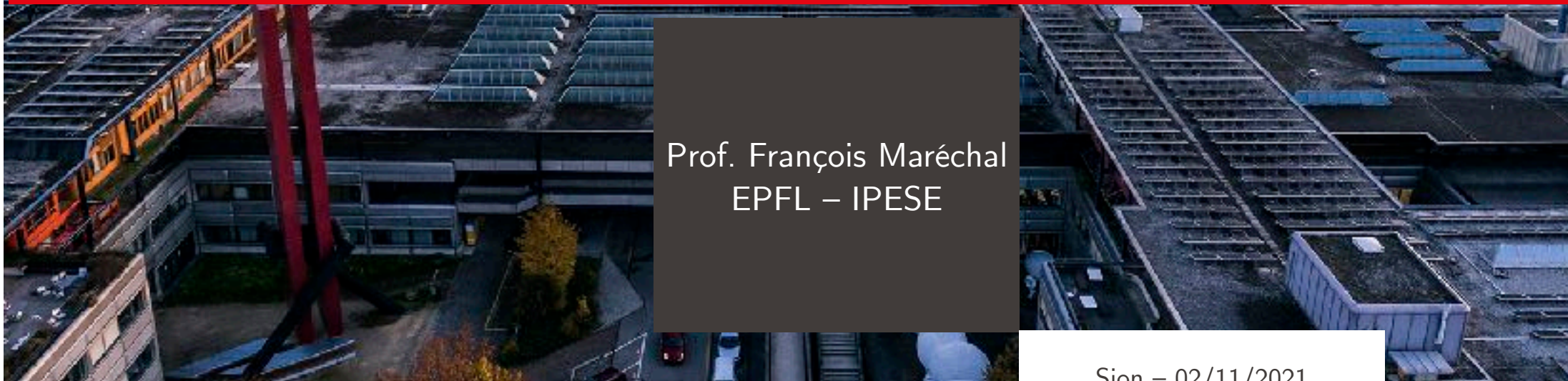


The top portion of the slide features a background image of a dramatic, cloudy sky at dusk or dawn, with soft light breaking through the clouds.

Life Cycle Analysis and The Energy System

The bottom portion of the slide features a background image of an aerial view of EPFL buildings, including a prominent red structural column and a yellow train on a track.

Prof. François Maréchal
EPFL – IPESE

Sion – 02/11/2021

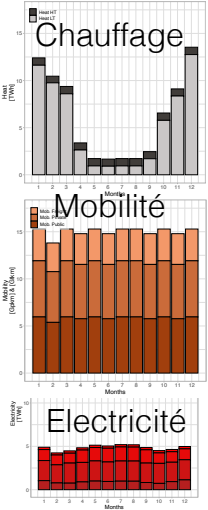
Deciding the energy transition



My needs

... Now

- Products
- Services
- Comfort
- Data
- Mobility
- Security of supply



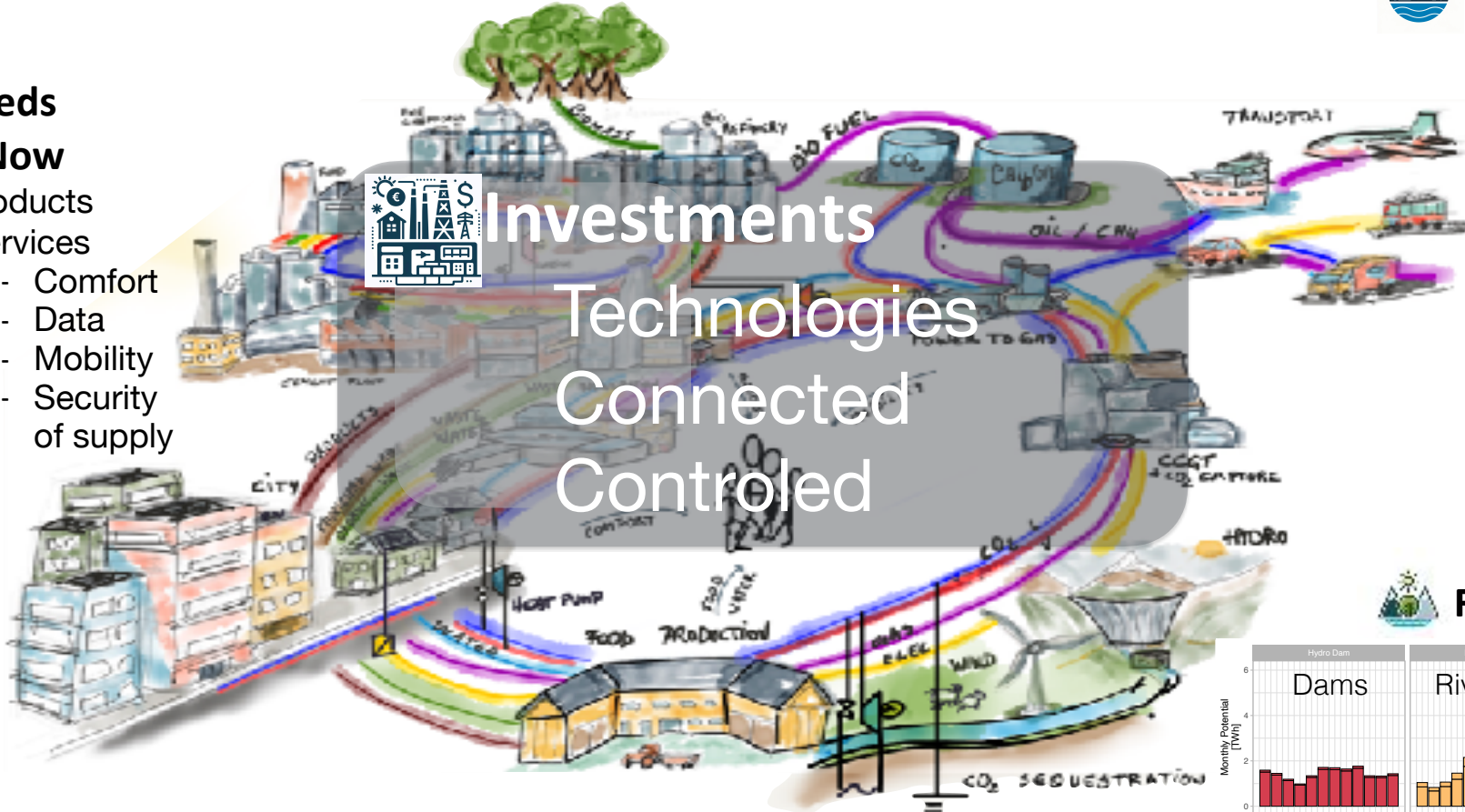
My Waste

Recycling
Valorising



Investments

Technologies
Connected
Controlled



Air



Cooling source
Climate change
Quality

Water



Potable
Used
Irrigation
Cooling
Floods

Earth



Urbanism
Forest
Landscape
Food
Wildlife
Flora



Fire

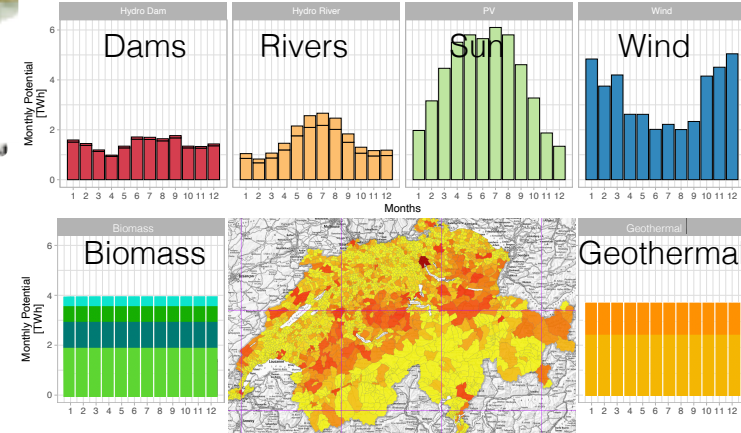
ESG* Impact

Future Generations

Environment

Well-being

Economy



FOR A
BRIGHTER
FUTURECLEAN
ENERGY

SYNTHESIS GAS

HYDROPOWER

MIX KIT



WIND

SOLAR

ENERGIES GO GREEN

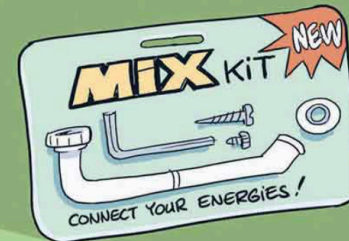
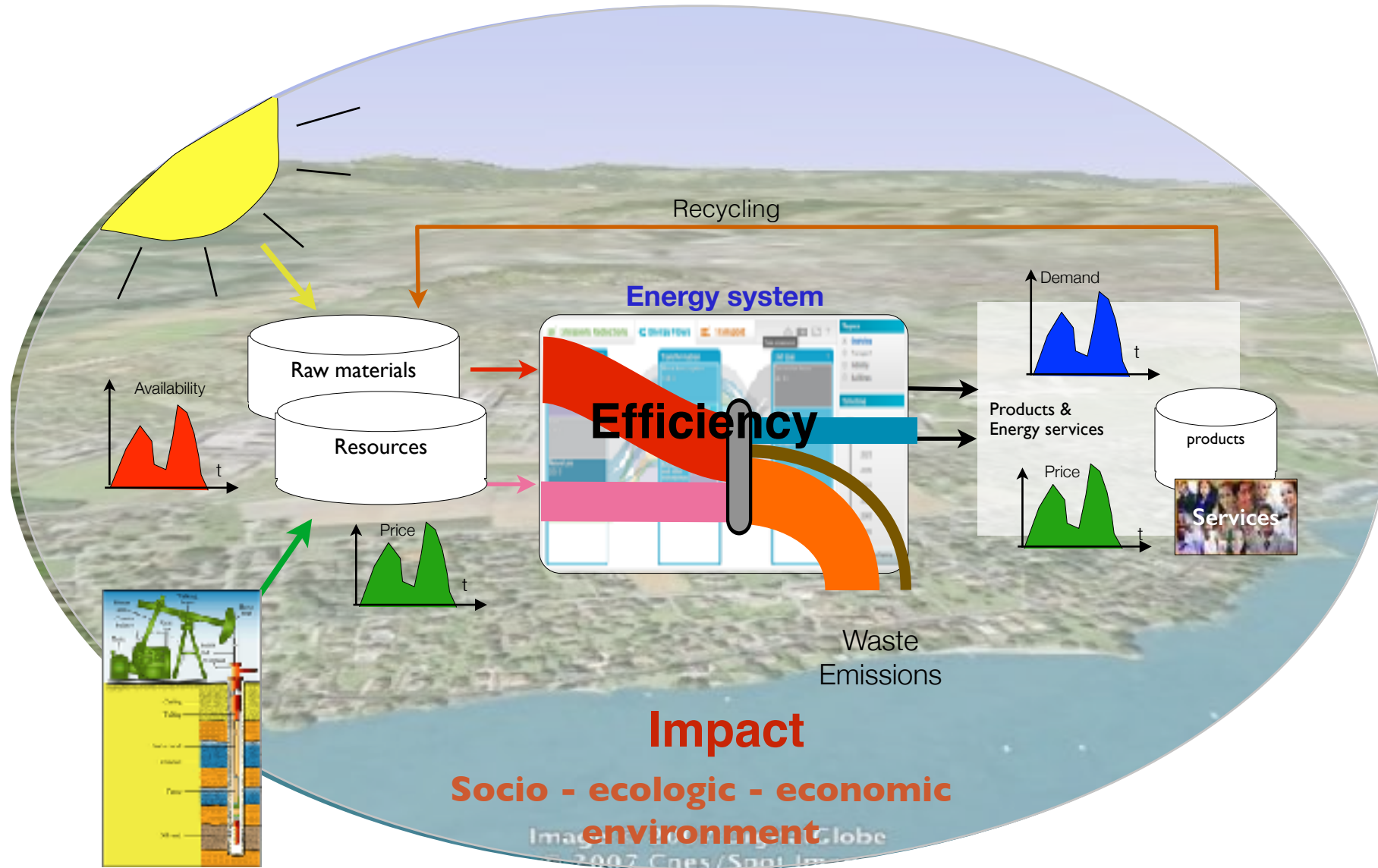


Illustration Éric Buche

<https://longread.epfl.ch/en/dossier/energies-go-green/>

EPFL Flows in the society



$$[kJ_p/hab/an] = \eta_e[kJ_p/kJ_e] \cdot \eta_s[kJ_e/kJ_s] \cdot e_d[kJ_s/an/m^2] \cdot d_{hab}[m^2/hab] \cdot hab[hab]$$

Primary energy

Extraction->resource



Conditioning

resource->distributed



Conversion

distributed->energy



Services

Energy->services



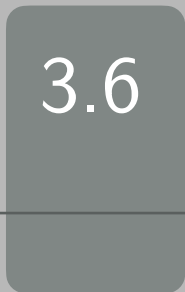
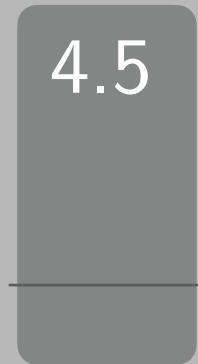
Needs

services->cap



Population

cap



20% to harvest Conversion efficiency = 60% Efficiency = 50%

Distribution losses = 8%

SWISS ENERGY SYSTEM



80
CHF/month/cap

15
kg CO2/day/cap



47%



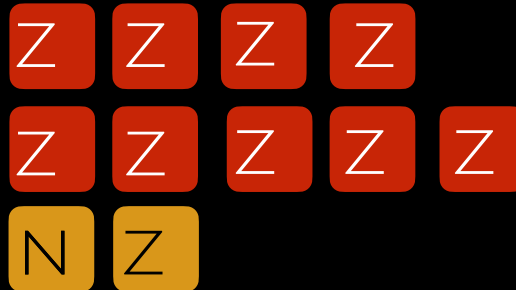
36%



products

17%

2%



80-140

CHF/month/cap

24

kg CO2/day/cap



Import



Mix

50-90

gCO2/kWhe



Export



Subsidies from our children

250

CHF/month/cap

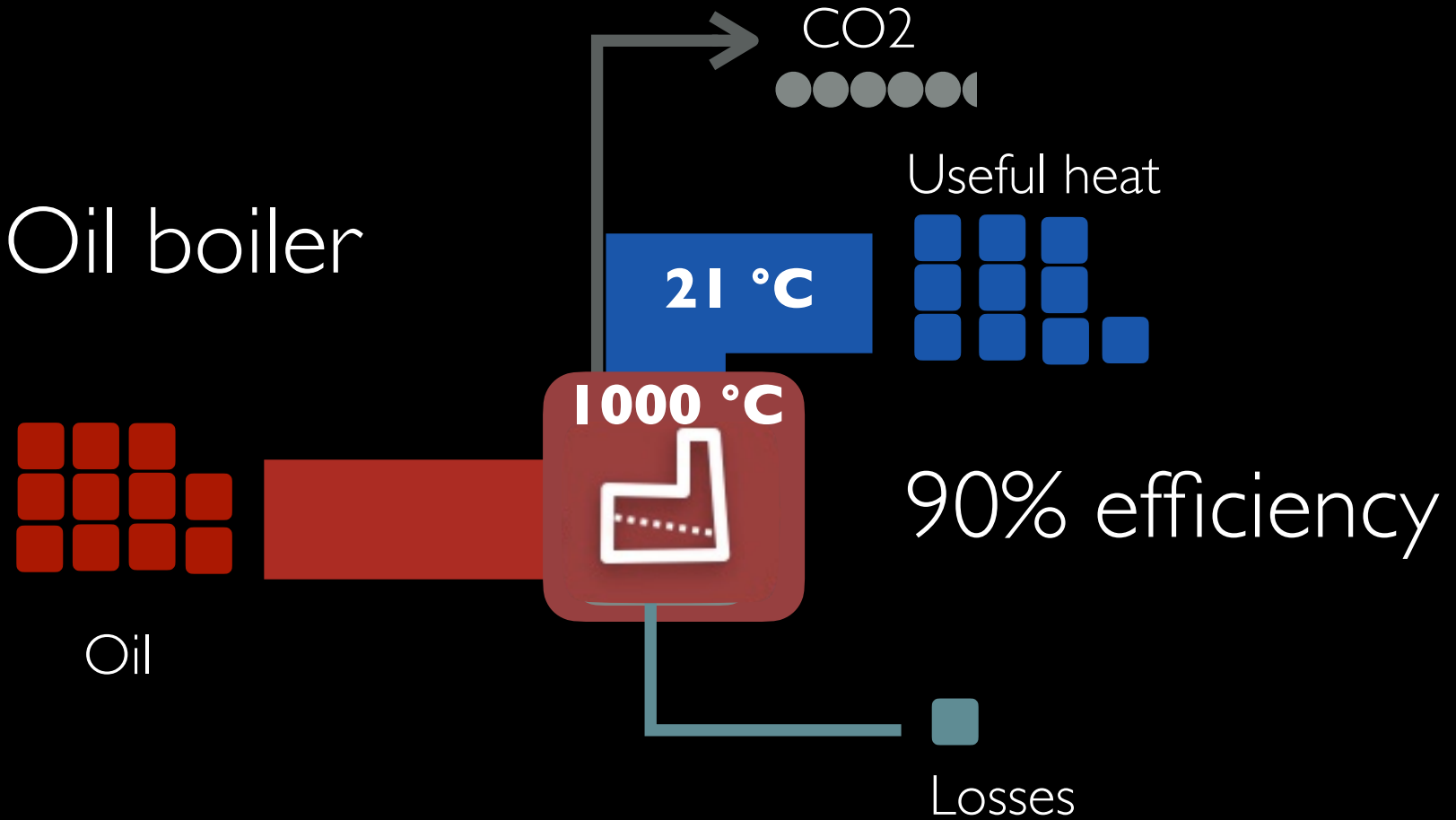
Fossil

Human energy needs
100 l gasoline/year/cap

Electricity

HOW DO WE SATISFY THE ENERGY NEEDS IN A BUILDING ?

“Good” Oil boiler



ENERGY NEEDS OF A BUILDING

Economy

170-280

CHF/month/100 m²

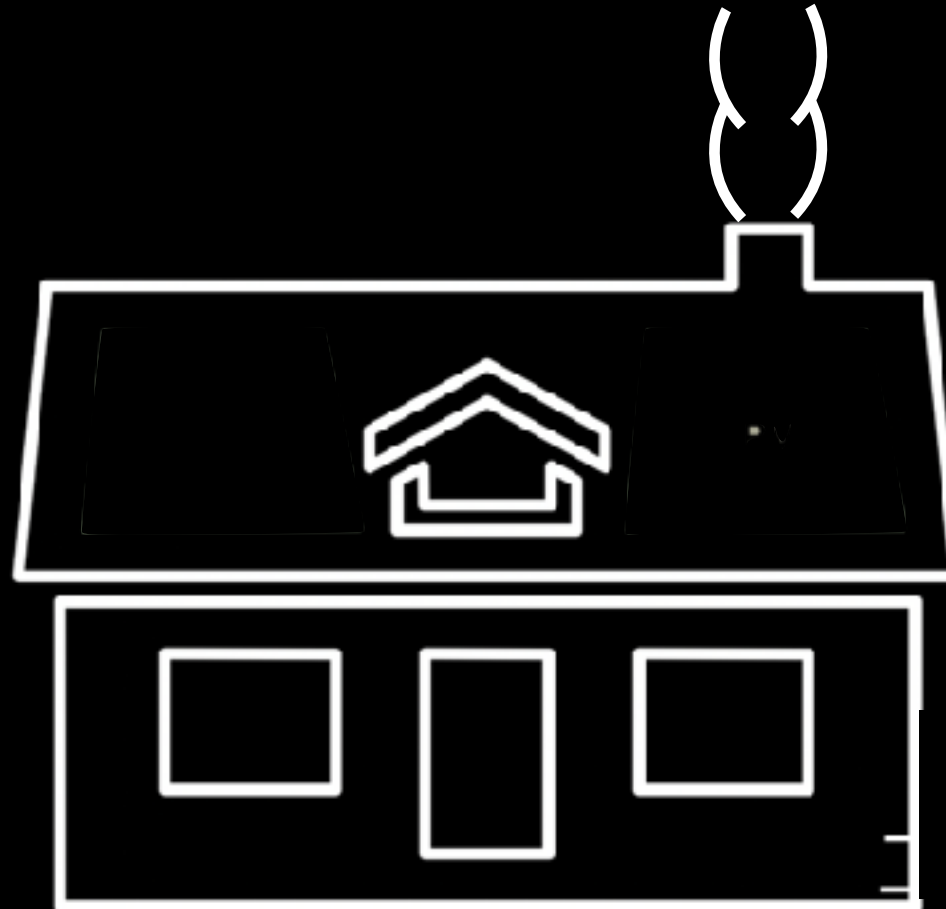
Energy (Oil)

140-250 CHF/month/100 m²

in which 105-215 CHF/month/100
m² import

Boiler

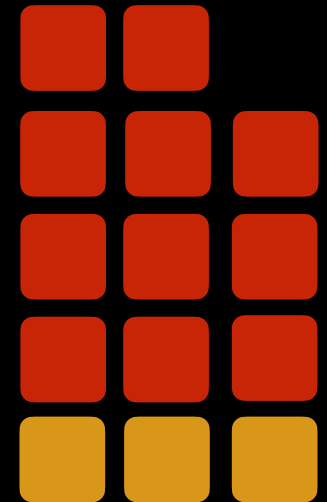
30 CHF/month/100 m²



Impact

3.8

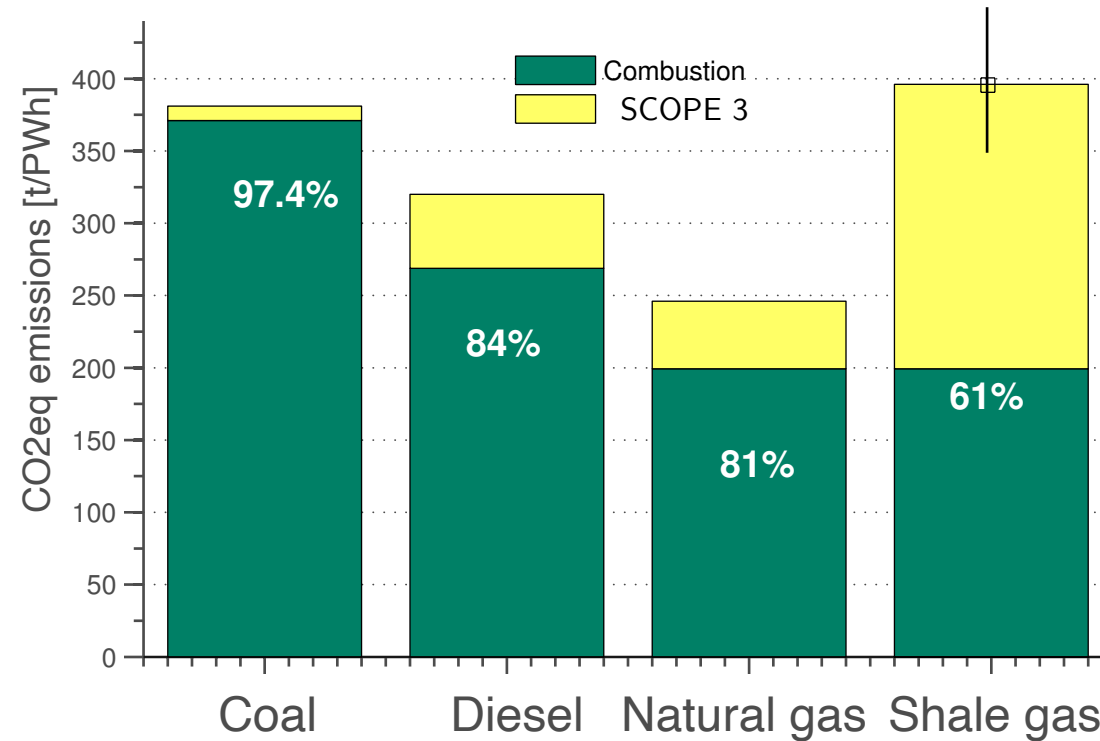
tons **CO₂** /year/100 m²
63 CHF/month/100 m²



Environmental impact of a fuel

■ Importance of the fuel life cycle

-  • Extraction
-  • Conditioning
-  • Transport
-  • Refining
-  • Distribution
-  • Combustion



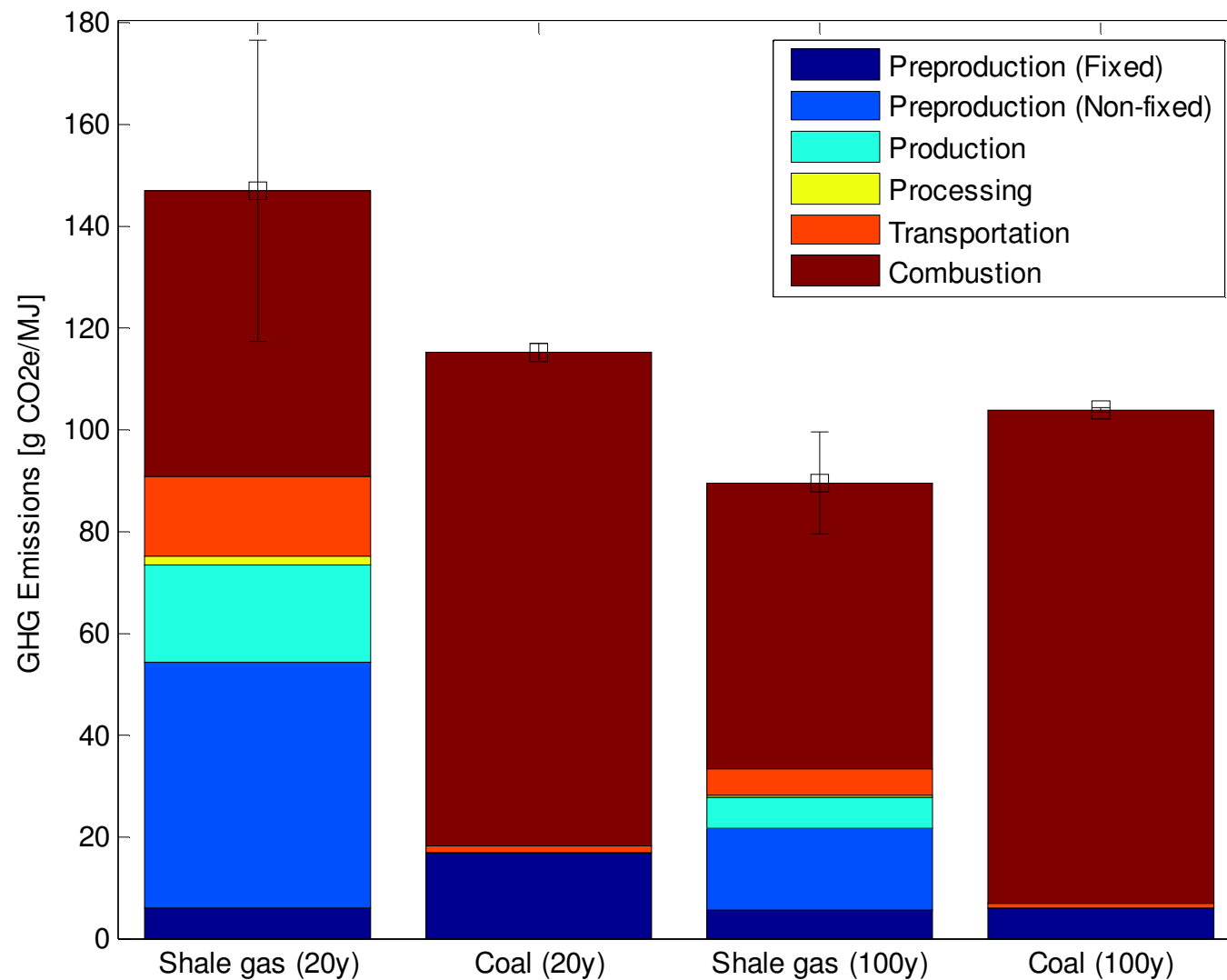
CO₂ eq : is a measure of the global warming potential of the emissions over the overall conversion chain up to combustion. The global warming potential is considering not only the CO₂ emissions but also other emissions like CH₄ (that has a GWP of 20 CO₂ eq), NO_x and other gases in the complete life cycle chain.

EPFL Life cycle assessment : emissions before the use

15 to 40% of the CO2 emissions have been made to prepare the fossil fuels

		Natural gas	Wood	Gasoline	Diesel
	kg/Nm3	0.7	240	0.8	0.8
LHV	MJ/kg	50	17.8	44.4	43.4
	GJ/Nm3	0.0359	5.3-9.6	35.5	34.7
CO2	g CO2/MJ	49.3	0	67	72
supply CO2equiv	g CO2/MJ	11.6	1.4-1.8 (production) 0.19 (20 MW) <u>-1.1 (320 MW)</u> 1.6 - 2.9	16.7	13.4
	g CO2/MJ	60.9	1.6-2.9	83.7	85.4
		19%	-	20%	16%
Cost	cts/kWh	10	3 - 7.5	18.6	19.2
industry	cts/kWh	3.4			

Emissions before use ->



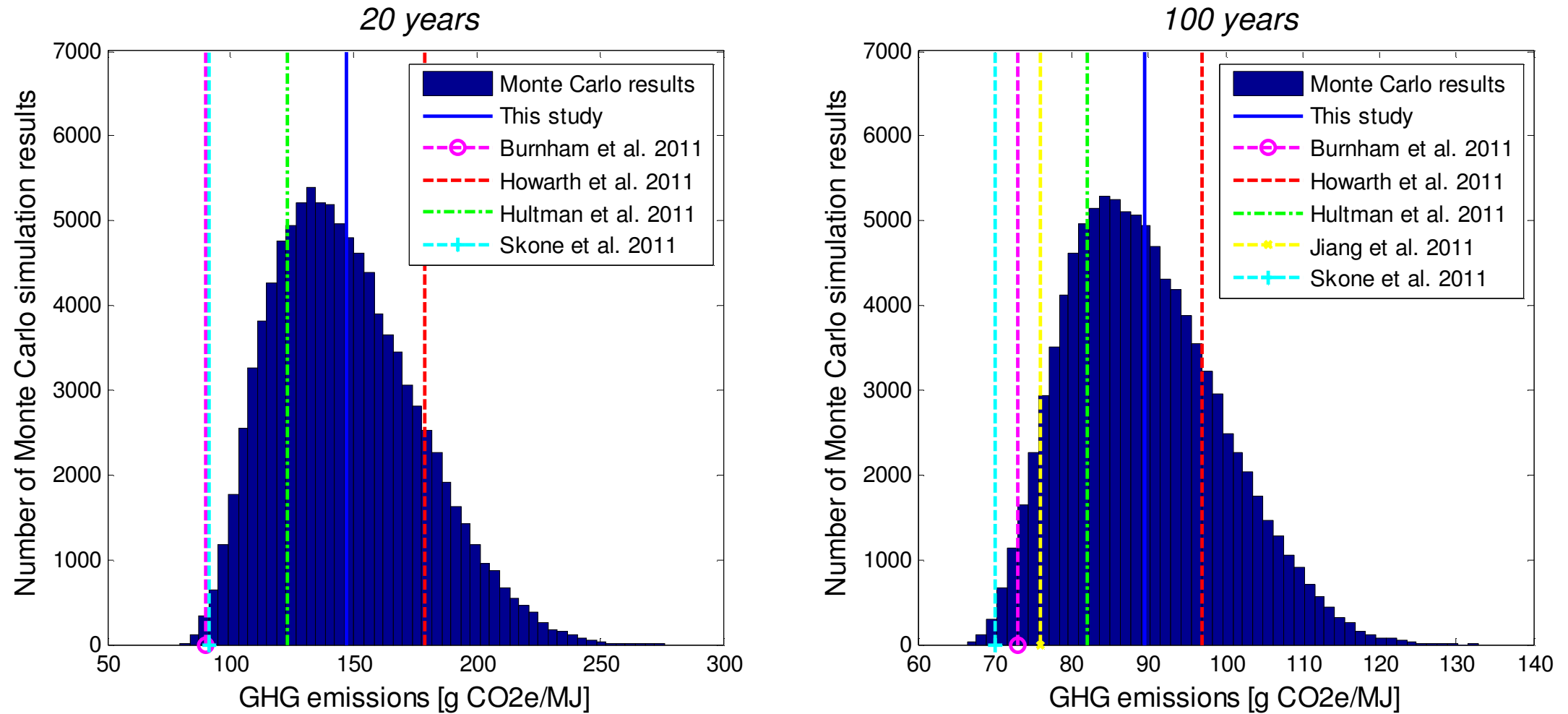


Figure 27 Comparison with other studies considering heat production

- Efficiency of conversion
 - Natural gas : 60%
 - Coal : 38%

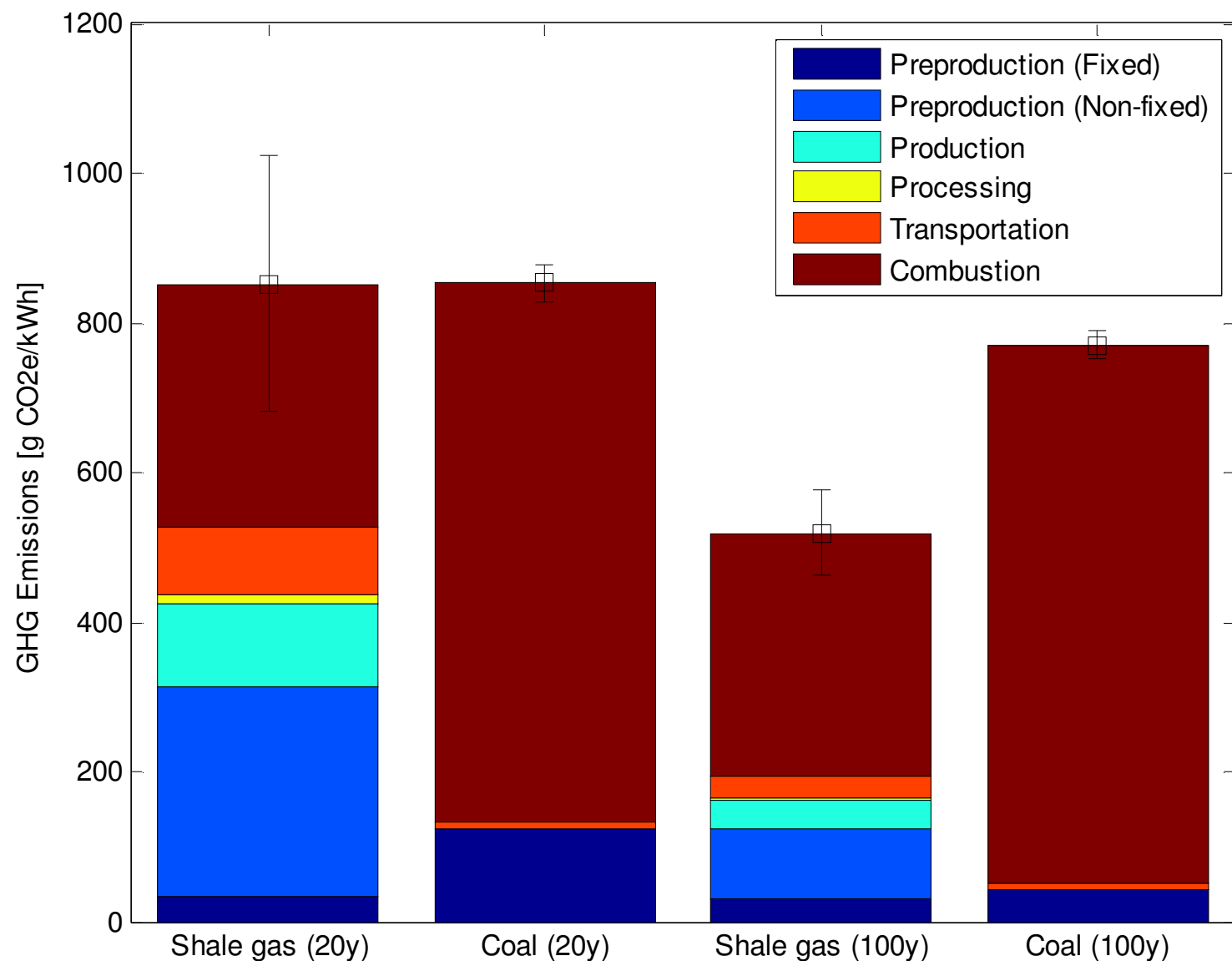


Figure 26 GHG emissions of the different phases of shale gas and coal life cycles

- Measure 1
 - Flaring of off-gases
- Measure 2
 - Green completion : send back
- Measure 3
 - Tracking fugitive emissions

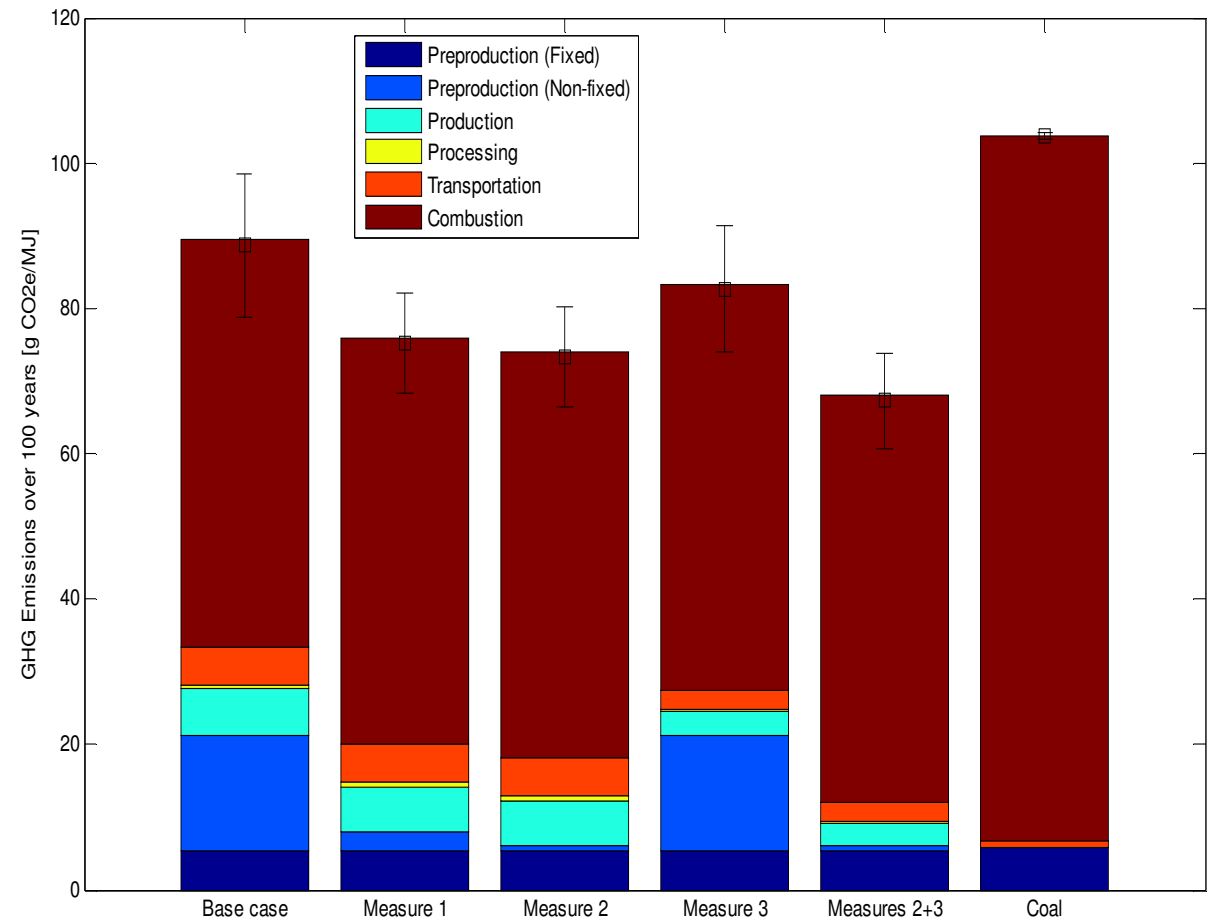


Figure 33 hale gas life cycle GHG emissions according to different potential mitigation measures over the 100 year timeframe

Environmental impact of efficiency

RENOVATING BUILDINGS

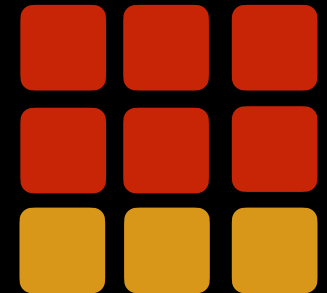
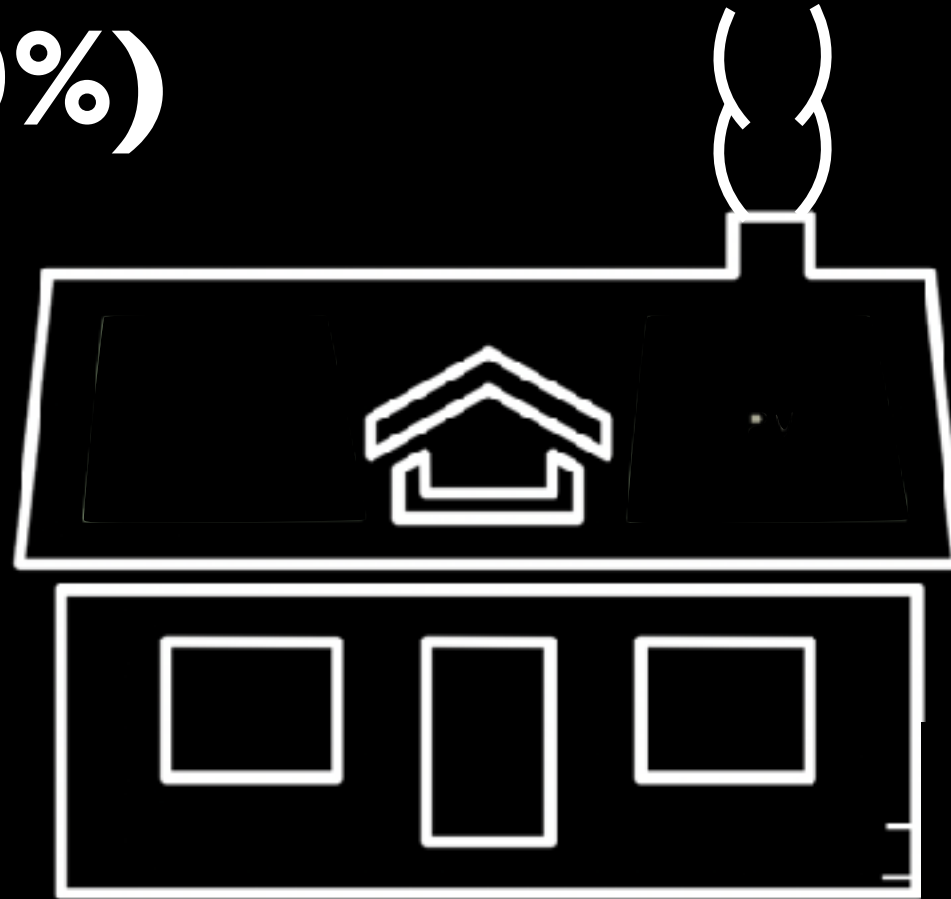
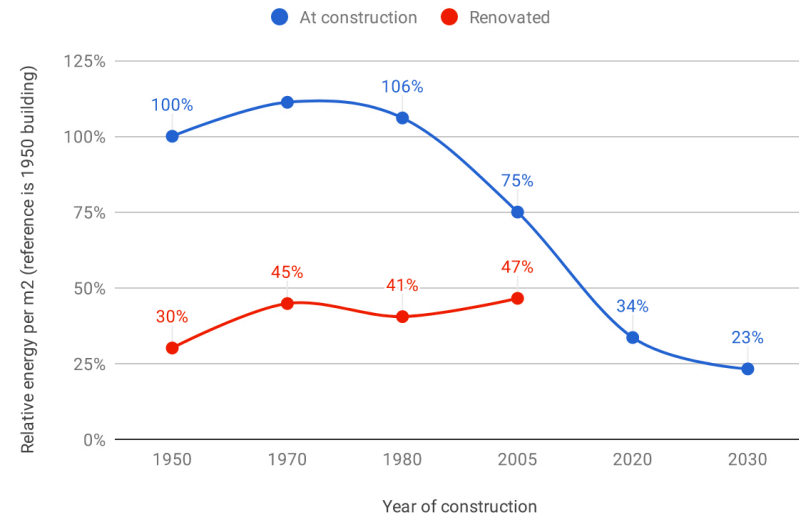
104-160 (- 40%)

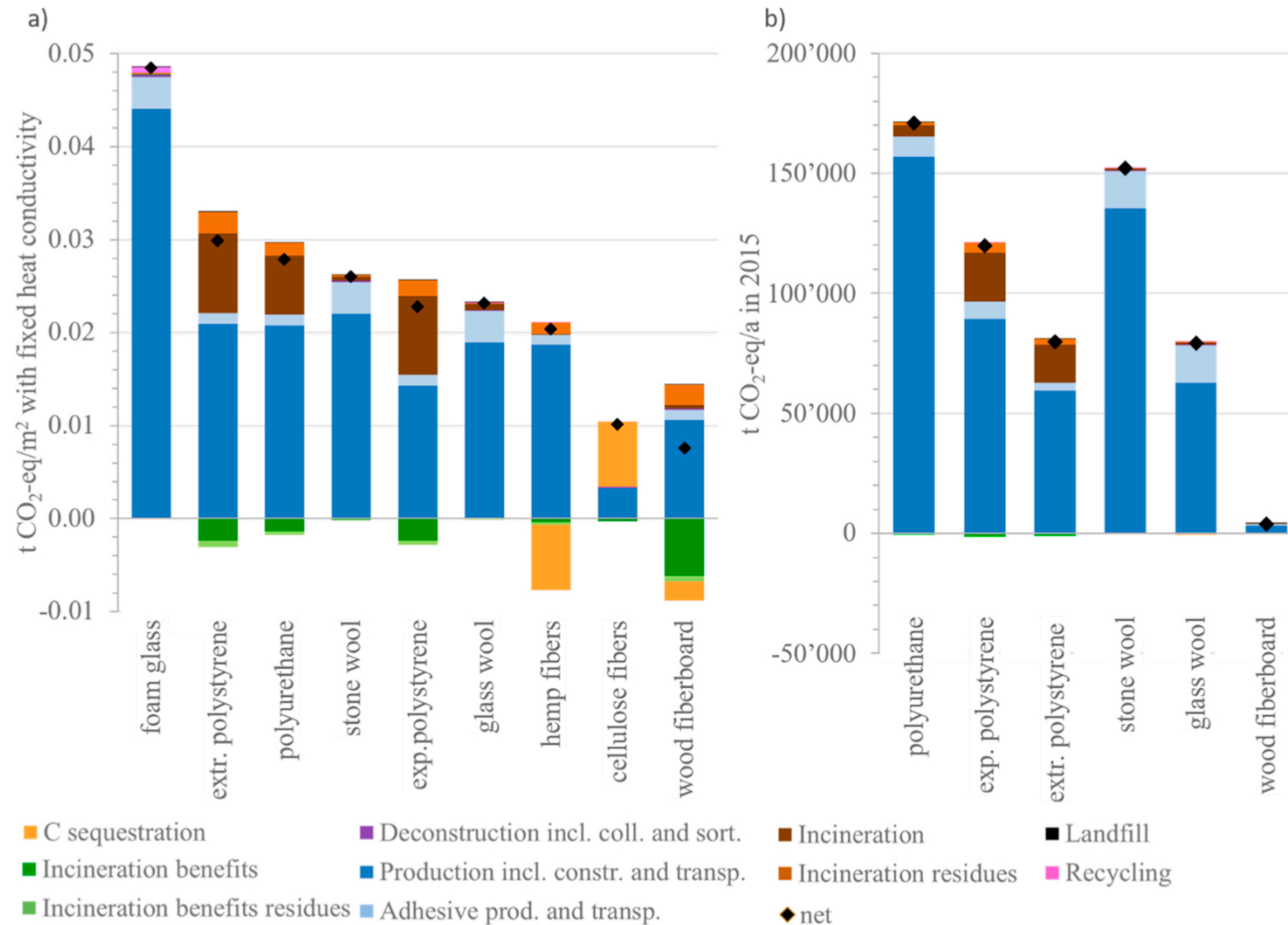
CHF/month/100 m²

2.0

tons **CO₂** /year/100 m²
33 CHF/month/100 m²

Annual energy per m2 as a function of the year of construction





Life cycle for the insulation materials

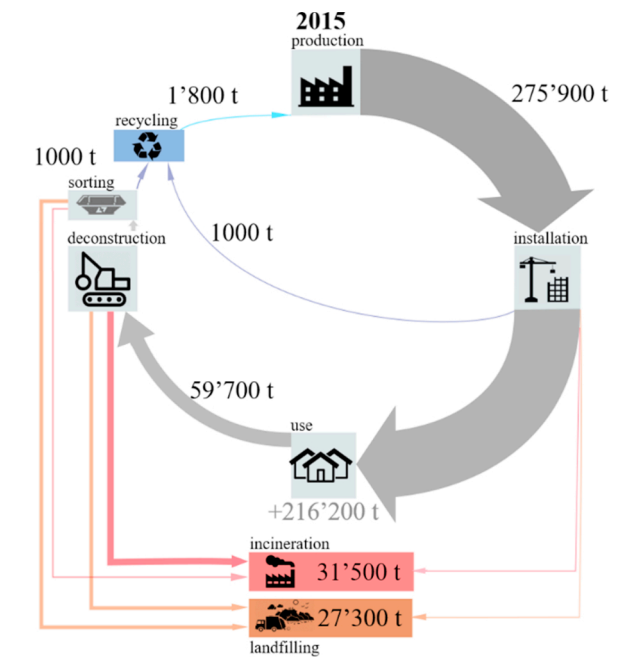


Fig. 2. Material flows of thermal insulation materials, without contaminants or residues, added to, and deconstructed from, Swiss residential buildings in 2015.

Fig. 3. Impacts on climate change (a) for different insulation materials per m² with fixed heat conductivity and (b) for the total thermal insulation system, added to, and deconstructed from, Swiss residential buildings in 2015. Insulation material added to, and deconstructed from Swiss residential buildings in 2015. exp. = expanded, extr. = extruded.

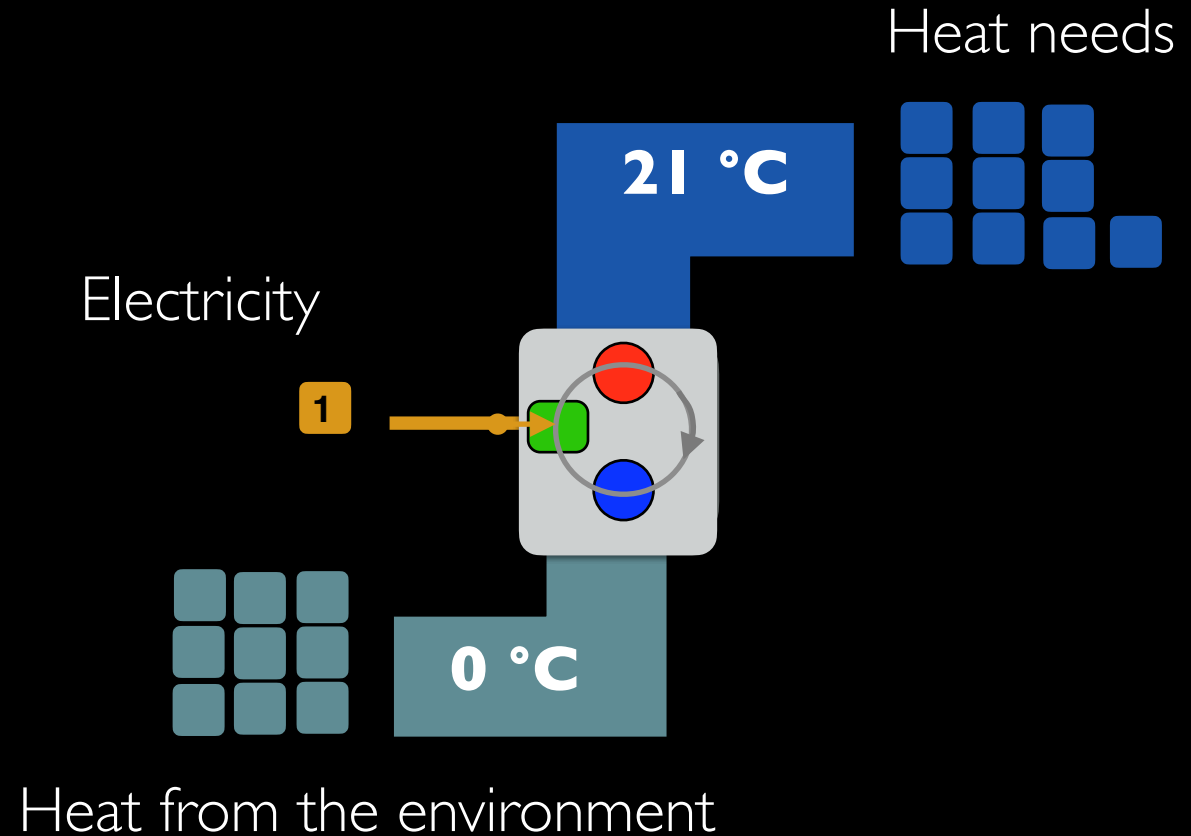
EFFICIENCY IN SUPPLY ASK THERMODYNAMICS

1 units of electricity supplies 10 units of heat with 9 units of the environment

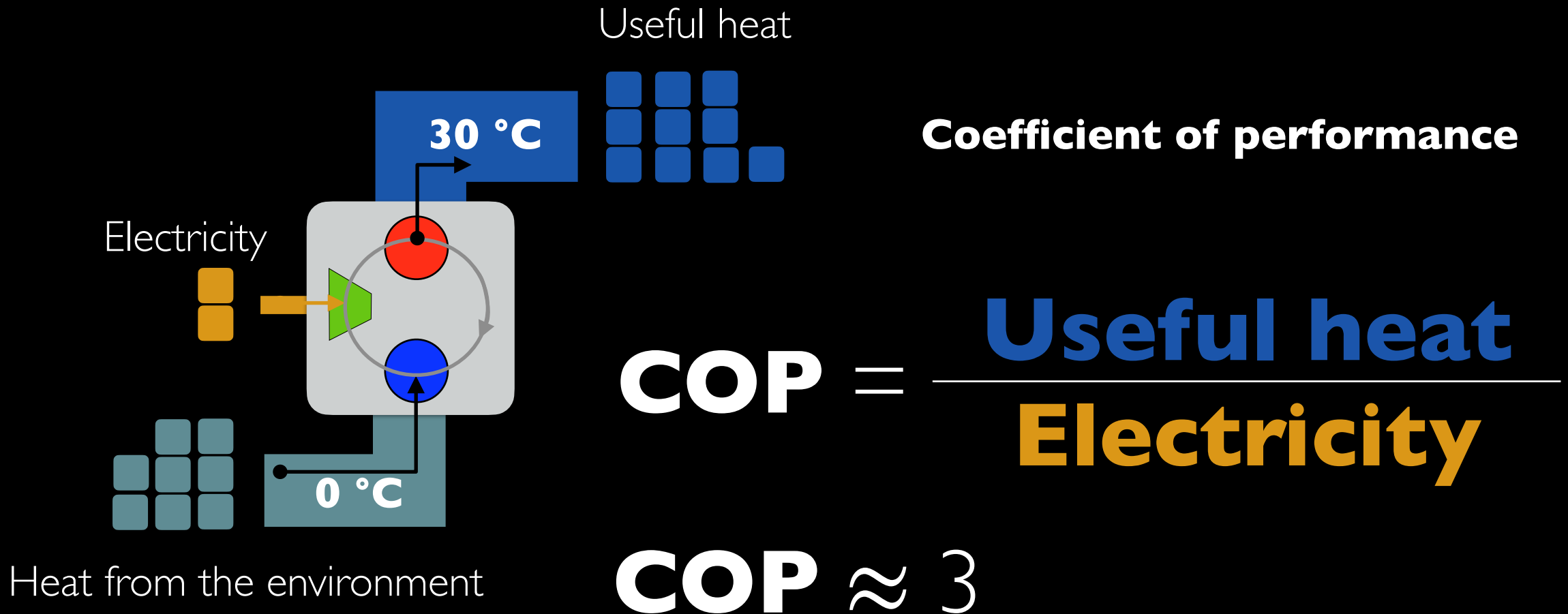


Nicolas Léonard Sadi CARNOT (F)
1796 - 1832

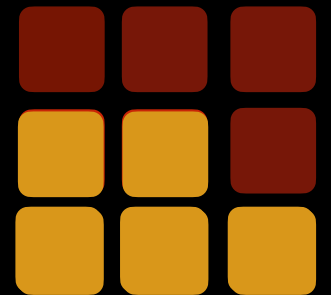
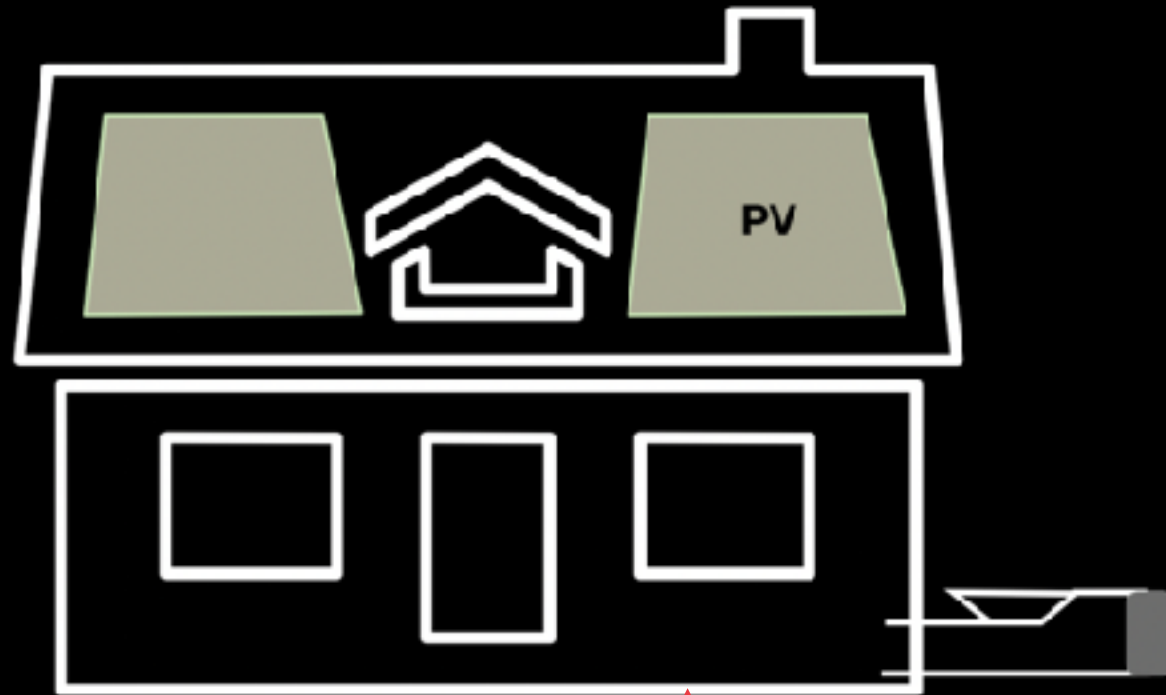
$$\dot{E} = \dot{Q} \left(1 - \frac{T_{cold}}{T_{hot}} \right)$$



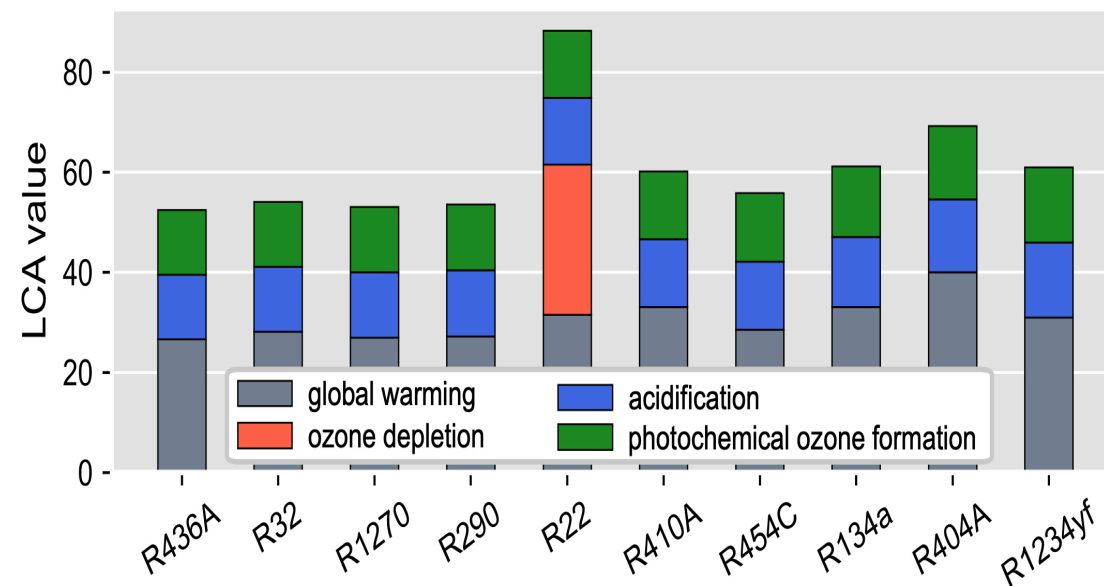
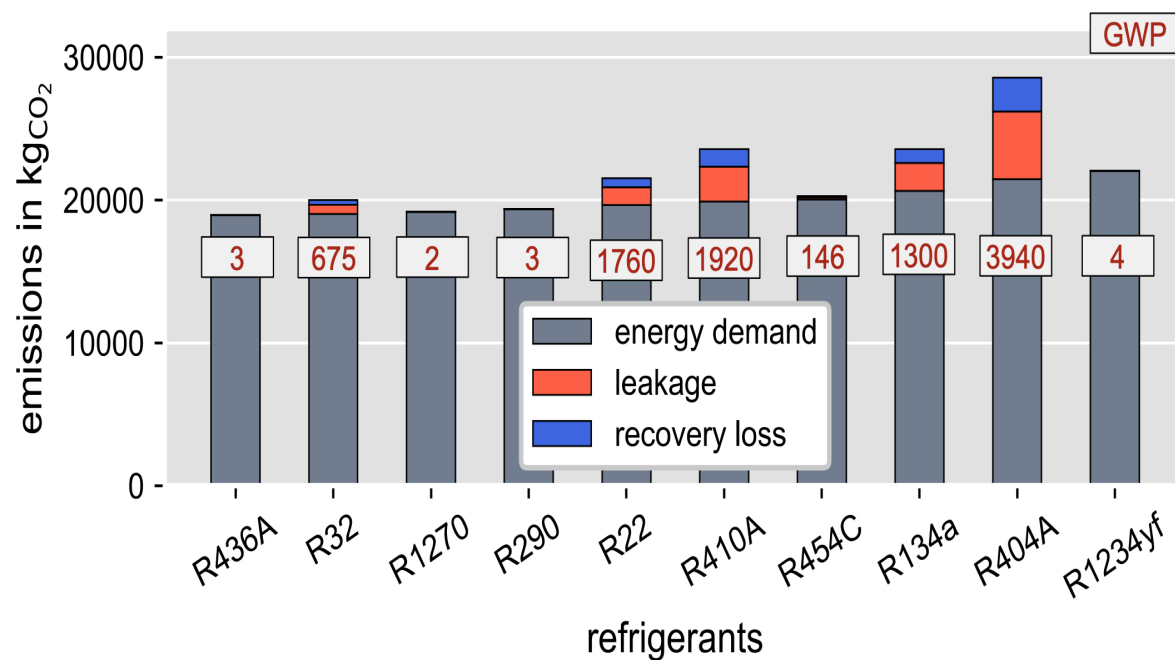
HEAT PUMP IS THE ENGINEER'S ANSWER



HEAT PUMP INTEGRATION IN A BUILDING

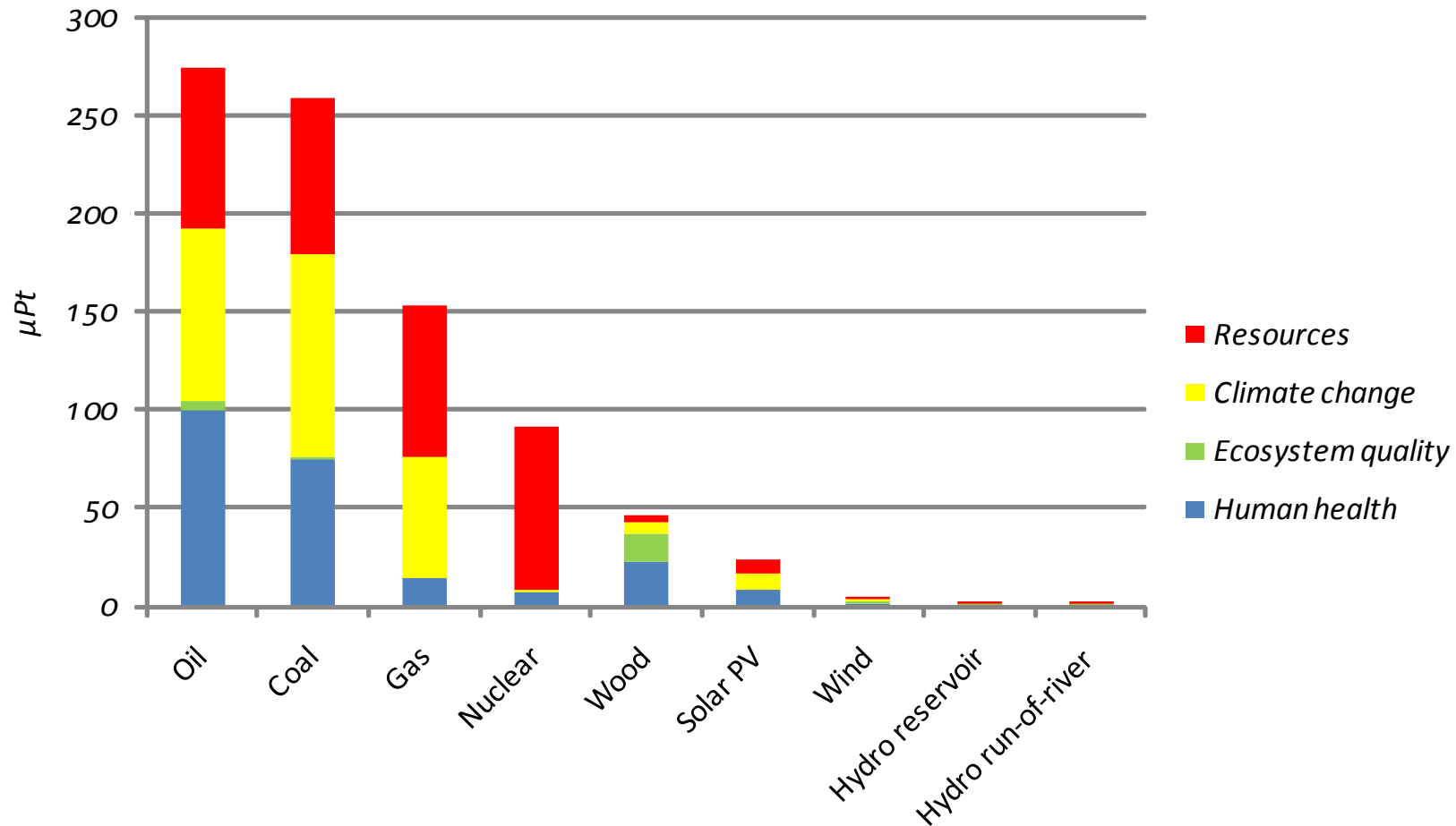


Electrical grid



Environmental impact of electricity

The potential impacts of electricity generation



Inventory : ecoinvent 2.2 (European averages)
LCIA method : IMPACT 2002+ (single score)
functional unit : 1 kJe

Current electricity mix

Coal	Oil	Gas	Nuclear	Wind	Solar	Hydro	Geothermal	Biomass	Other fossils	Other renewables
17%	0.7%	21%	29%	14%	4.4%	9.4%	0.2%	3.8%	0.3%	0.2%
772*	32*	953*	1317*	636*	200*	423*	9*	173*	14*	9*

* Values in TWh

VS

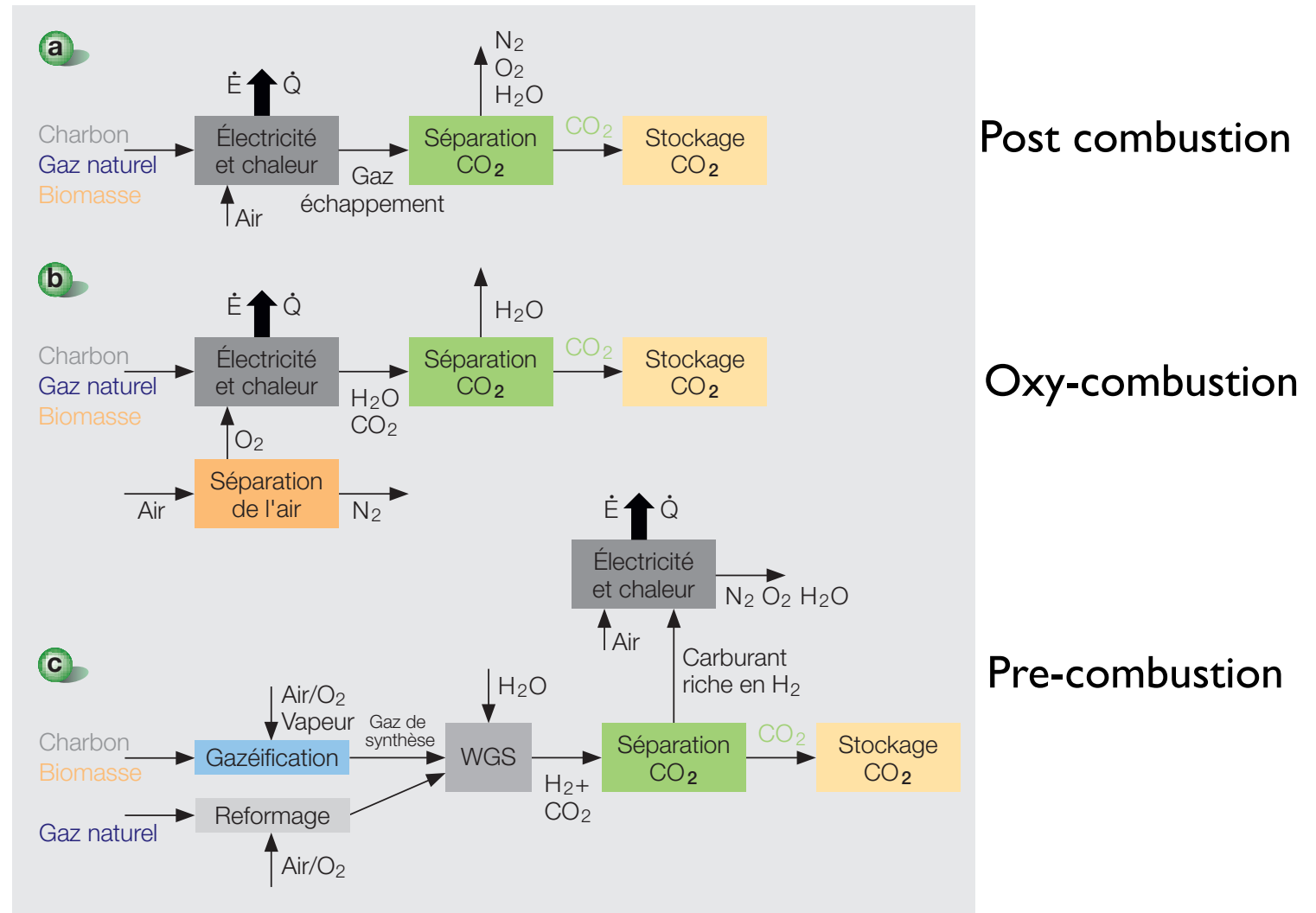
Future Renewable electricity mix

Wind onshore	Wind offshore	Solar	Hydro run-of-river
51%	4%	17%	28%
2547*	200*	849*	1398*

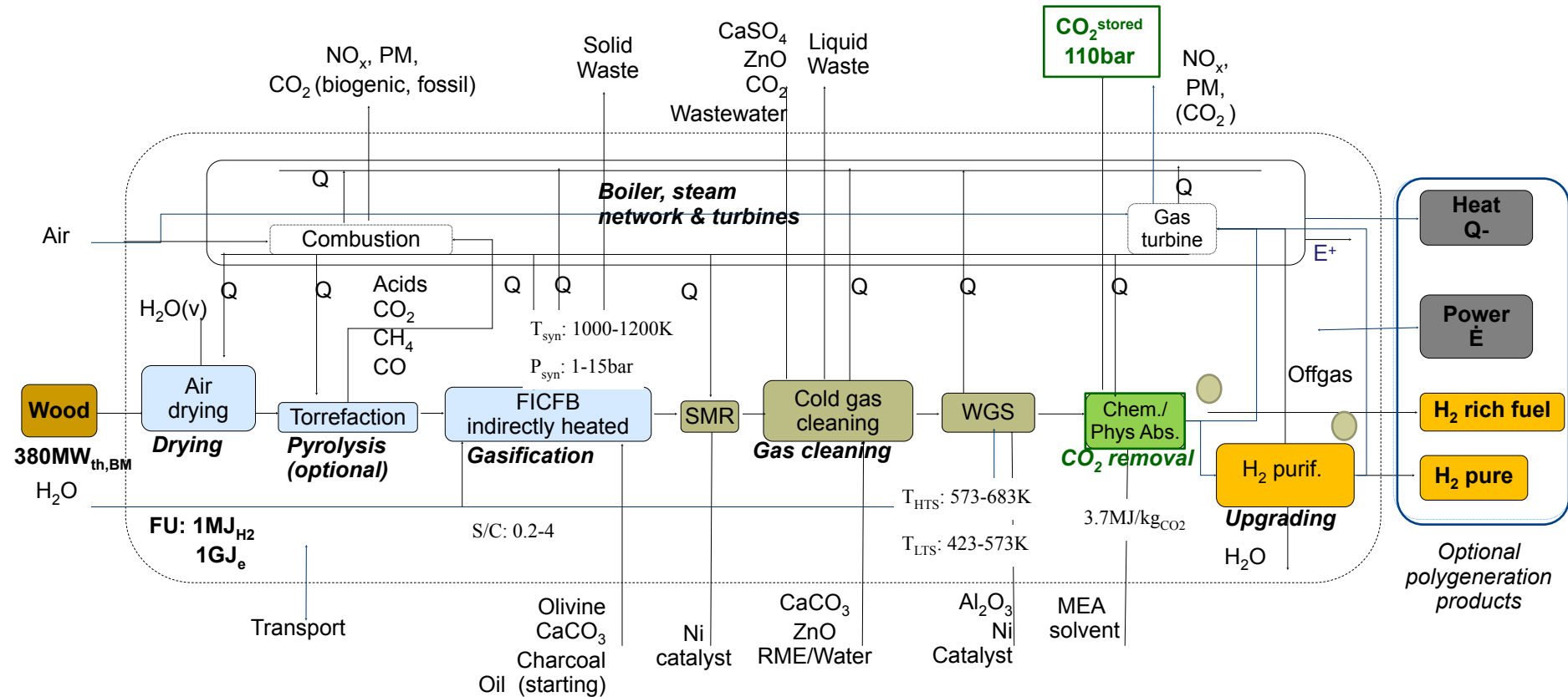
* Values in TWh

Total yearly electricity generation with deep electrification: 4540 TWh (current mix) and 4994 (renewable mix)

- Energy Penalty
 - Compression
 - 2% (LHV)
 - Capture :
 - 4-7% (LHV)
 - Total
 - 6 à 9% (LHV)
- Investment
 - + 30%



Biomass Electricity with CO2 capture and sequestration (BECCS) : negative emissions



➤ Configurations (380MW_{th,BM})

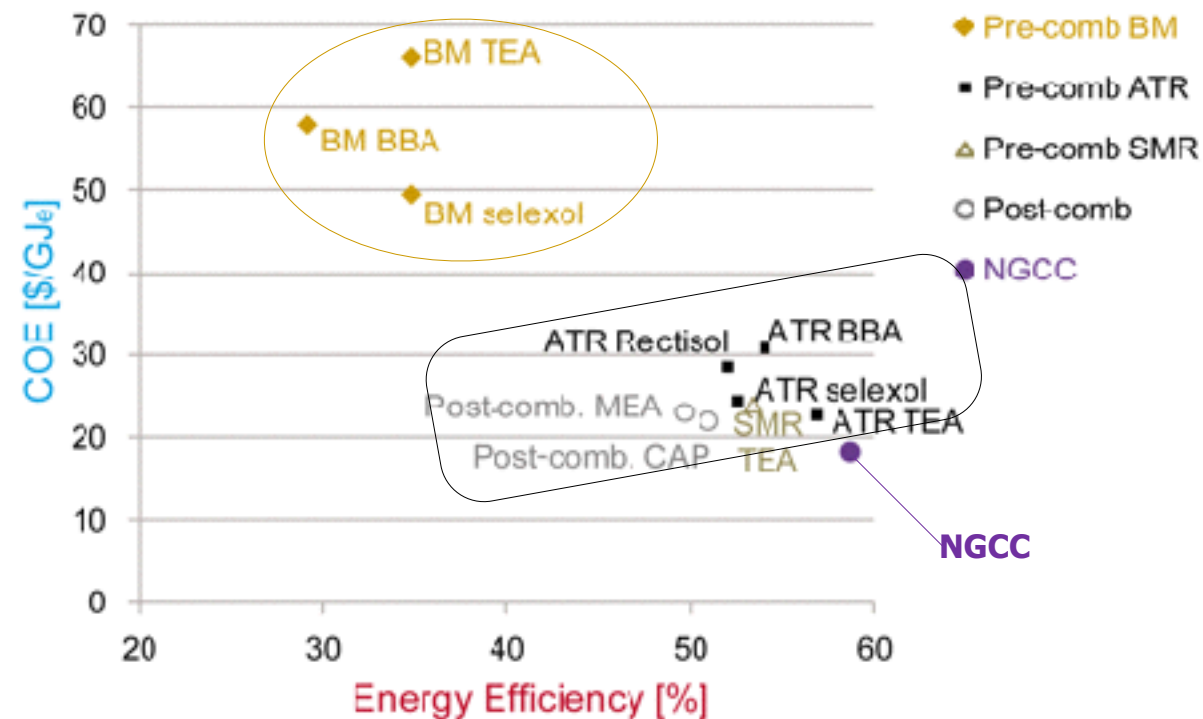
- Without/with CO₂ capture (compression to 110bar)
- H₂ process with $\dot{E}$ import or self-sufficient or $\dot{E}$ generation

CO₂ capture options comparison

◆ CO₂ capture energy and cost penalty

➤ Different process configurations

- Natural gas fed processes 90% CO₂ capture, biomass 60%

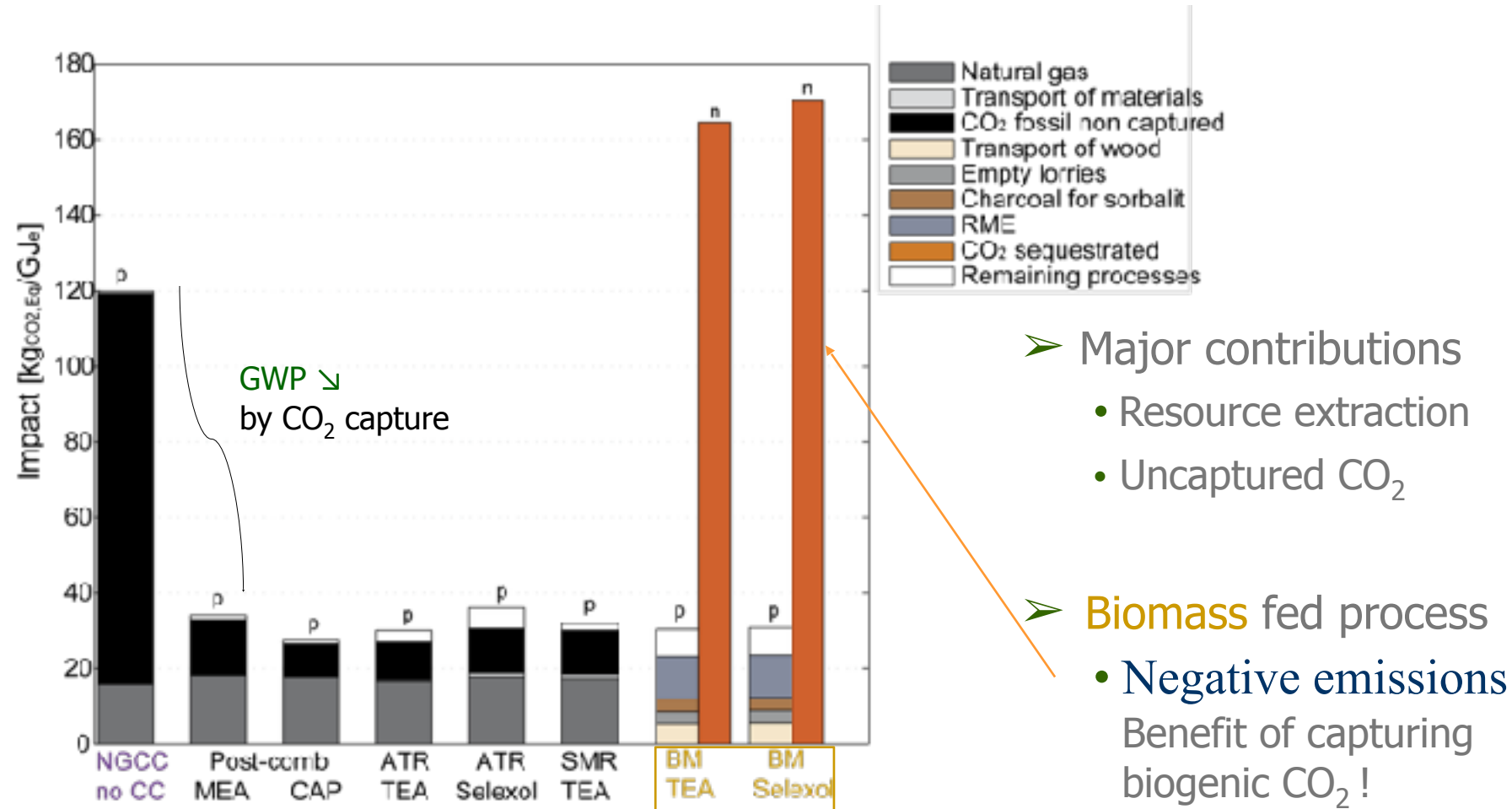


➤ Competition between post- and pre-combustion

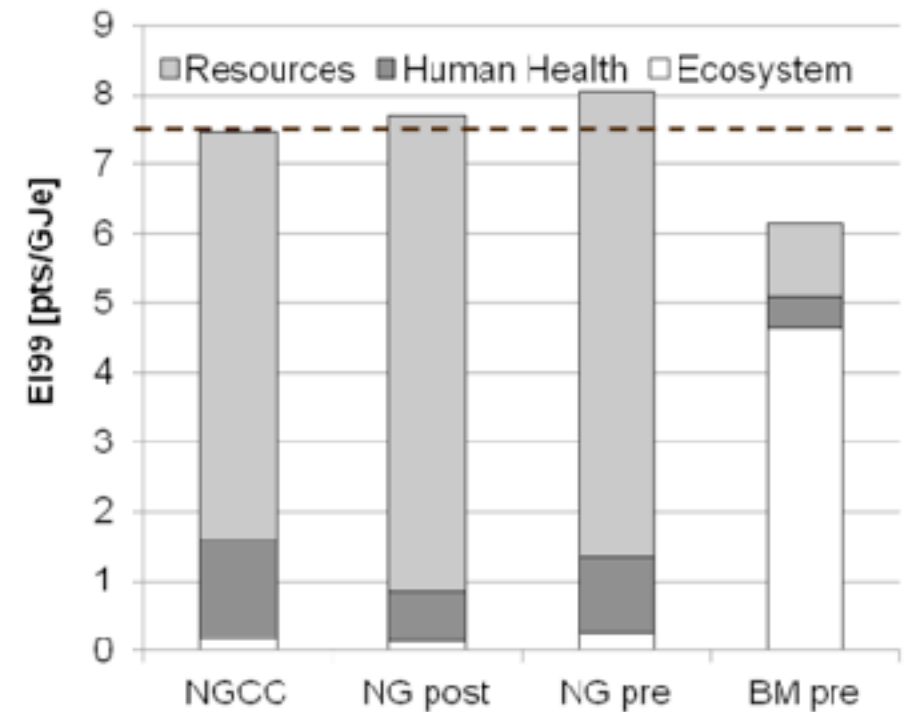
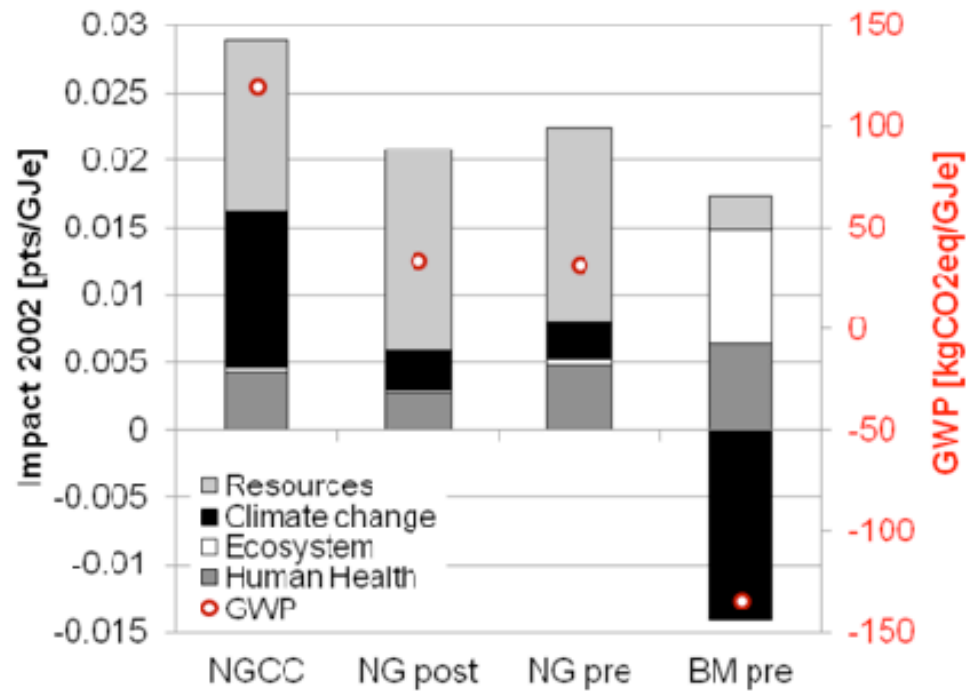
CO₂ capture options comparison

◆ CO₂ capture environmental performance

- IPCC 07: Global warming potential (FU=1GJe)

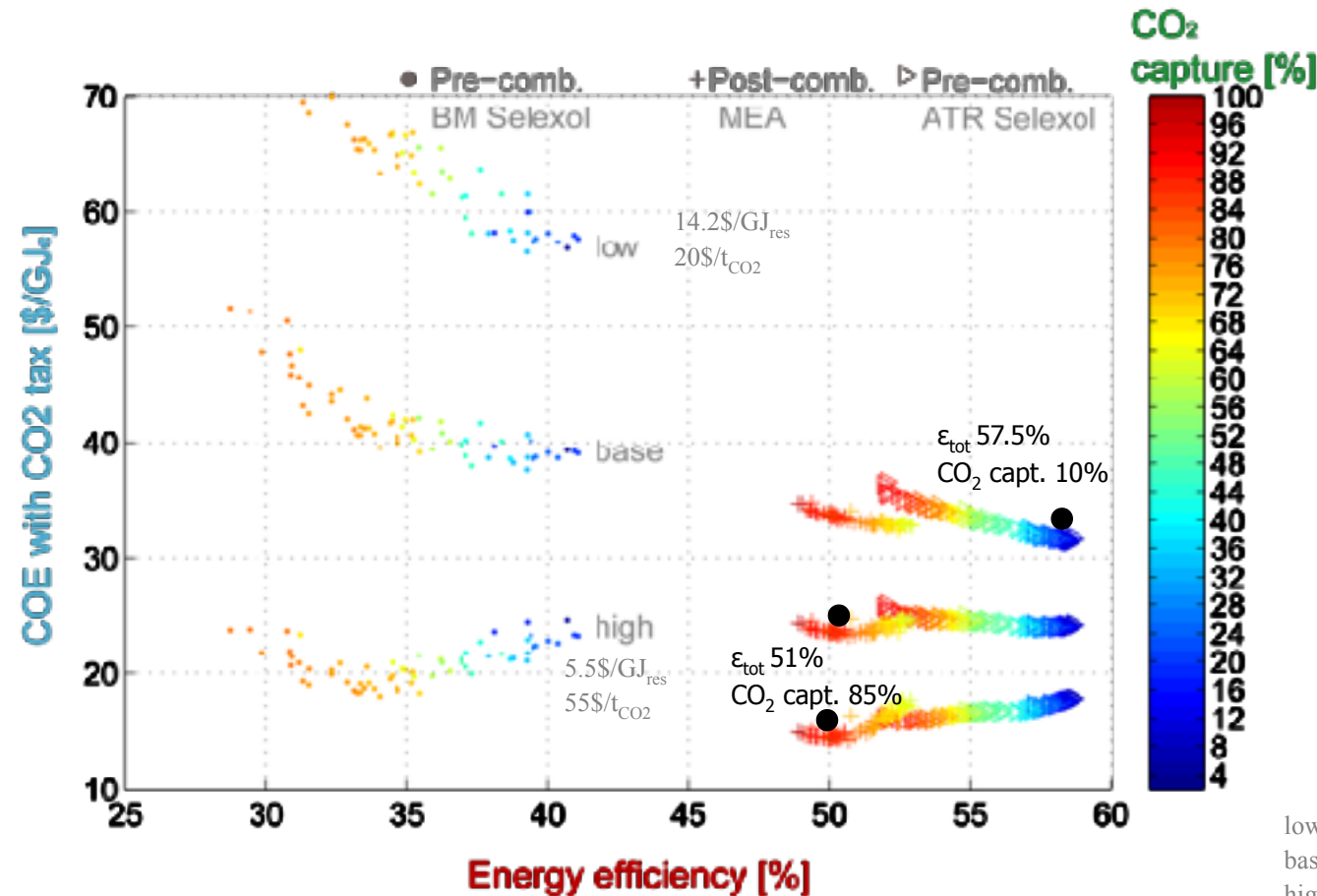


Impact is different if we consider different indicators



Use LCA for decision making

- ◆ Economic competitiveness of process configurations
 - Influenced by economic conditions



- Strategy for supporting decision-making?

low: 14.2\$/GJ_{res}, 20\$/t_{CO2}, 4500h/y, 15y, 4%ir
base: 9.7\$/GJ_{res}, 35\$/t_{CO2}, 7500h/y, 25y, 6%ir
high: 5.5\$/GJ_{res}, 55\$/t_{CO2}, 8200h/y, 30y, 8%ir

Decision-making

◆ Most economically competitive process configurations

System	NGCC	Post-comb	ATR	BM
Performance	no CC	MEA	Selexol	Selexol
Feed [MW_{th}]	559	582	725	380
CO ₂ capture [%]	0	82.9	78.6	69.9
ϵ_{tot} [%]	58.75	50.6	53.5	35.4
Net electricity [MW_e]	328	295	383	135
[$kg_{CO_2, local}/GJ_e$]	105	13.9	22.2	-198.1
COE incl. tax[\$/GJ _e]	18.2-28.8	9-40	12.8-42	15-69
Avoid. Costs incl. tax [\$/ $t_{CO_2, avoided}$]	-	-63-121	-49-127	0-253

➤ CO₂ capture penalty

- **Efficiency** ▼: 6-10%-pts (CO_2 compression ~2%-pts)
- **COE** ⬆: 20-25%

➤ Best performing process

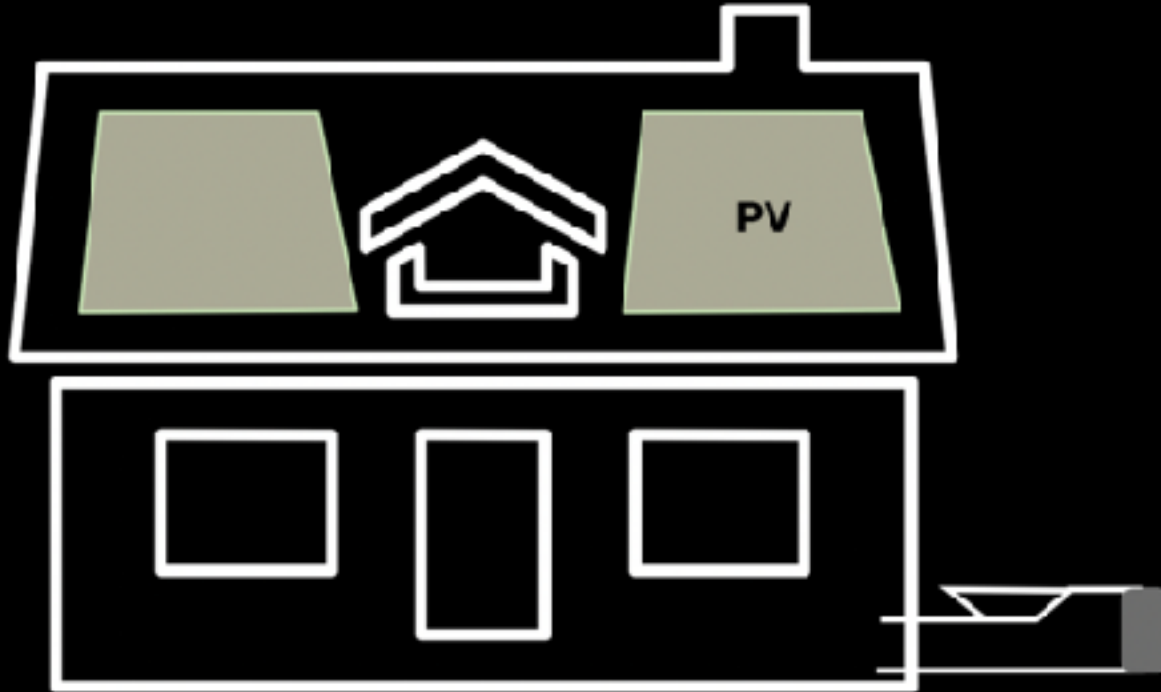
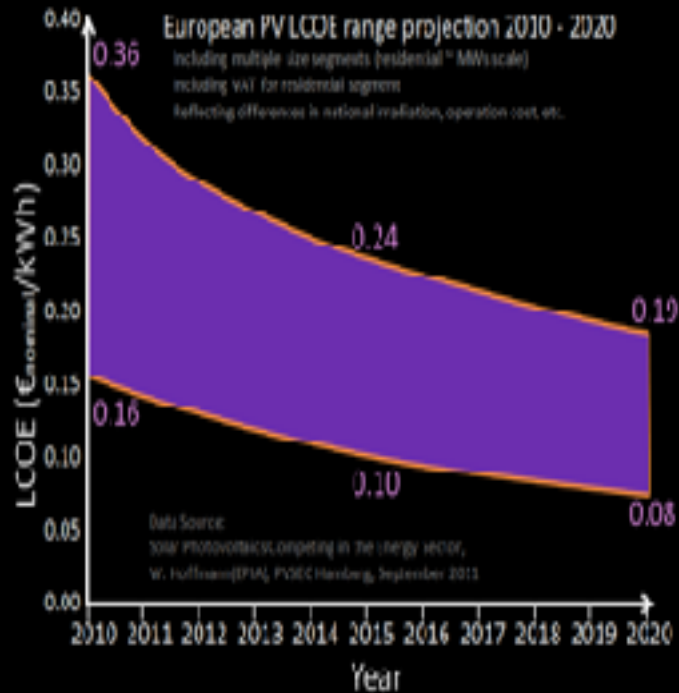
- **Efficiency**: Nat gas. pre-comb.
- **Economic**: Nat gas. post-comb.
- **Environmental**: Biomass pre-comb.

➤ Competition between processes and objectives!

Harvesting renewable energy sources

HEAT PUMP INTEGRATION IN A BUILDING

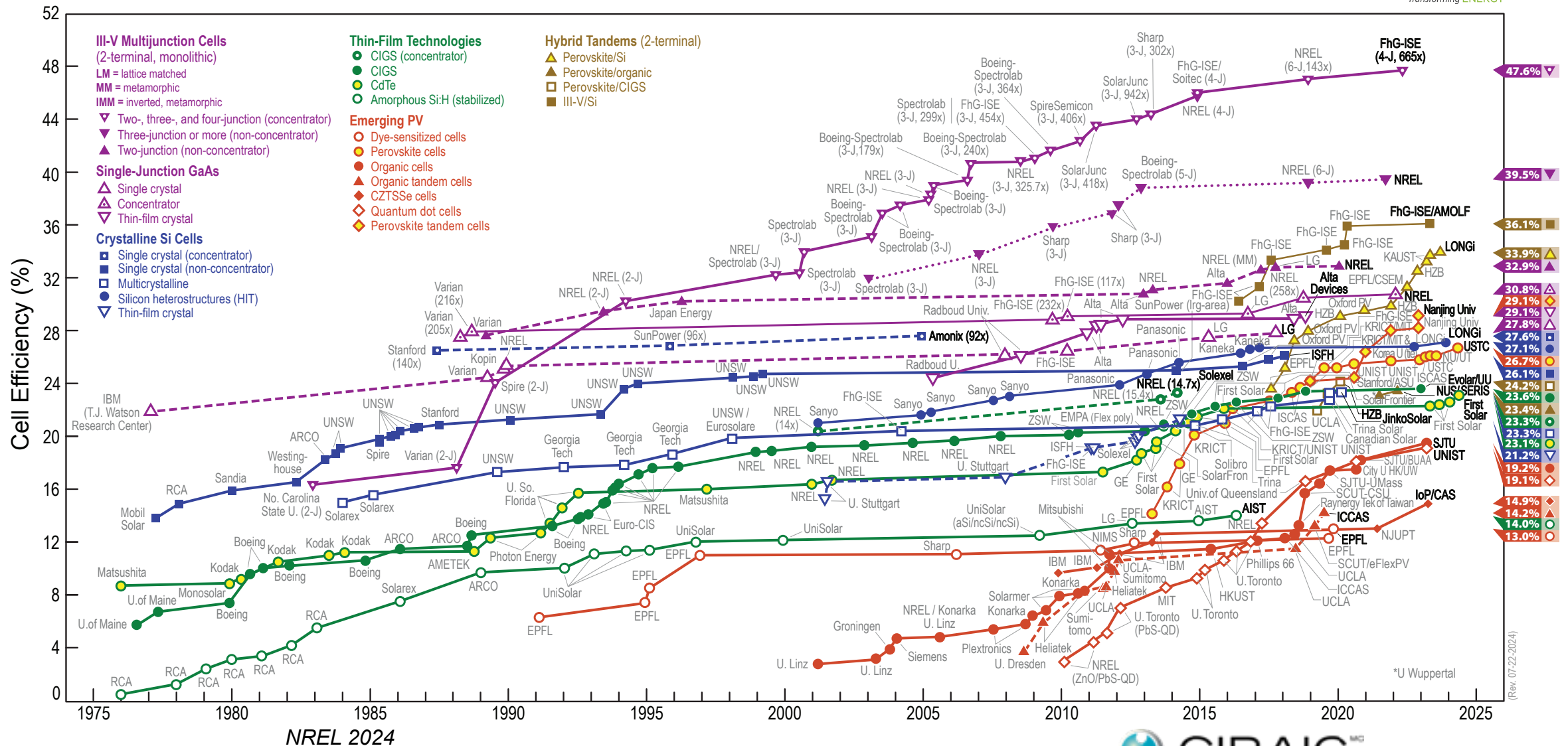
PV costs projections



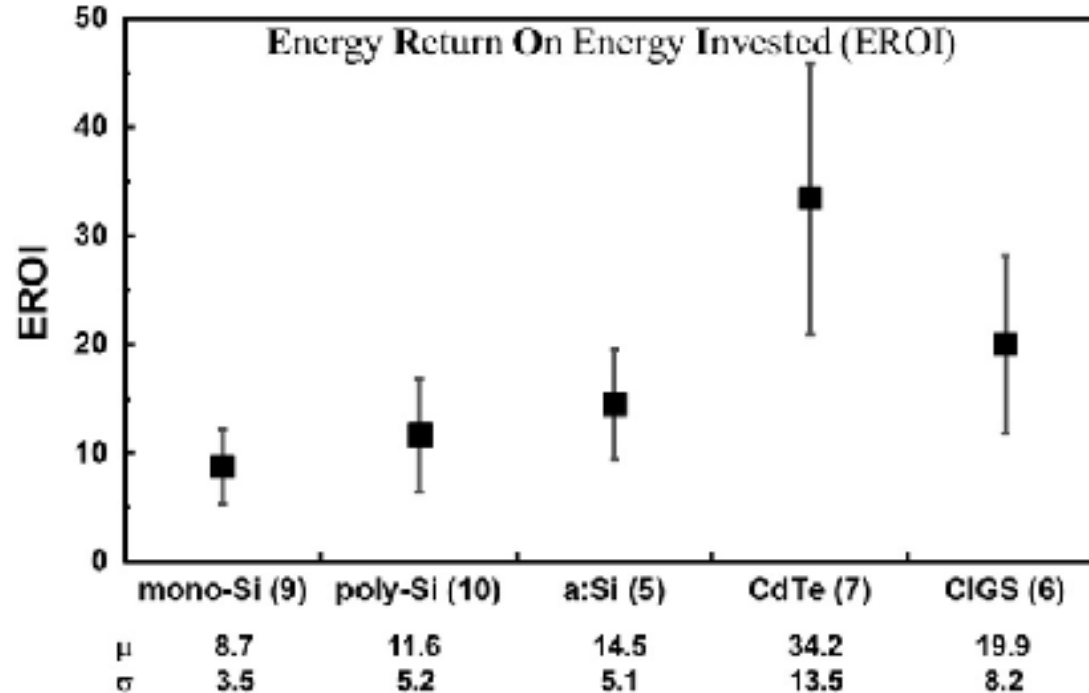
<http://www.toitsolaire.ch>

PV efficiency

Best Research-Cell Efficiencies



Energy return on energy invested



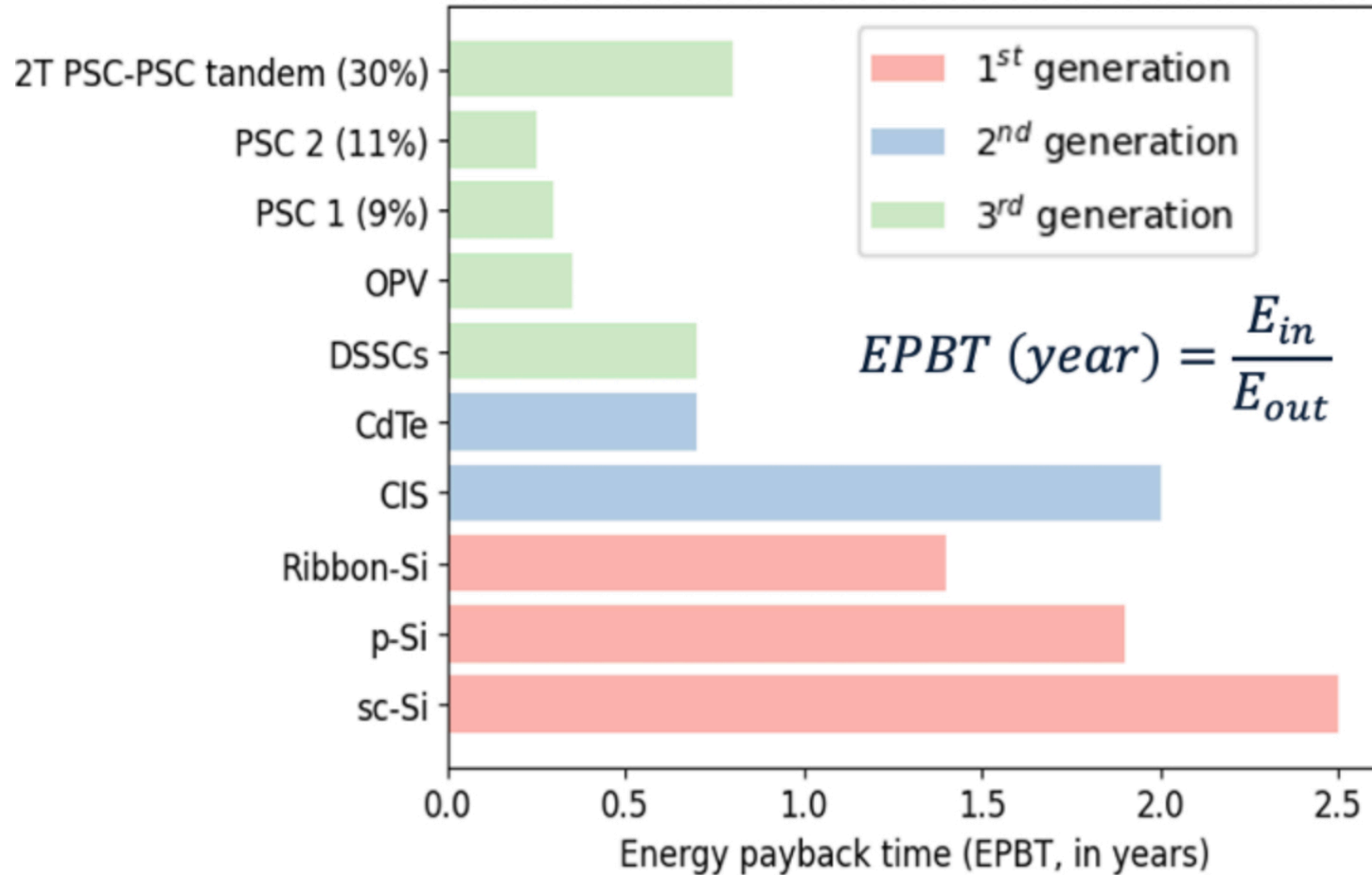
$$EROI = \frac{\text{Electricity produced}}{\text{Energy for panel production}}$$

« variation in embedded energy was greater than the variation in efficiency ... suggesting that the relative ranking of the EPBT of different PV technology today and in the future depends primarily on the embedded energy and not the efficiency »

Energy pay-back time of Photovoltaics systems (meta-analysis)

Photovoltaic pannel (# studies)	Median (years)	Standard deviation
Mono-SI (9)	4.1	2.0
Poly-SI (10)	3.1	1.3
a:SI (5)	2.3	0.7
CIGS (4)	1.7	0.7
CdTe (7)	1.0	0.4

(Bhandari, K. P., Collier, J. M., Ellingson, R. J., & Apul, D. S. (2015). Energy payback time (EPBT) and energy return on energy invested (EROI) of solar photovoltaic systems: A systematic review and meta-analysis. Renewable and Sustainable Energy Reviews, 47 133-141.)



Comparison of Environmental impacts indicators for different solar cells

(Muteri et al. 2020. Review on Life Cycle Assessment of Solar Photovoltaic Panels. Energies, 13, 252-?)

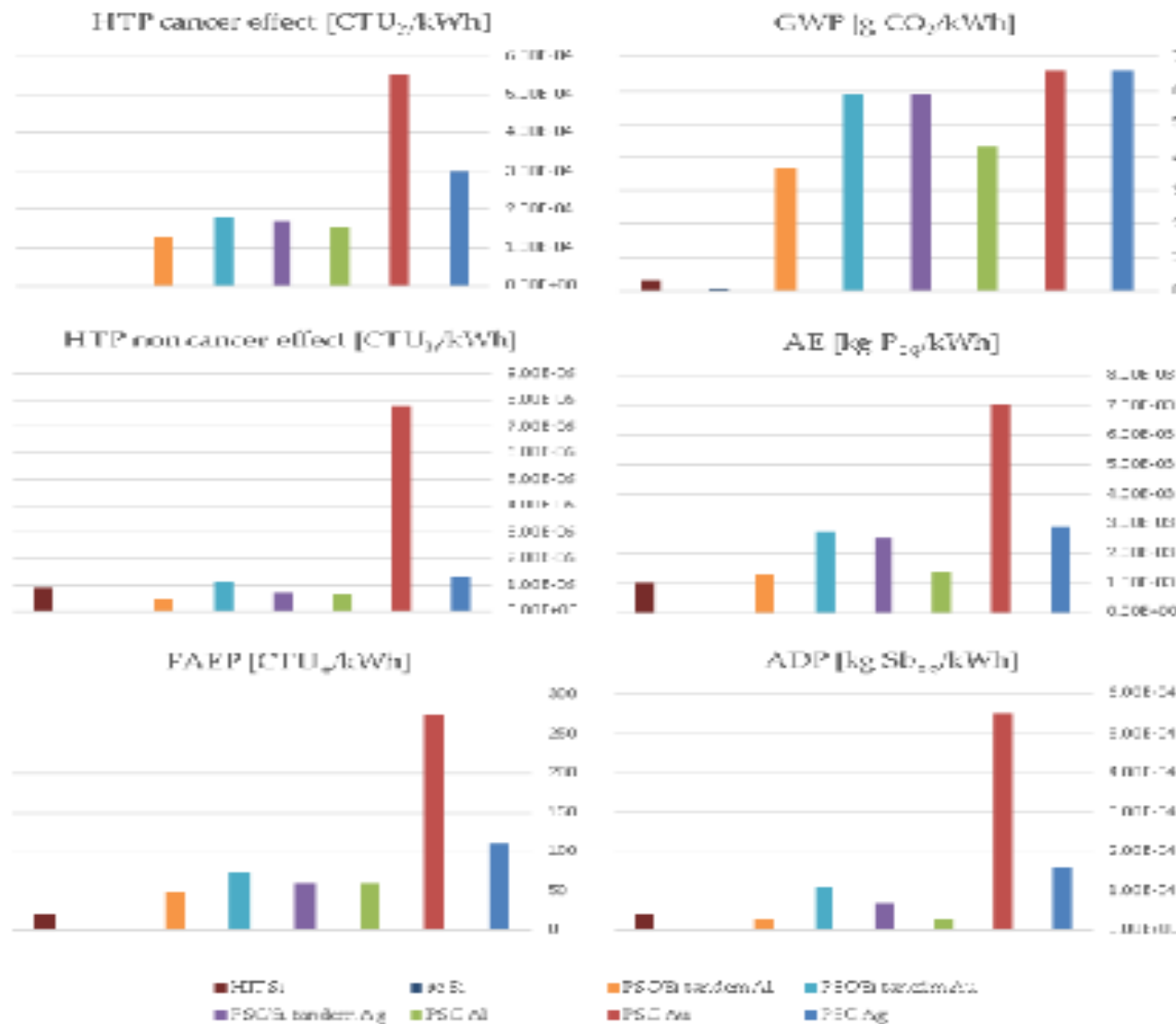
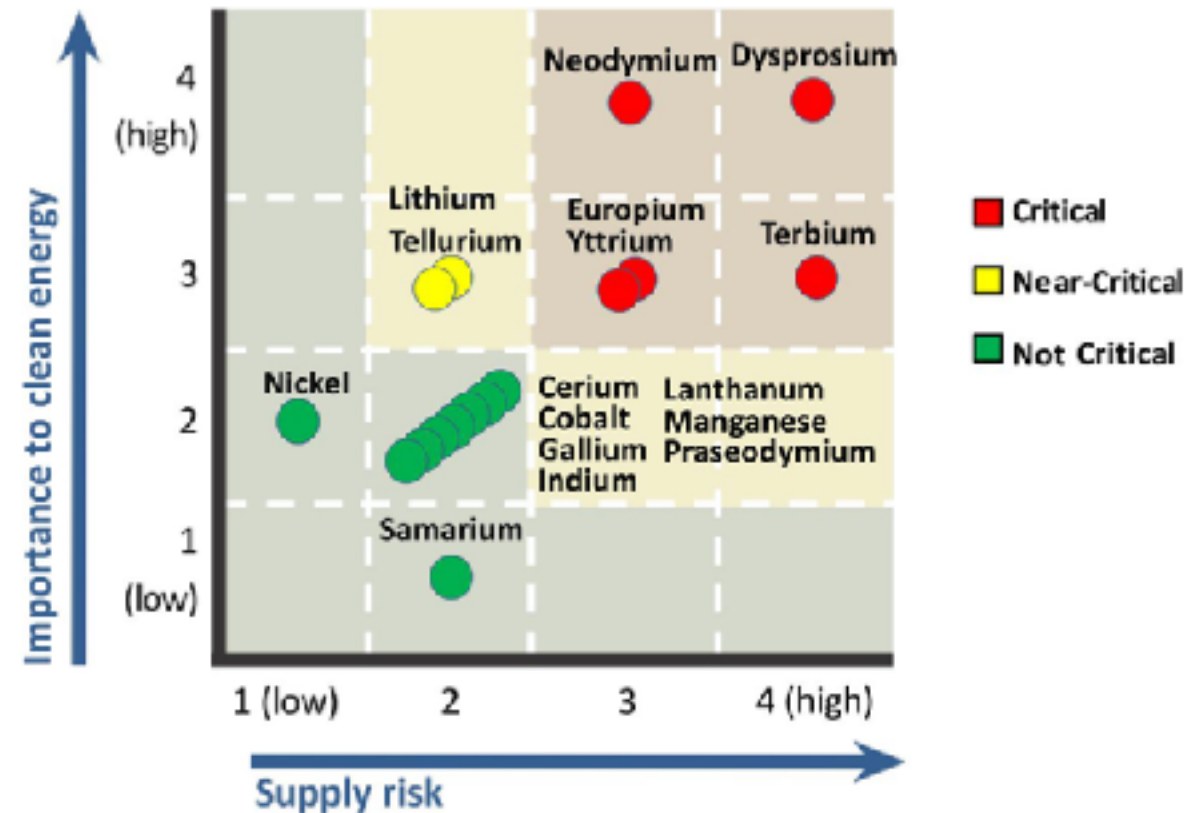


Figure 2. Environmental impacts of different solar cells [66].

Medium term material criticality in (U.S. Dep of Energy)

Innovation is needed in the long term to contribute reducing the quantity of critical metals used in energy technologies



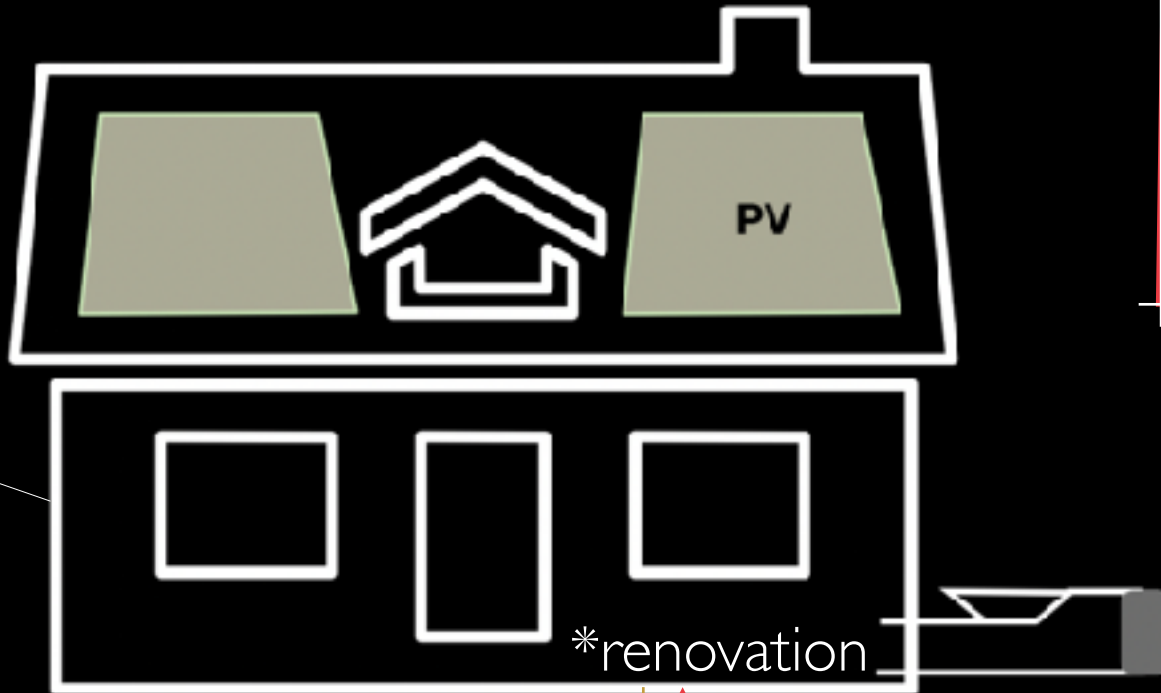
(U.S. Dep of Energy. 2011. Critical Material Strategy)

RENEWABLE ENERGY HUB



Big data - Forecasting

Model based
Predictive control



Batteries

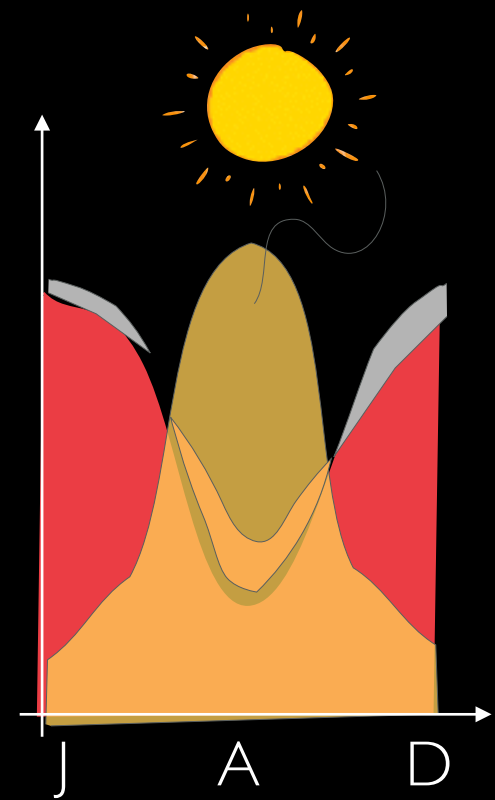


Hot water tanks

Heat pumps

Peak power

Electrical grid

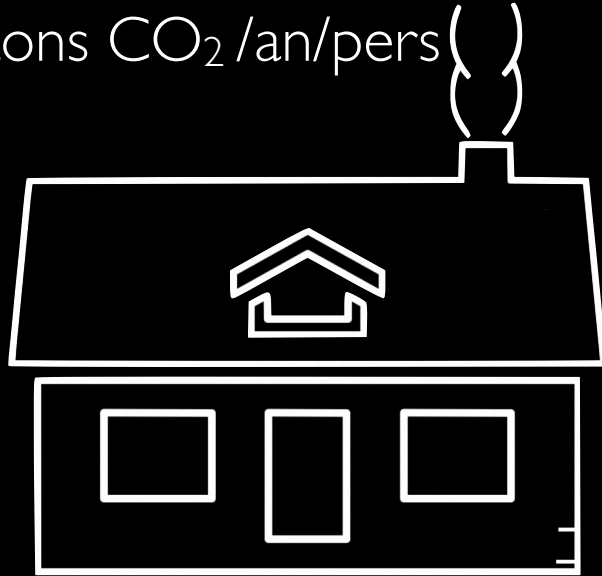
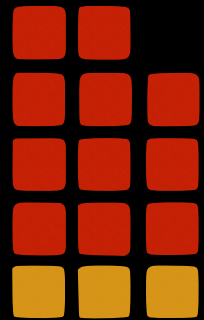


BUILDINGS : RENEWABLE ENERGY HUB

90+ % CO₂ EMISSIONS REDUCTION

2.20

tons CO₂ /an/pers{ }



Oil: 6 cts/kWh
Electricity: 18 cts/kWh

572

CHF/y/cap

Energy :

542 CHF/y/cap

Investment :

30 CHF/y/cap



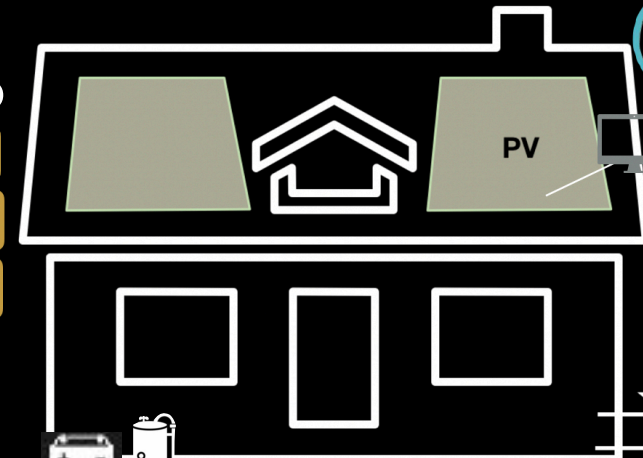
2021

0.25 - 0.04

tons CO₂ /y/cap

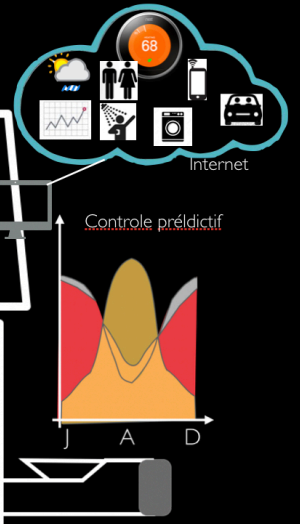
15.5
m²PV/cap

Direct
Achat
Vente



Feed-in: 8 cts/kWh

Electricity: 18 cts/kWh



209

CHF/y/cap

PV feed-in :

-139 CHF/y/cap

Energy :

118 CHF/y/cap

Investment :

230 CHF/y/cap

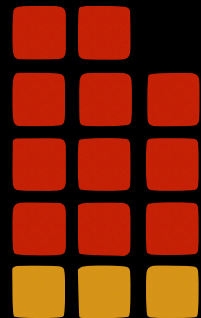


BUILDINGS : RENEWABLE ENERGY HUB

90+ % CO₂ EMISSIONS REDUCTION

2.20

tons CO₂ /y/cap { }



Oil: 11 cts/kWh

Electricity: 28 cts/kWh

1132

CHF/y/cap

1102 CHF/y/cap

Energy :

Investment :

30 CHF/y/cap



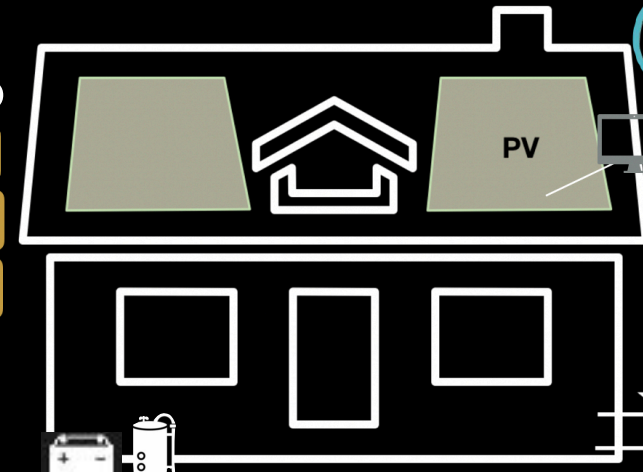
2023

0.25 - 0.04

tons CO₂ /y/cap

15.5
m²PV/cap

Direct
Achat
Vente



Feed-in: 16 cts/kWh

Electricity: 28 cts/kWh



Contrôle prédictif



138

CHF/y/cap

PV feed-in :

-278 CHF/y/cap

Energy :

184 CHF/y/cap

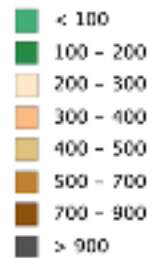
Investment :

230 CHF/y/cap





IPCC 2013 climate change -
GWP100a [gCO₂-eq./KWh]



26th January 2020 12:00

**GWP100a associated to
electricity generation**





26th January 2020 12:00

**GWP100a associated to
electricity consumption**



- Impact from the system design
 - Harvesting
 - Efficiency
 - Conversion
- Impact from the operation
 - Costs vs CO2 content vs Life Cycle Impacts
- Impact from the mix grid
 - 25 years (life time) perspective

Integrating personal mobility

François Maréchal



Démêler le vrai du faux

La voiture à hydrogène est-elle l'avenir du véhicule particulier ?

🕒 Temps de lecture: 10 min

Dernière modification: 17 octobre 2022

Rédaction Tesla Mag | 17 octobre 2022



Rouler au GNC ménage l'environnement et votre budget

Une technologie éprouvée qui convient à chaque utilisation. Par rapport à une voiture à essence ou diesel, un véhicule au GNC ne vous demande aucun changement particulier: vous roulez et faites le plein comme d'habitude, mais dans des stations-service de GNC. Tout ce à en soulageant l'environnement. Les voitures au GNC sont des véhicules d'une polyvalence optimale qui conviennent aux trajets de toute longueur. Leur coût total de possession est un autre très avantage.

TRANSPORTS La voiture électrique est-elle vraiment écolo ?

LE 21 OCTOBRE 2022 09 min

Sur l'ensemble de son cycle de vie, la voiture électrique est généralement plus écolo que sa concurrente thermique. Mais cela dépend de nombreuses conditions, et son futur développement ne règle pas notre dépendance au tout-voiture.

Pourquoi la voiture électrique n'est pas la solution miracle pour se déplacer sans polluer

A l'occasion du Mondial de l'automobile qui se tient à Paris, Emmanuel Macron et son gouvernement veulent promouvoir cette filière, pourtant pas si vertueuse.



Source :

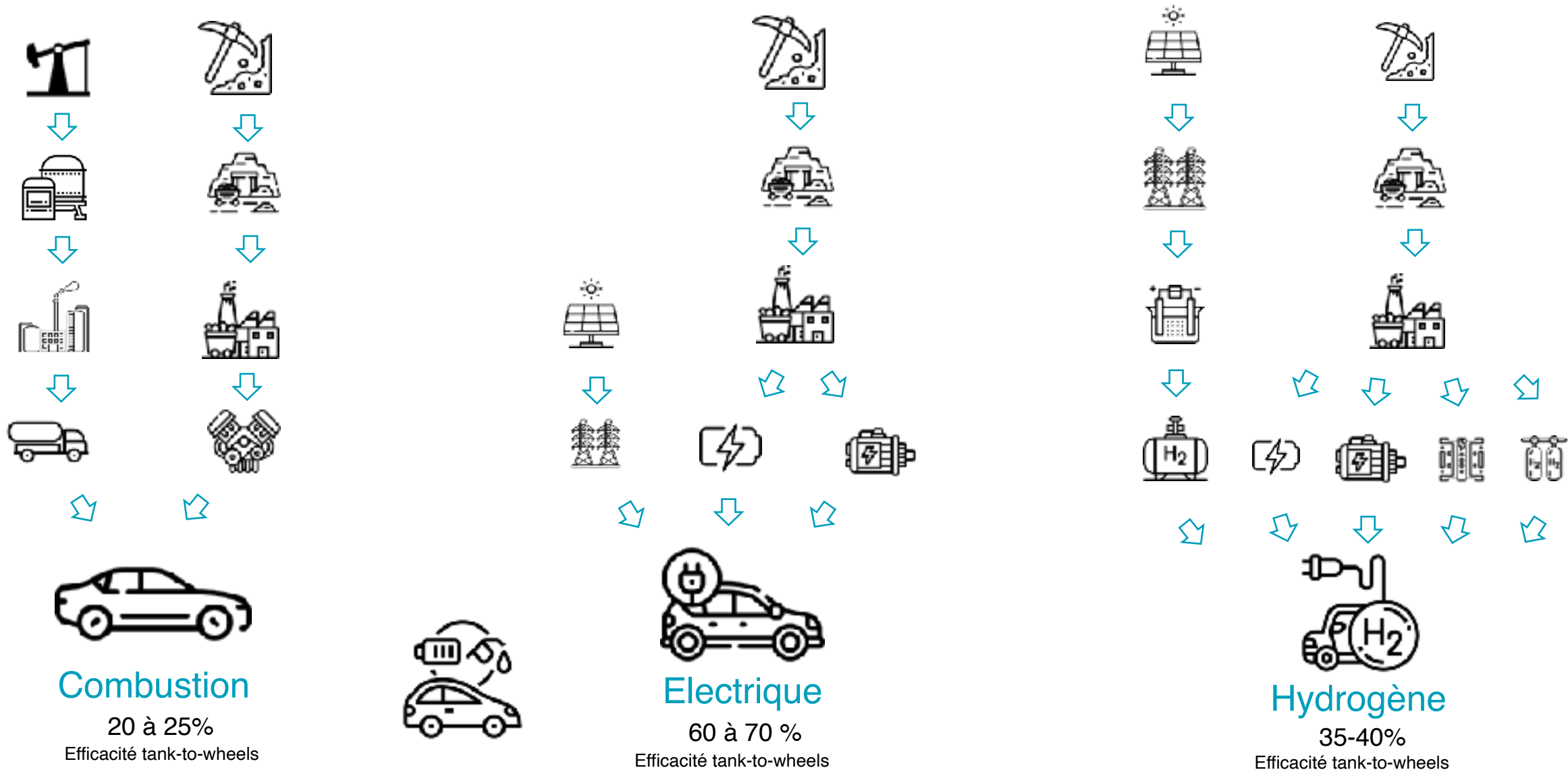
<https://www.alternatives-economiques.fr/voiture-electrique-vraiment-ecolo/00104884>

https://www.francetvinfo.fr/meteo/climat/pourquoi-la-voiture-electrique-n-est-pas-la-solution-miracle-pour-se-deplacer-sans-polluer_5425306.html

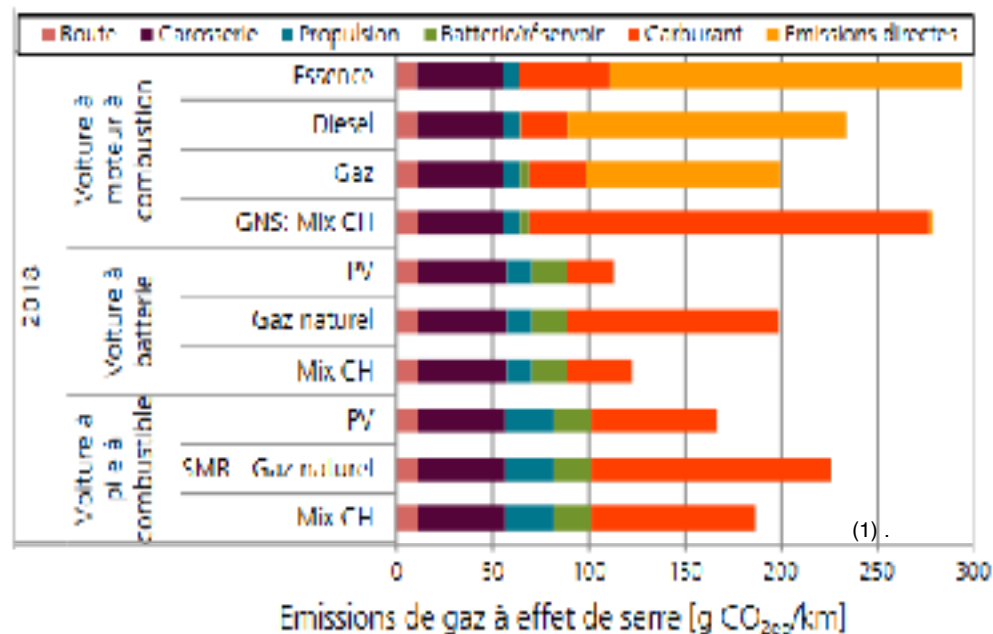
<https://www.tesla-mag.com/la-voiture-a-hydrogene-est-elle-l-avenir-du-vehicule-particulier/>

<https://www.energie360.ch/fr/energie360/savoir/mobilite-ecologique/avantages-voiture-au-gaz/>

Different technologies



Comparing different types of individual mobility



La voiture électrique émettent 2 à 3 fois moins de GES que les voitures à combustion

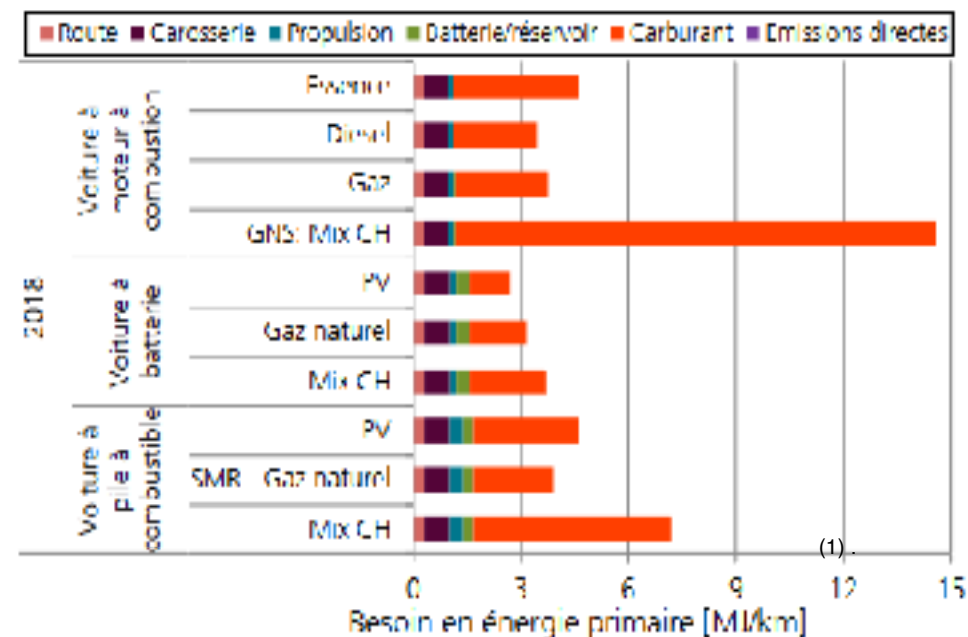
La batterie électrique des voitures à batterie est considérée à 36kWh.

PV : photovoltaïque,

GNS : gaz naturel synthétique, produit par électrolyse avec le mix électrique suisse et le CO₂ de l'atmosphère.

Gas : 80% gaz naturel et 20% de biométhane.

L'hydrogène pour les voitures à pile à combustible est produit par reformage de gaz naturel (**SMR**) ou par électrolyse (mix électrique suisse ou PV)



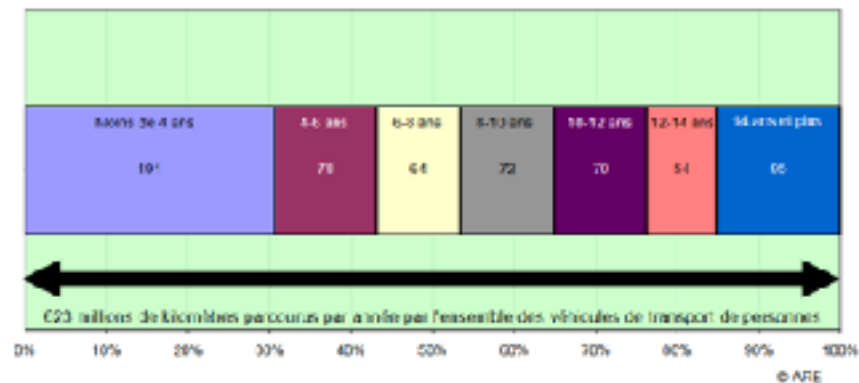
L'hydrogène nécessite beaucoup d'énergie primaire pour être produit, car les rendements des électrolyseurs sont aujourd'hui de 60 à 75%(2)

Functional unit (km) and life cycle

3.3.1 Distances parcourues par l'ensemble des véhicules

623 millions de kilomètres ont été parcourus annuellement par les véhicules de transport de passagers (trolleybus non compris), dont 31% par les véhicules de moins de 4 ans et tout de même 15% par les véhicules âgés de 14 ans et plus.

Véhicules de transport de passagers : nombre total de kilomètres parcourus annuellement (en millions de kilomètres) par les véhicules, présentés par classe d'âge (PEFA 2009)



<https://www.news.admin.ch/news/message/attachments/1587.pdf>

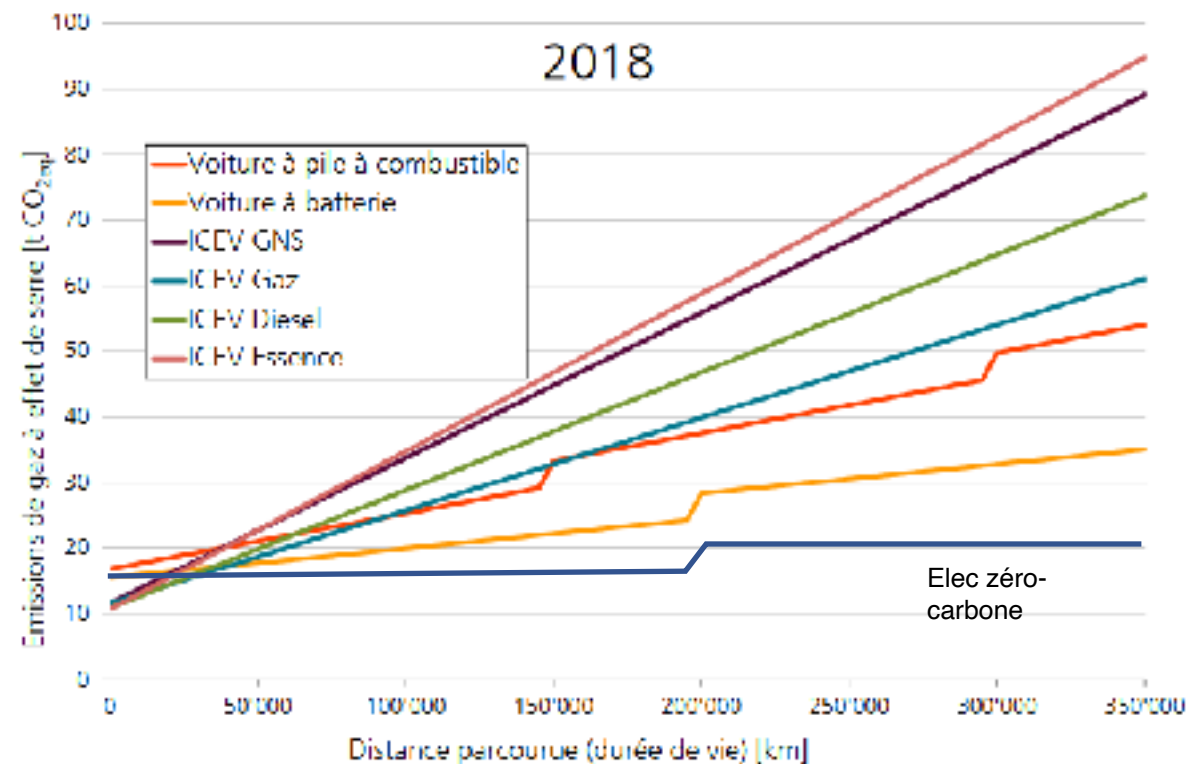


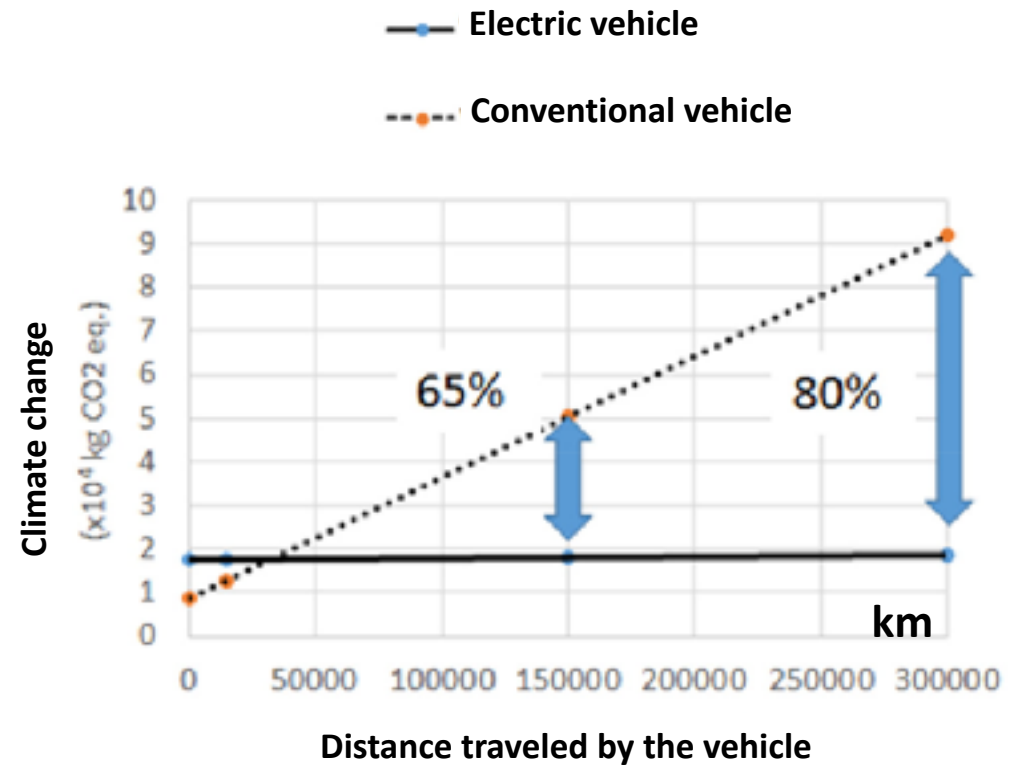
Figure 3: Émissions de gaz à effet de serre pendant toute la durée de vie de différents véhicules, aujourd'hui (à gauche) et en 2040 (à droite). «ICEV»: voiture à moteur à combustion, «GNS»: gaz naturel synthétique, produit par électrolyse avec le maé électrique suisse et le CO₂ de l'atmosphère. Le maé électrique suisse est aussi utilisé pour charger les batteries des véhicules à batterie et produire l'hydrogène des voitures à pile à combustible. «Gaz» est un mélange composé à 80% de gaz naturel et à 20% de biométhane. Les batteries et les piles à combustible sont remplacées respectivement après 150 000 km et 200 000 km.

Electric vehicles vs conventional vehicles (QC)

EV more impactful than CV at purchase (x 1.5 – 2)

Breakeven point ~ 30,000 km

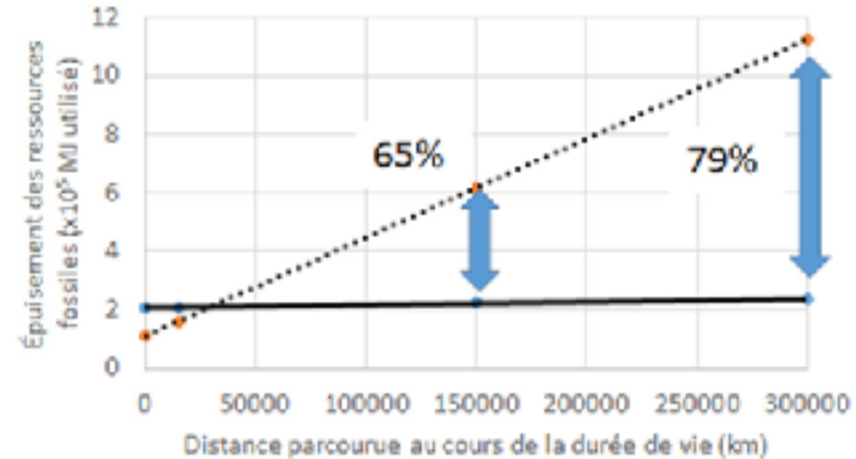
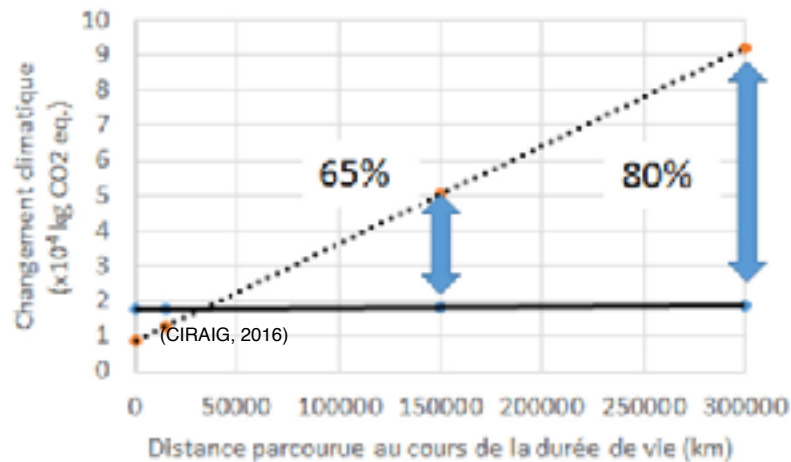
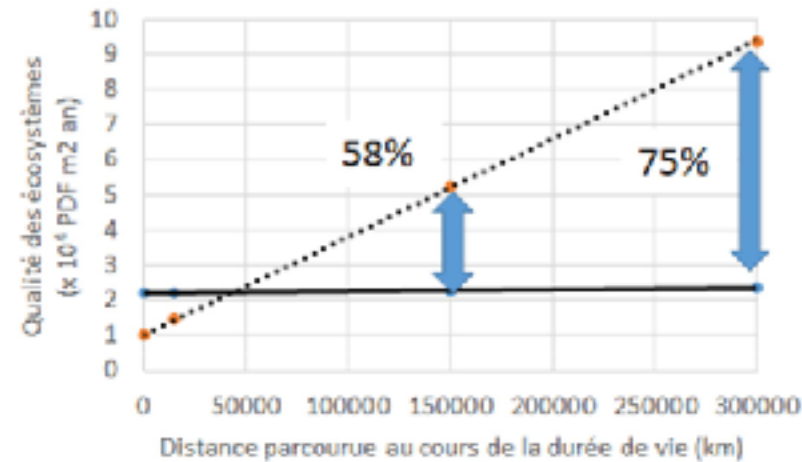
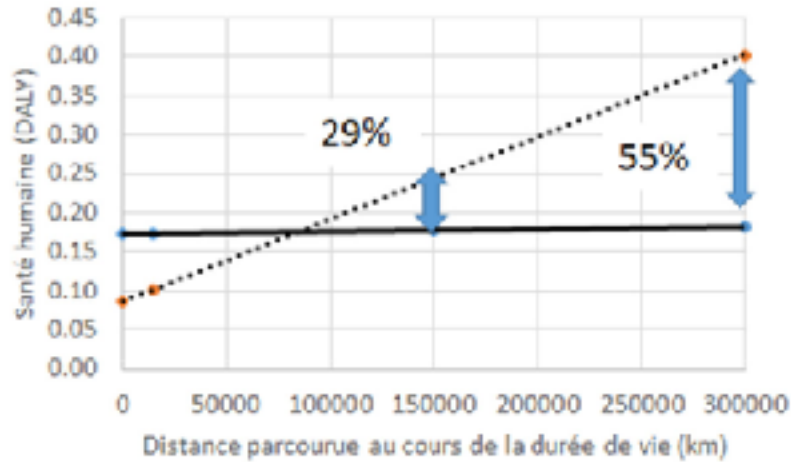
Gap increases with vehicle lifetime



(CIRAIG, 2016)

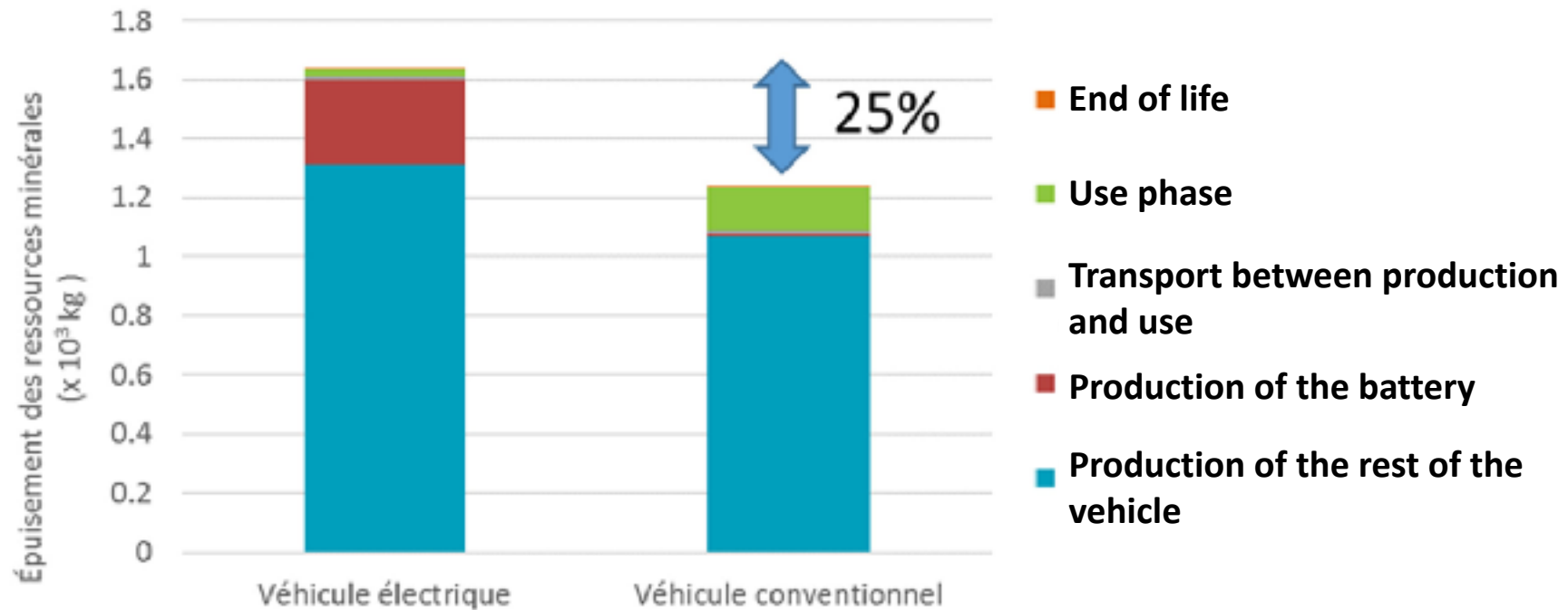
Electric vehicles vs conventional vehicles (QC)

Similar trend for the « human health », « ecosystem quality » and « resource depletion – non renewable »

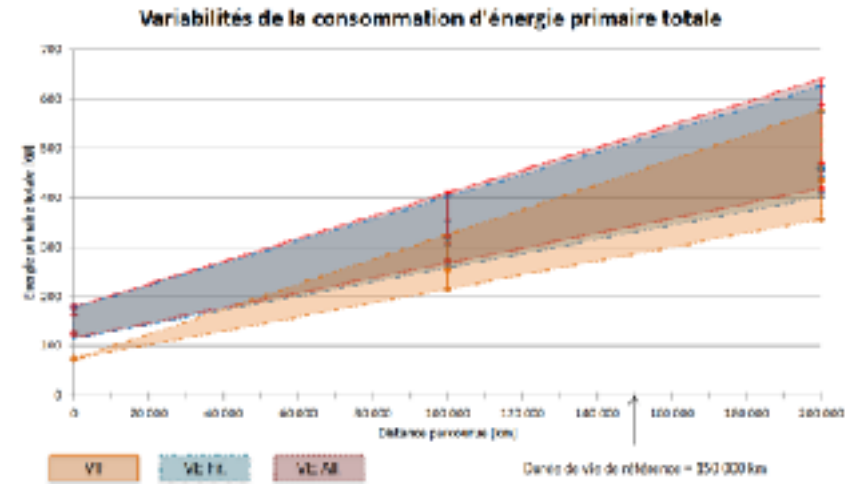
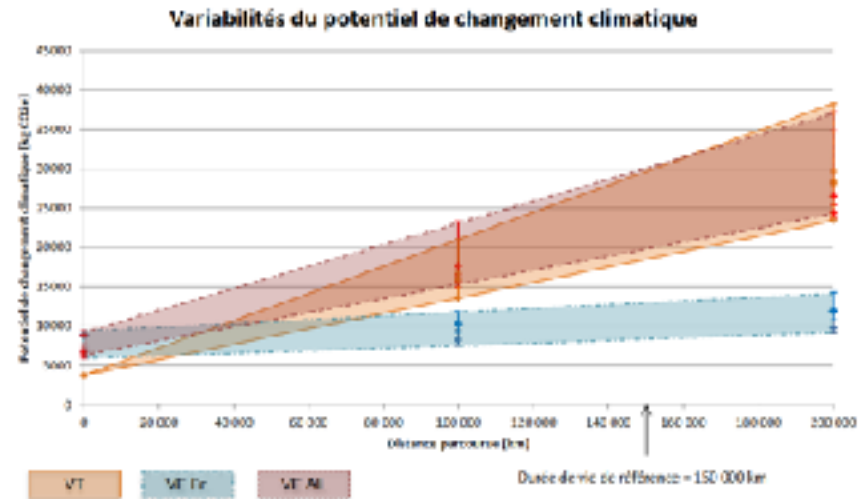


Electric vehicles vs conventional vehicles (QC)

Trends are reversed for the indicator « depletion of mineral resources»



Electric vehicles vs conventional vehicles in other context (FR and DE)



(ADEME, 2013)

Conventional vehicle Electric vehicle

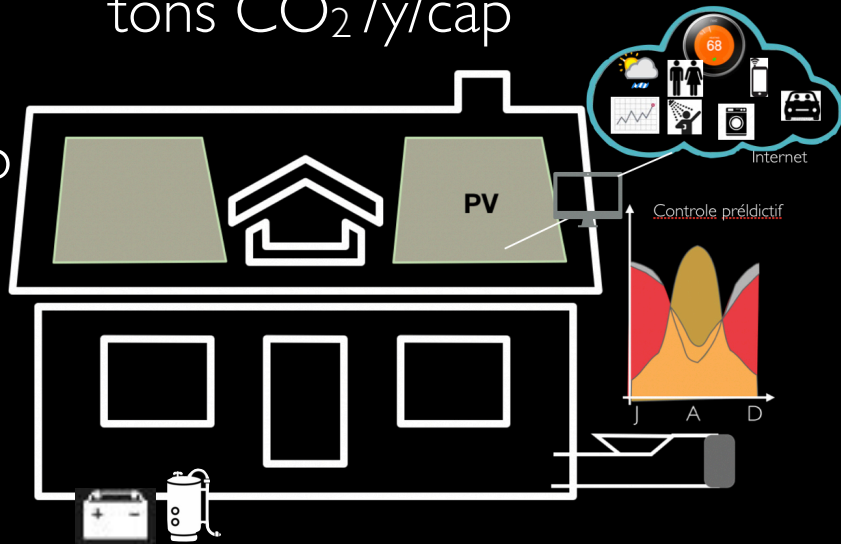
RENEWABLE ENERGY HUB AND E-VEHICLES

0.25 + 1.74

tons CO₂/y/cap

15.5
m²PV/cap

Direct
Achat
Vente



138

CHF/y/cap

PV feed-in : **-278** CHF/y/cap
Energy : **184** CHF/y/cap
Investment : **230** CHF/y/cap
Building

+ 88

CHF/y/cap

88 CHF/y/cap

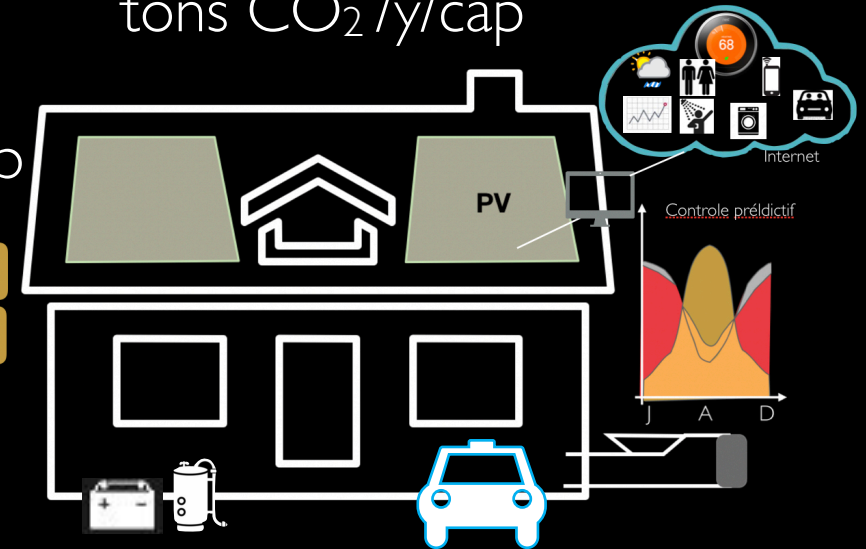
Gasoline car

0.32 (-83%)

tons CO₂/y/cap

15.5
m²PV/cap

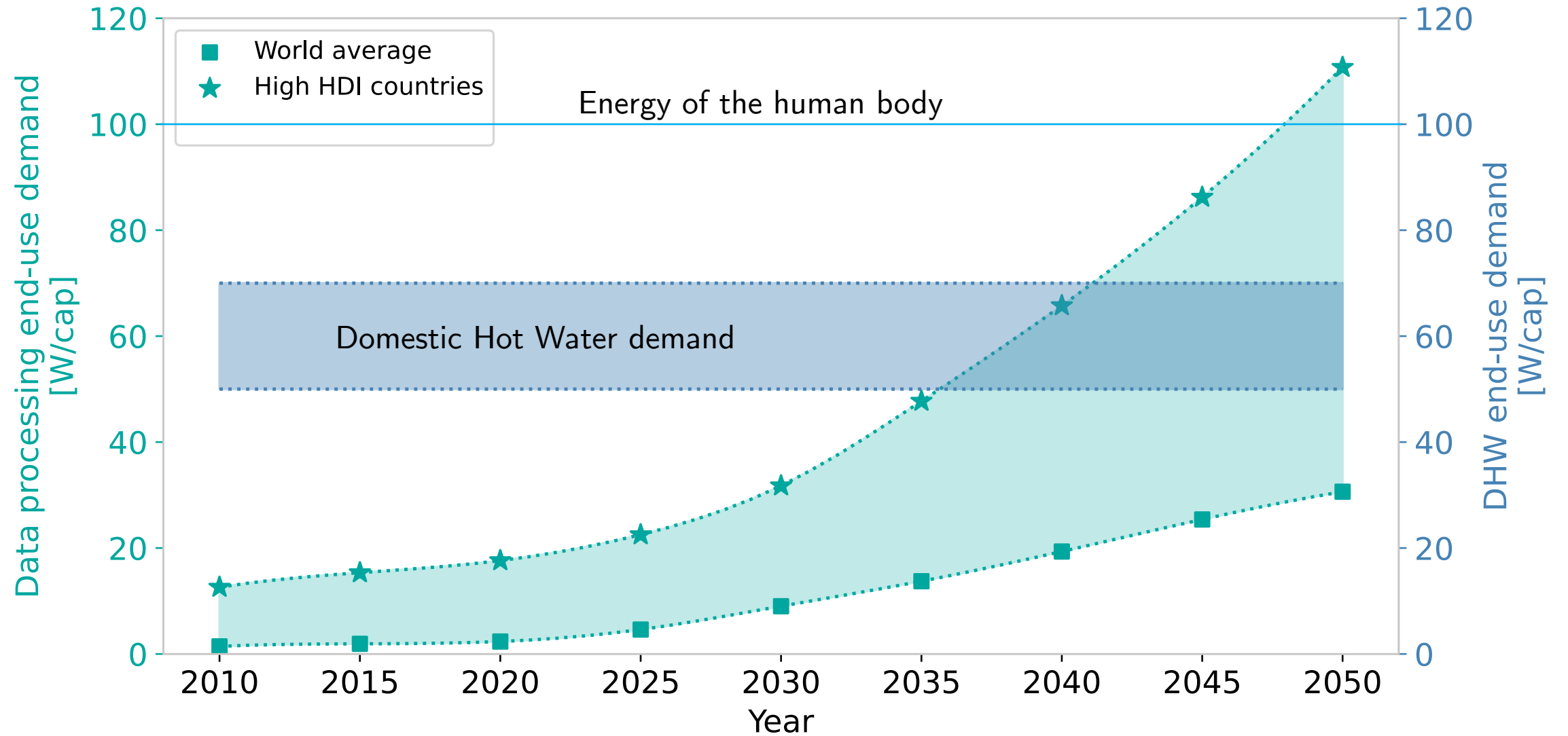
Direct
Achat
Vente



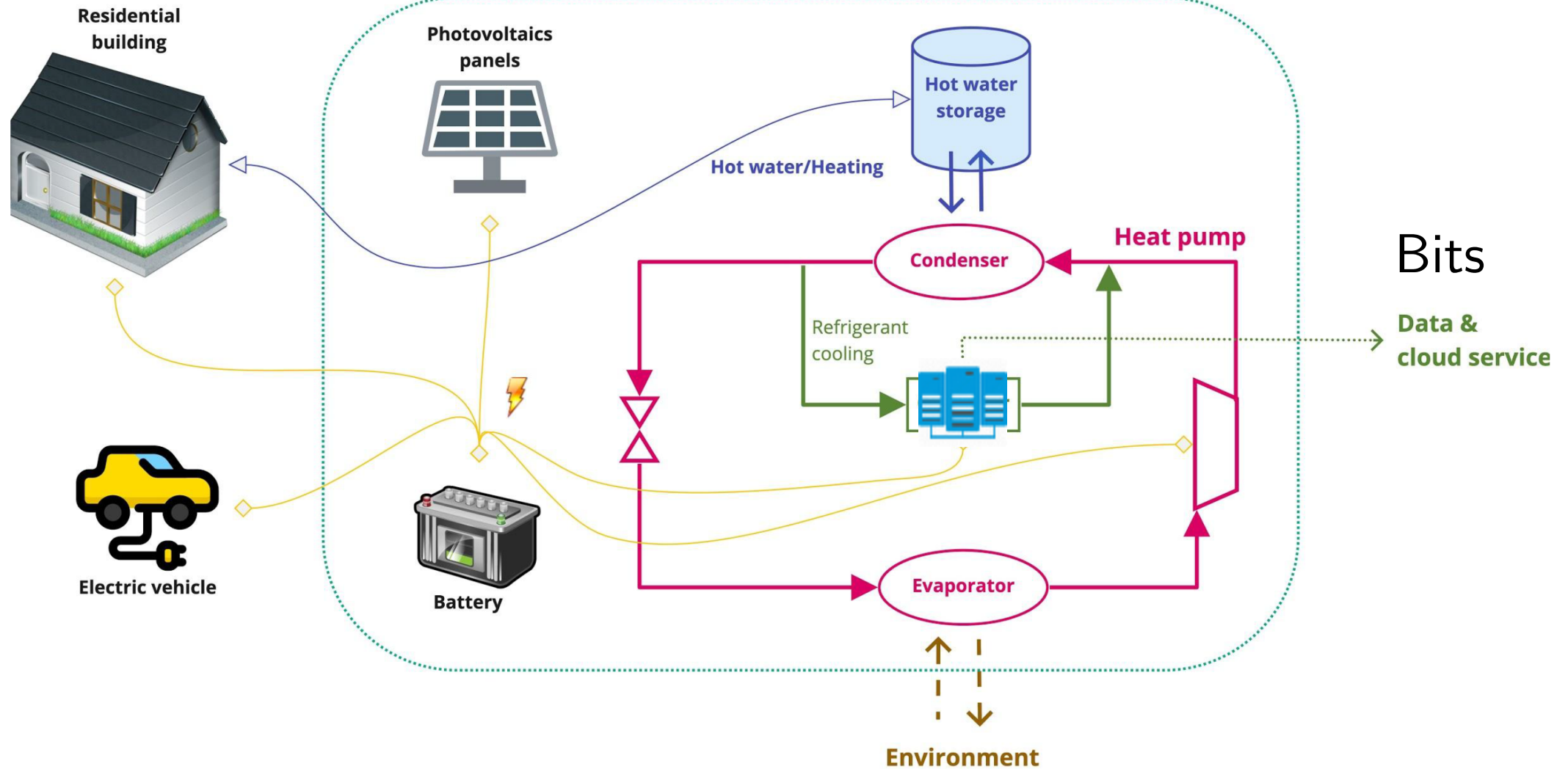
208 (-79%)

CHF/y/cap

PV feed-in : **-226** CHF/y/cap
Energy : **204** CHF/y/cap
Investment : **230** CHF/y/cap



HEAT WITH BITS - Combined heat and data system



Bits

Data & cloud service

Environment

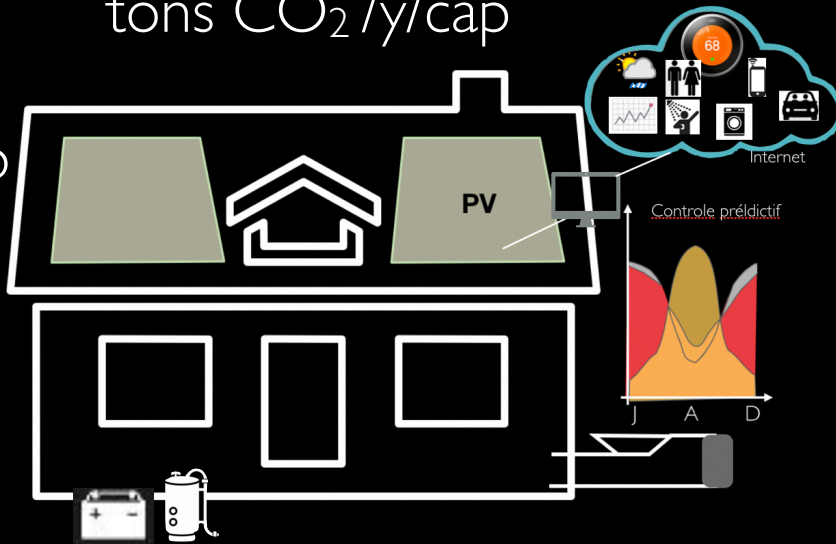
RENEWABLE ENERGY HUB AND DATA PRODUCTION

0.5 (0.25 + 0.24)

tons CO₂/y/cap

15.5
m²PV/cap

Direct
Achat
Vente



614 (138 + 476)

CHF/y/cap

PV feed-in : **-278** CHF/y/cap
Energy : **184** CHF/y/cap
Investment : **230** CHF/y/cap
Building



CHF/y/cap

290 CHF/y/cap
186 CHF/y/cap
Data center

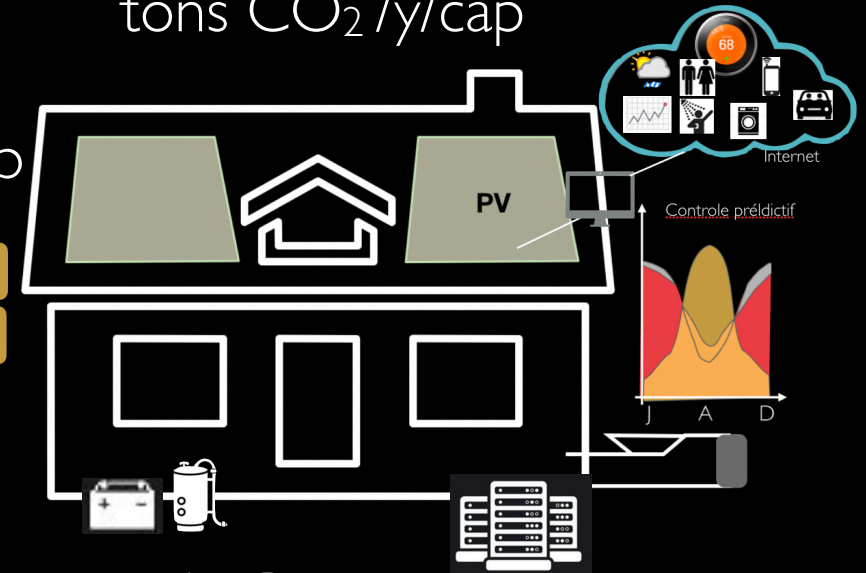


0.32 (-34%)

tons CO₂/y/cap

15.5
m²PV/cap

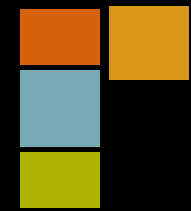
Direct
Achat
Vente



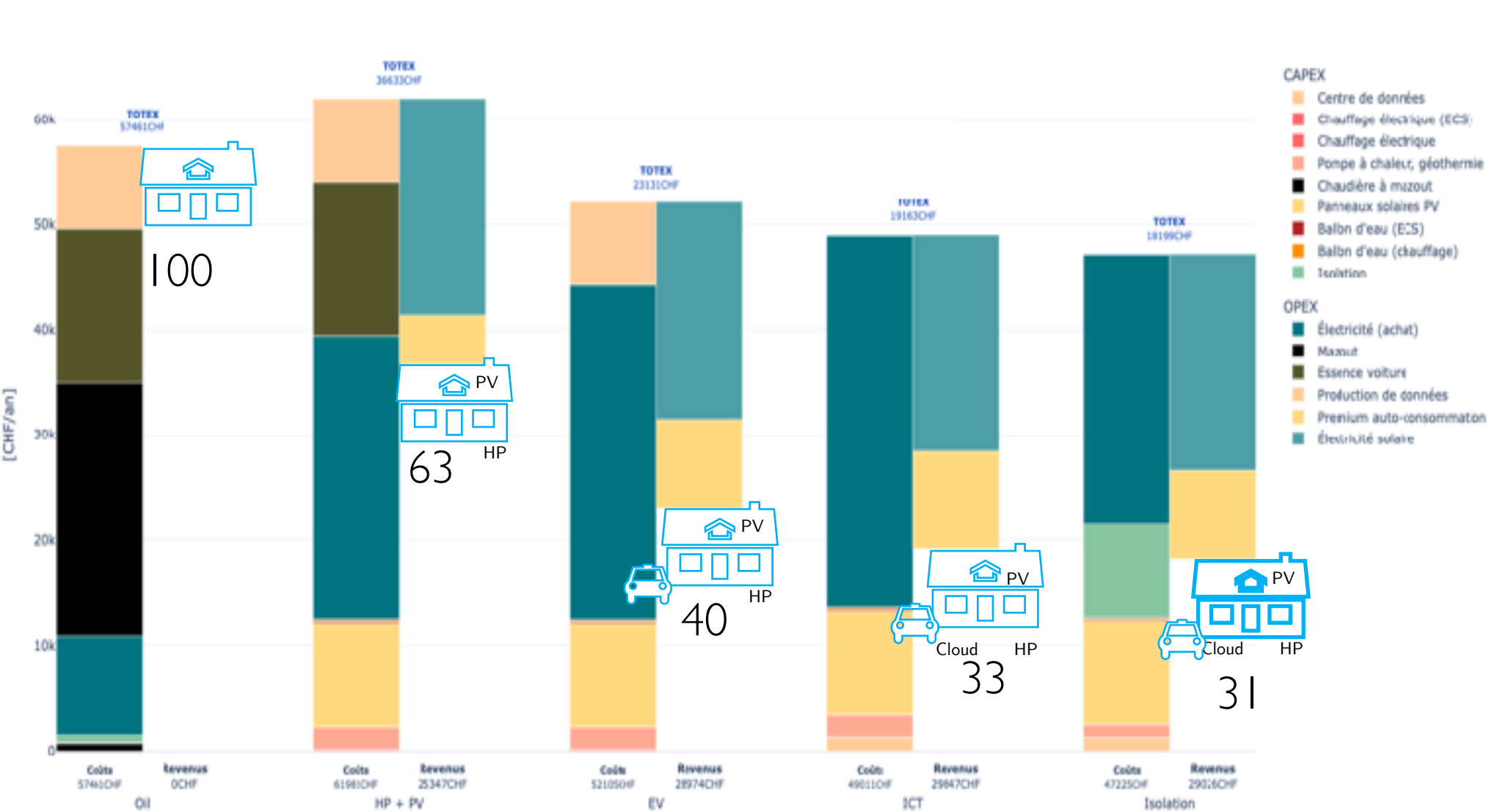
468 (-24%)

CHF/y/cap

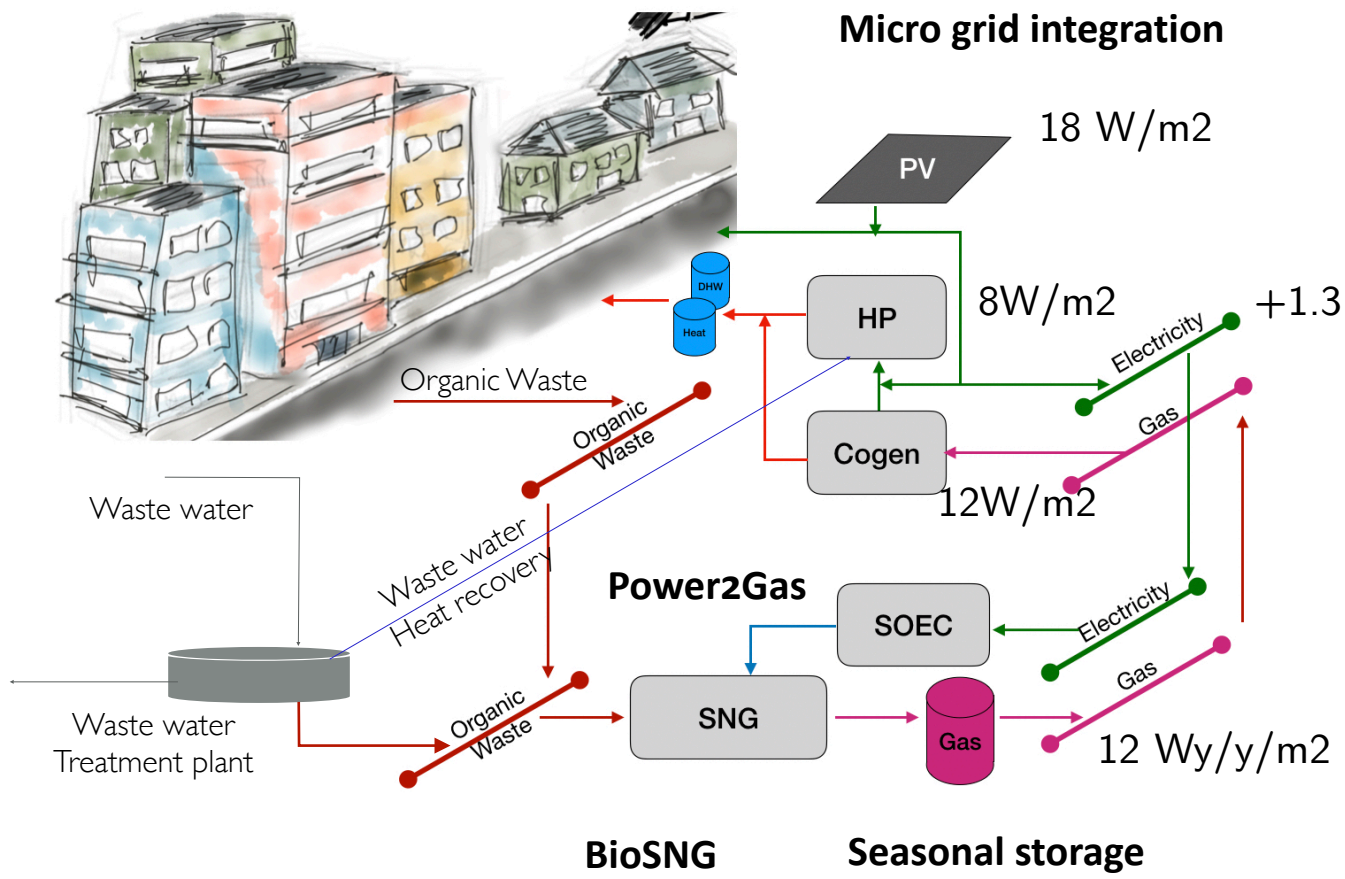
PV feed-in : **-232** CHF/y/cap
Energy : **224** CHF/y/cap
Investment : **250** CHF/y/cap
Bits heater : **226** CHF/y/cap



SOLAR PV + HEAT PUMPS + E-VEHICLES + INTEGRATED DATA CENTERS

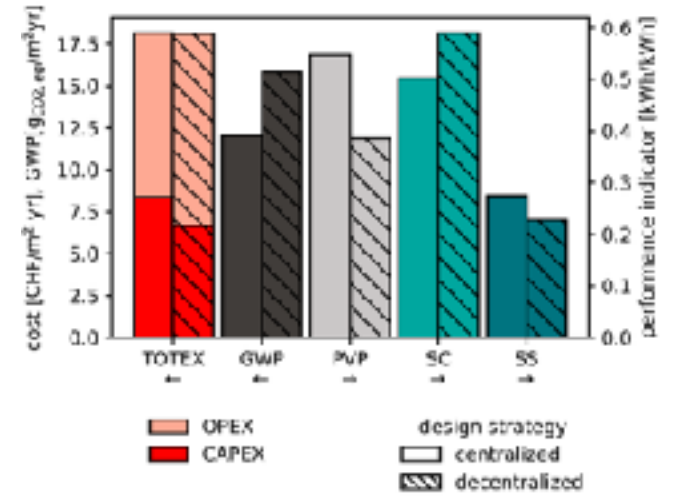


- District scale => interactions between buildings

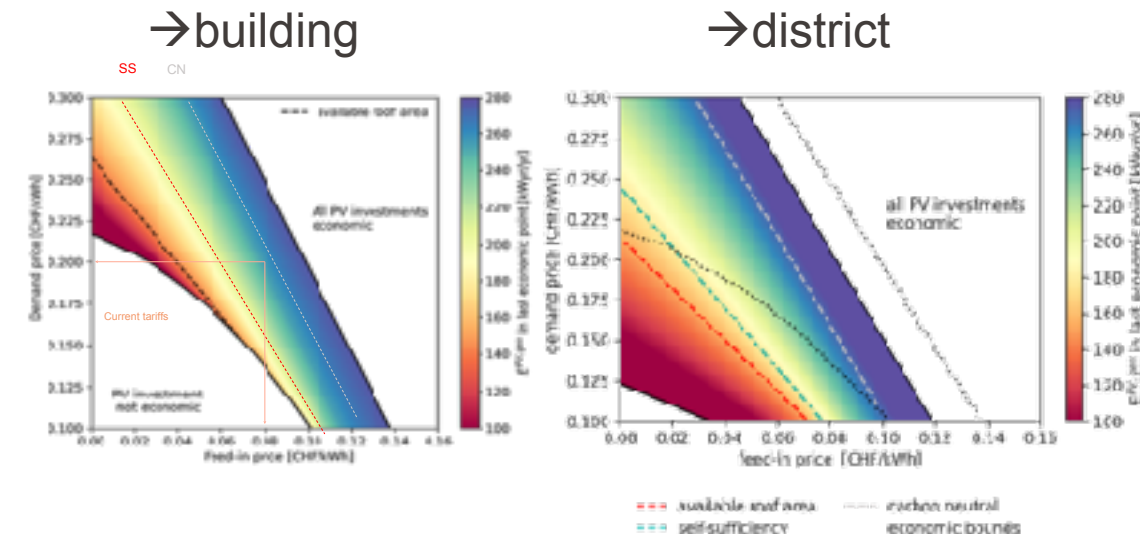


m2 = heated surface

building vs community



- 40% increase PV
- 20% GWP reduction
- 16-40% facades
- building
- district



INTEGRATING CITIES BY DISTRICT HEATING

Sources de chaleurs

Industrie: **>80°C**

Data center : **30°C**

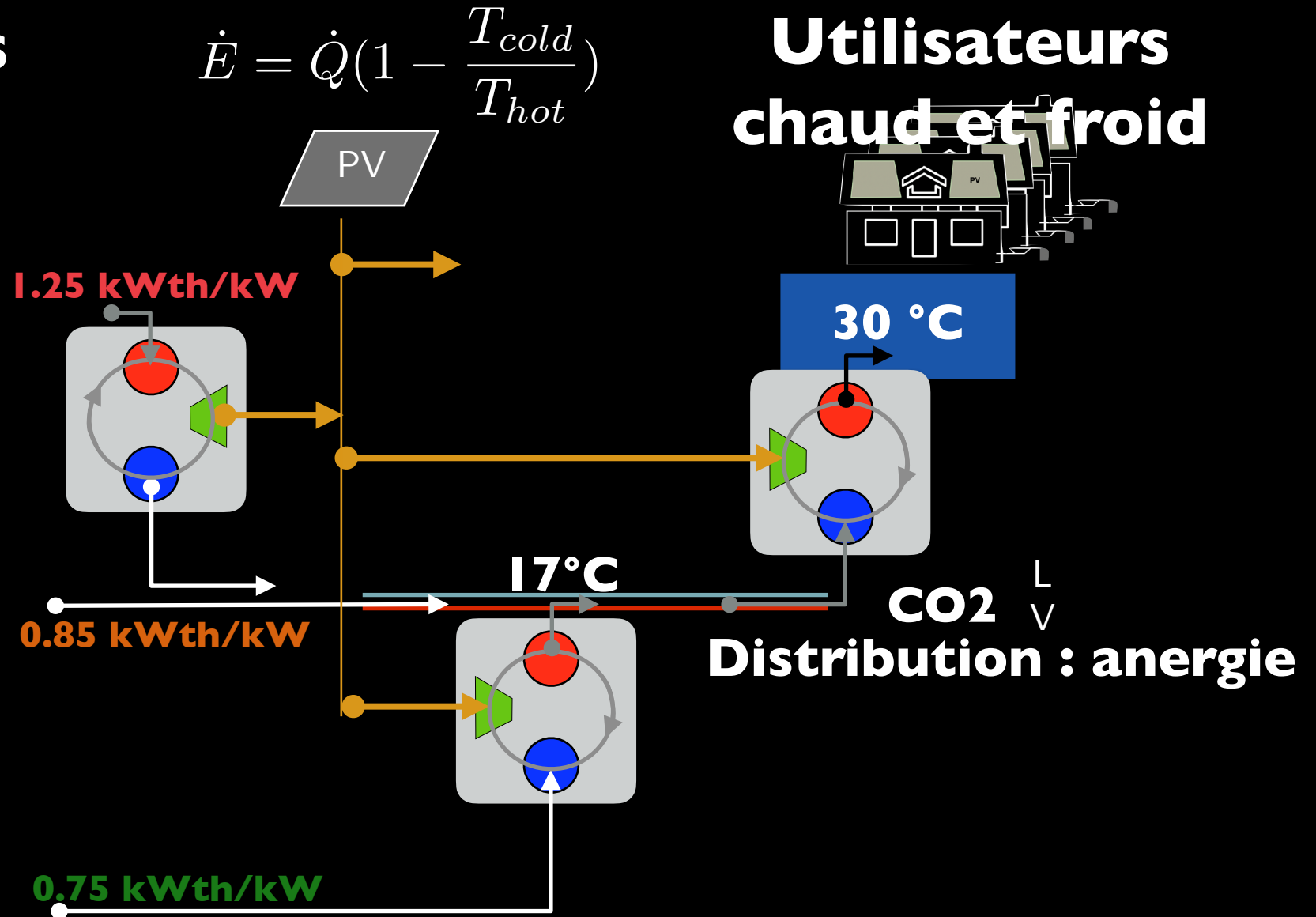
Eaux usées : **13-20 °C**

Eau Nappe : **10 °C**

Rivières/lac : **7°C**

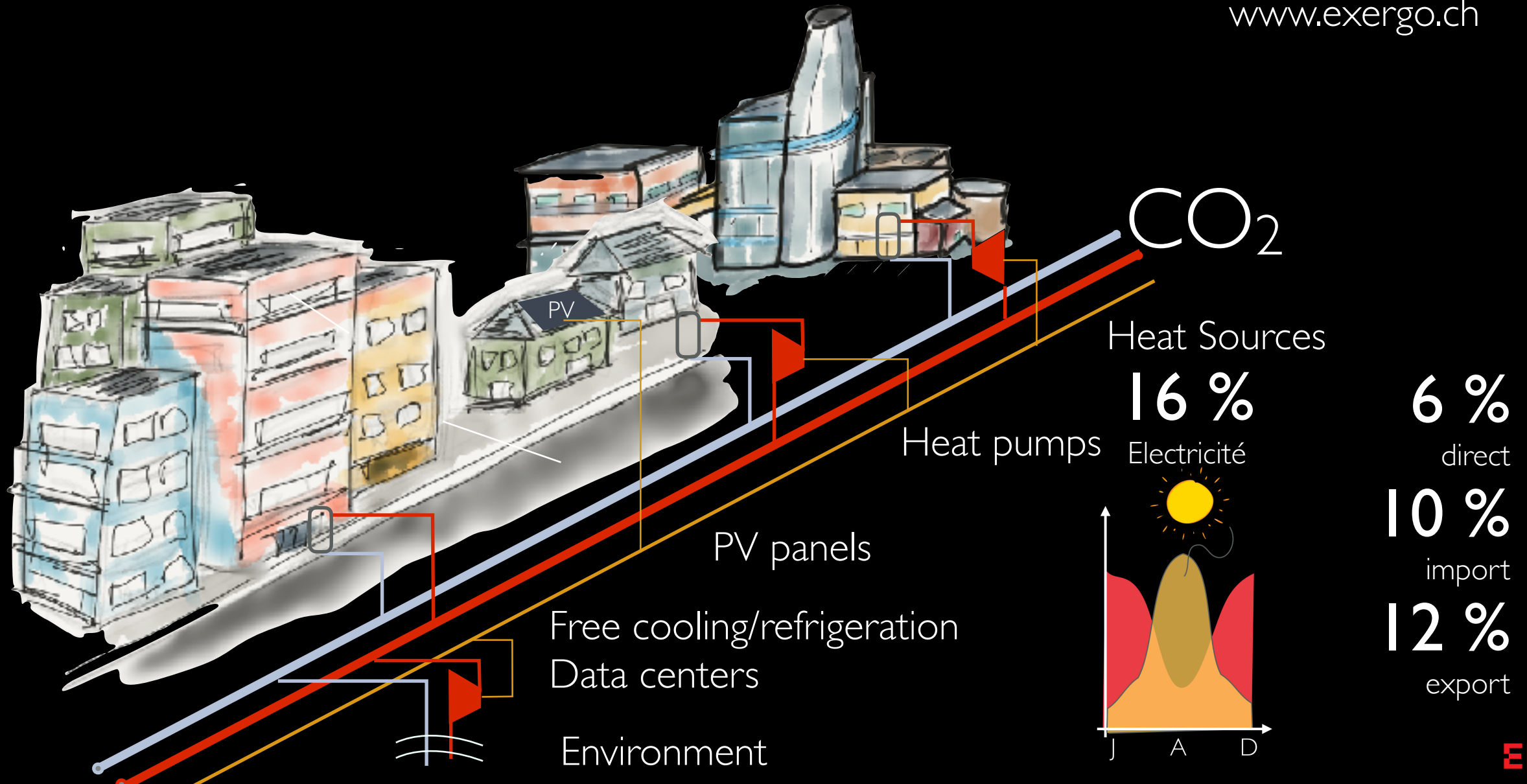
Géothermie : **>10 °C**

Refrigeration : **< 0°C**



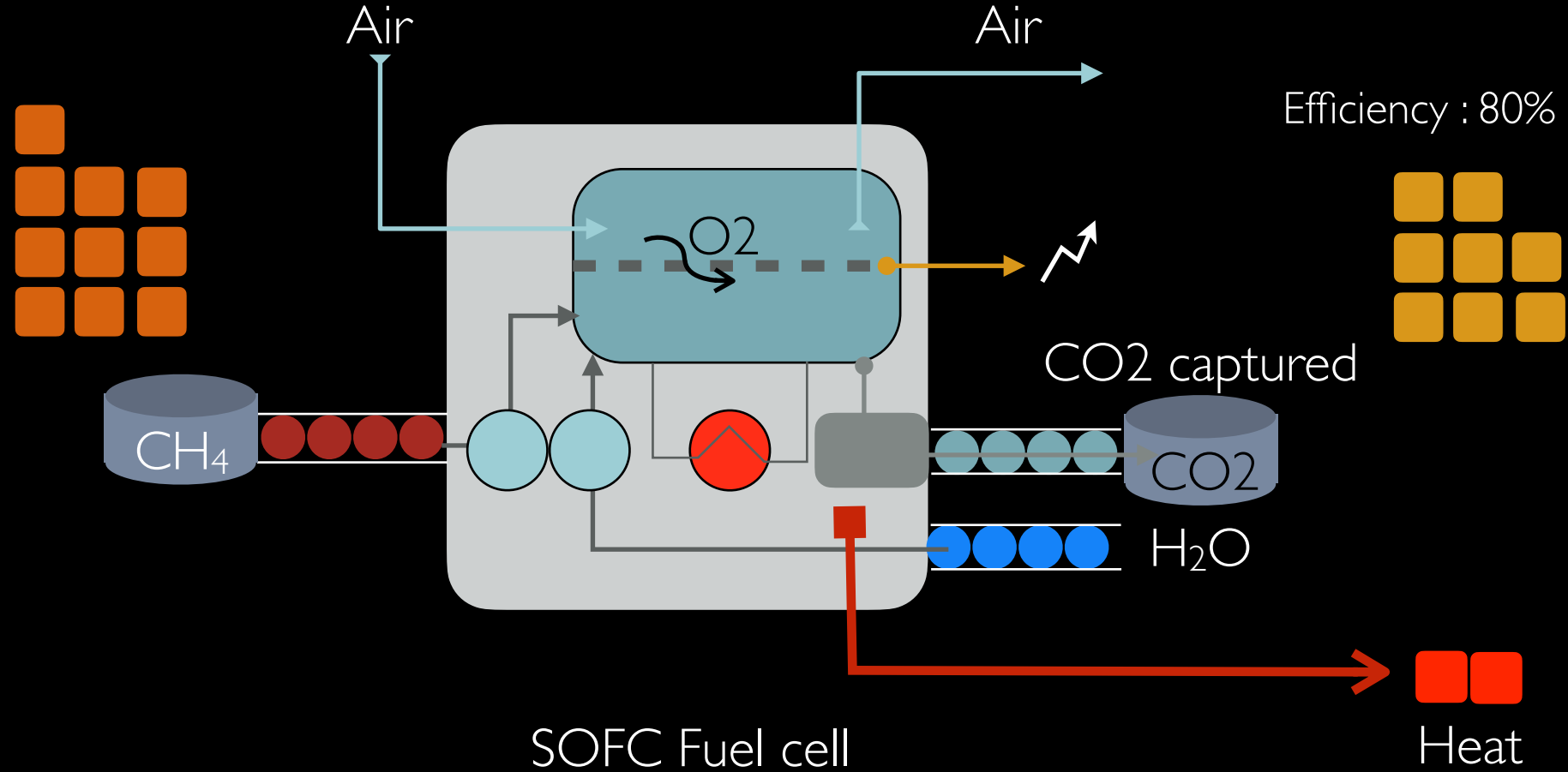
DISTRICT RENEWABLE ENERGY HUBS

www.exergo.ch

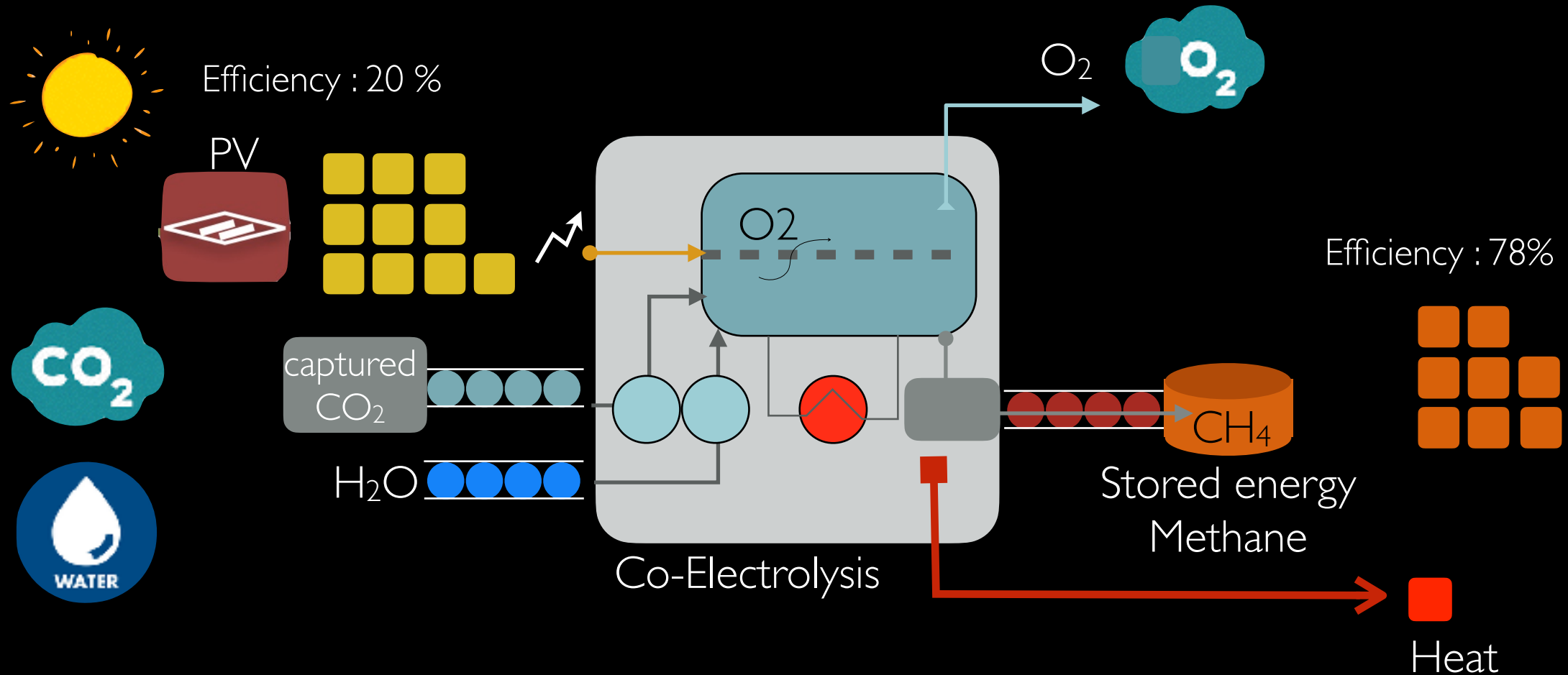


ENERGY MANAGEMENT

10% IMPORT : FUEL CELLS

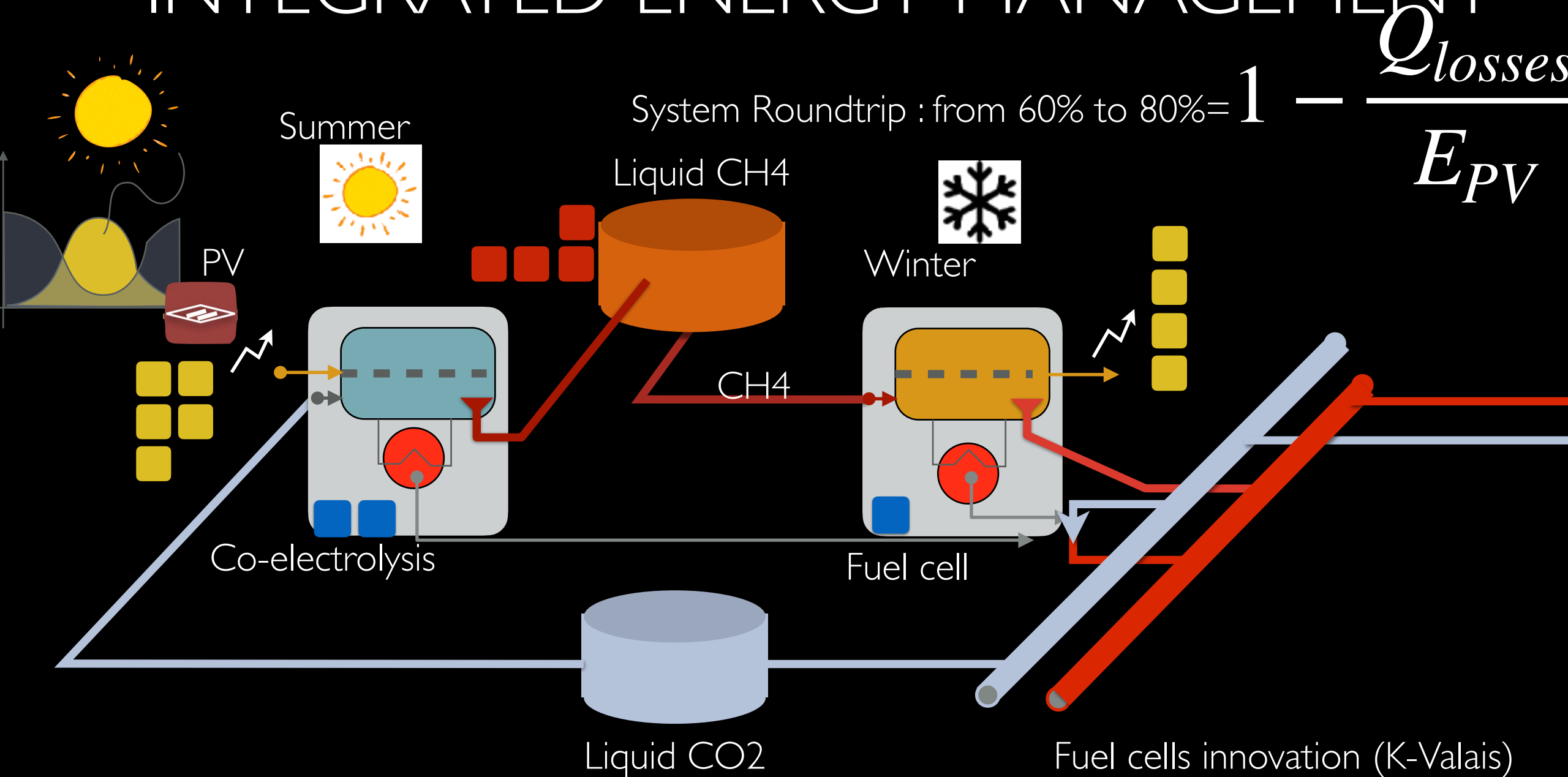


STORING EXCESS OF ELECTRICITY

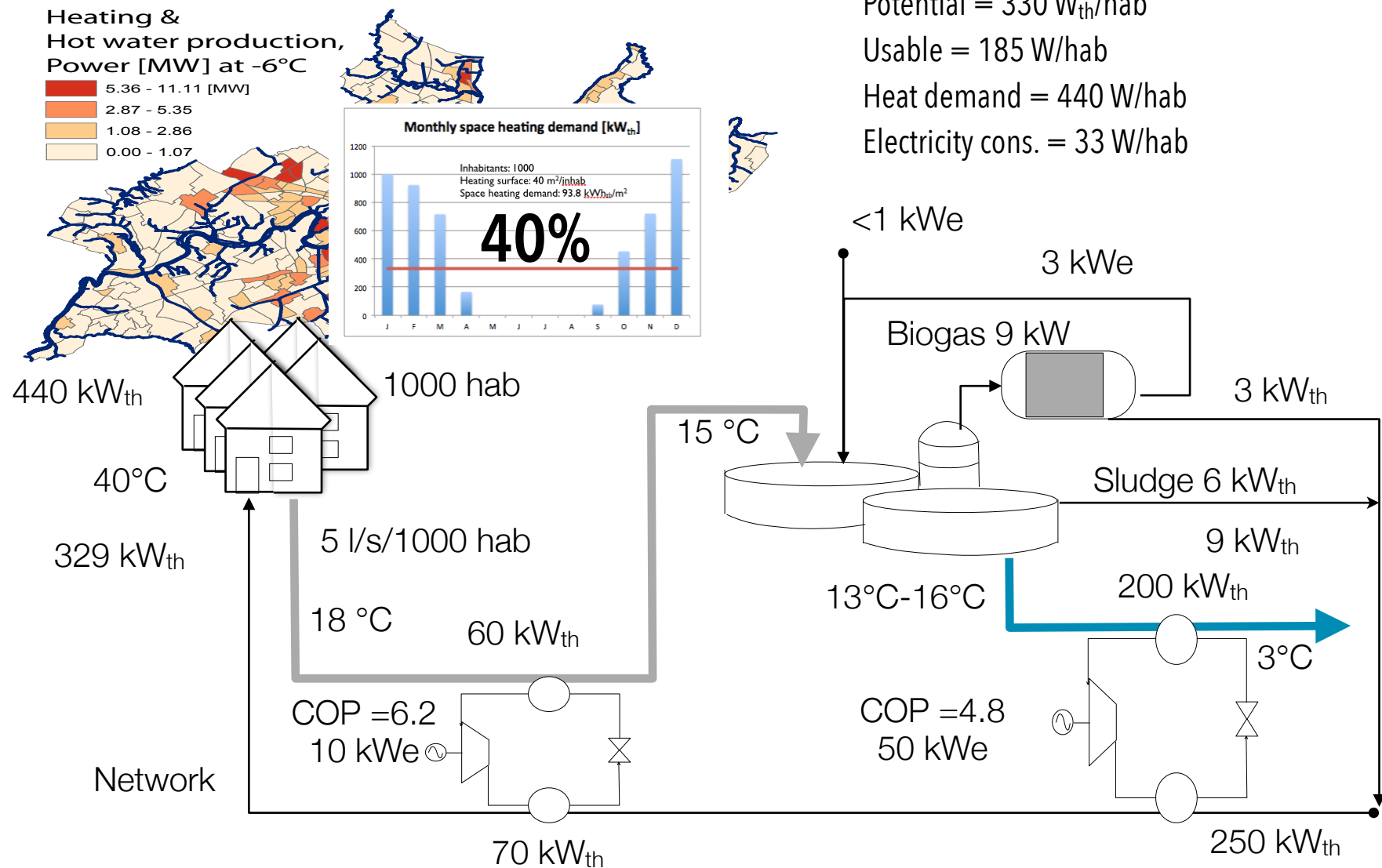


Artificial photosynthesis : 13-16 % Solar efficiency

INTEGRATED ENERGY MANAGEMENT



Waste water management : chasing the heat soruces



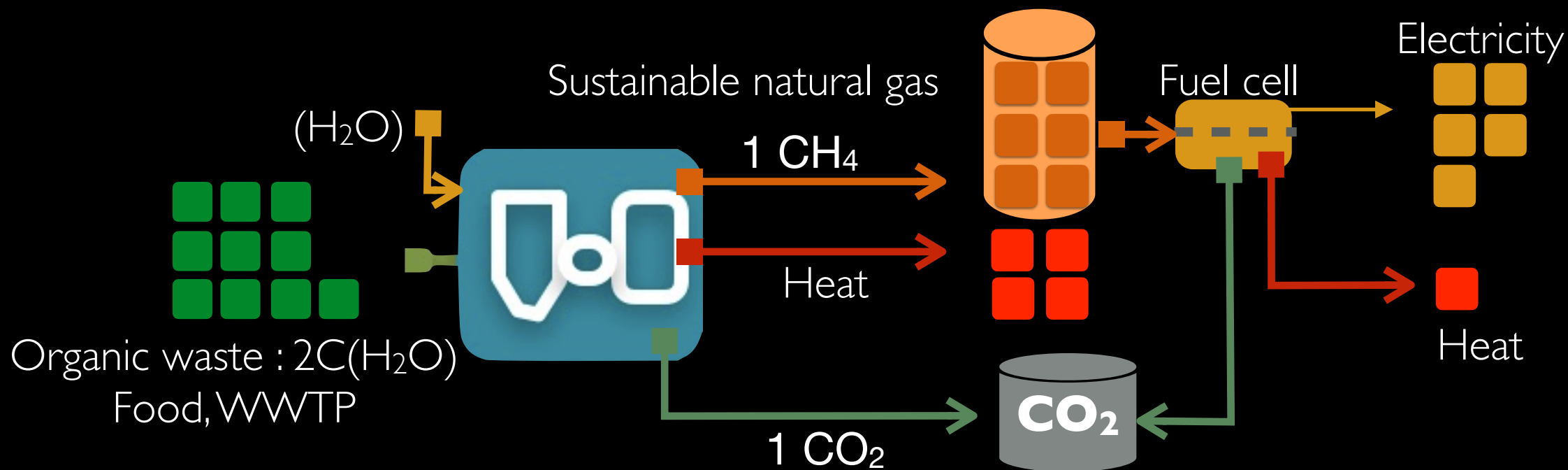
Potential = 330 W_{th}/hab
Usable = 185 W/hab
Heat demand = 440 W/hab
Electricity cons. = 33 W/hab

Biomass resource

Heat pump resource



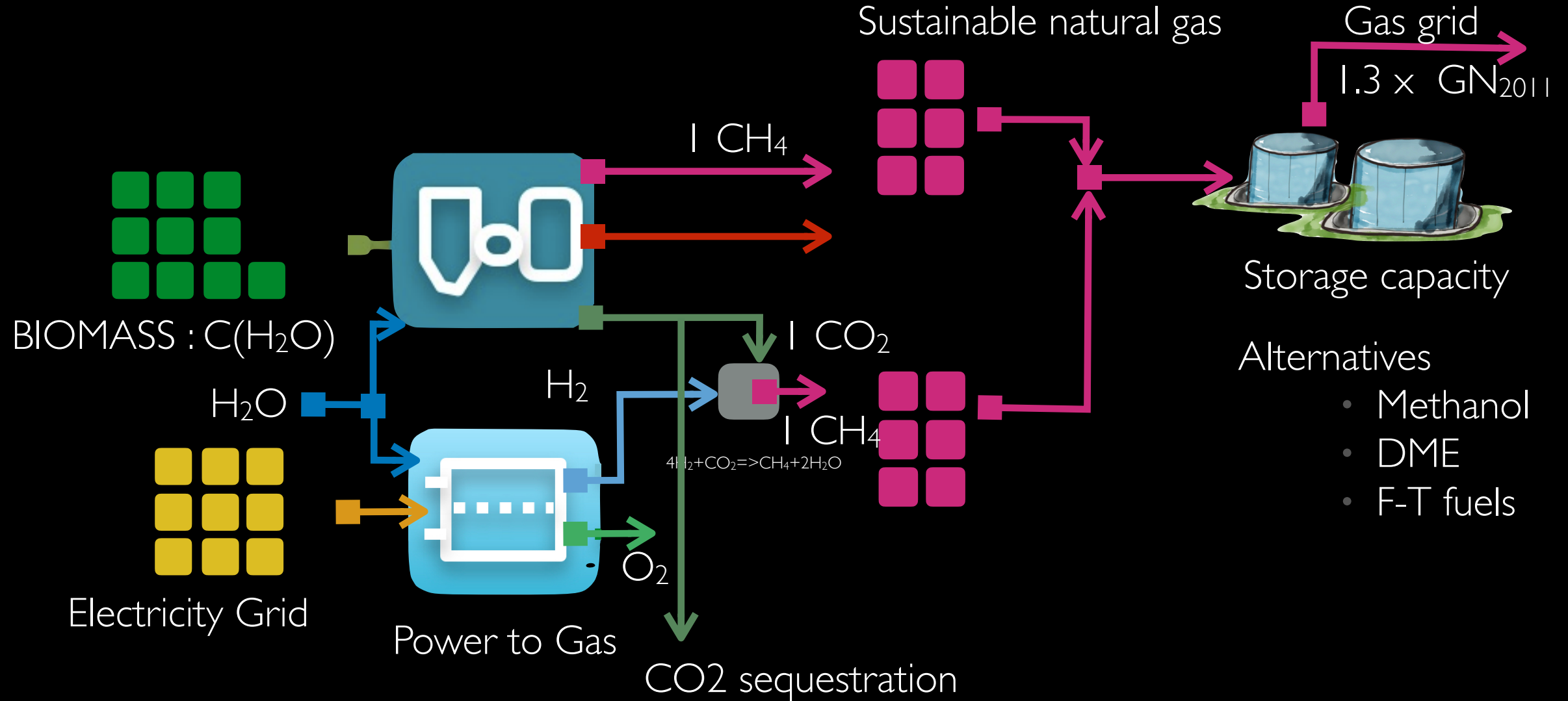
ORGANIC WASTE TO CLOSE THE ENERGY BALANCE



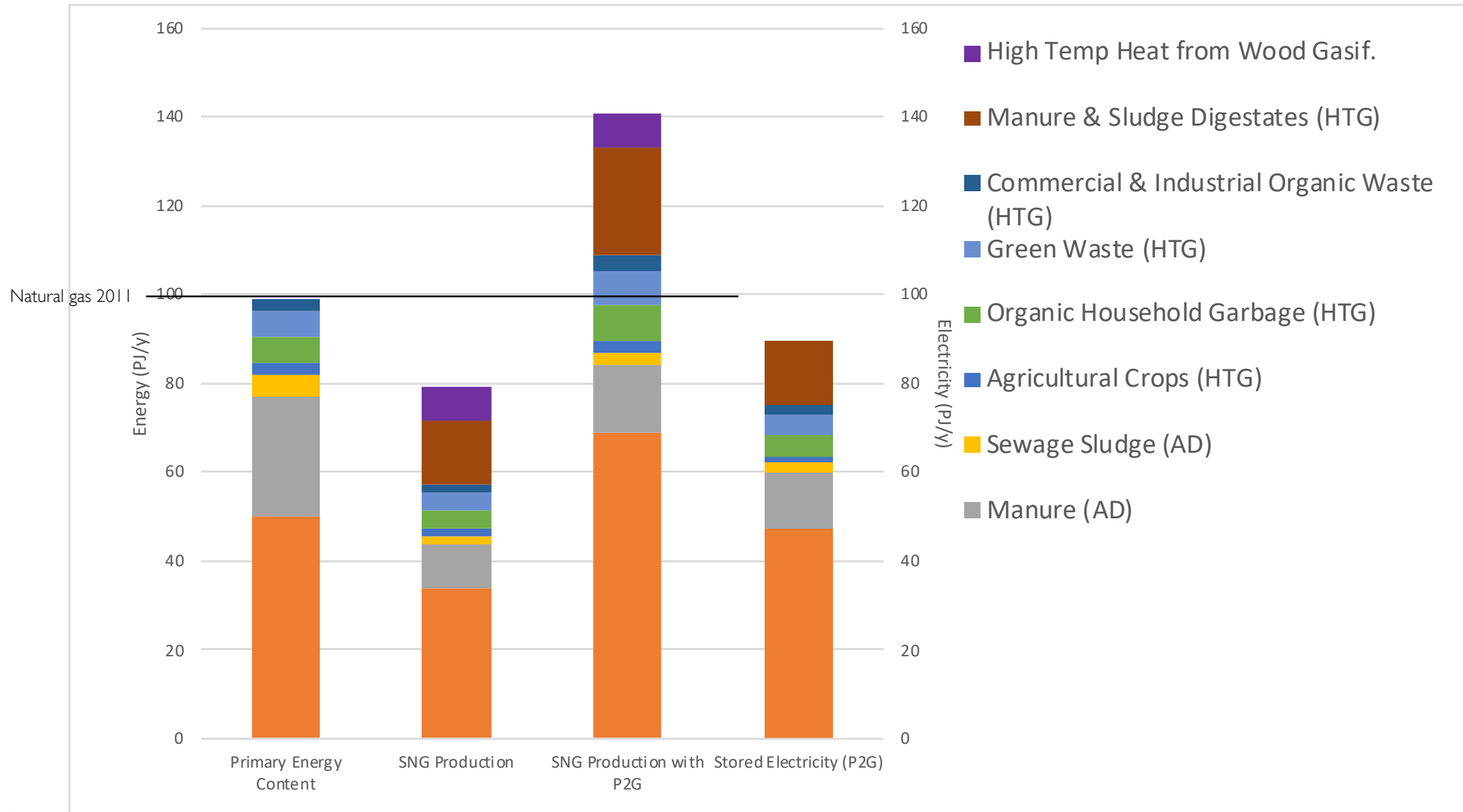
- 50% : Biomethanisation
- 70% : Hydrothermal gasification ()
- 70% : Synthetic Natural Gas



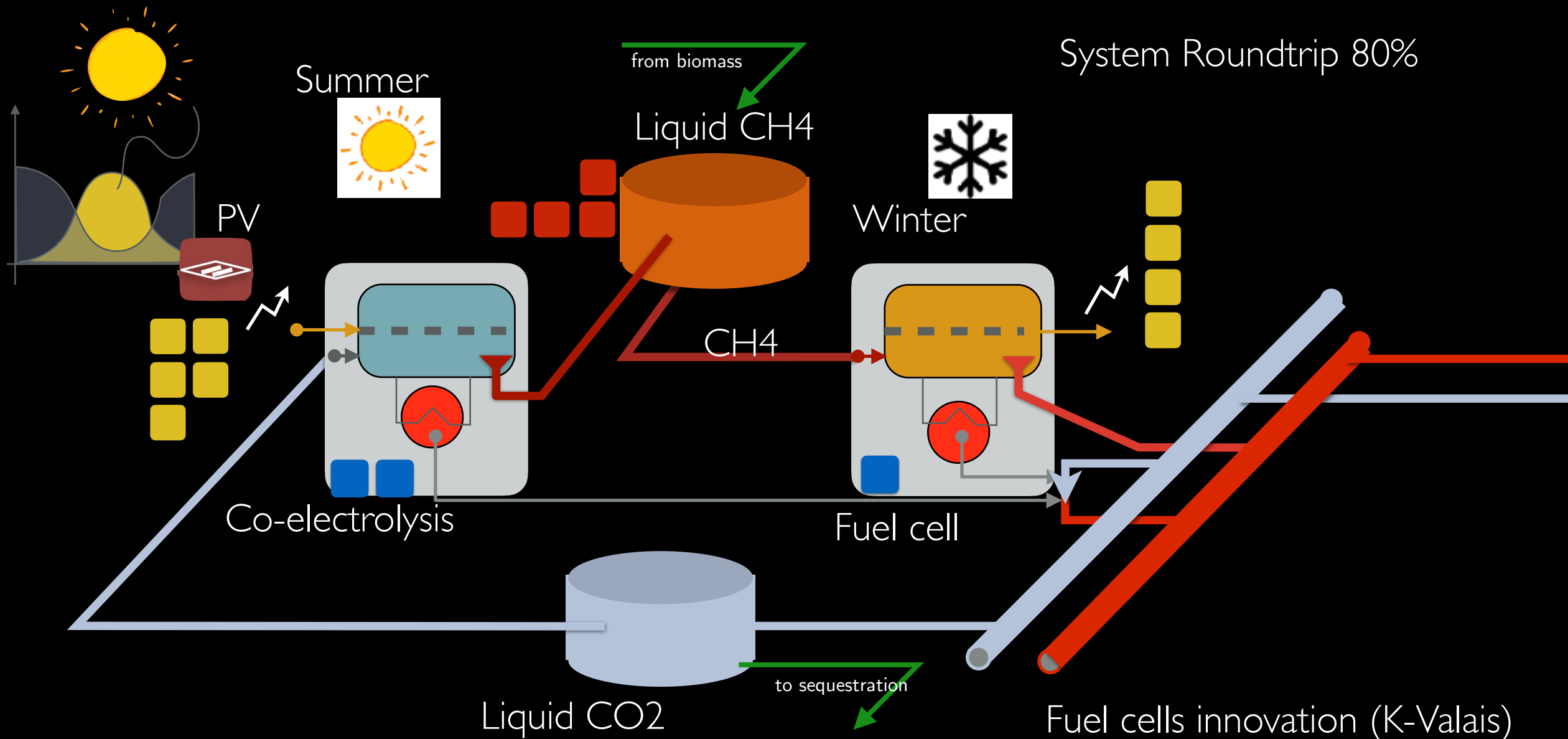
COMBINING BIOMASS CONVERSION AND ELECTROLYSIS



Biomass resource and conversion

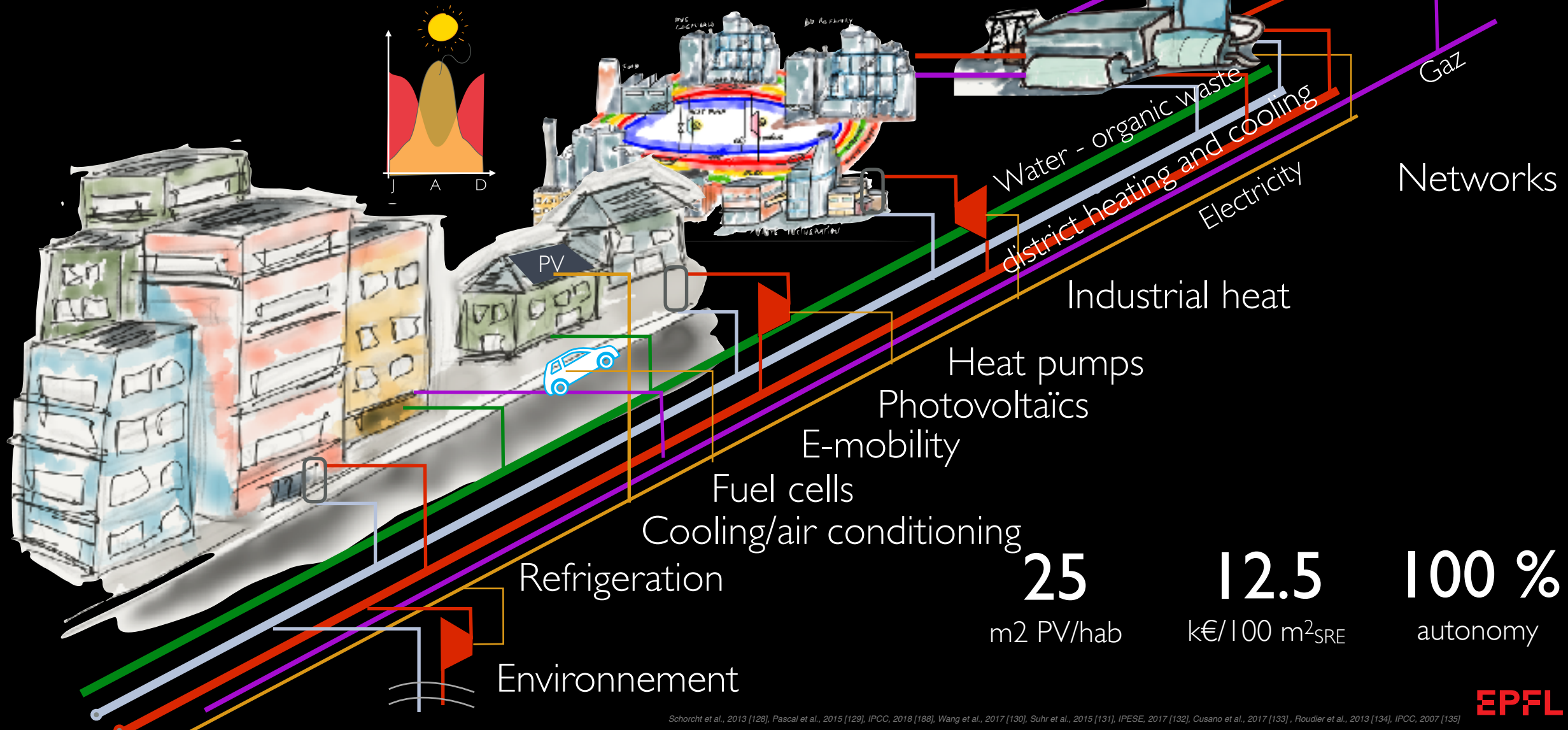


INTEGRATED ENERGY MANAGEMENT

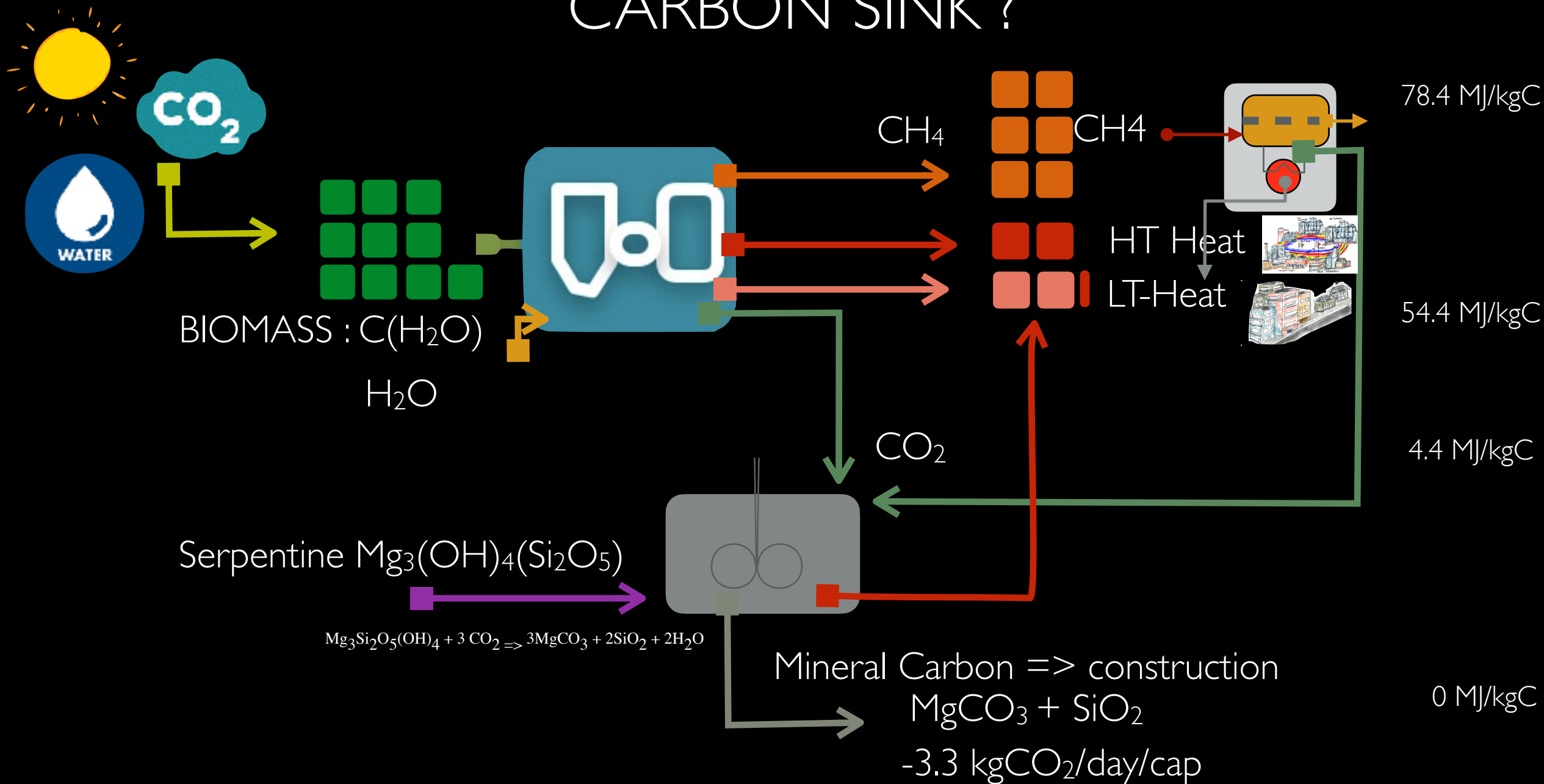


Al-Musleh, Easa I., Dharik S. Mallapragada, and Rakesh Agrawal. "Continuous power supply from a baseload renewable power plant." *Applied Energy* 122 (2014): 83-93.

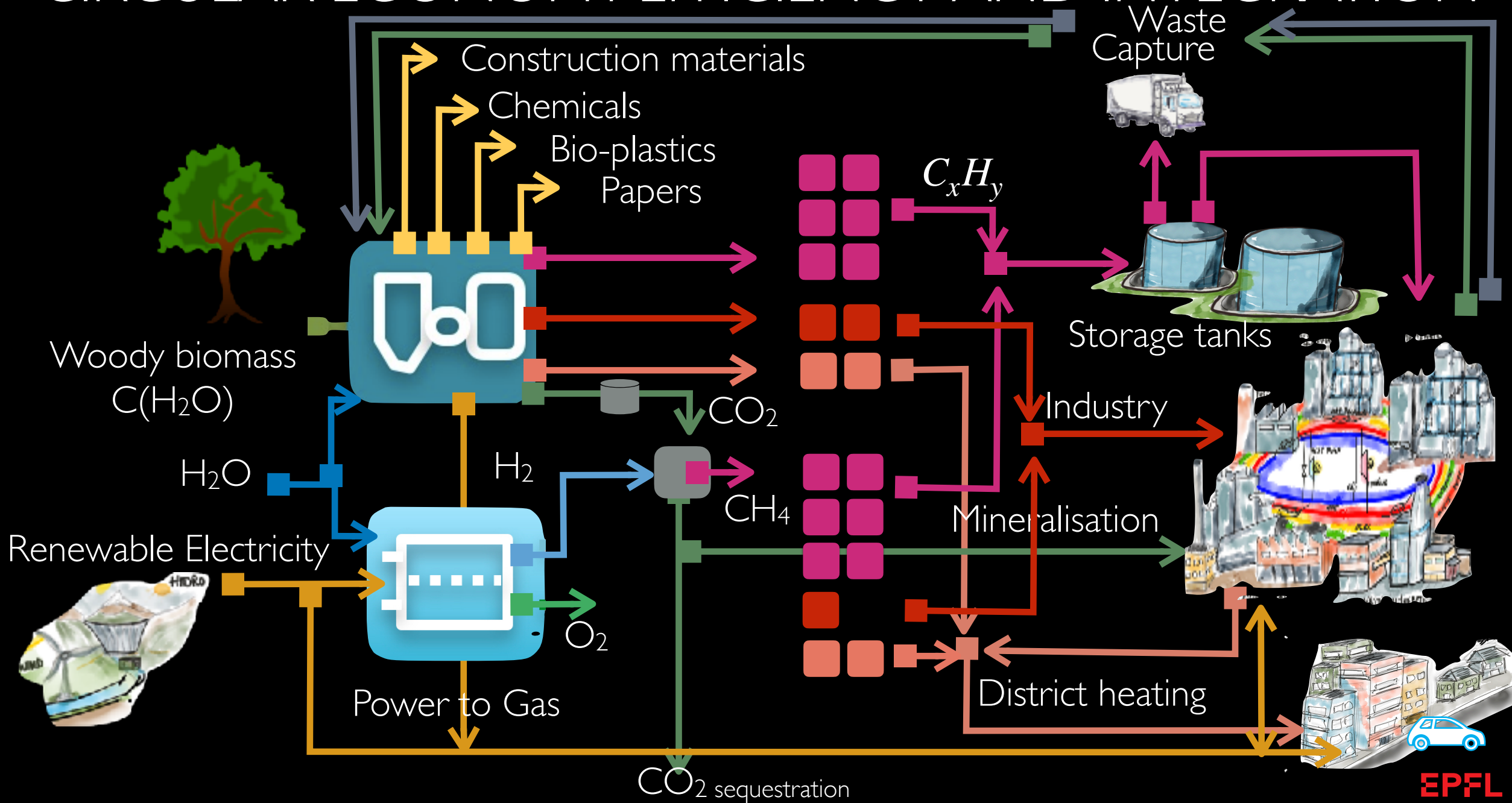
AUTONOMOUS CITIES



CARBON SINK ?



CIRCULAR ECONOMY-EFFICIENCY AND INTEGRATION



Biomass : 290 - 340 [W/cap]
Waste : 180 - 230 [W/cap]

Industry Elec: 110 - 140 [W/cap]
Industry heat: 210 - 250 [W/cap]

Building Elec: 270 - 320 [W/cap]
Building heat : 630 - 740 [W/cap]

HP : 460 - 680 [W/cap] (21 - 34 %)
DHN : 340 - 460 [W/cap] (48 - 72 %)
Other : 110 - 170 [W/cap] (19 - 33 %)

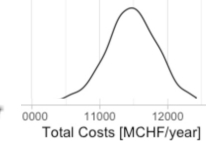
Chemical storage
Liquid fuel : 15 - 88 [W/cap]
CH₄ : 140 - 170 [W/cap]

TRANSPORT

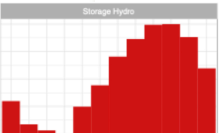
Transport Air : 240 - 290 [W/cap]
Freight : 70 - 90 [W/cap]
Public: 60 - 90 [W/cap]
Private: 100 - 140 [W/cap]

Investment

Technologies : 1000 - 2000 [CHF/y/cap]
Infrastructure : 1350-1600 [CHF/y/cap]



PV : 230 - 1800 [W/cap]
Wind : 20 - 80 [W/cap]
Hydro : 380 - 500 [W/cap]



CO₂ seq : 0.8-1.2 [t/y/cap]
Net CO₂ emission: -0.6 - 0 [t/y/cap]

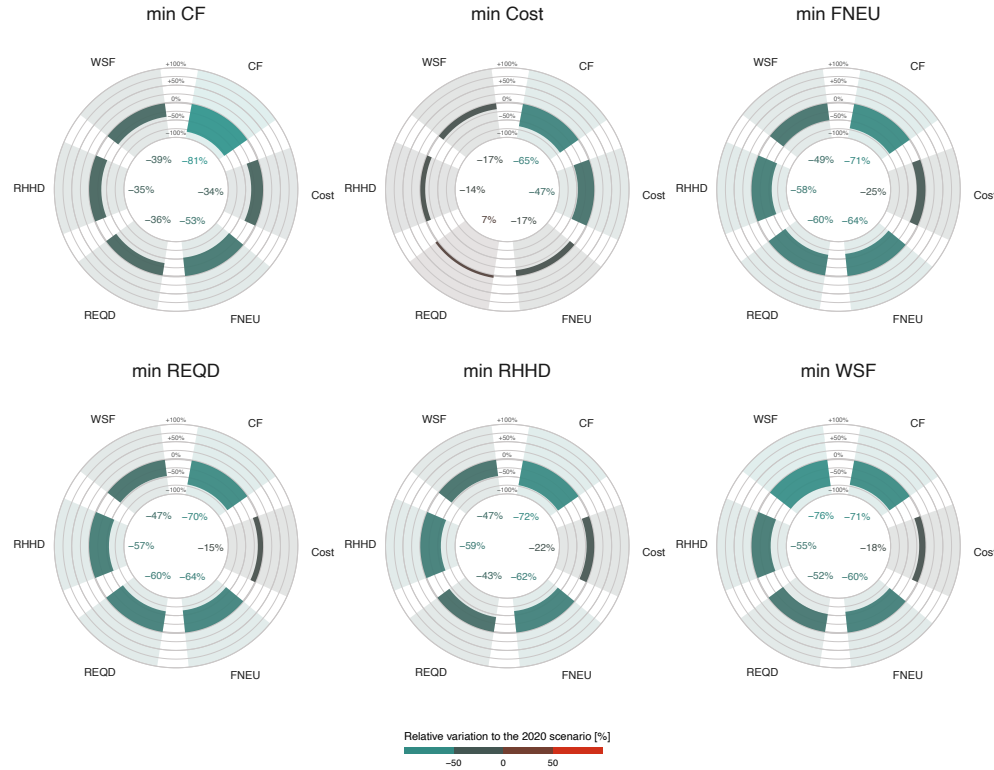


Figure 3: OF values comparison for SOO. Each sub-figure corresponds to an individual optimization. The height of the segments corresponds to the OF's relative variation to the 2020 reference scenarios OFs values [%].

CF: Carbon Footprint, **Cost:** Total Cost, **FNEU:** Fossil and Nuclear Energy Use, **REQD:** Remaining Ecosystem Quality Dammage, **RHHD:** Remaining Human Health Dammage, **WSF:** Water Scarcity Footprint

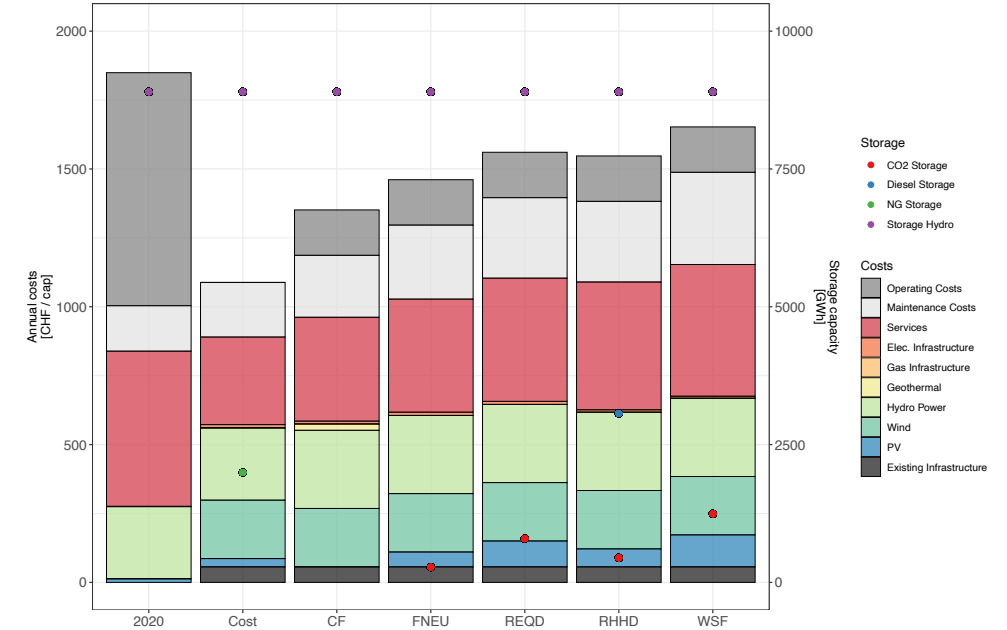


Figure 4: Overall cost composition of energy systems for single-objective optimizations. The secondary axis highlights installed storage capacity. The 2020 scenario represents the current Swiss energy system and the other six represent hypothetical scenario for an energy-independent Switzerland 2020 with single objective optimization.

- Impact is not only local emissions
- People define the needs
 - functional unit definition
- Renewable energy means harvesting
 - Impact is associated to investment => construction and End of life phases
- Efficiency define the energy consumption at the systemic level
 - Investment in efficiency creates an impact
- Think system and circularity
 - Life time of the investment
 - Reuse-recycling-upcycling
 - Waste is a resource
 - Grid connected systems + Energy management
- The energy system is used to produce the investment
 - Solar panels will be created by renewables based energy mix
 - So as batteries