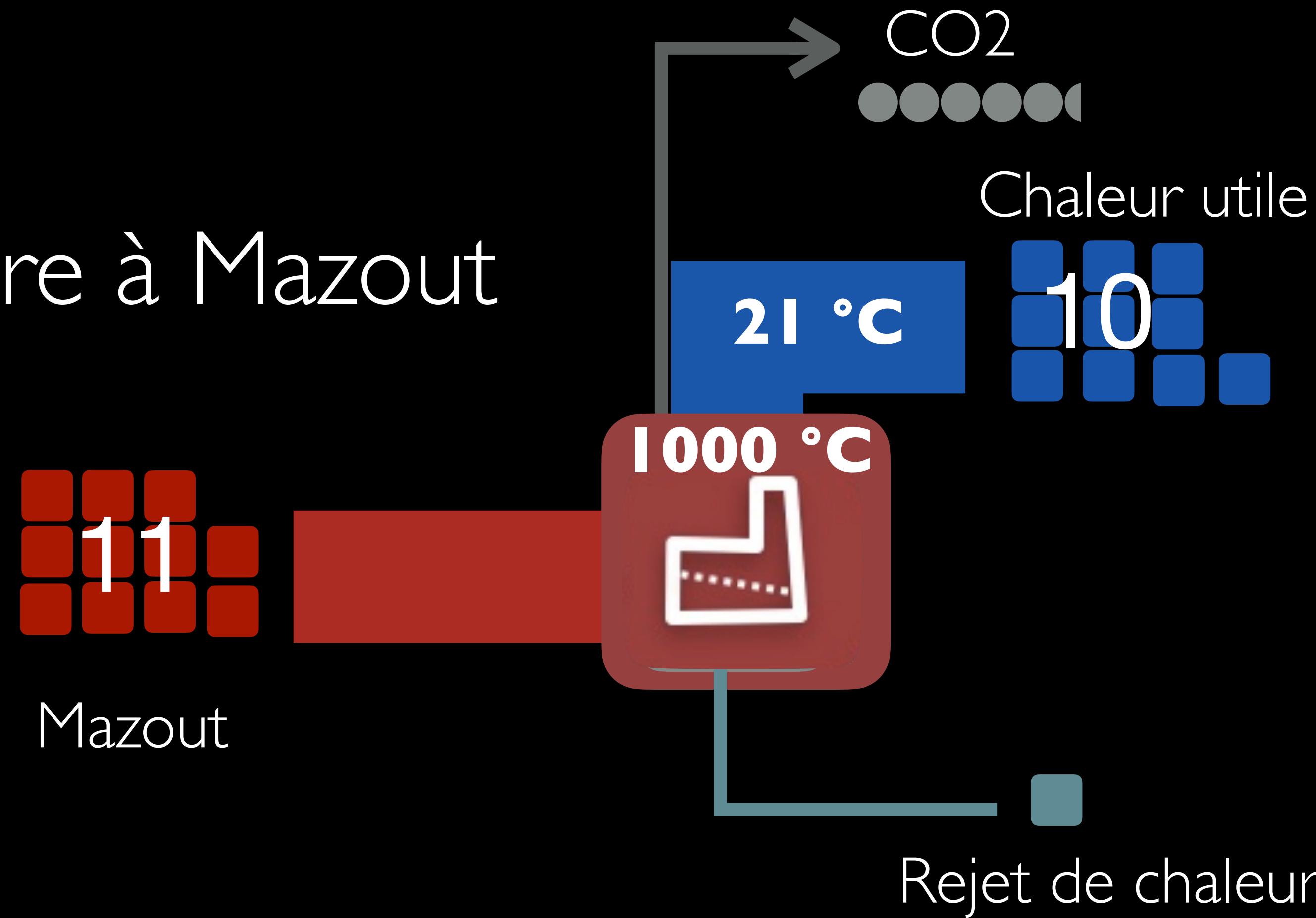
8.6 M hab

9.9 M hab



LA RESSOURCE POUR LE BÂTIT [MJ_{th}/hab]

La chaudière à Mazout



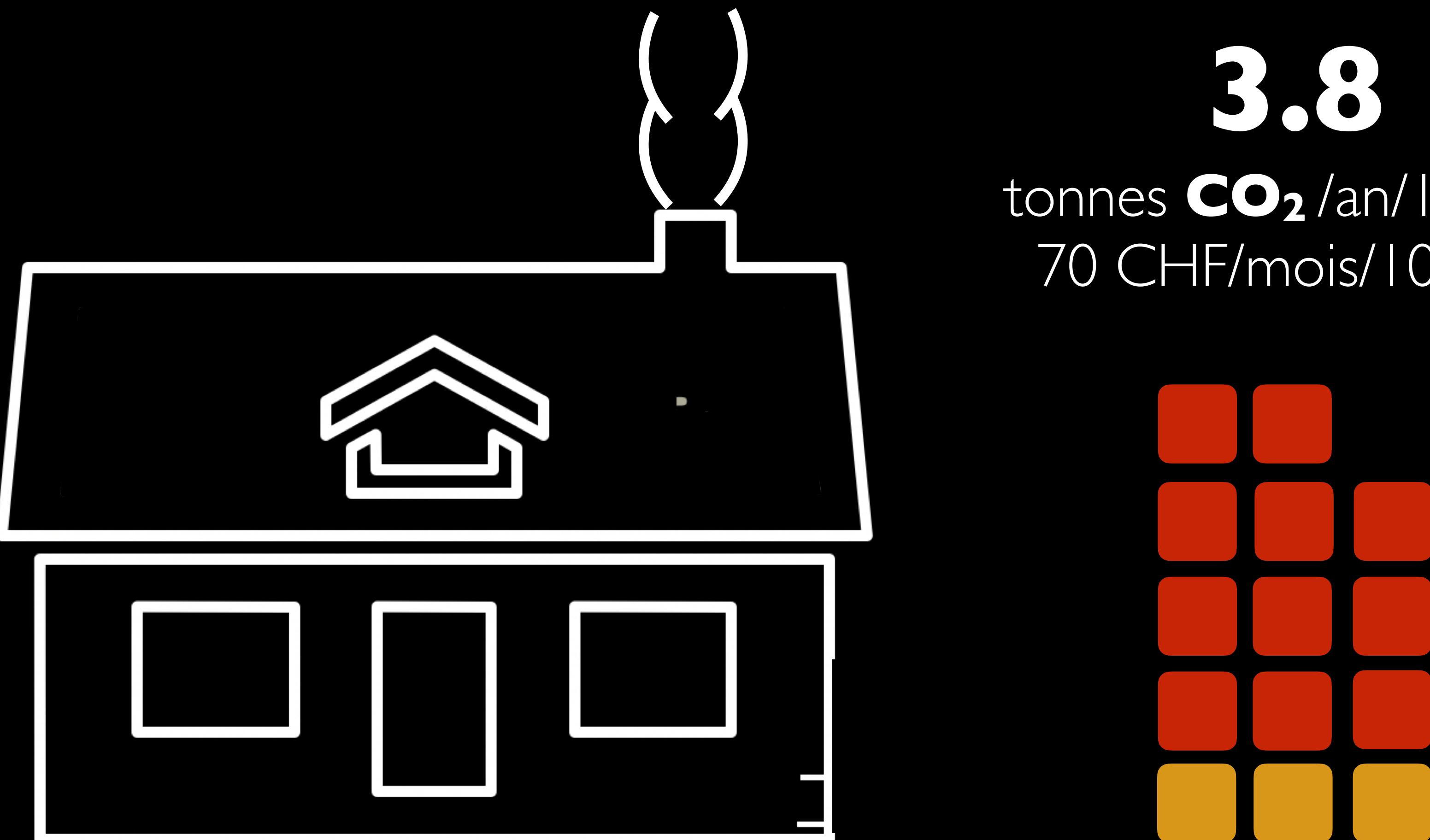
LES BESOINS ÉNERGÉTIQUES D'UN BÂTIMENT

| 70
CHF/mois/100 m²

Energie
| 40 CHF/mois/100 m²

| 75% import

Chaudière
30 CHF/mois/100 m²



Maison unifamiliale typique

1830 : LA FORMULE MAGIQUE



Nicolas Léonard Sadi CARNOT (F)

1796 - 1832

$$\dot{E} = \dot{Q}_{chauffage} \cdot \left(1 - \frac{T_{source}}{T_{chauffage}}\right)$$

Fraction venant de l'environnement

LEARNING FROM THERMODYNAMICS

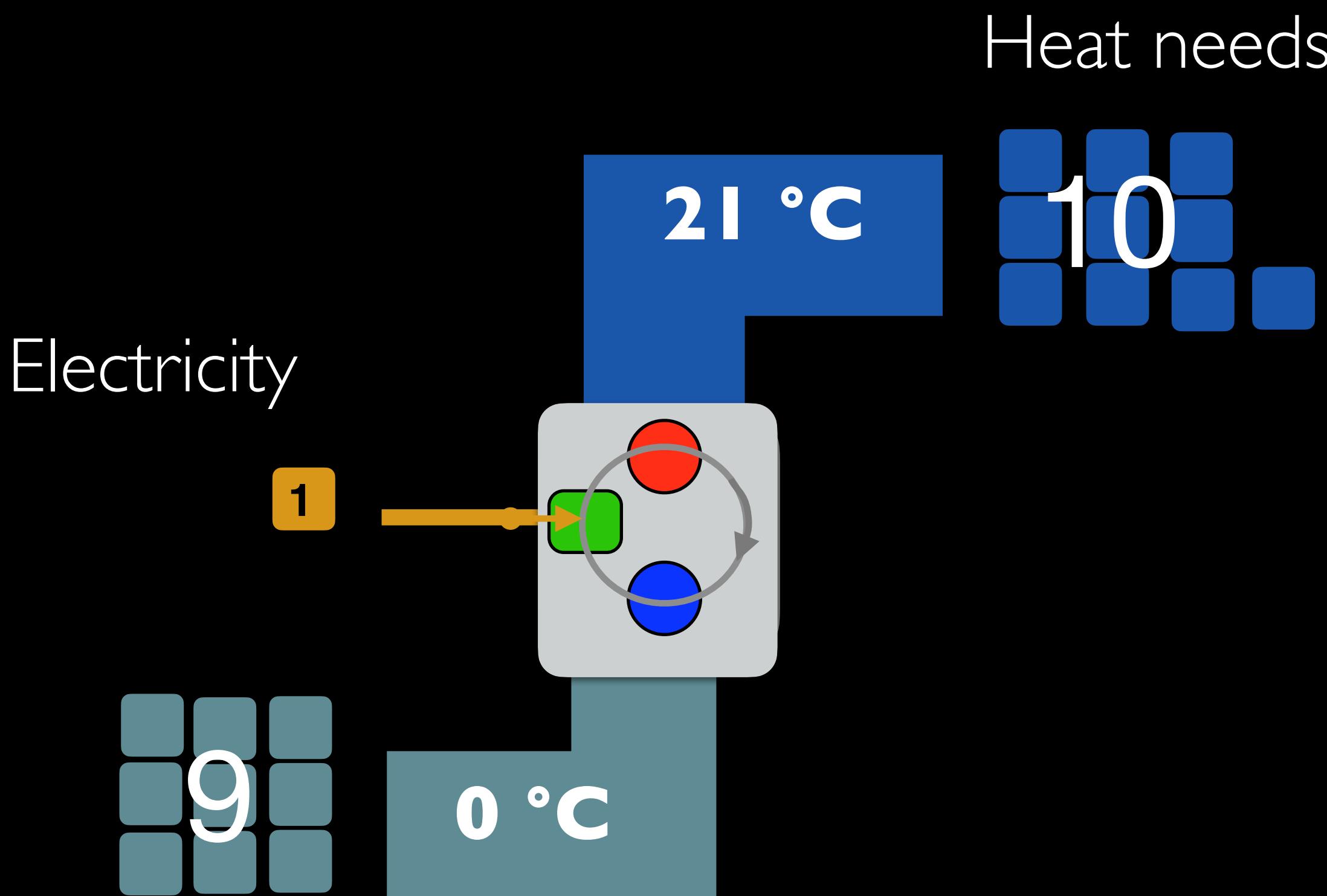
Use heat pumps



Nicolas Léonard Sadi CARNOT (F)

1796 - 1832

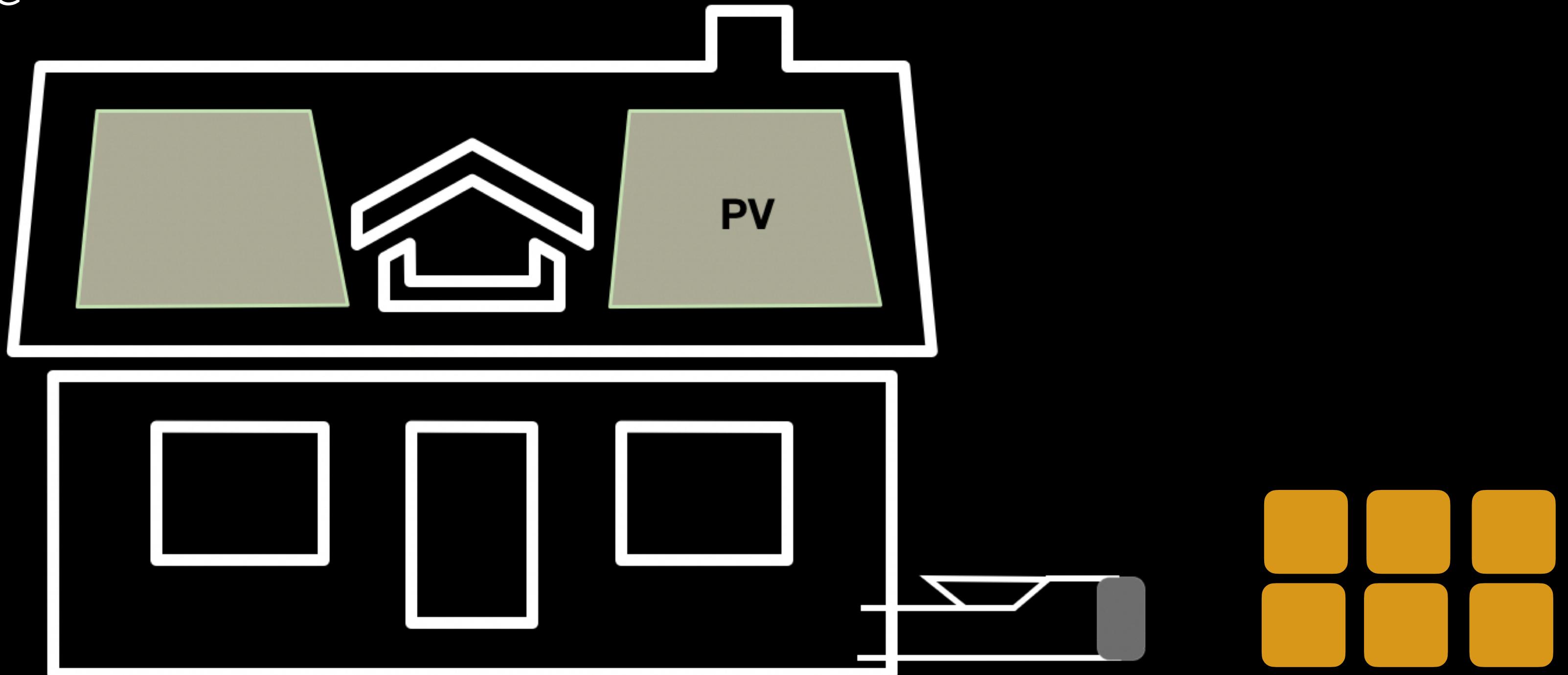
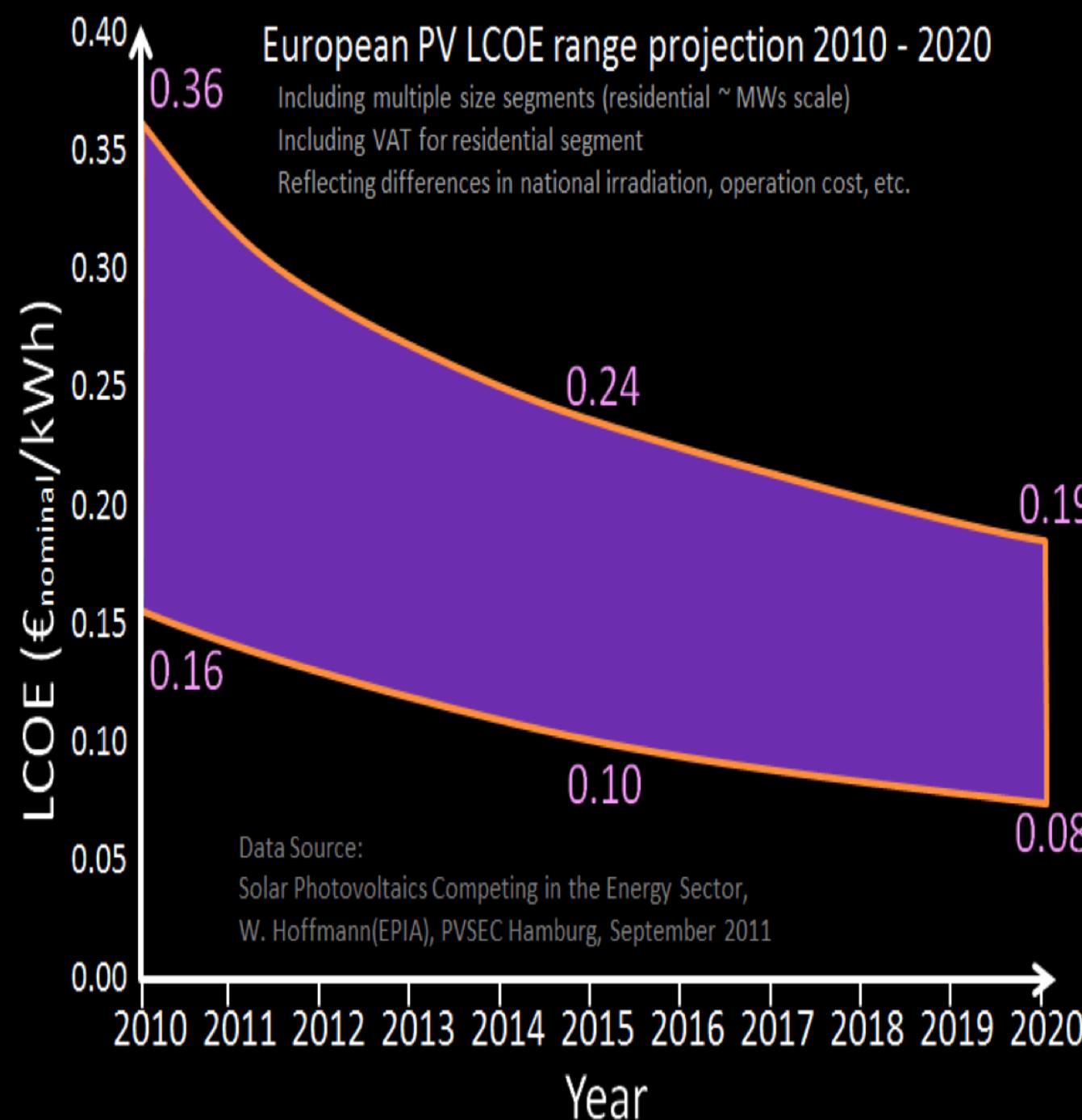
$$\dot{E} = \dot{Q}_{chauffage} \cdot \left(1 - \frac{T_{source}}{T_{chauffage}}\right)$$



Renewable energy from the environment

CONVERSION: INTEGRATION D'UNE POMPE À CHALEUR DANS UN BÂTIMENT

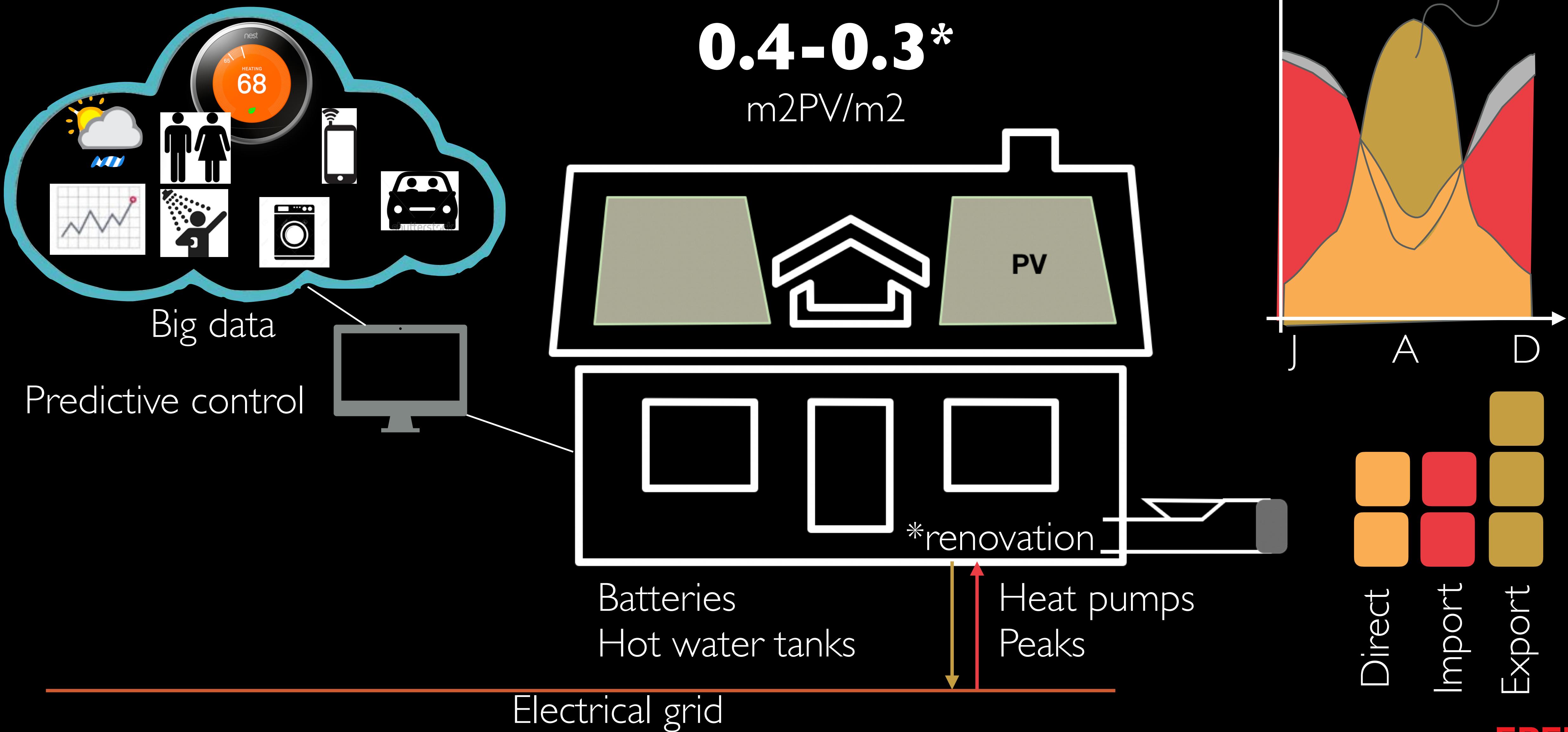
Projections coûts photovoltaïque



SYSTEM INTEGRATION

0.4-0.3*

m²PV/m²



90+% CO₂ EMISSIONS REDUCTION

3.8

tons CO₂ /year/100 m²



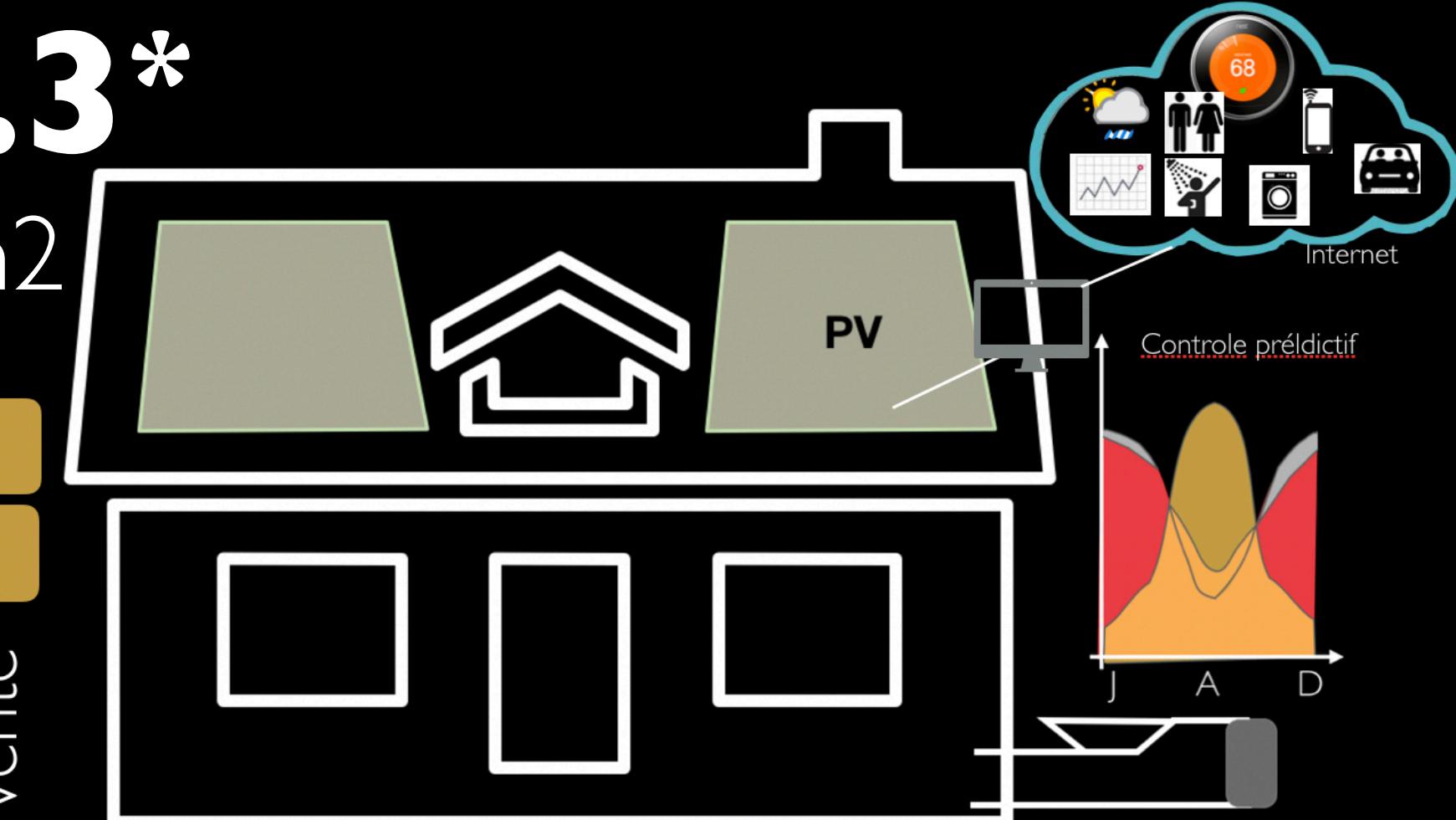
0.18-0.07*

tons CO₂ /year/100 m²

0.4-0.3*

m²PV/m²

Direct Achat Vente



*renovation

170

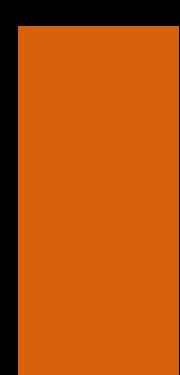
CHF/month/100 m²

Energy :

Investment :

140 CHF/month/100 m²

30 CHF/month/100 m²



163

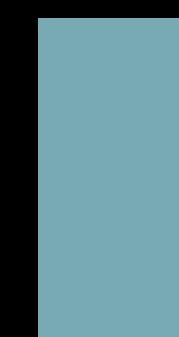
CHF/month/100 m²

Energy :

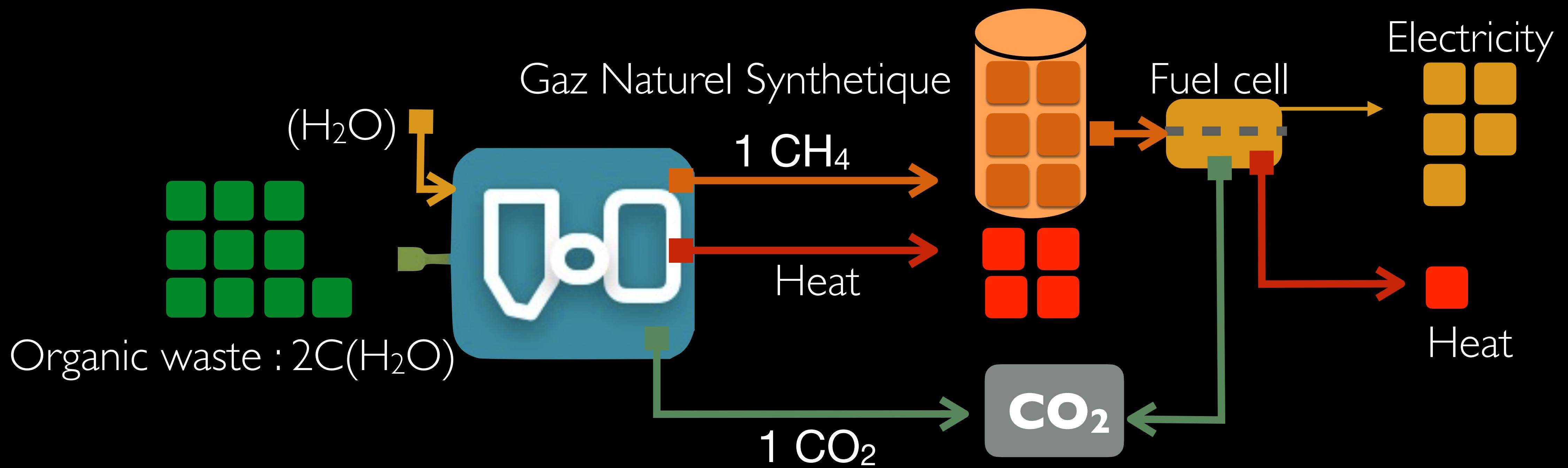
Investment :

50 CHF/month/100 m²

113 CHF/month/100 m²



L'ENERGIE DE NOS DÉCHETS ...

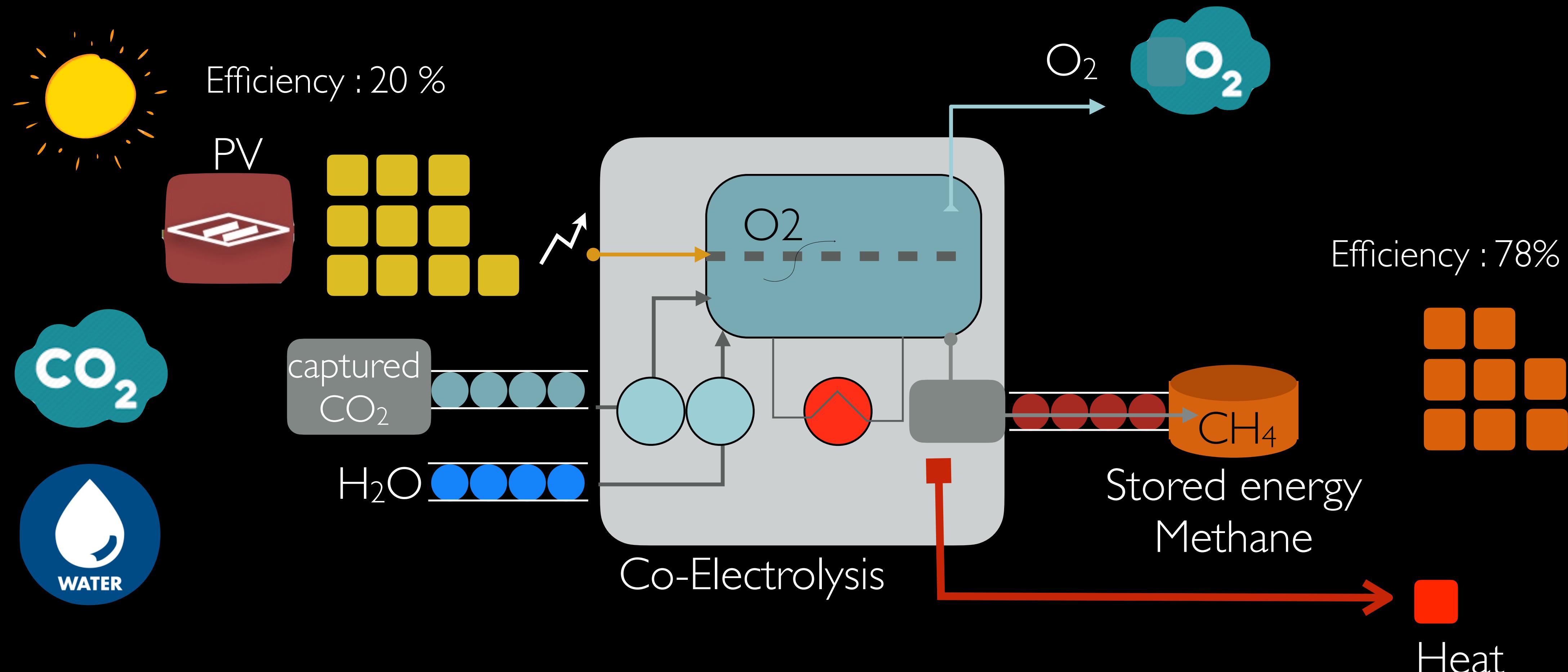


30% : Biomethanisation

70% : Hydrothermal gasification (<http://tre-a-tech.com>)

70% : Synthetic Natural Gas

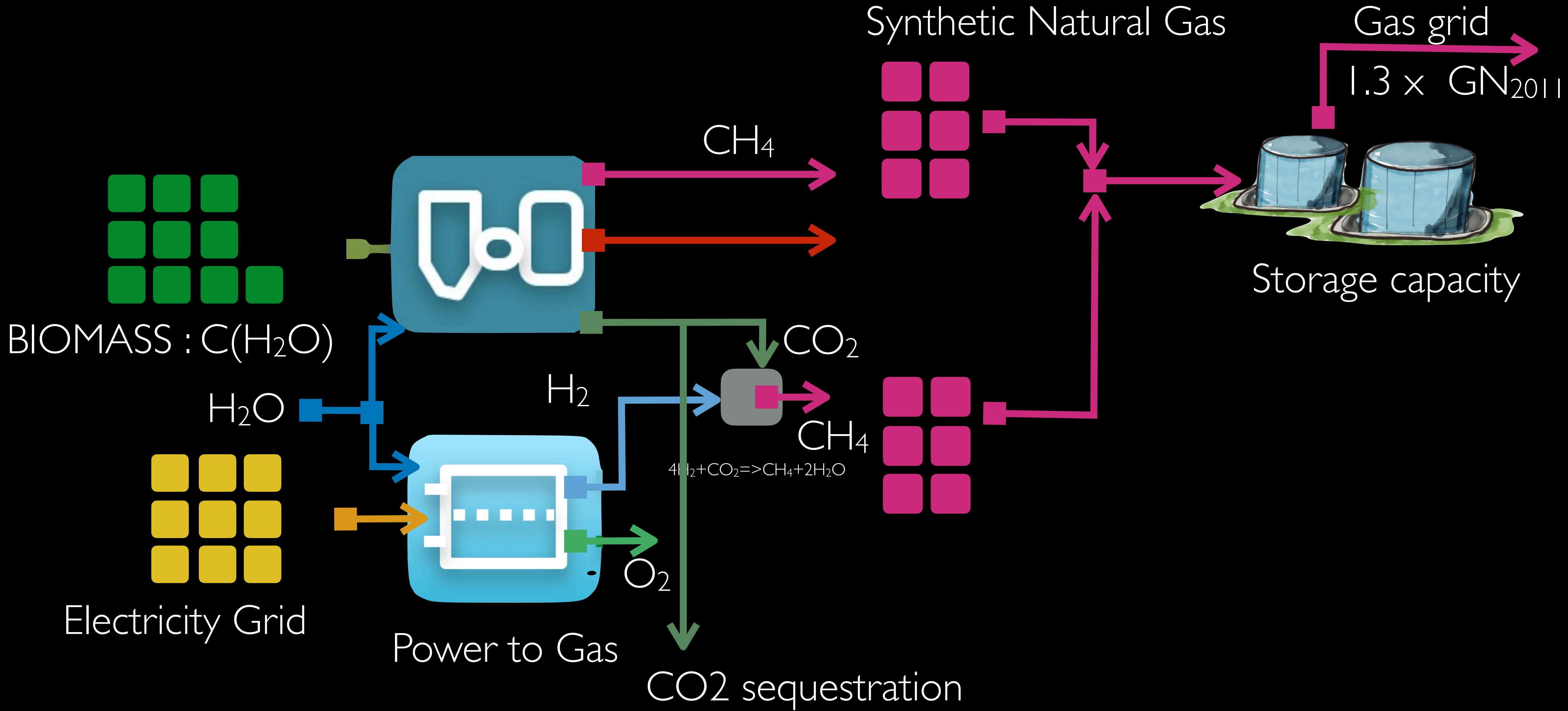
STOCKER L'EXCÈS D'ELECTRICITÉ



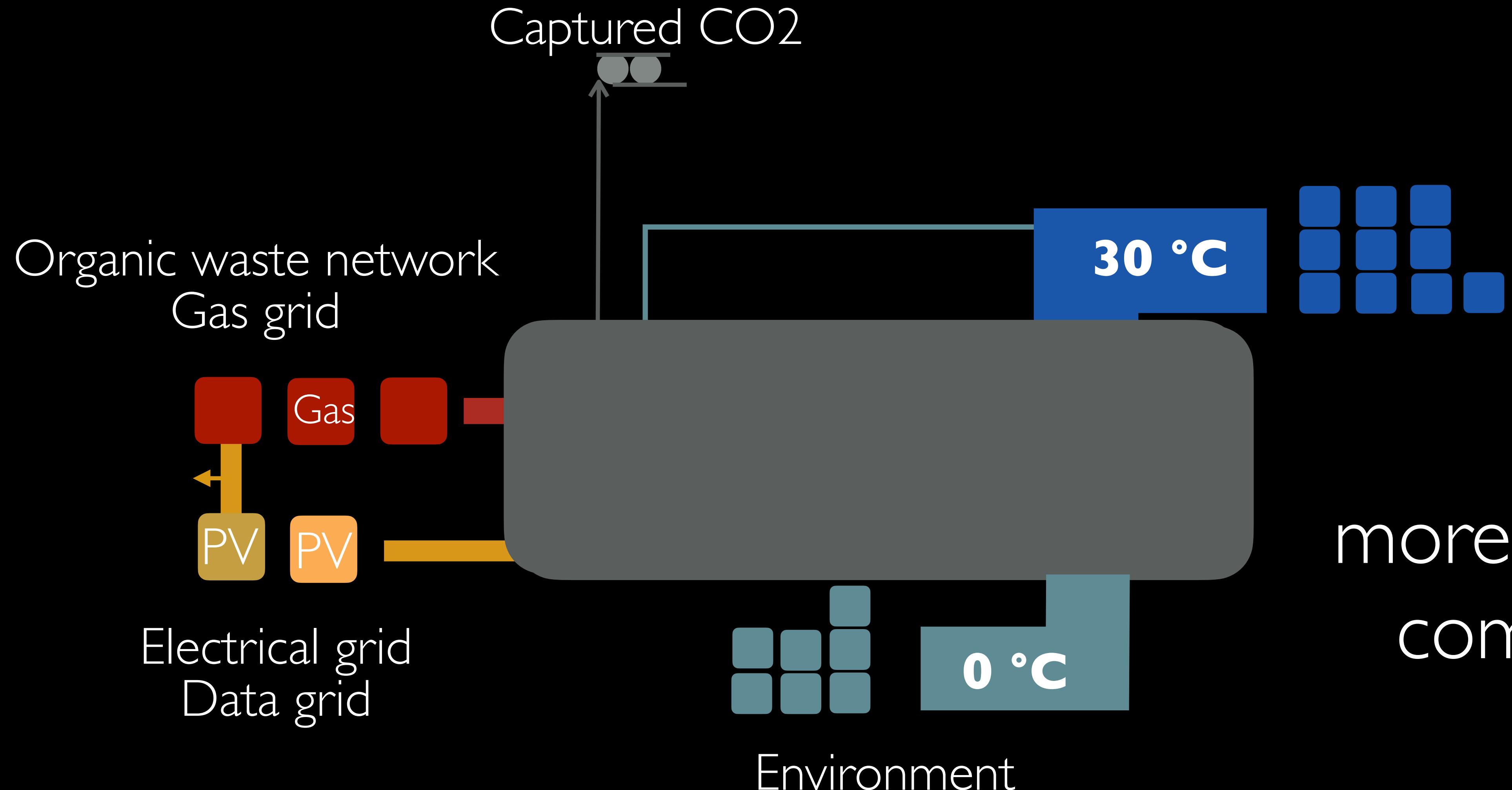
Artificial photosynthesis : 13-16 % Solar efficiency



ON THE USE OF BIOMASS AS AN ENERGY MANAGEMENT SOURCE



A NEW GAS BOILER



5x
more heat than
combustion

HARVESTING EFFICIENCY : DISTRICT HEAT PUMPING

$$\dot{E} = \dot{Q}(1 - \frac{T_{cold}}{T_{hot}})$$

Decentralised Energy harvesting

Waste heat industry: **>80°C**

Data center : **30°C**

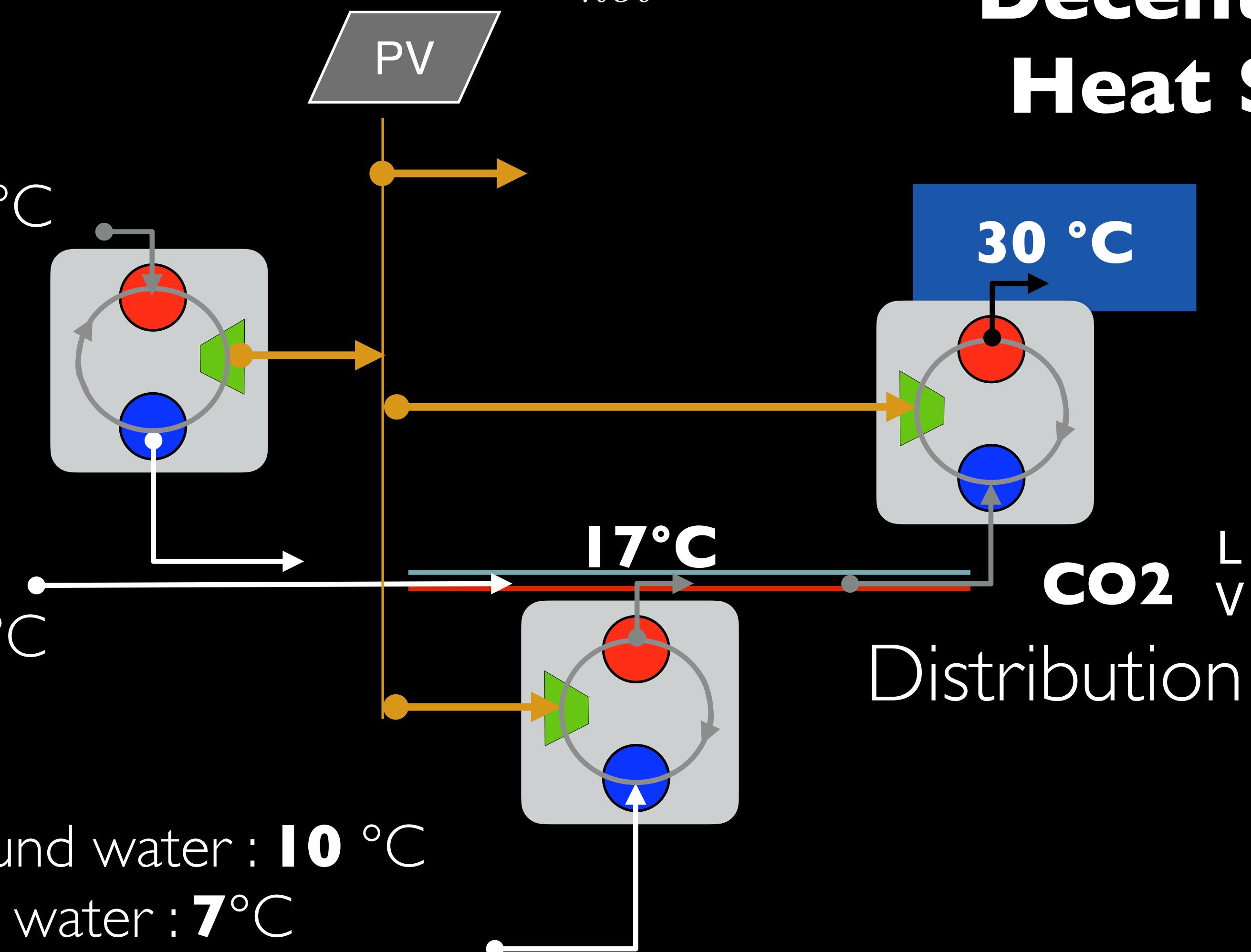
Waste water : **13-20 °C**

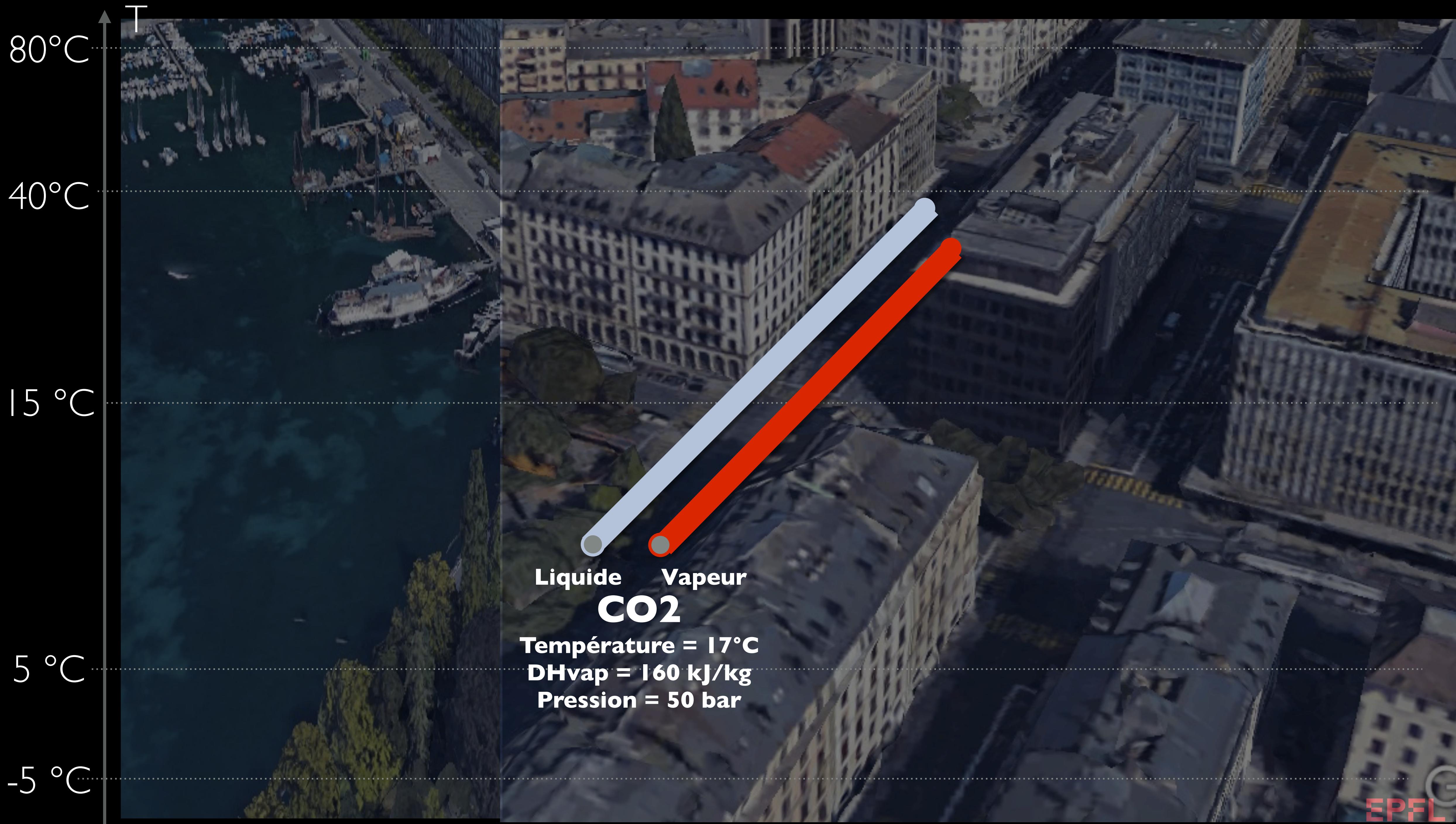
Ground water : **10 °C**

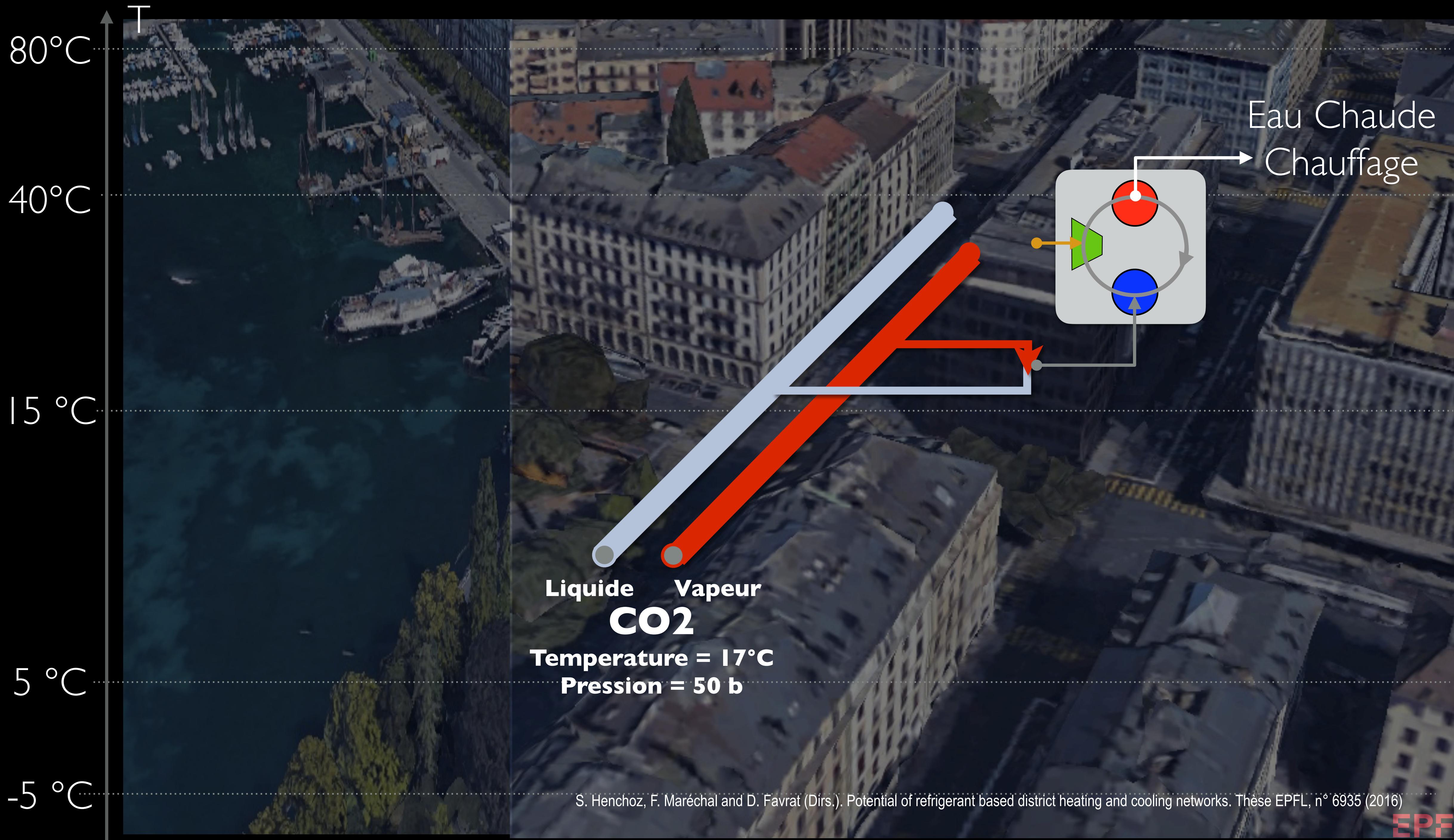
Lake water : **7°C**

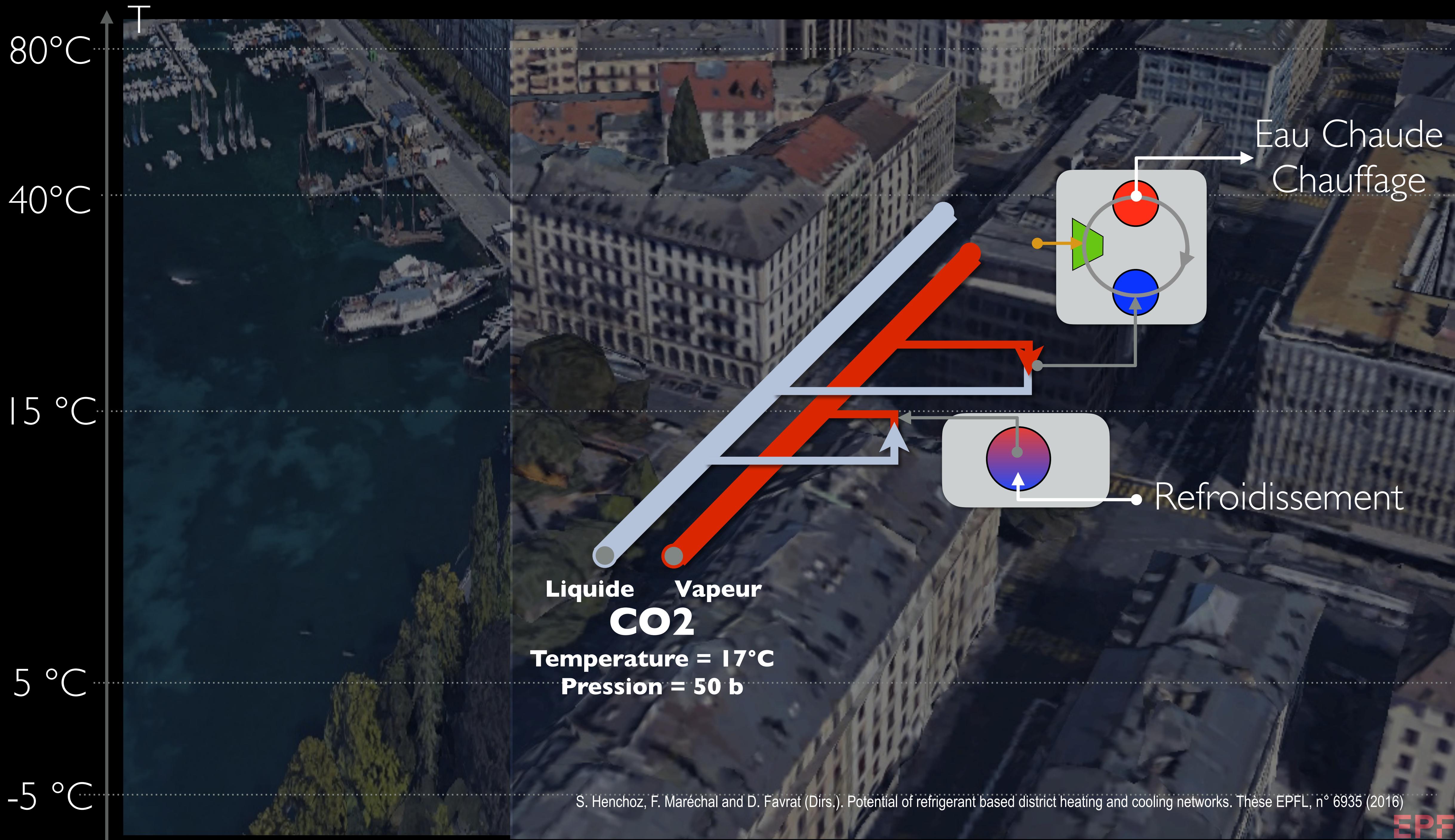
Refrigeration : **< 0°C**

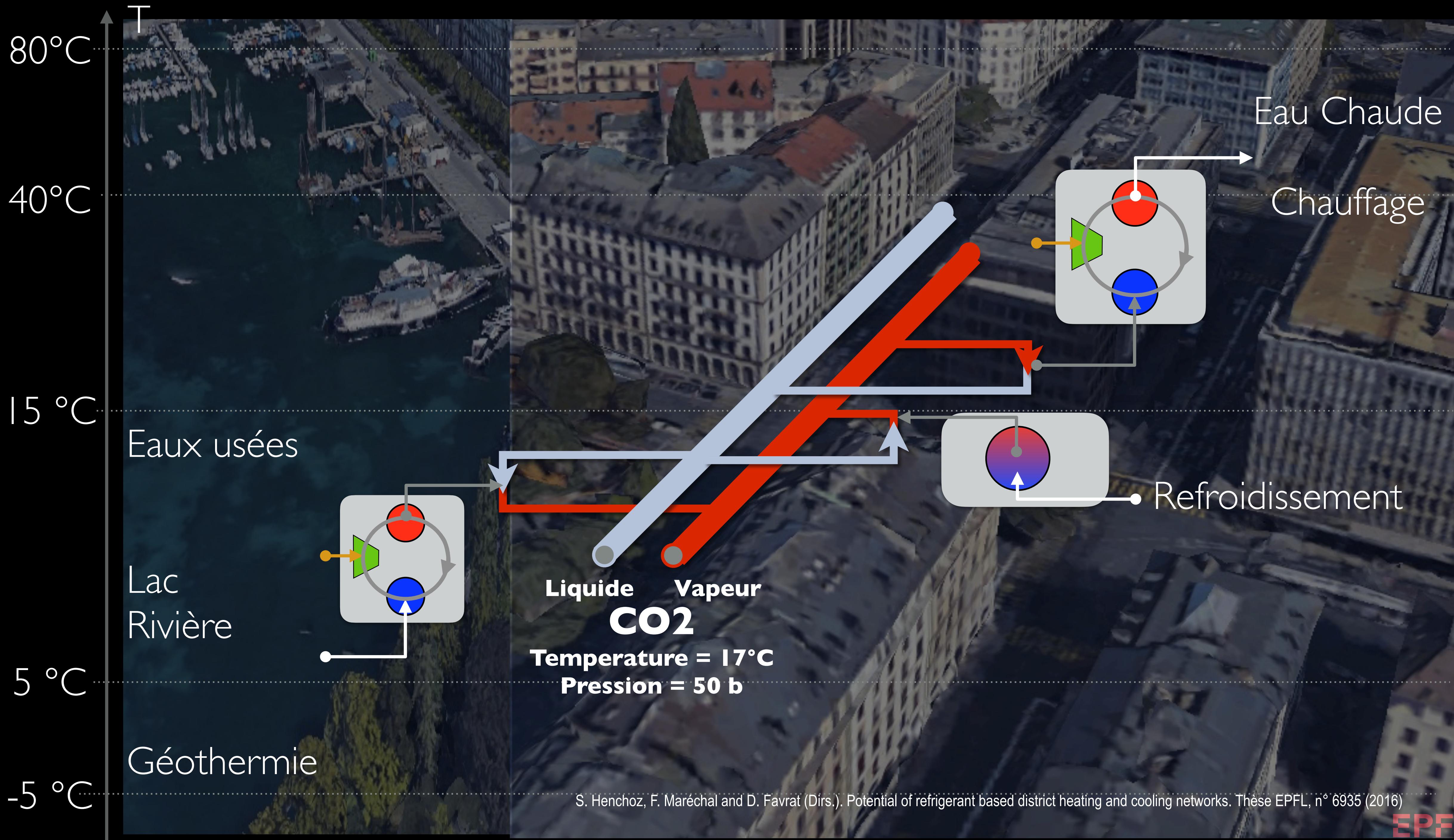
Decentralised Heat Supply

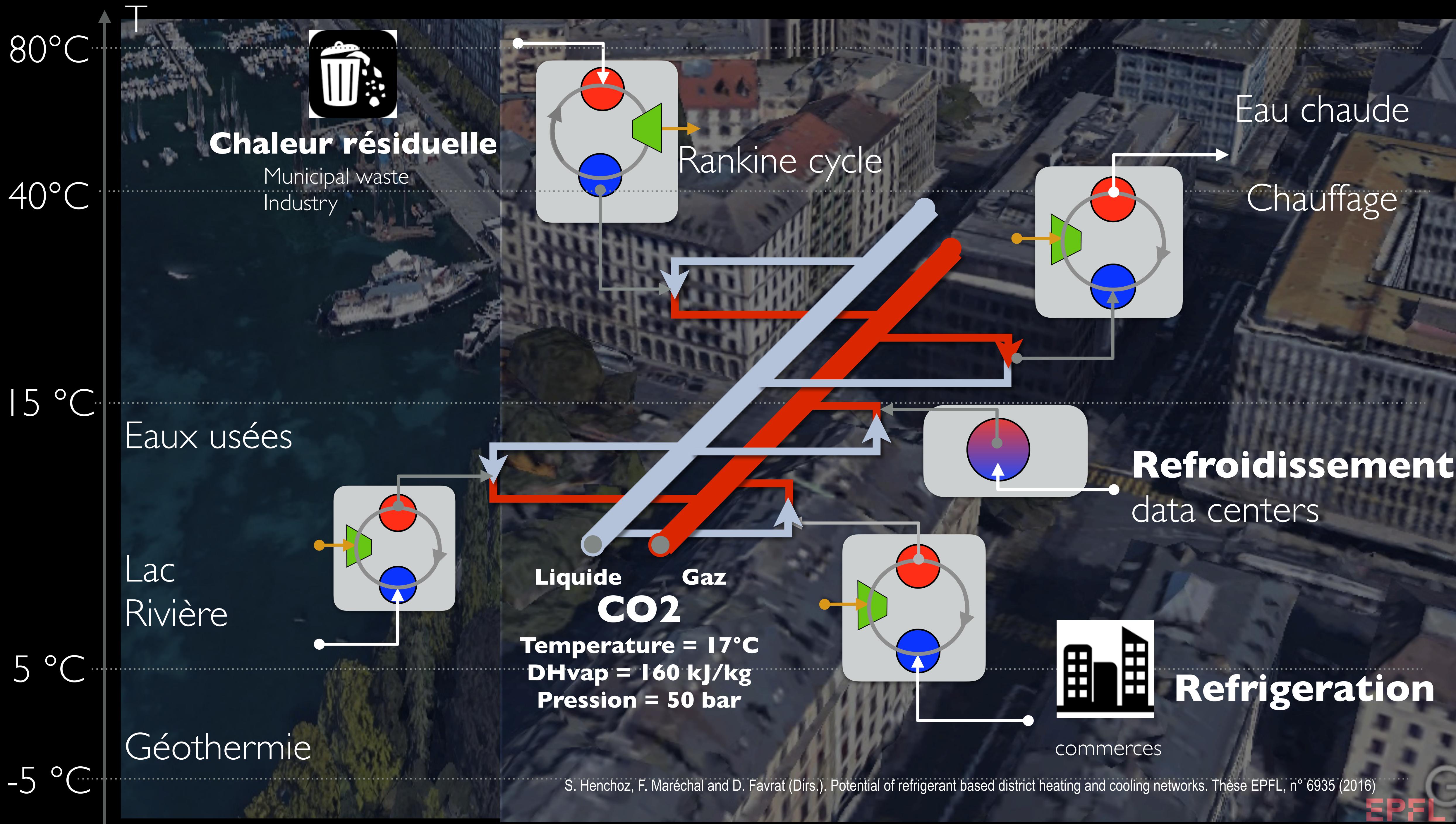




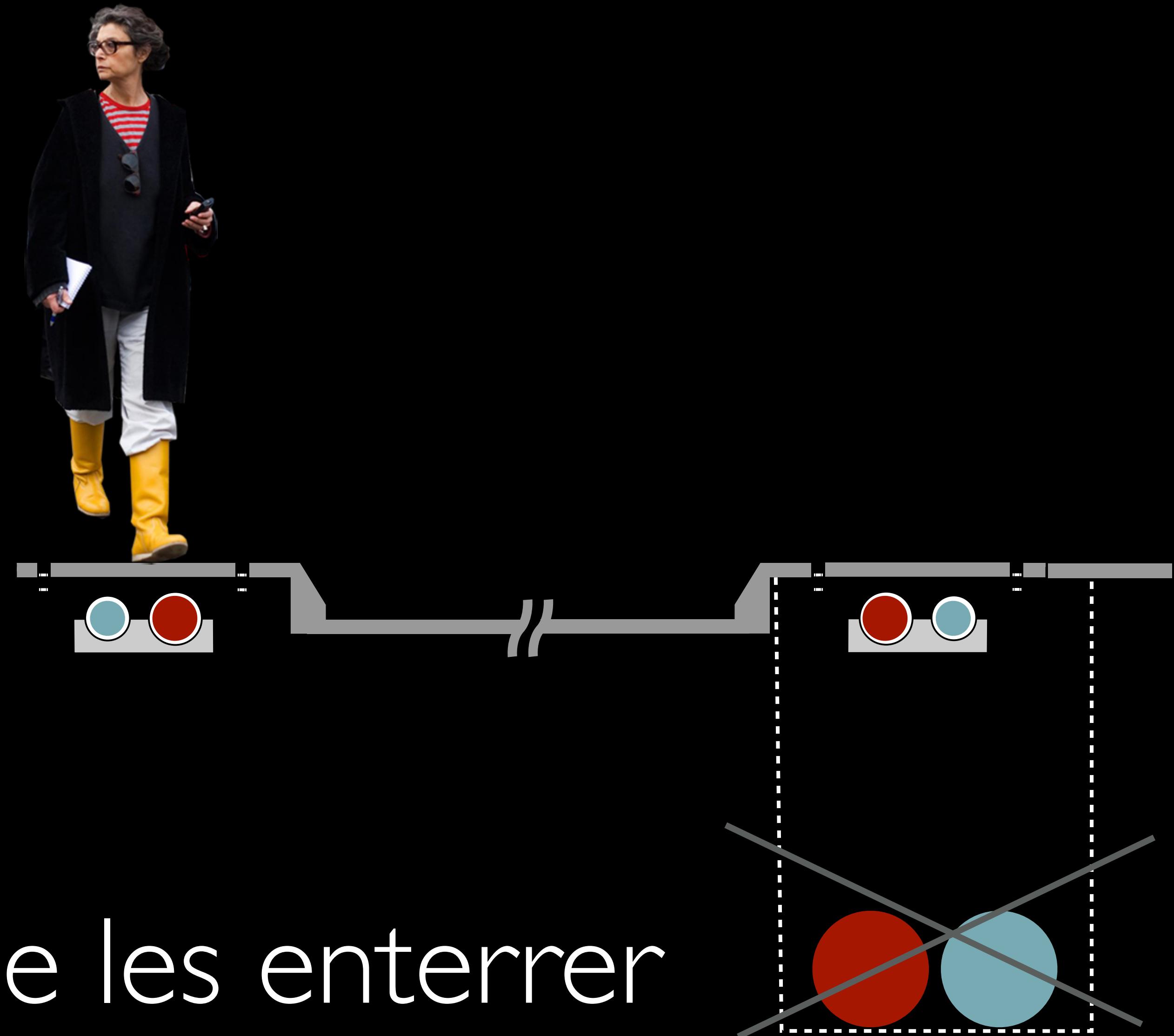






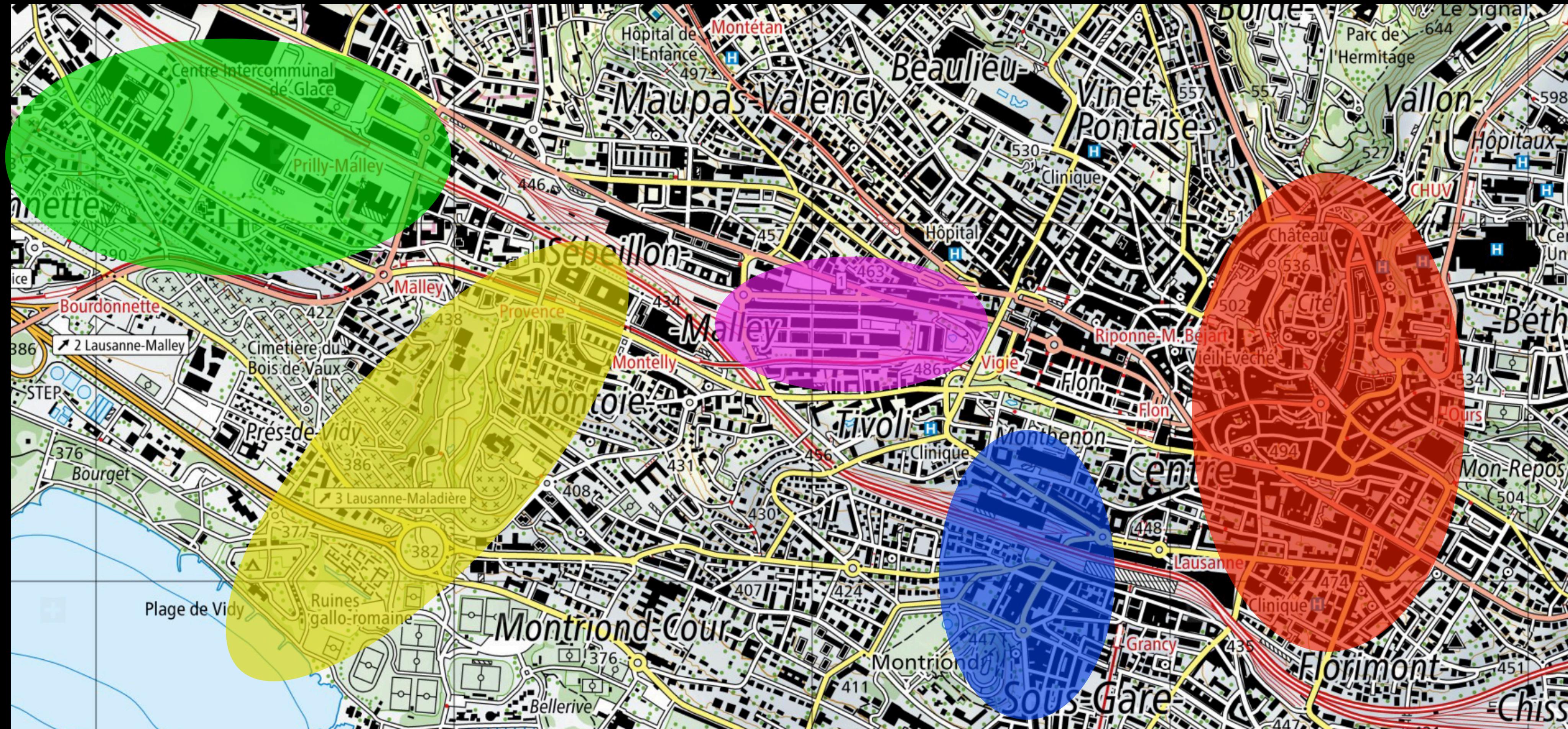


METTRE LES TUYAUX DANS LES TROTTOIRS



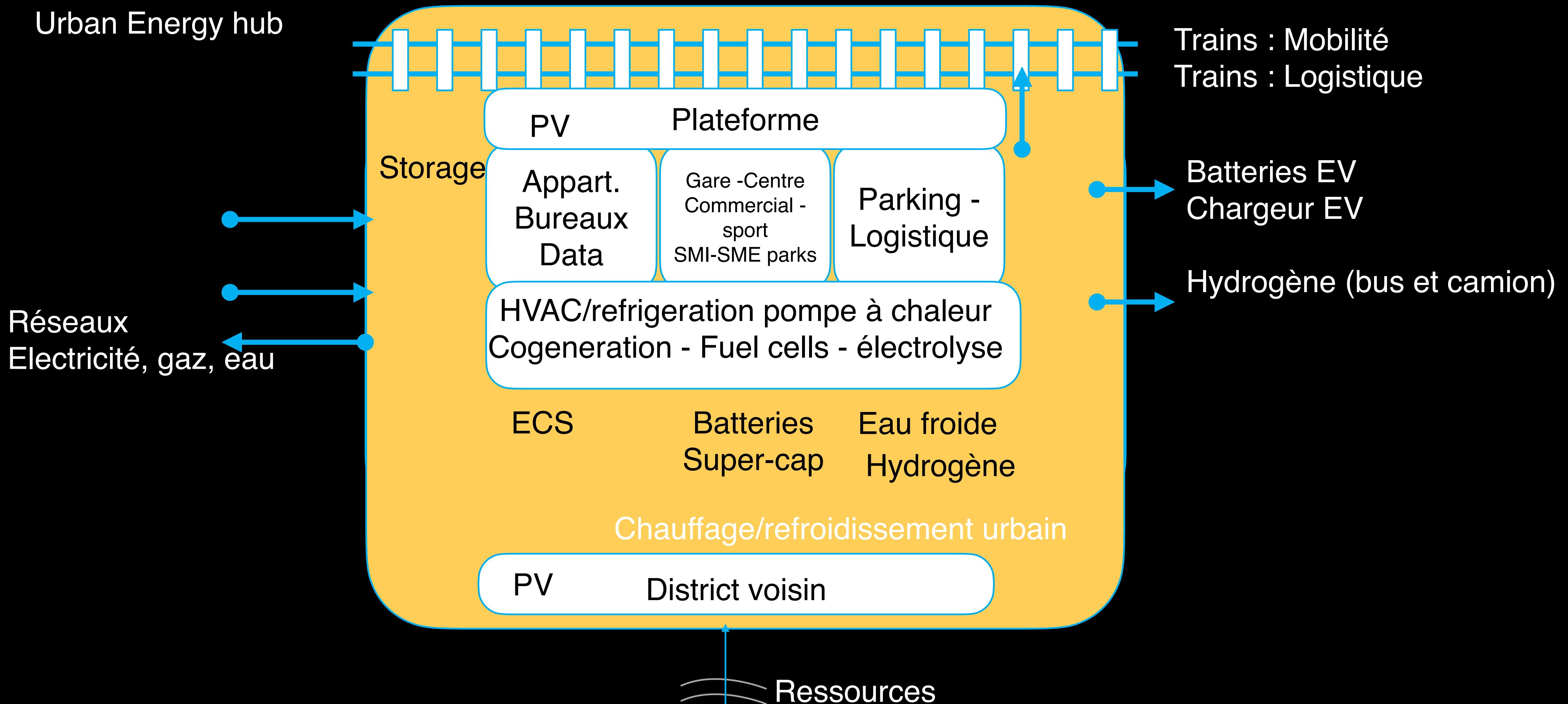
plutôt que de les enterrer

LES NOYAUX ENERGETIQUES DE LA VILLE



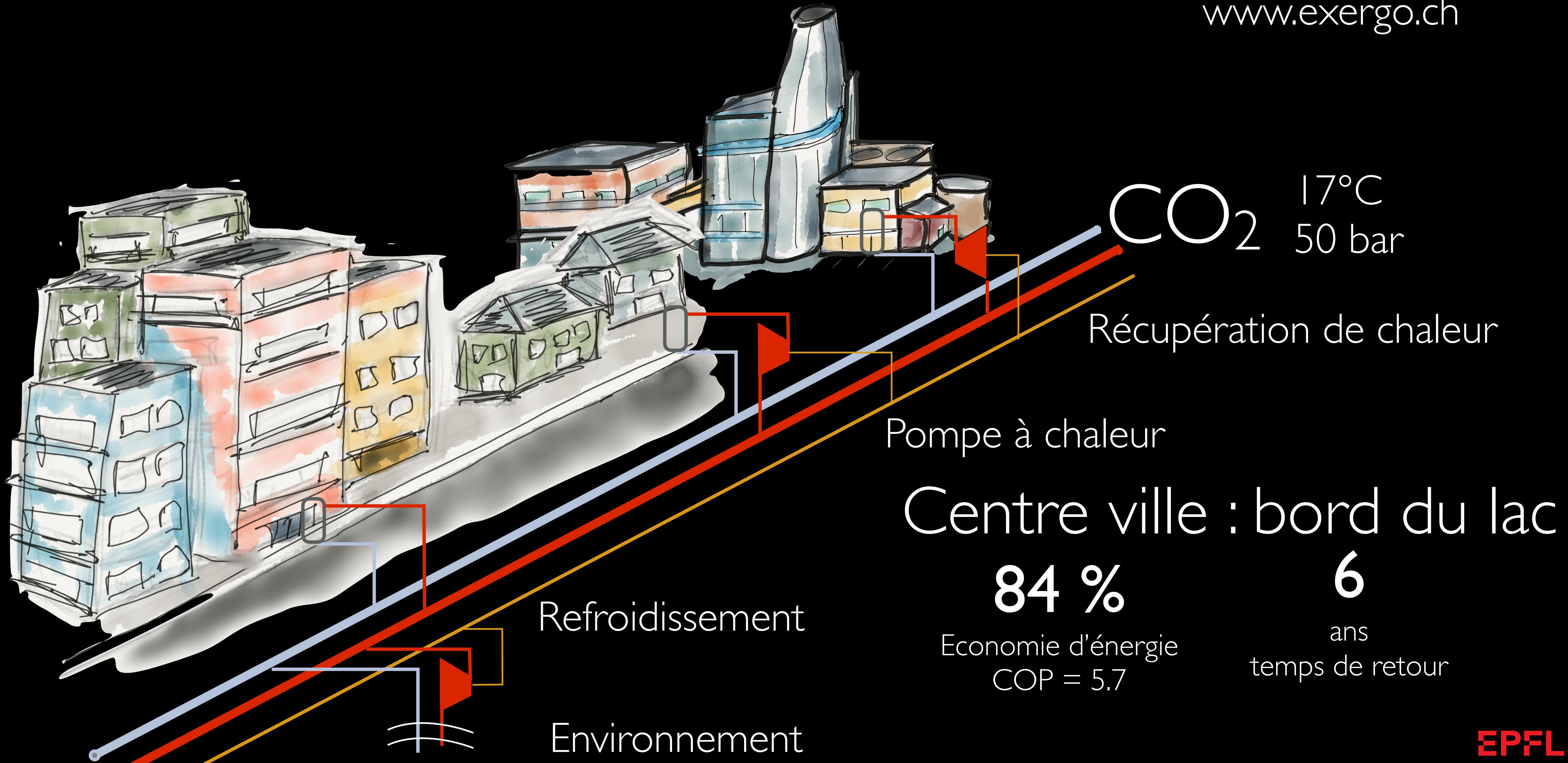
<http://urb.io> : aide à la décision pour la planification urbaine multi-critère

GARE - CENTRE COMMERCIAL - PME : NOYAU ÉNERGÉTIQUE



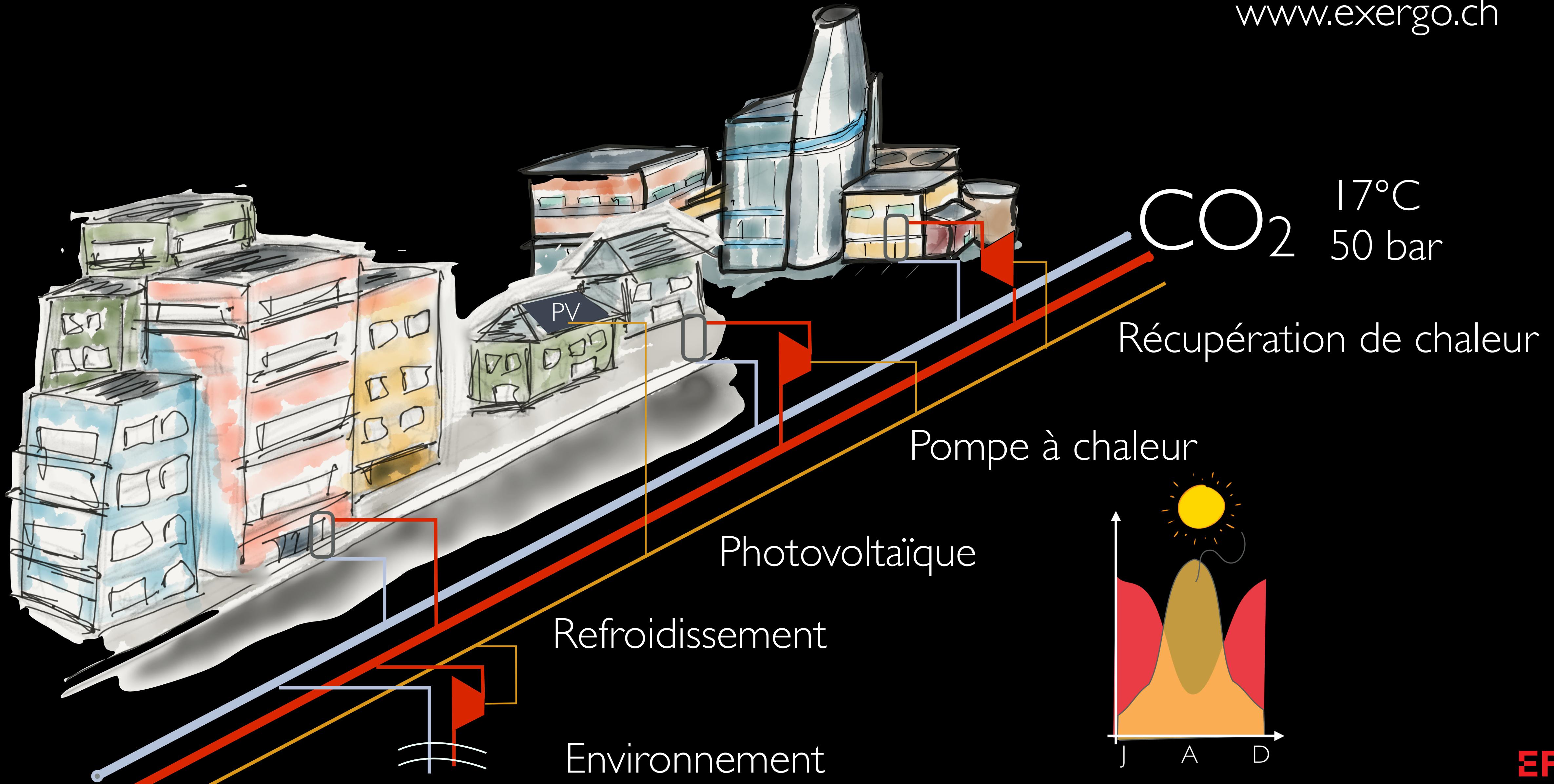
POMPE À CHALEUR URBAINE

www.exergo.ch

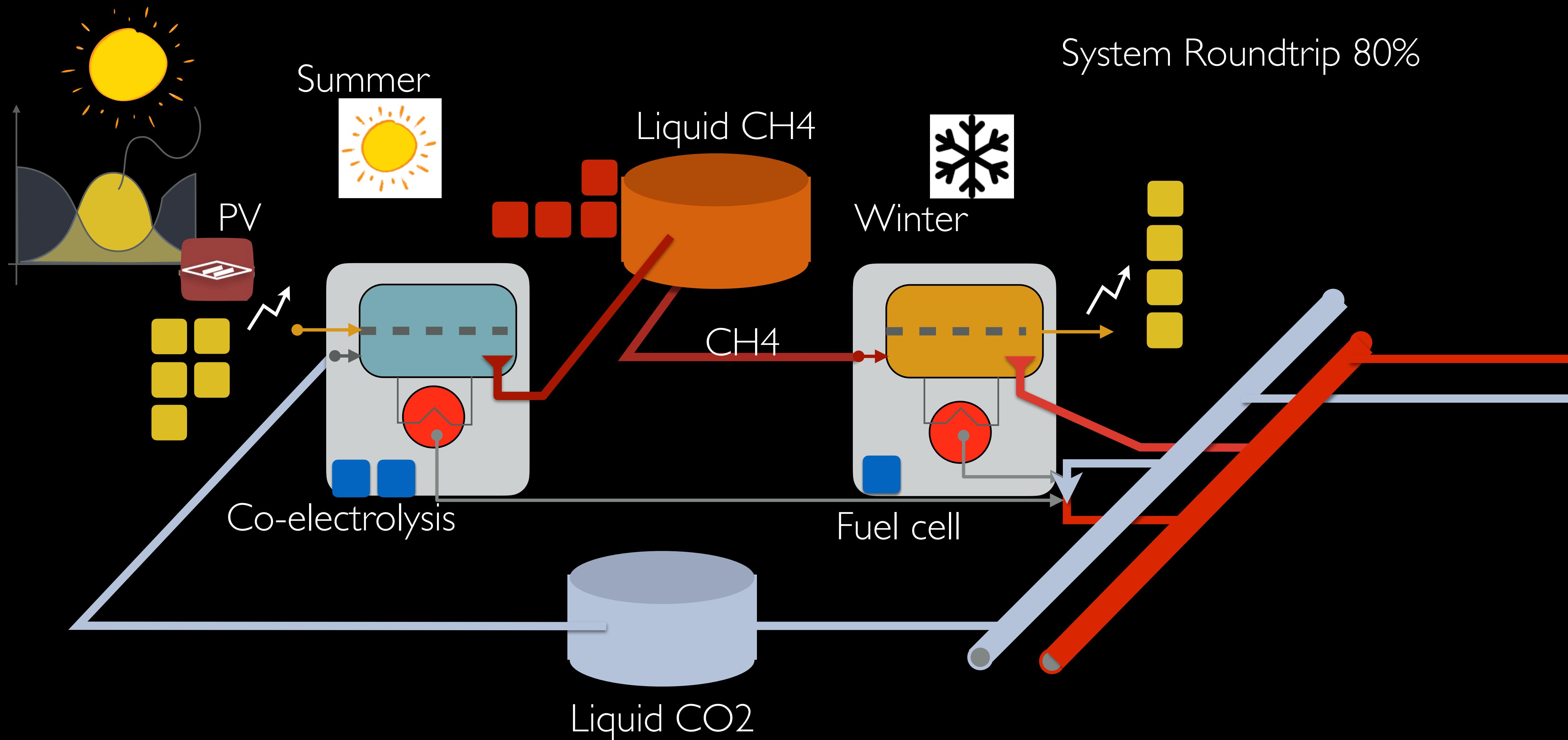


POMPE À CHALEUR URBAINE ET PV

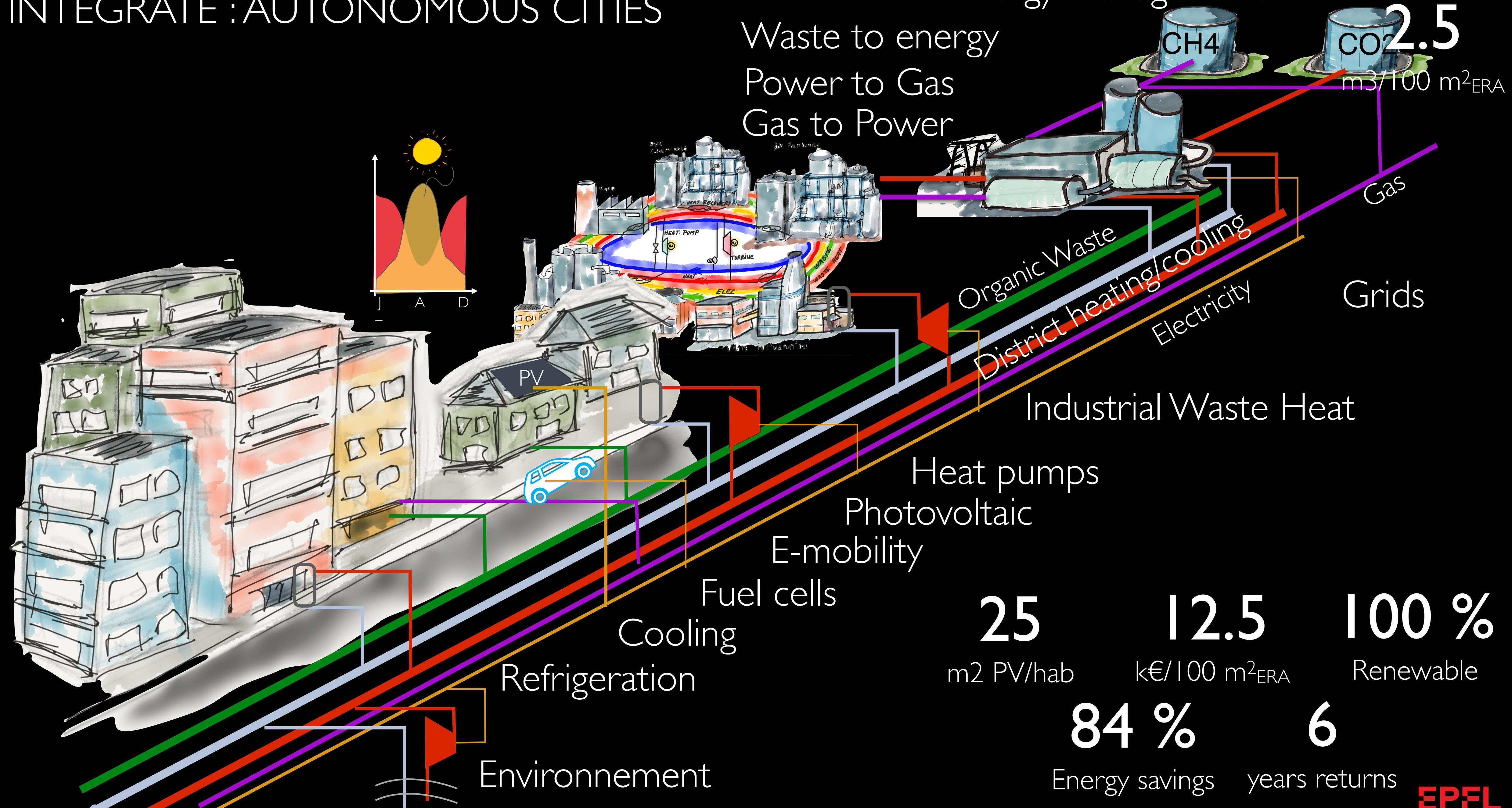
www.exergo.ch



INTEGRATED ENERGY MANAGEMENT



INTEGRATE :AUTONOMOUS CITIES



DEFOSILIZING INDUSTRY

Technology efficiency

*Technology improvement
Optimal operation*

Efficiency

Heat recovery

Heat valorisation

Heat pumping
Waste heat to
electricity

Energy conversion

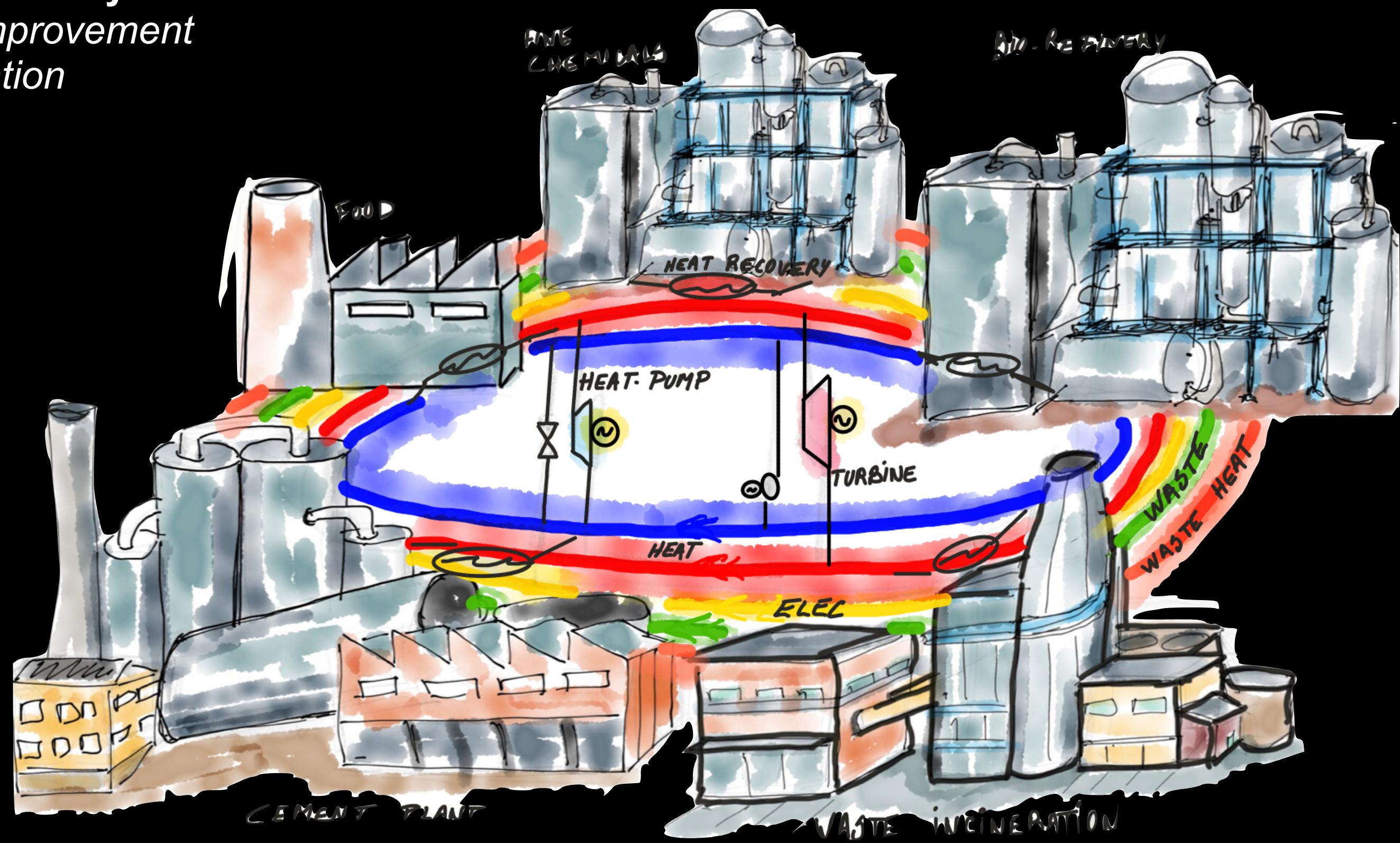
*Renewable resources
Combined Heat and Power
Combined Heat and Fuel*

CO₂

Capture, reuse, sequestrate

Energy Audits

Energy Drivers



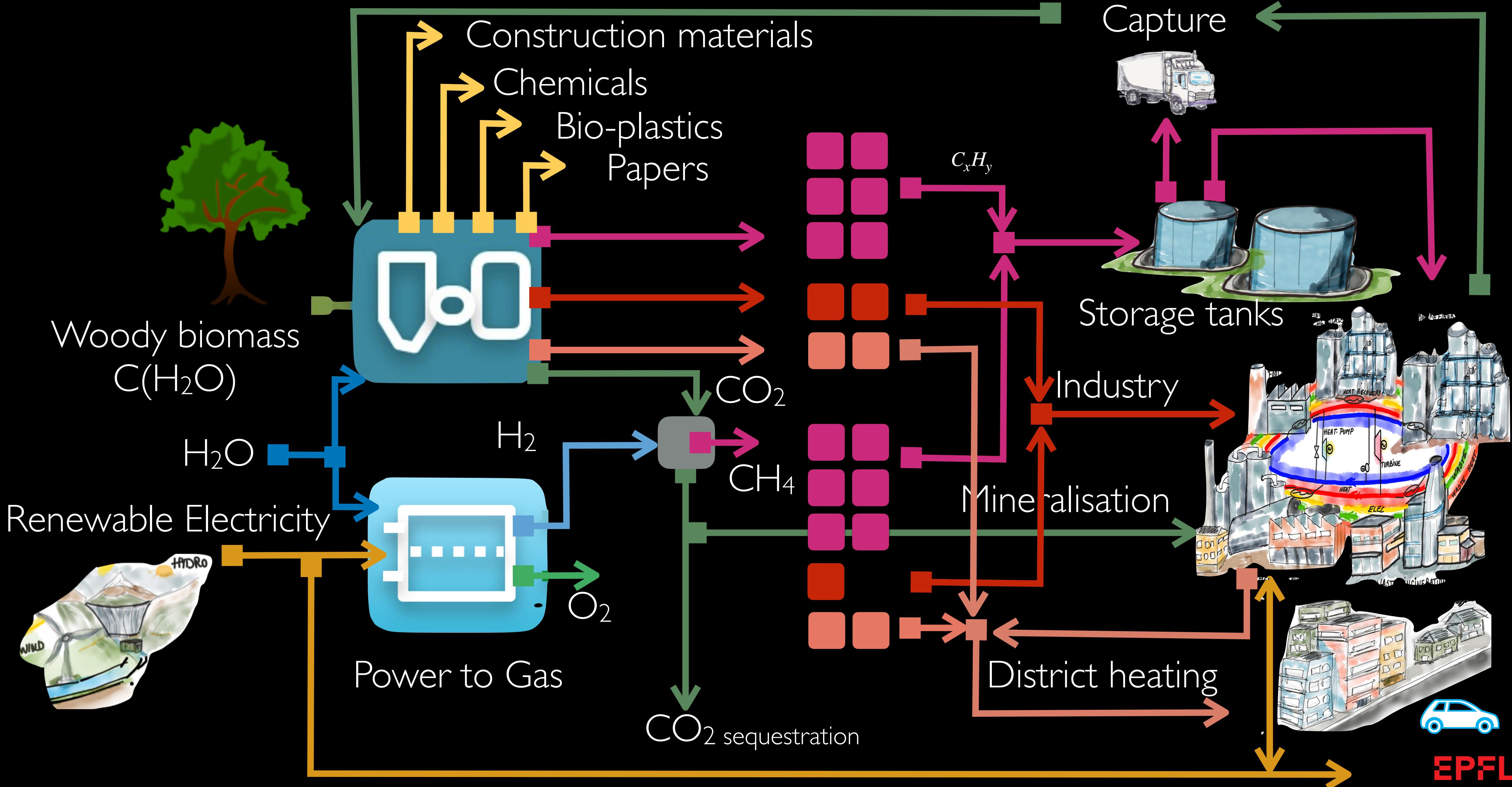
Energy system integration

*RES integration
Heat and electricity storage
Hydrogen & power 2 X*

System expansion

*Industrial symbiosis
Waste to products
Waste-water-energy
Circular economy
District heating/cooling*

BIOMASS AS THE MATERIAL AND ENERGY RESOURCE



LA MOBILITÉ



36%

Efficacité

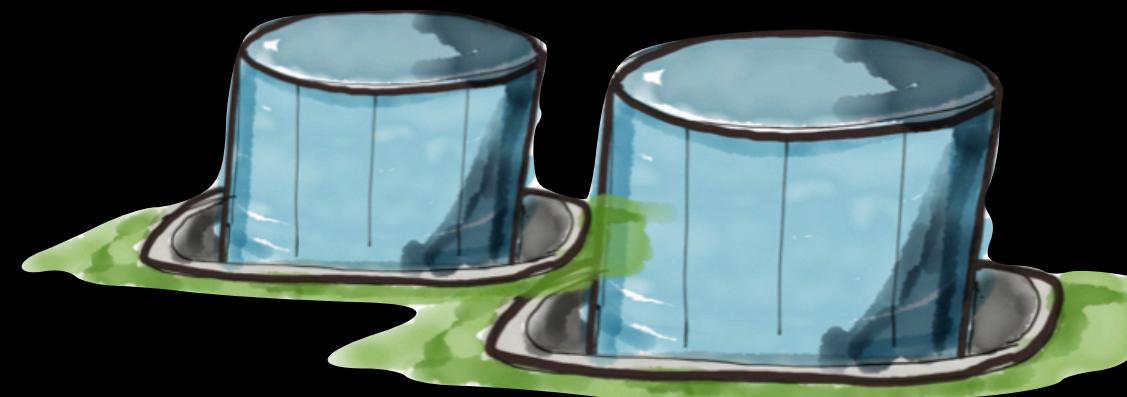


Transport Public : électrique/hybrid

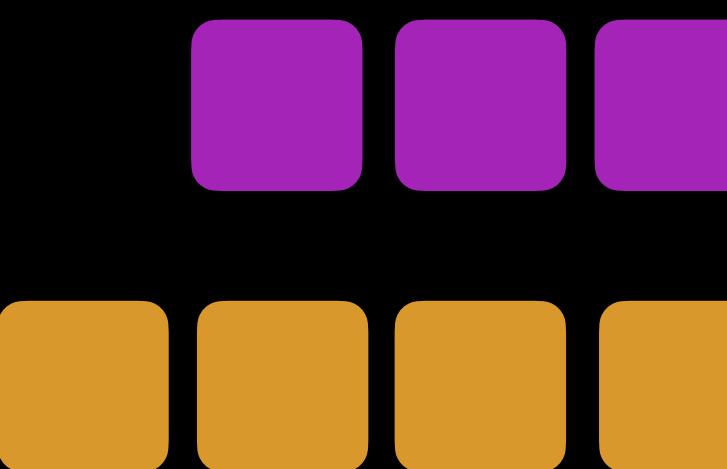
Véhicules électriques

Véhicules Hybrides et range extenders (H₂, CH₄)

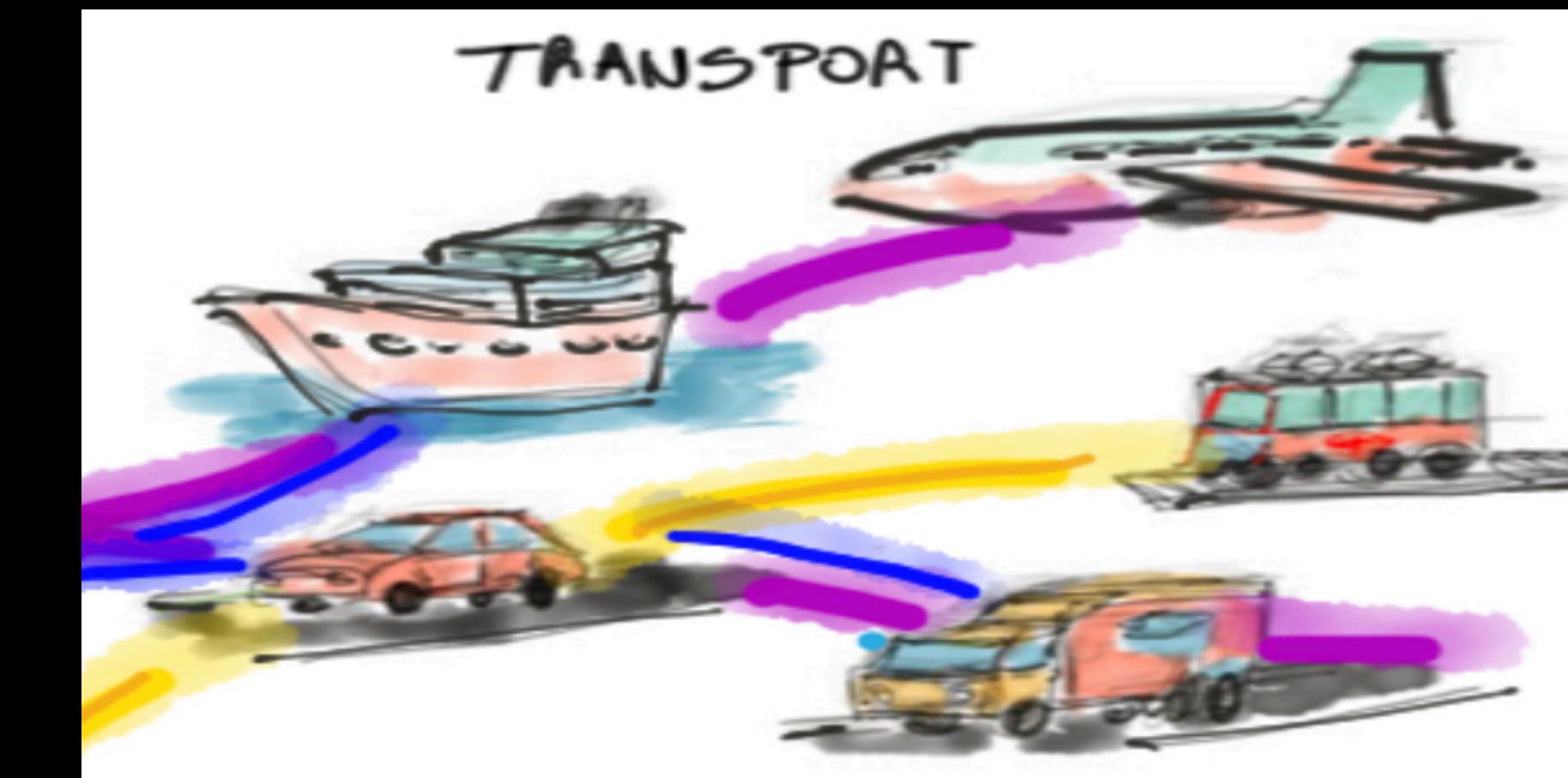
Capture du CO₂ sur les véhicules



Bio-Fuel



100 l gasoline/hab/year

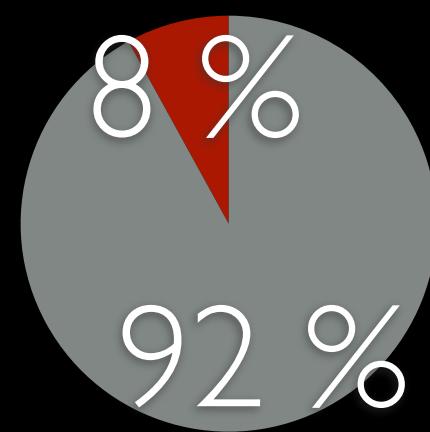
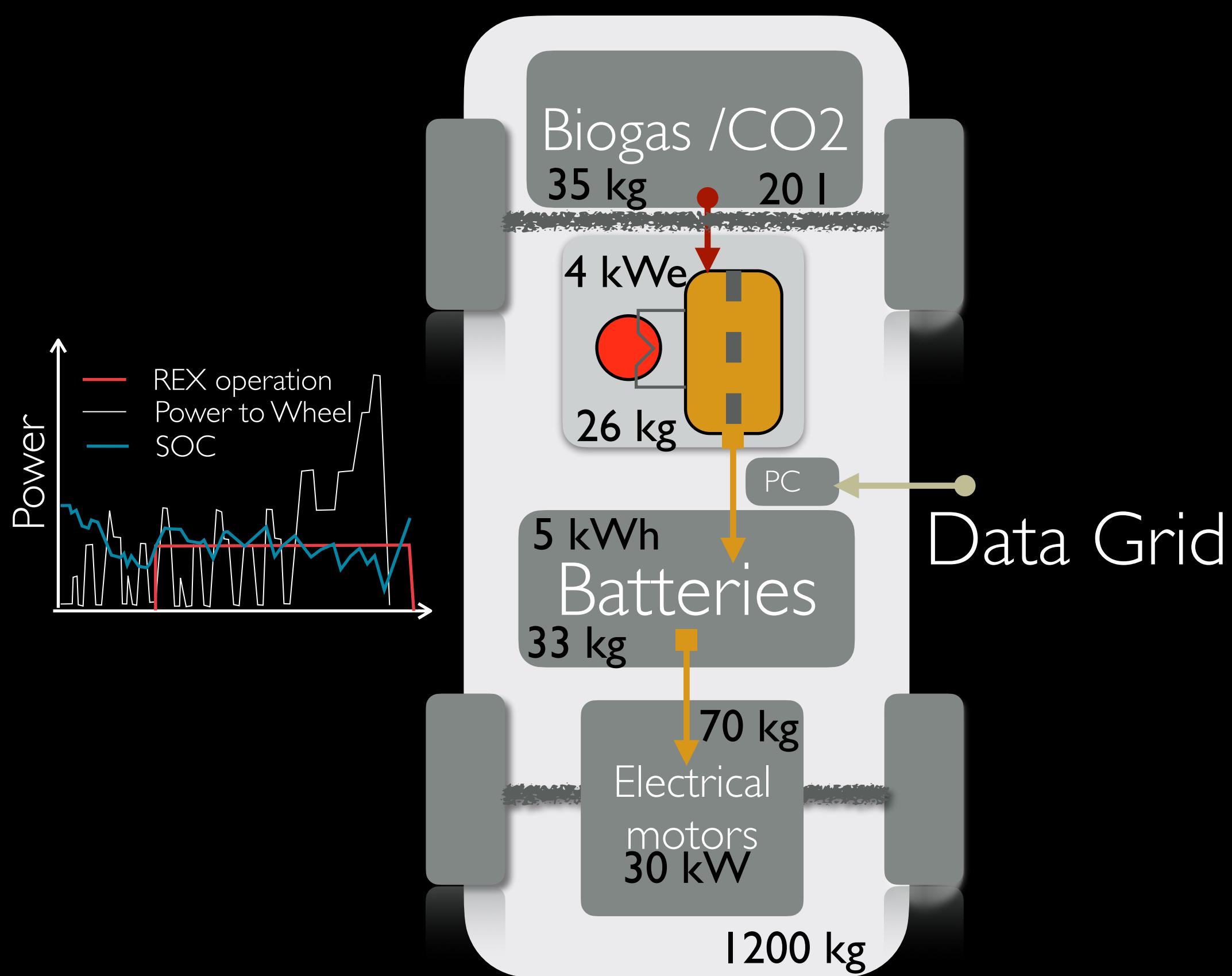


VEHICLES “RANGE EXTENDERS”

Driving mode

Autonomie : 950 km

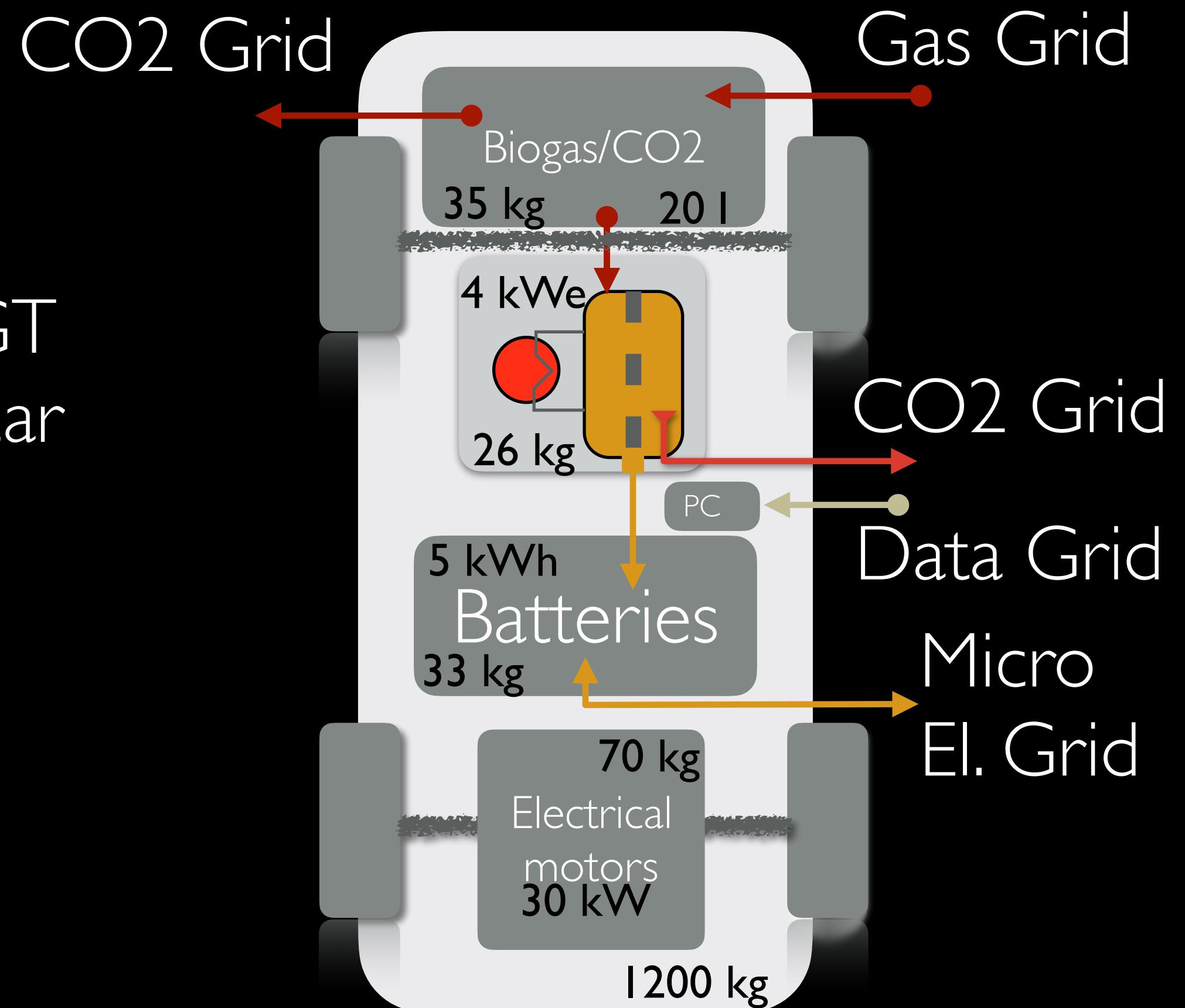
Cons : 1.1 l/100 km



Parking mode

Centrale électrique : 3.5 kW_e (eff. >70%)

Batterie : 5 kWh



CAPTURER LE CO₂ SUR LES CAMIONS

www.qaptis.com

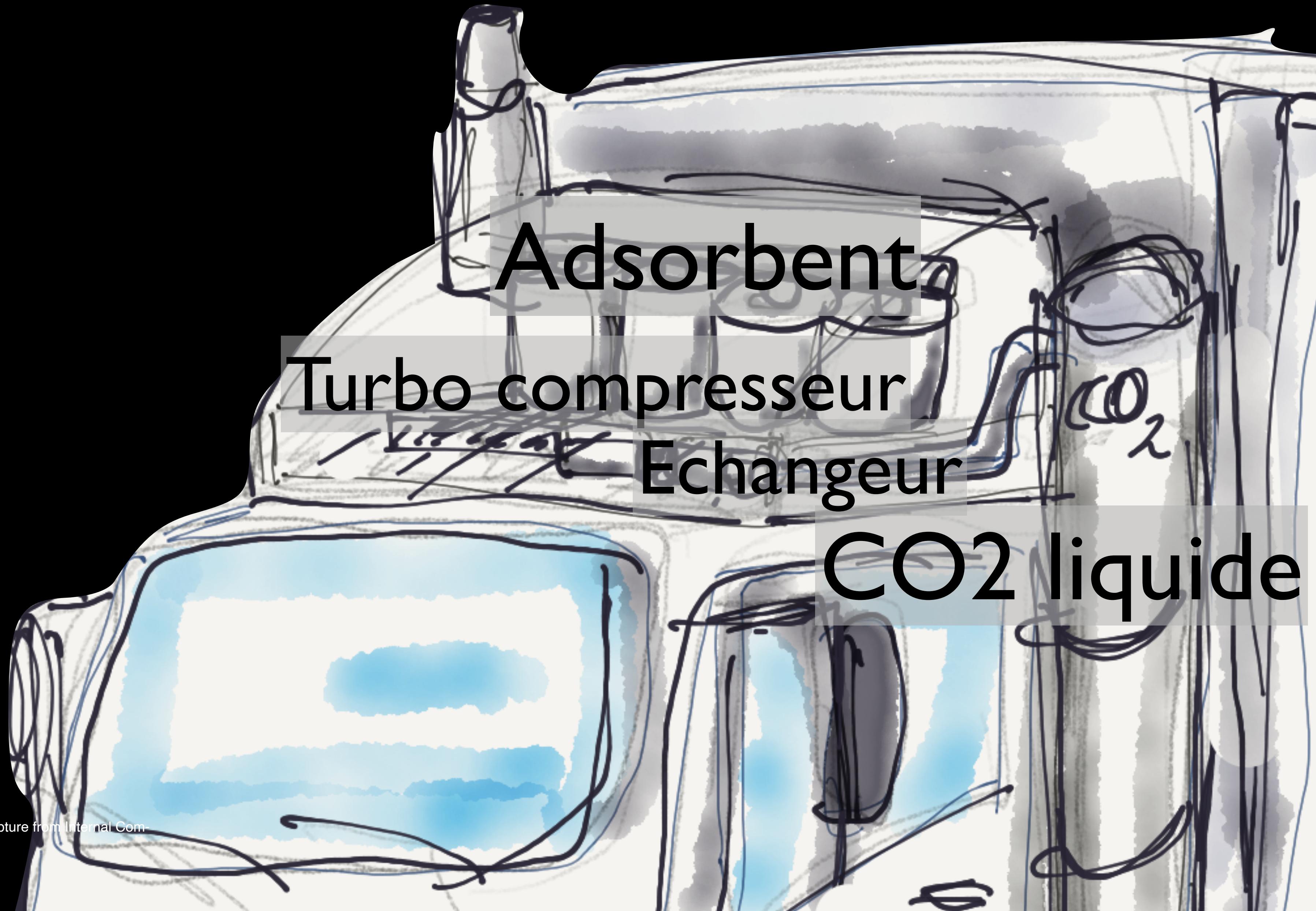
90% CO₂ capture

3

l CO₂/l fuel

5%

kg CO₂/kg payload



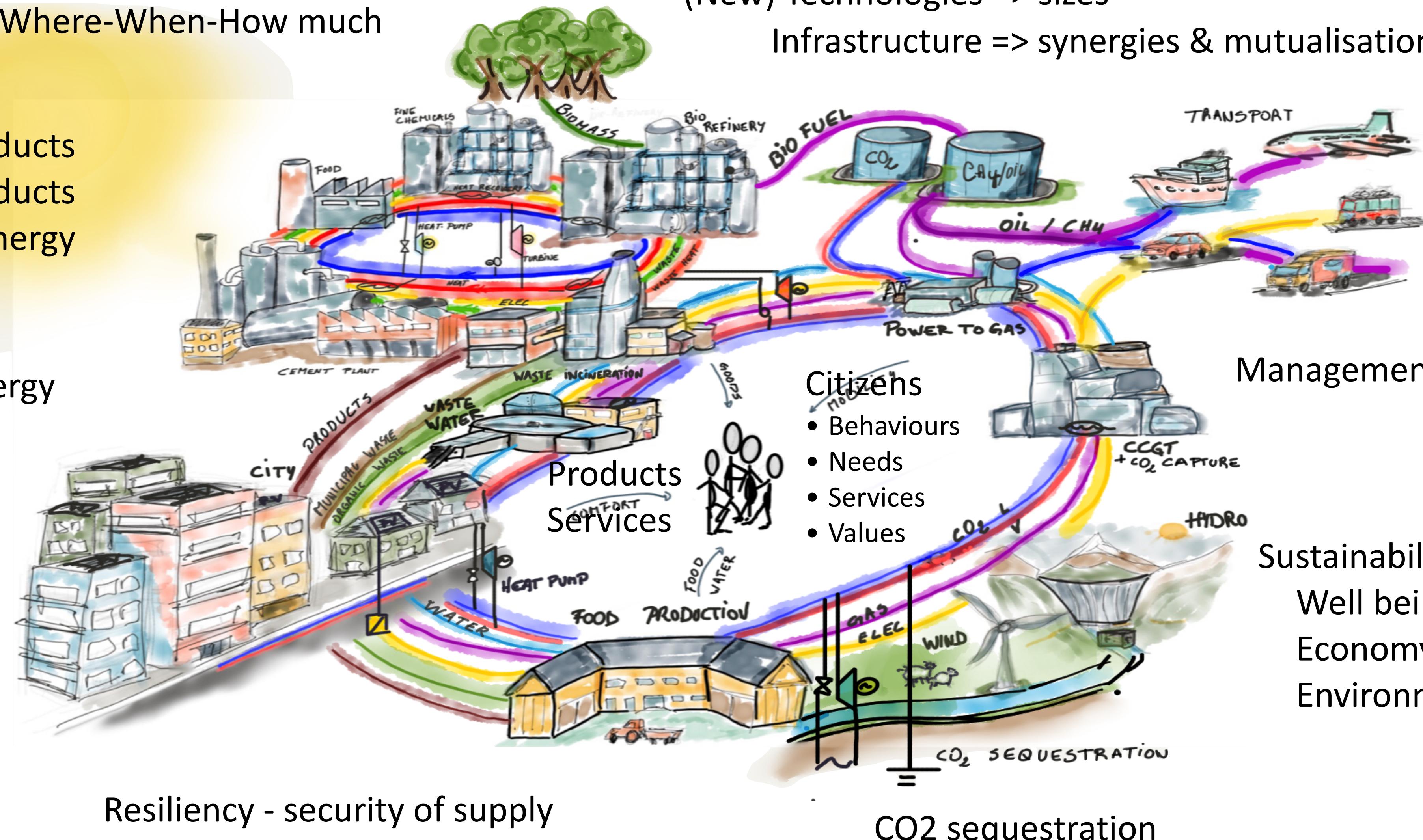
Une Suisse indépendante et neutre : une multitude de solutions - une vision systémique

Renewable resources
Where-When-How much

Circularity
Waste to products
CO₂ to products
Waste to energy

Waste-Water-Energy

Investments
(New) Technologies => sizes
Infrastructure => synergies & mutualisation



Management => operation

Sustainability (metrics)
Well being/happiness
Economy
Environment

REMERCIEMENTS

- **Soleil** : pour nous fournir l'énergie
- **Mère Nature** : pour nous montrer la voie de la gestion de l'énergie
- **Carnot** : pour nous apprendre l'importance de l'efficacité et de l'environnement
- **Recherche** : pour fournir les méthodes et les fondements technologiques
- **Ingénieurs** : pour choisir, développer, assembler et opérer les technologies
- **Industrie** : pour fournir les technologies
- **Autorités** : pour développer le système éducatif et les infrastructures
- **Finance** : pour utiliser l'(notre) argent de manière responsable envers les générations futures
- **Citoyens** : pour adopter des comportements responsables