Green house gas emissions: What ? How much ? Who ? What for ?

Jérôme Guilet

Plan

1 - Definitions & global perspectives on GES emissions

2 – Emissions by sectors

- Energy
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Unit of global warming potential: CO_2 equivalent (CO_2eq)

Usual units : tCO_2eq = tonne of CO_2 equivalent

Sometimes (but less often), global warming potential is instead expressed as carbon equivalent: 1 tCO_2eq = 12/44 tCeq = 0.2727 tCeq



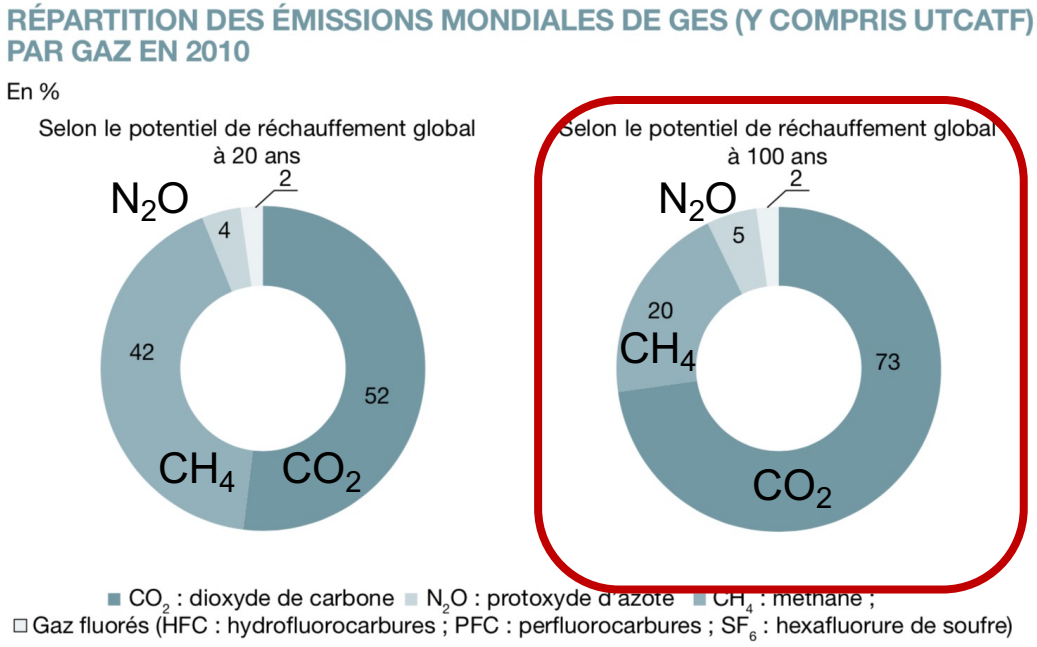
« CUBES CO_2: Visualize a Tonne of Change »
@ COP15 in Copenhaguen 2009 (designed by A. Bonanno & C. Cornubert)

Several green house gases: there is more than CO_2

Measures global warming potential over a given period (usually 100 years)

Main green house gases:

- CO_2: fossil fuel, deforestation
- Methane (CH_4) : livestock, agriculture, waste disposal, industry
- N_2O: agriculture, fertilisers, industry



https://www.statistiques.developpement-durable.gouv.fr/chiffres-cles-du-climat-france-europe-et-monde-edition-2019

GWP values and lifetimes from 2013 IPCC AR5 p714 (with climate-carbon feedbacks)[8]	Lifetime (years)	GWP	
		20 years	100 years
Methane	12.4	86	34
HFC-134a (hydrofluorocarbon)	13.4	3790	1550
CFC-11 (chlorofluorocarbon)	45.0	7020	5350
Nitrous oxide (N_2O)	121.0	268	298
Carbon tetrafluoride (CF_4)	50000	4950	7350

https://en.wikipedia.org/wiki/Global_warming_potential

Time evolution of world CO_2 emission

Technical Summary

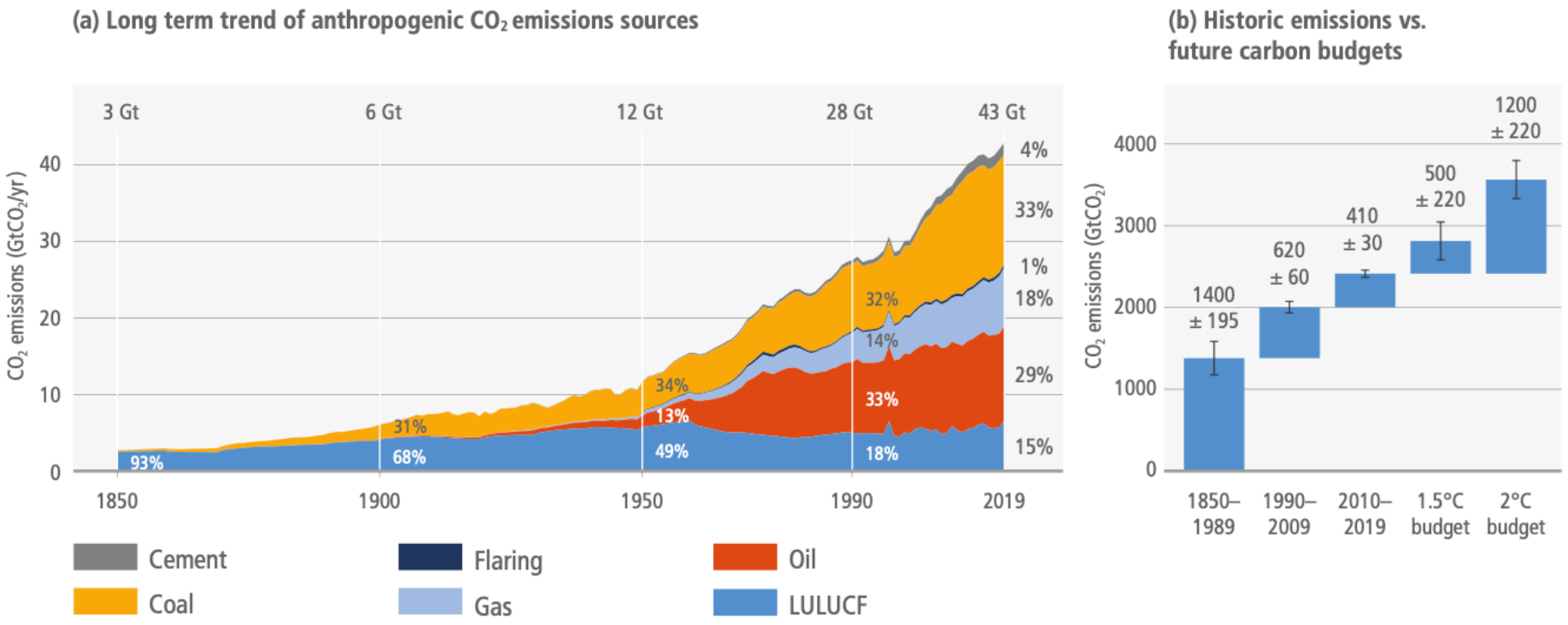
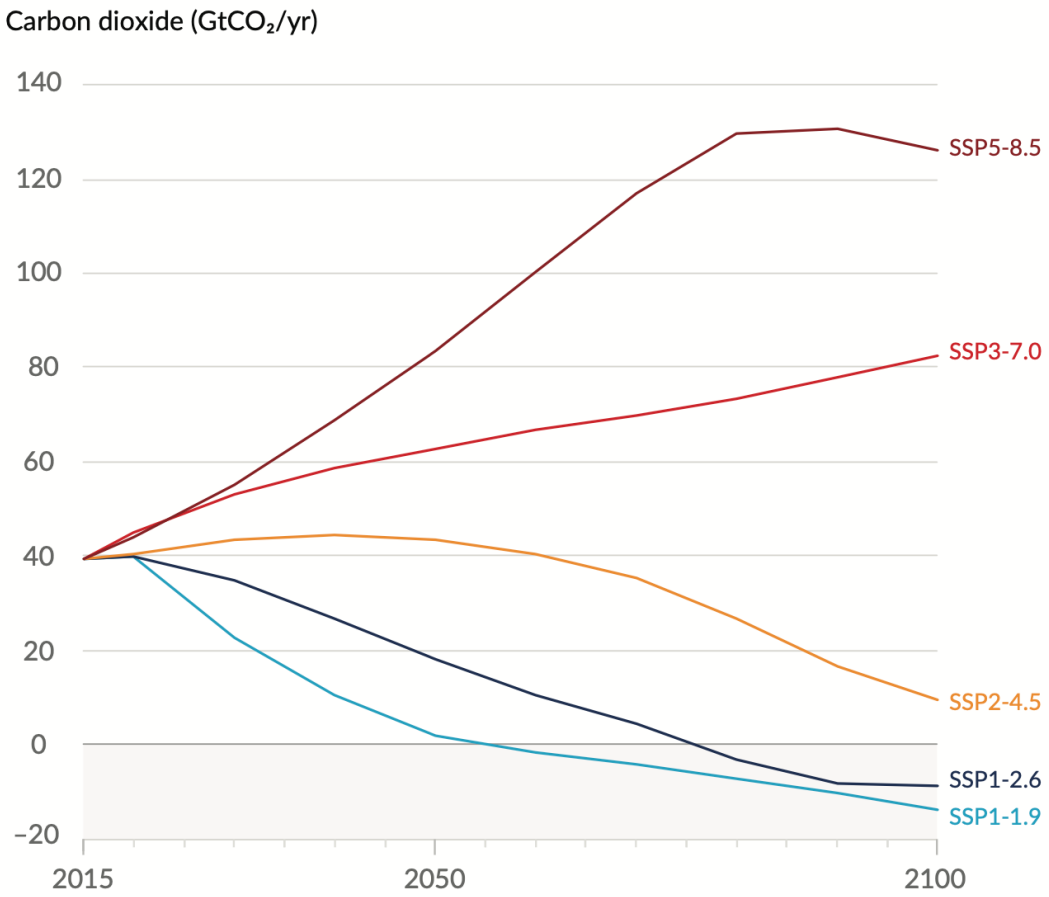
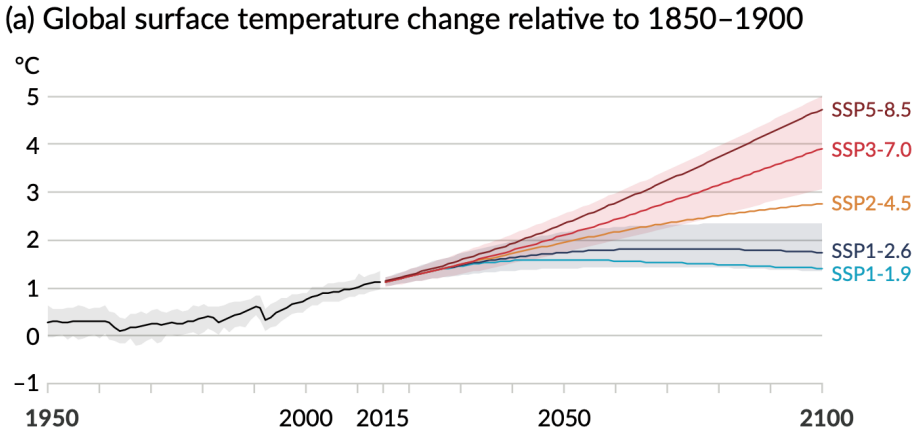


Figure TS.3 | Historic anthropogenic CO_2 emission and cumulative CO_2 emissions (1850–2019) as well as remaining carbon budgets for limiting warming to 1.5°C (>67%) and 2°C (>67%). Panel (a) shows historic annual anthropogenic CO_2 emissions ($GtCO_2$ yr^{-1}) by fuel type and process. **Panel (b)** shows historic cumulative anthropogenic CO_2 emissions for the periods 1850–1989, 1990–2009, and 2010–2019 as well as remaining future carbon budgets as of 1 January 2020 to limit warming to 1.5°C and 2°C at the 67th percentile of the transient climate response to cumulative CO_2 emissions. The whiskers indicate a budget uncertainty of ±220 $GtCO_2$-eq for each budget and the aggregate uncertainty range at one standard deviation for historical cumulative CO_2 emissions, consistent with WGI. {Figure 2.7}

IPCC AR6 WGIII FullReport, P.62

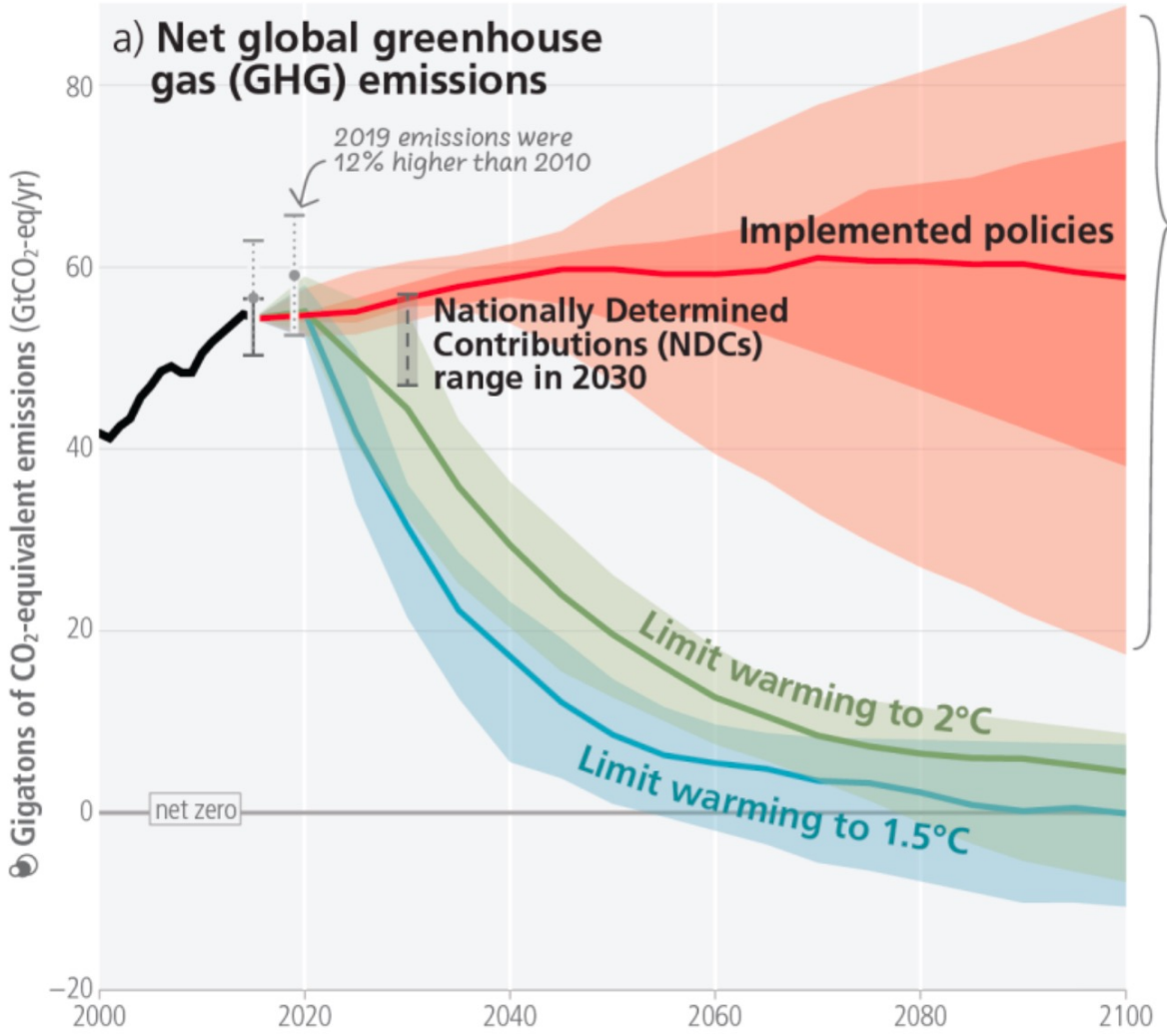
Different scenarios of future emissions





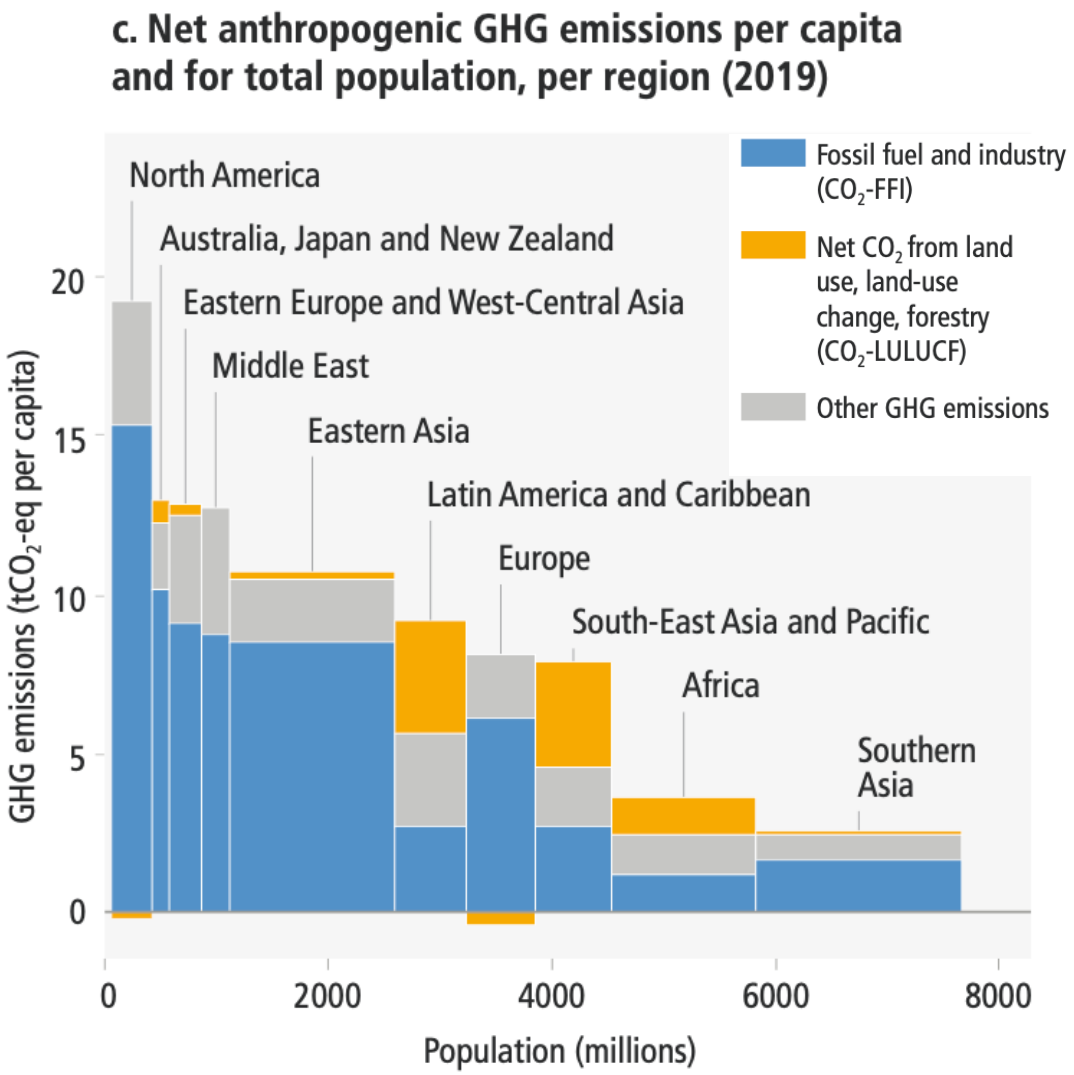
IPCC 2021 AR6

Which emission curve for the future ?



GIEC 2021, AR6

Per capita emissions



Typical numbers :

World average: 7.5 tCO_{2eq}

US : 20 tCO_{2eq}

France : 6.5 tCO_{2e}

China: 11 tCO_{2e}

1.5° goal (world average) :

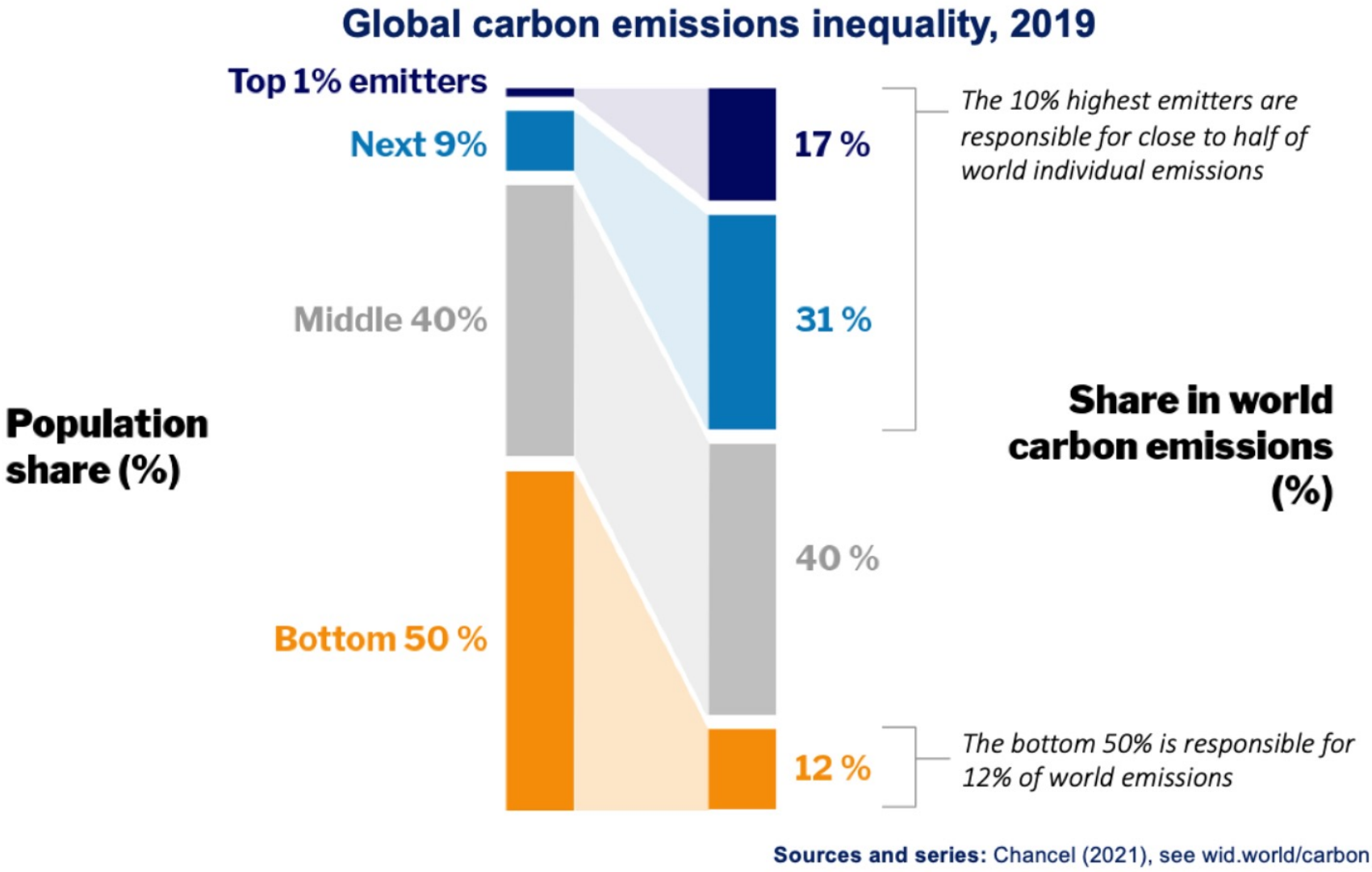
2030 : 4 tCO_{2eq}

2050 : 2 tCO_{2eq}

But beware of importations ! (see later)

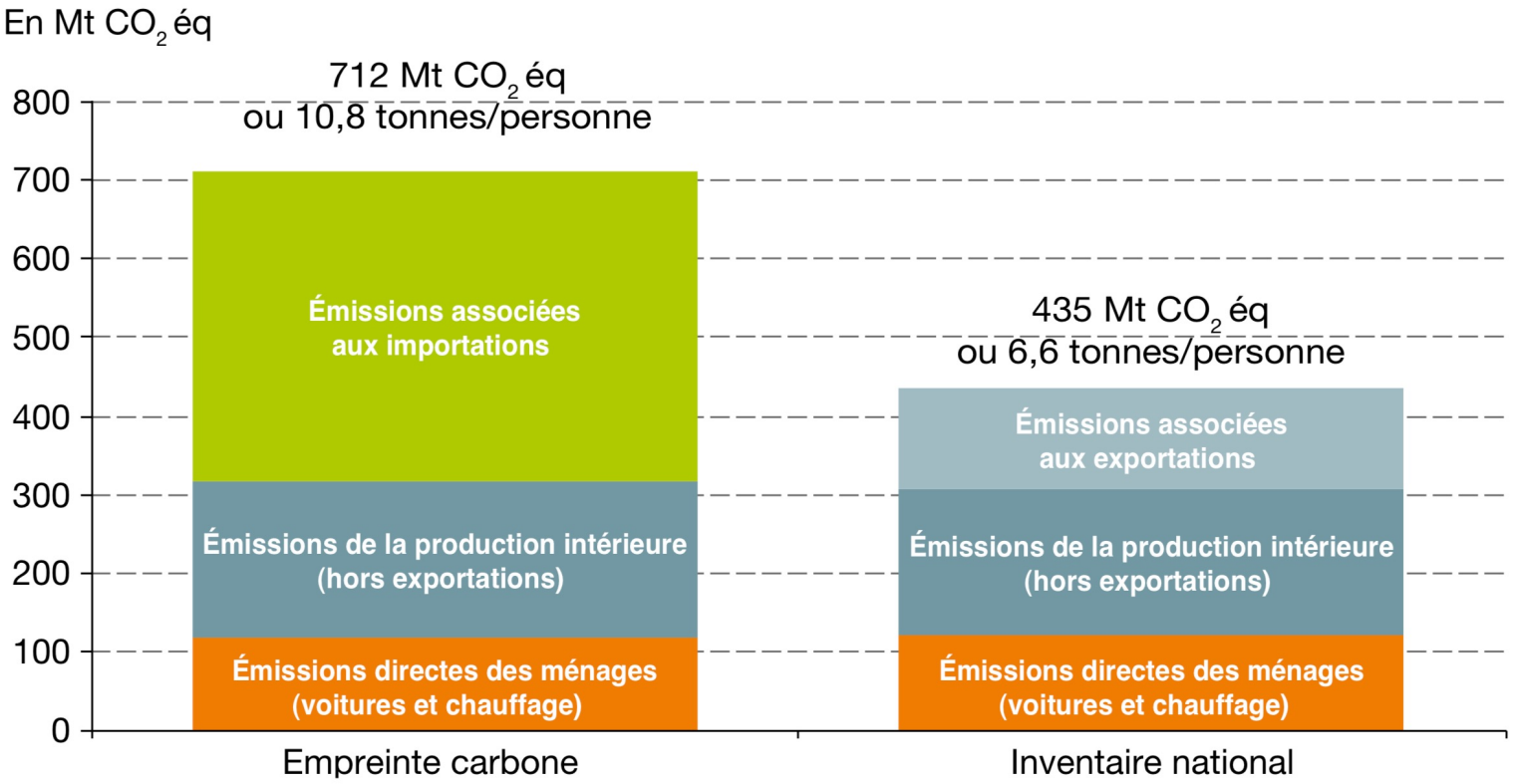
IPCC AR6 WGIII FullReport, P.10

Carbon emissions are unevenly distributed



Including or excluding import/export

COMPARAISON DE L'EMPREINTE CARBONE ET DE L'INVENTAIRE NATIONAL EN 2014



Note : l'empreinte et l'inventaire portent sur les trois principaux gaz à effet de serre (CO_2, CH_4, N_2O).
***Sources :** Citepa ; AIE ; FAO ; Douanes ; Eurostat ; Insee. Traitements : SDES, 2018*

https://www.statistiques.developpement-durable.gouv.fr/sites/default/files/2018-12/datalab-46-chiffres-cles-du-climat-edition-2019-novembre2018_1.pdf

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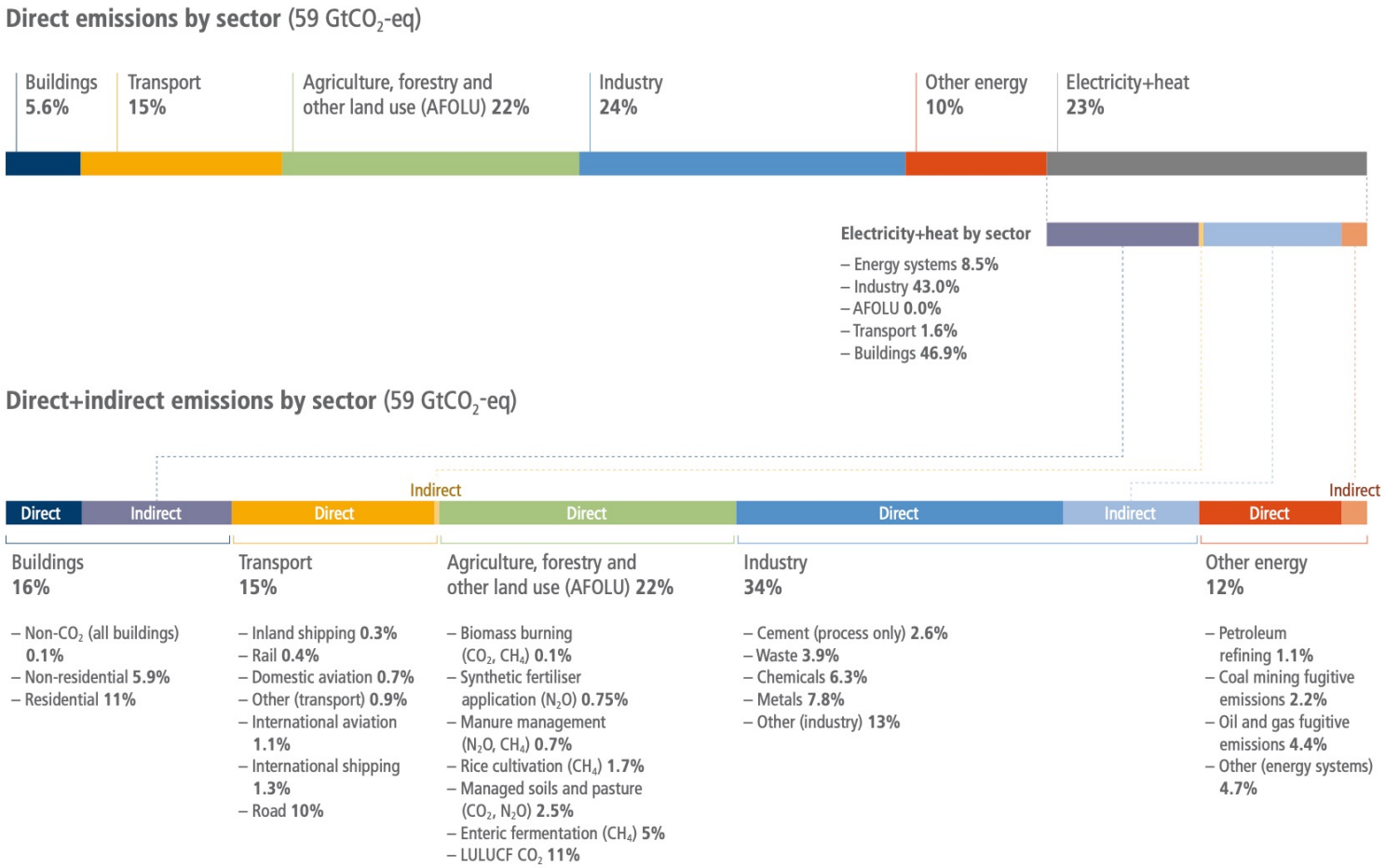
GES emission by sector: the producer point of view



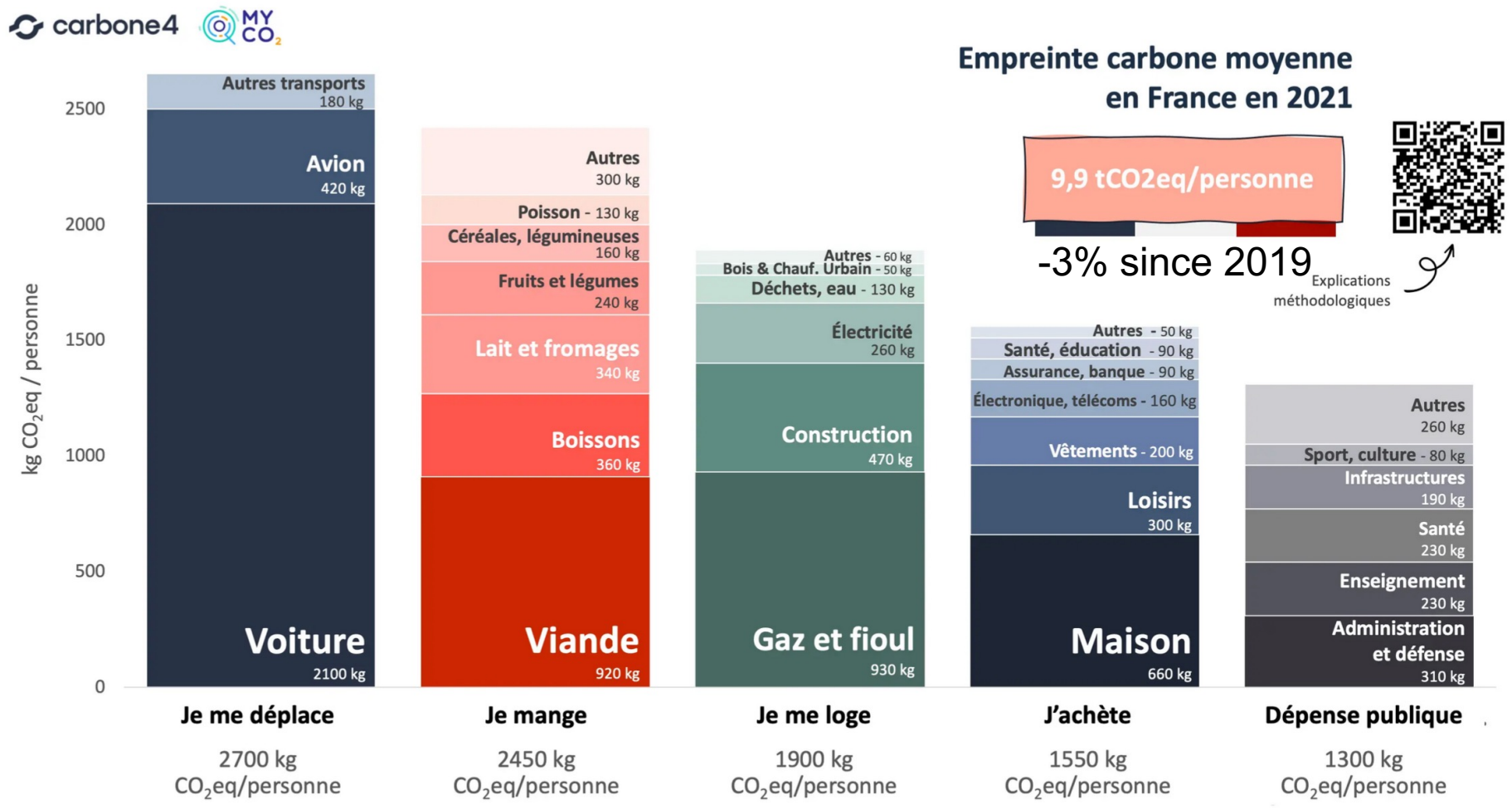
Scope 1 (only direct emission)

Scope 2 (direct emission + indirect from energy use)

Figure TS.6 | Total anthropogenic direct and indirect GHG emissions for the year 2019 (in $GtCO_2$-eq) by sector and subsector. Direct emissions estimates assign emissions to the sector in which they arise (scope 1 reporting). Indirect emissions – as used here – refer to the reallocation of emissions from electricity and heat to the sector of final use (scope 2 reporting). Note that cement refers to process emissions only, as a lack of data prevents the full reallocation of indirect emissions to this sector. More comprehensive conceptualisations of indirect emissions including all products and services (scope 3 reporting) are discussed in Section 2.3. Emissions are converted into CO_2-equivalents based on global warming potentials with a 100-year time horizon (GWP100) from the IPCC Sixth Assessment Report. Percentages may not add up to 100 across categories due to rounding at the second significant digit. {Figure 2.12, 2.3}

Source : IPCC AR6 WGIII FullReport

Footprint by sector: the consumer point of view (scope 3)



Gaz inclus : CO2 (hors UTCATF France), CH4, N2O, HFC, SF6, PFC, H_2O (traînées de condensation).
Source : MyCO2 par Carbone 4 d'après le ministère de la Transition écologique, le Haut Conseil pour le Climat, le CITEPA, Agribalyse V3 et INCA 3.

Transport, food, housing & industry contribute to roughly 1/5 to 1/4 each

=> one should act on all four aspects

https://www.carbone4.com/analyse-myco2-empreinte-carbone-moyenne-2021

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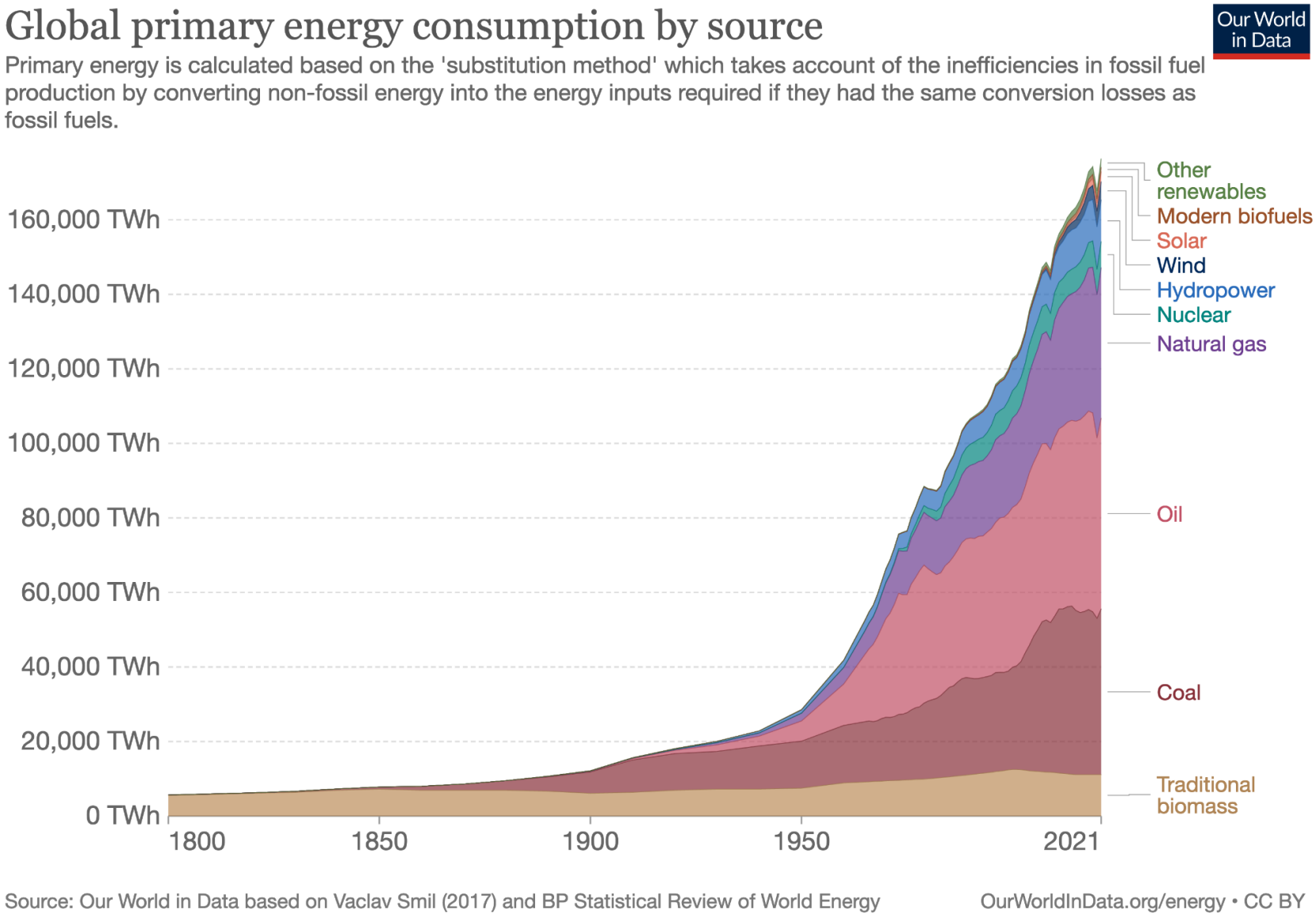
Energy consumption in time



Energy sources and use

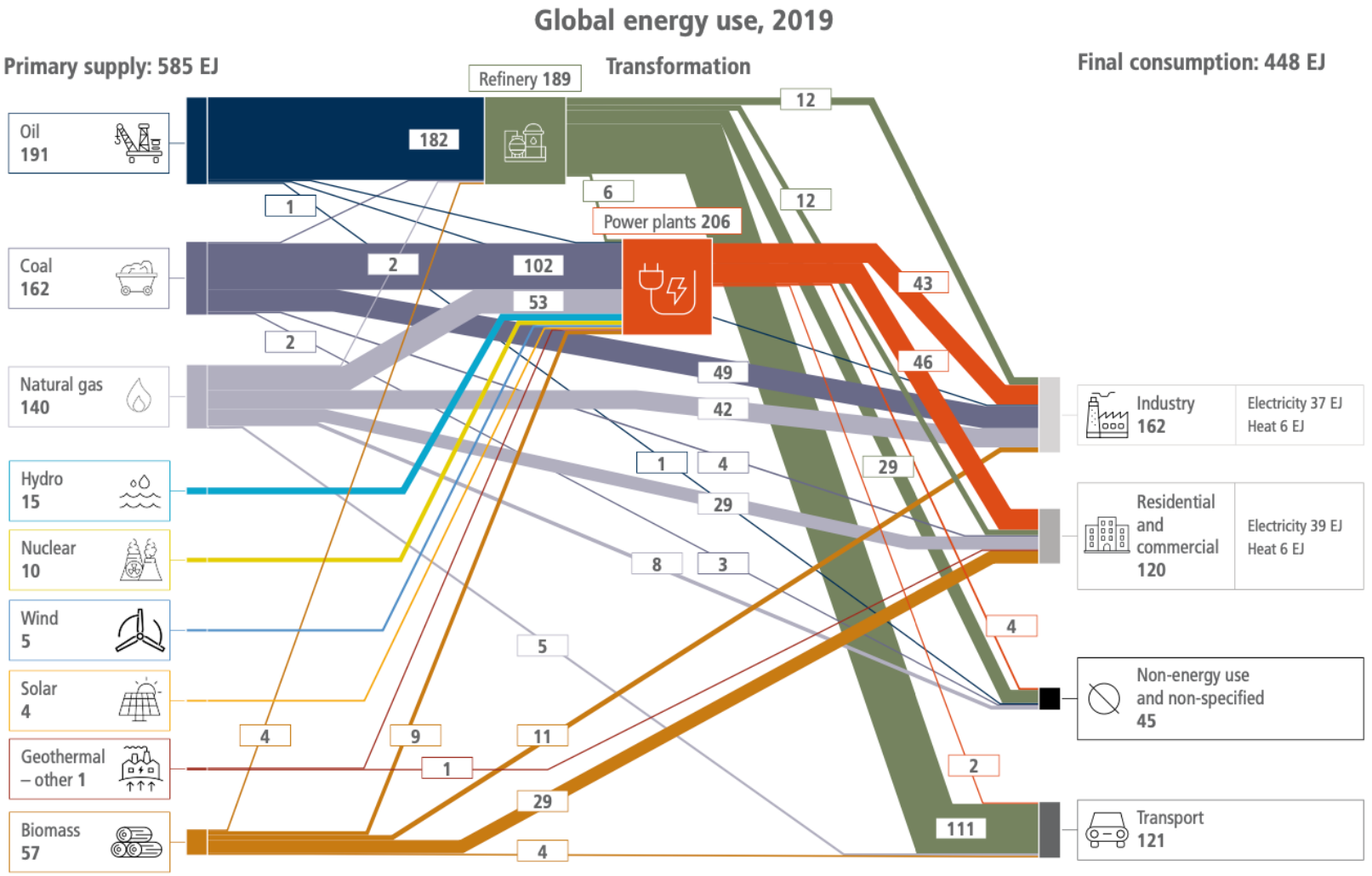
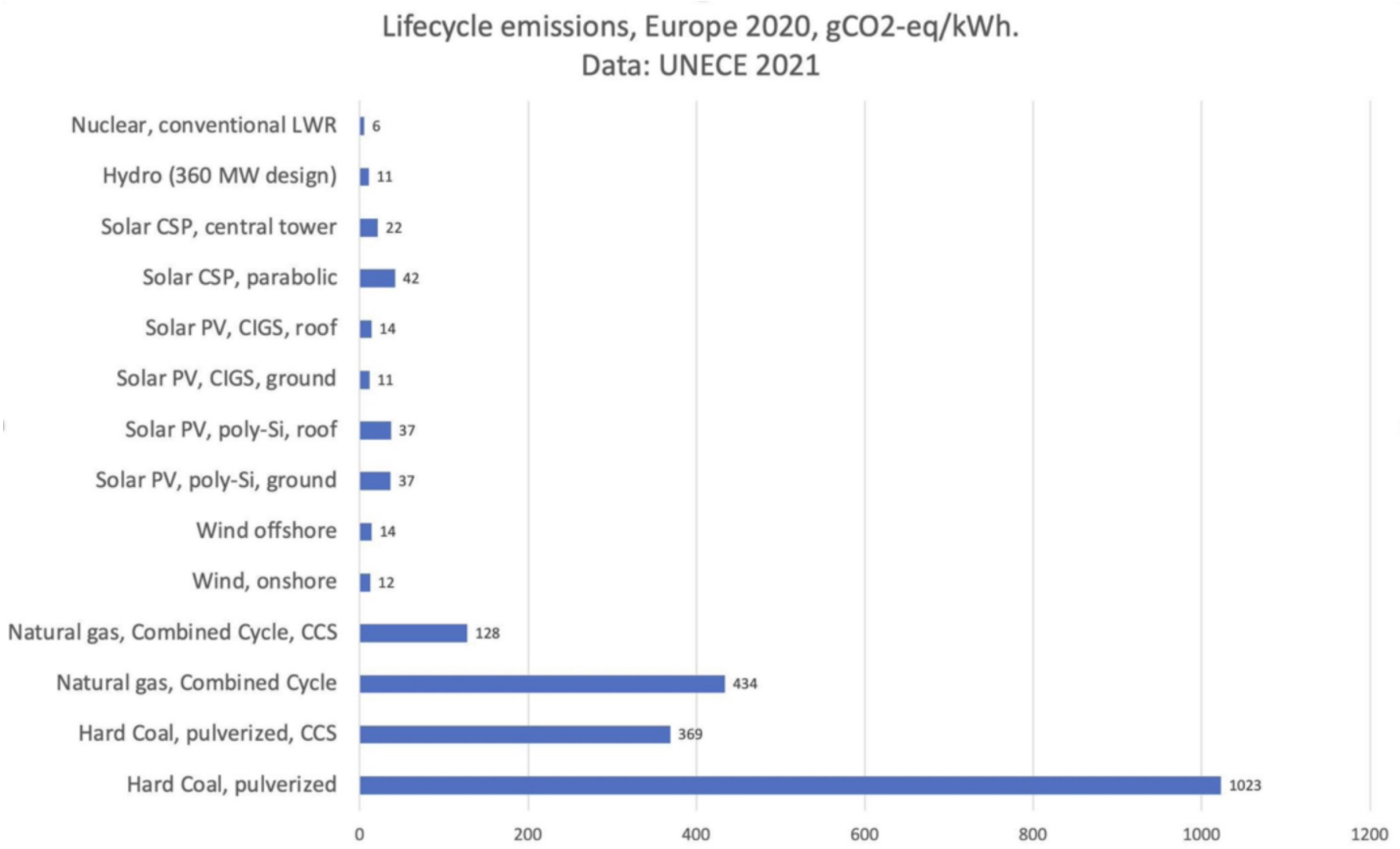


Figure TS.11 | Global energy flows within the 2019 global energy system (top panel) and within two illustrative future, net-zero CO_2 emissions global energy system (bottom panels).

Source : IPCC AR6 WGIII FullReport

GES emission by type of energy



Source : UNECE 2020

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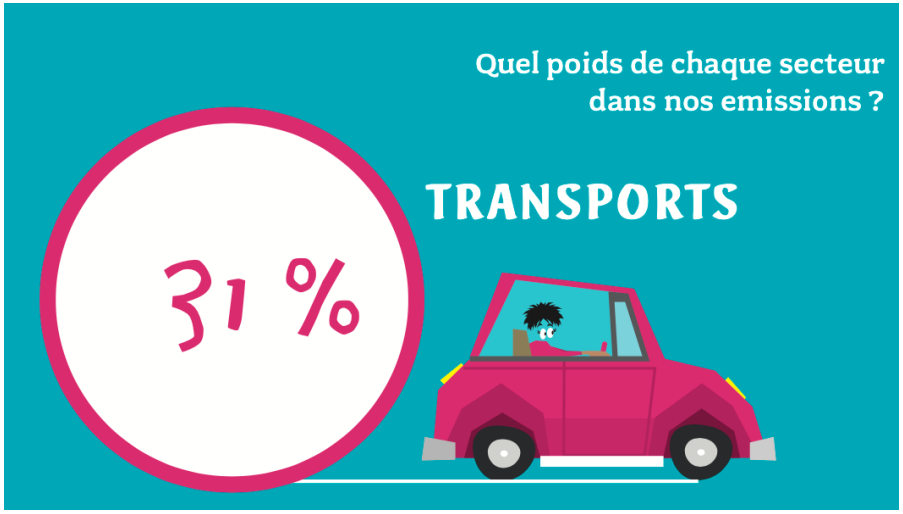
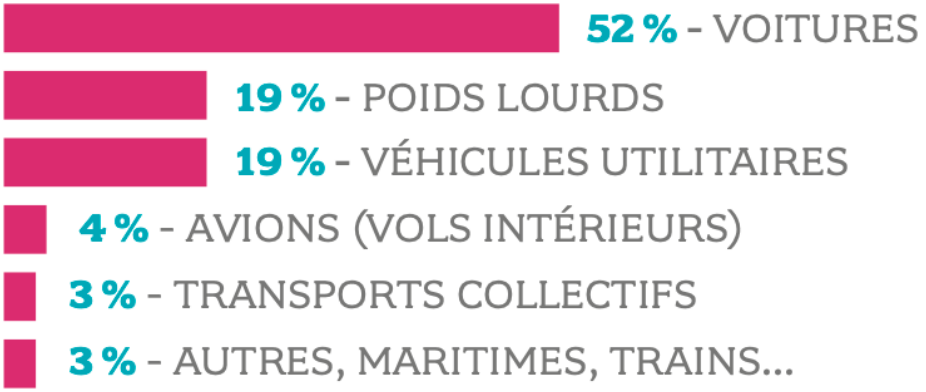
Footprint of different transport methods (France)





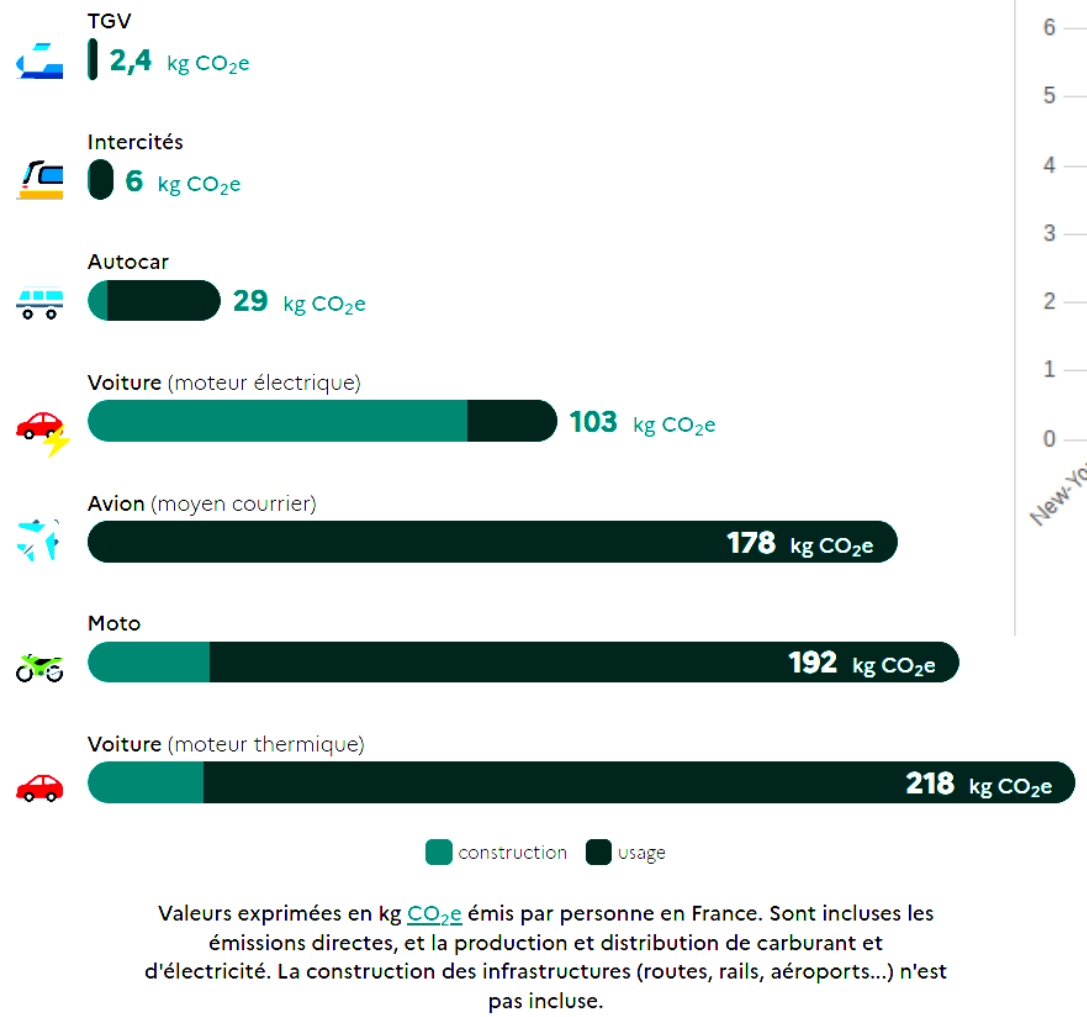
NB: this national inventory excludes international flights

Source : Haut conseil pour le climat, 2019

$gCO_2eq/km/pers$ of different transport methods

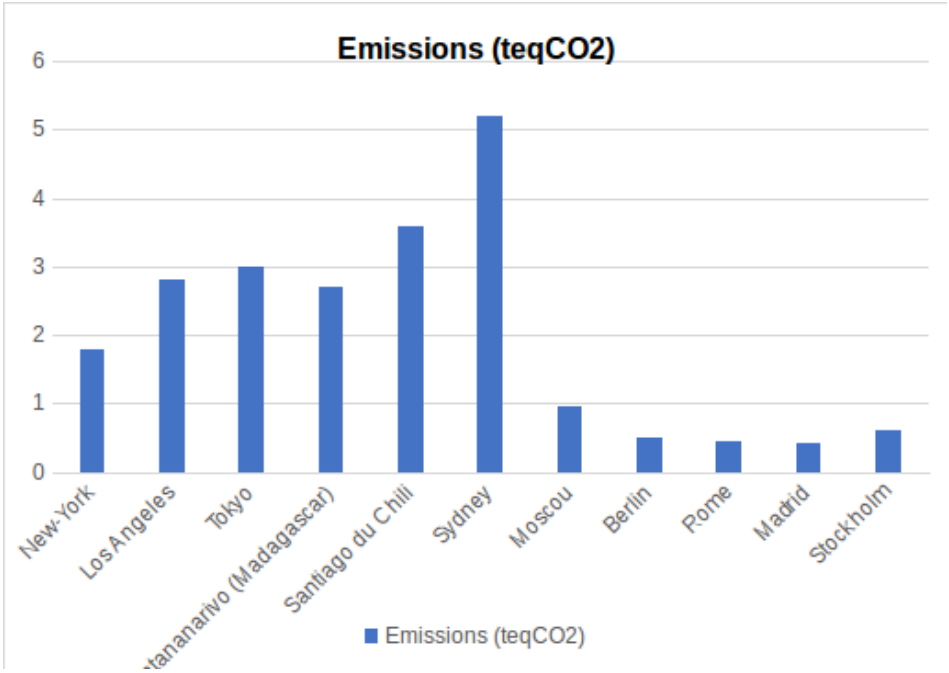
Valeurs ADEME pour 1000 km

https://datagir.ademe.fr/apps/mon-impact-transport/



Valeurs exprimées en kg CO_2e émis par personne en France. Sont incluses les émissions directes, et la production et distribution de carburant et d'électricité. La construction des infrastructures (routes, rails, aéroports...) n'est pas incluse.

Flights from Paris (return, with contrails, GES 1point5)



http://bilans-ges.ademe.fr/fr/basecarbone/donnees-consulter/

http://www.esu-services.ch/fileadmin/download/jungbluth-2018-IntJLCA-GWP-aviation-recommendations.pdf

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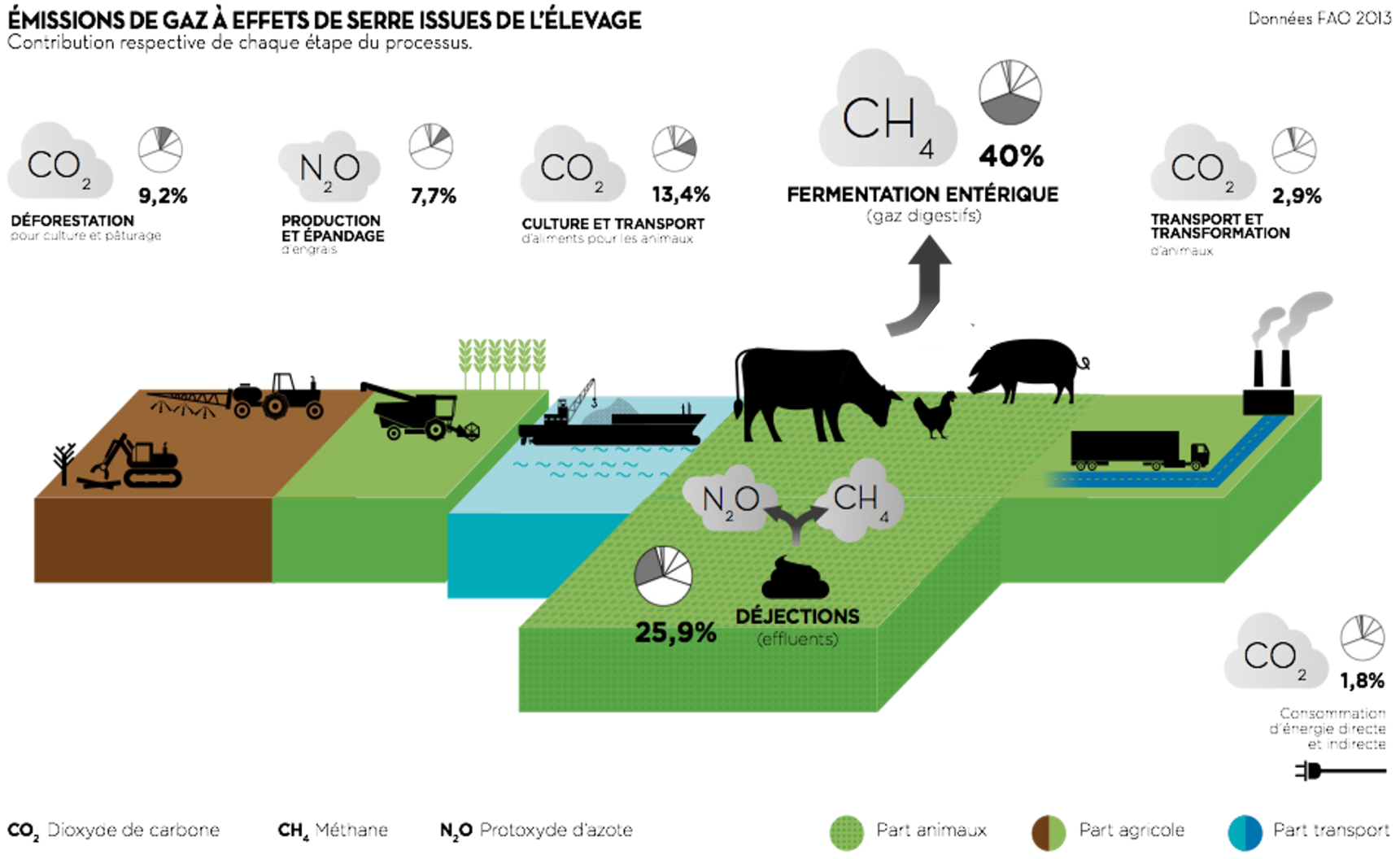
Agriculture GES emissions



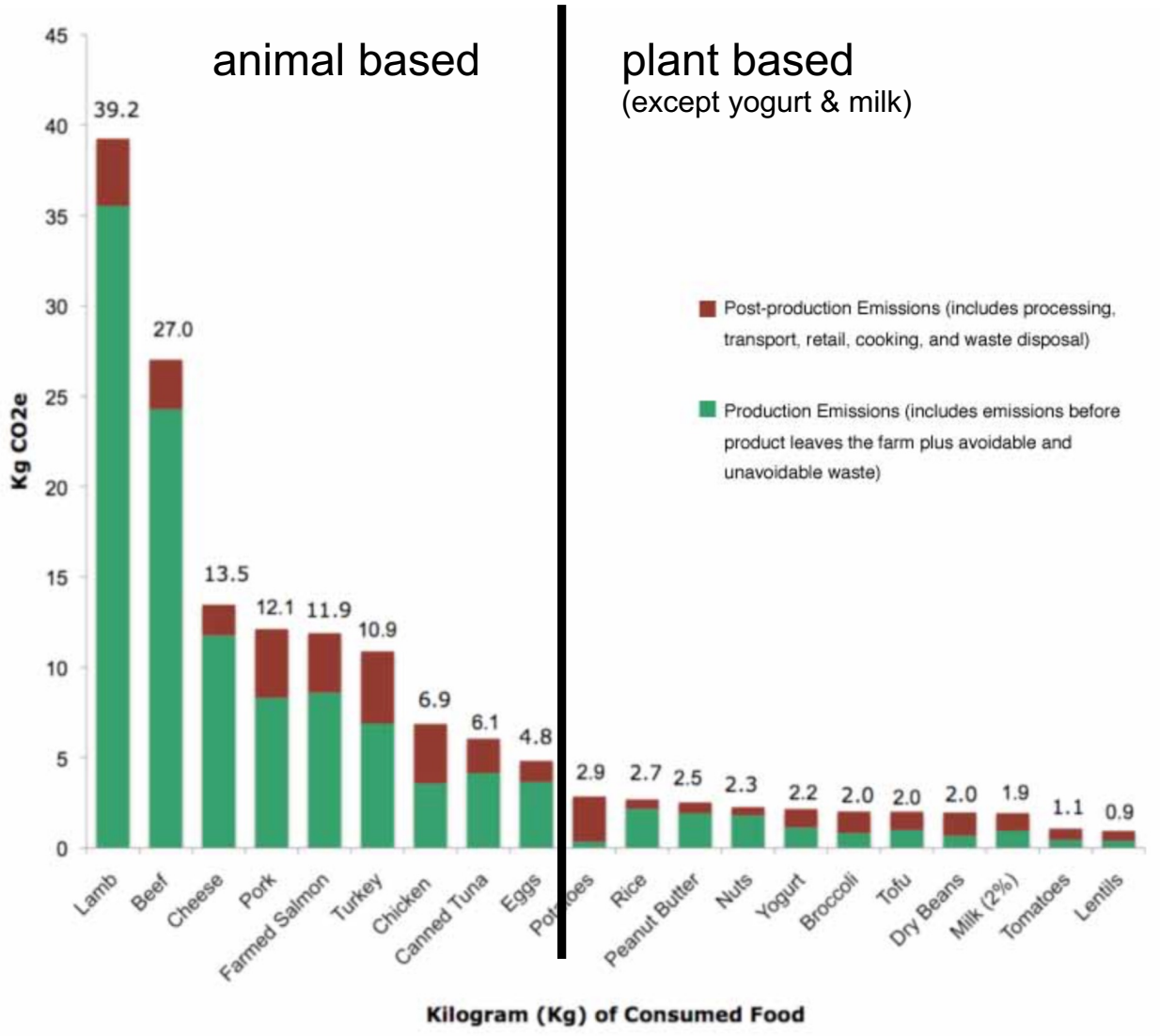
AVF, données FAO, 2013

CO_2eq footprint of different food: the good, the bad & the ugly

The good: 0-4 kgCO_2eq/kg
Plant-based (vegan)

The bad: 5-15 kgCO_2eq/kg
Meat, cheese, fish, egg

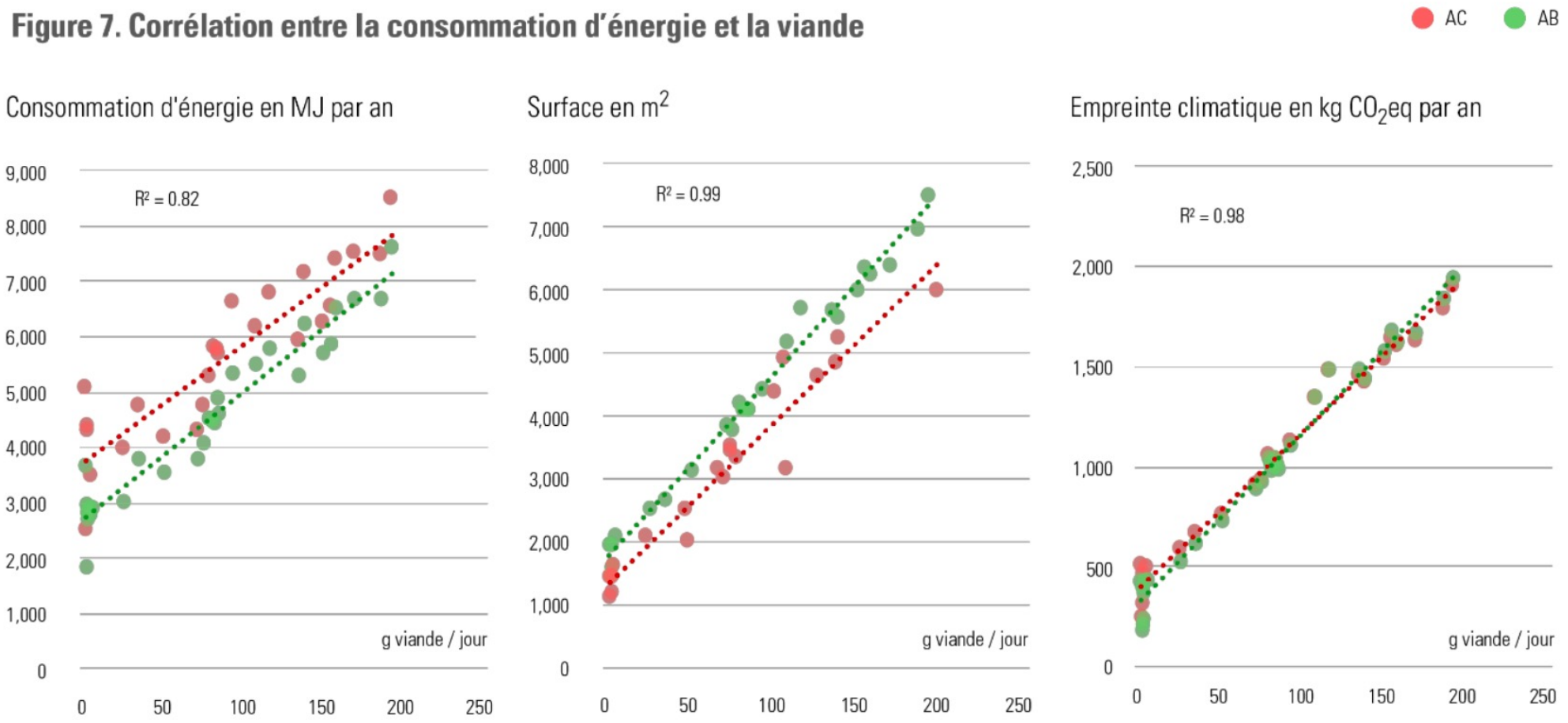
The ugly: 25-40 kgCO_2eq/kg
Lamb, beef



Source: http://static.ewg.org/reports/2011/meateaters/pdf/methodology_ewg_meat_eaters_guide_to_health_and_climate_2011.pdf

Food footprint depending on the diet

Figure 7. Corrélation entre la consommation d'énergie et la viande



Source: ADEME, Empreinte sol énergie et carbone de l'alimentation 2022

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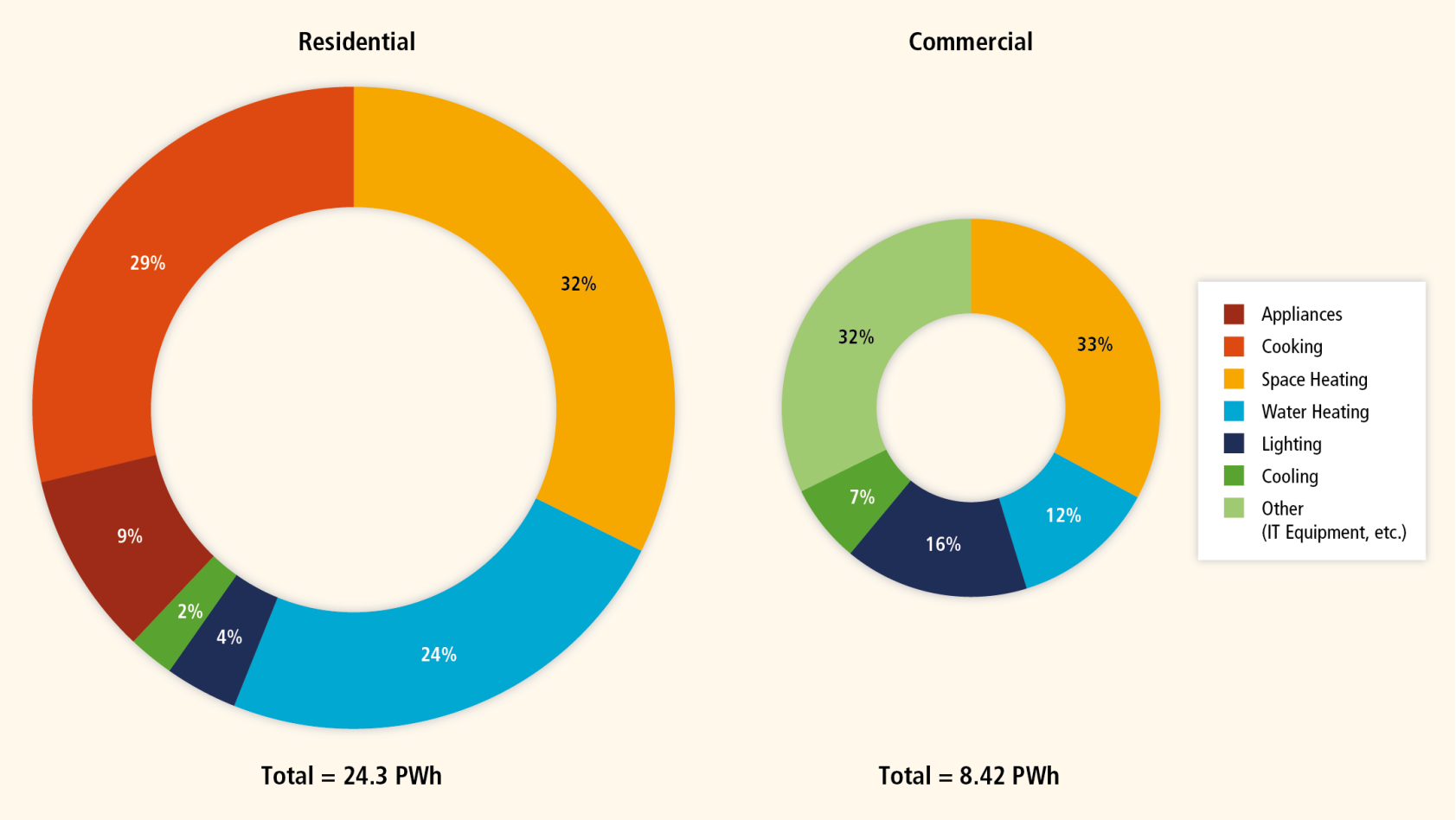
Buildings energy use in the world (/year)



3 500 kWh/pers

1.4 tCO_2eq

1 200 kWh/pers

0.5 tCO_2eq (assuming kWh=0.4 $kgCO_2eq$)

Source: IPCC 2014 report

Building heating energy use

$$\text{power used} = \frac{\text{average temperature difference} \times \text{leakiness of building}}{\text{efficiency of heating system}}$$

** Room temperature : 22° - 18°
average delta T : 10.7° - 7.2°

** Leakiness:
old house: 3-4 W/m²/K
new house: 1-1.5 W/m²/K
passive house: 0.5 W/m²/K

** Efficiency:
Electrical device: 1
Heat pump: 3 - 4

	U-values (W/m²/K)		
	old buildings	modern standards	best methods
Walls		0.45–0.6	0.12
solid masonry wall	2.4		
outer wall: 9 inch solid brick	2.2		
11 in brick-block cavity wall, unfilled	1.0		
11 in brick-block cavity wall, insulated	0.6		
Floors		0.45	0.14
suspended timber floor	0.7		
solid concrete floor	0.8		
Roofs		0.25	0.12
flat roof with 25 mm insulation	0.9		
pitched roof with 100mm insulation	0.3		
Windows			1.5
single-glazed	5.0		
double-glazed	2.9		
double-glazed, 20 mm gap	1.7		
triple-glazed	0.7–0.9		

Source: « sustainable energy without the hot air » by David MacKay

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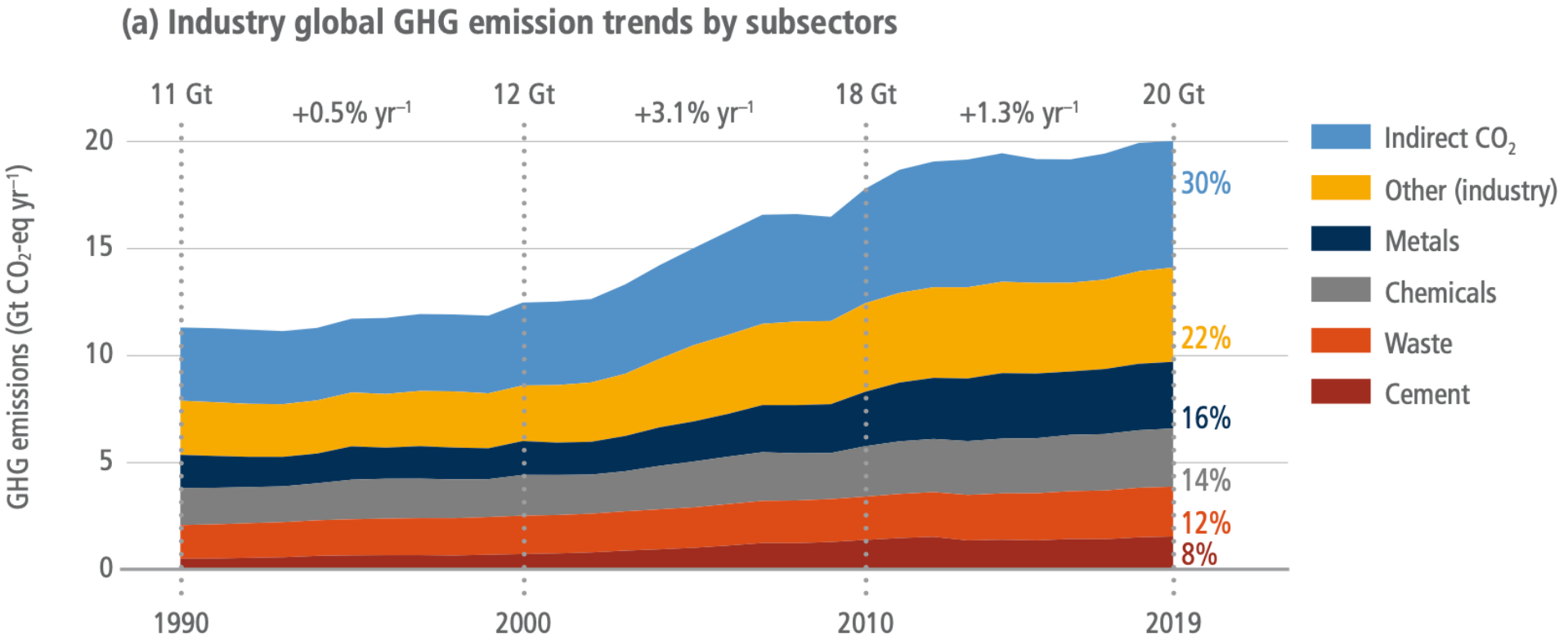
Emission by industrial subsectors



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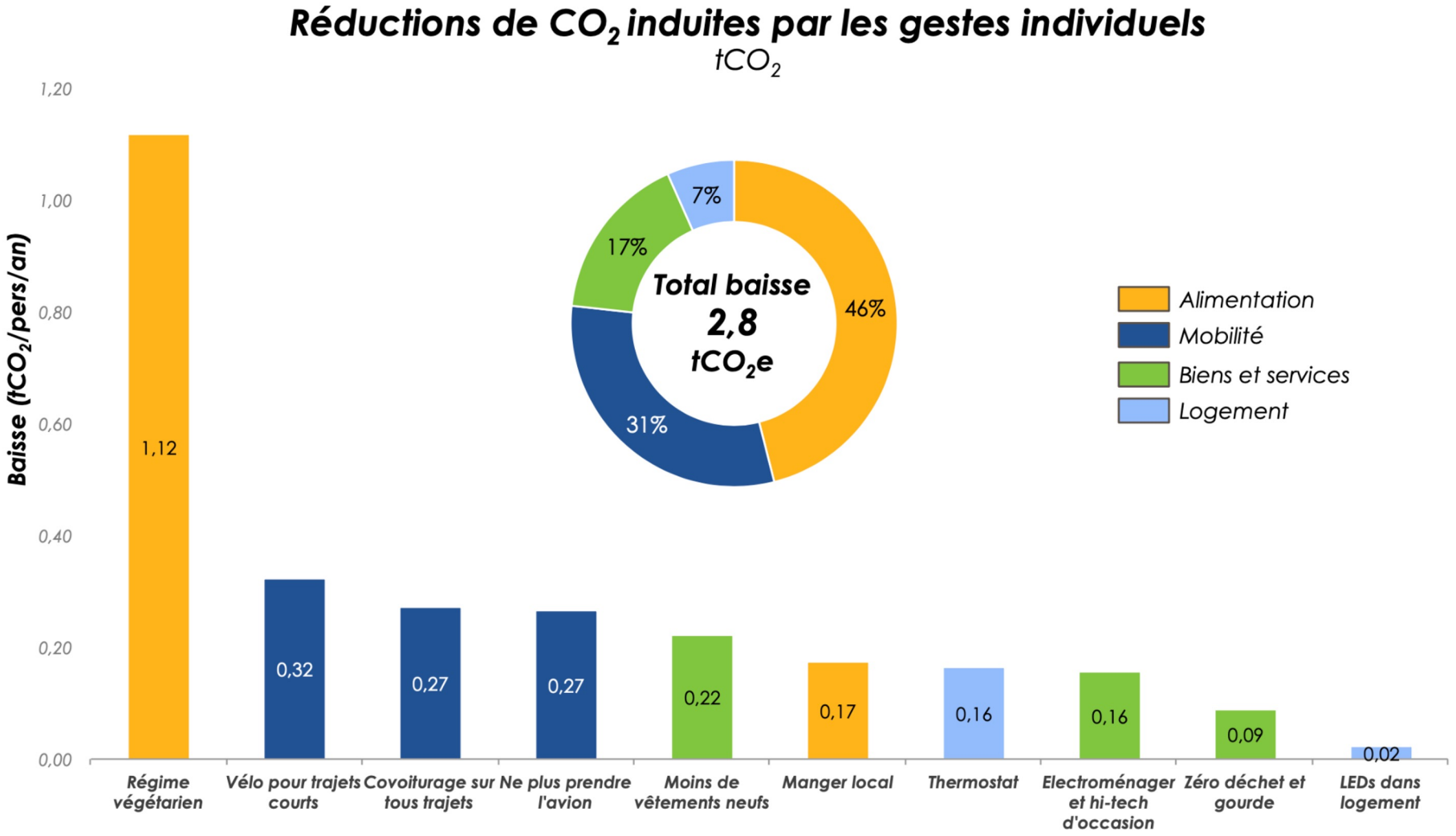
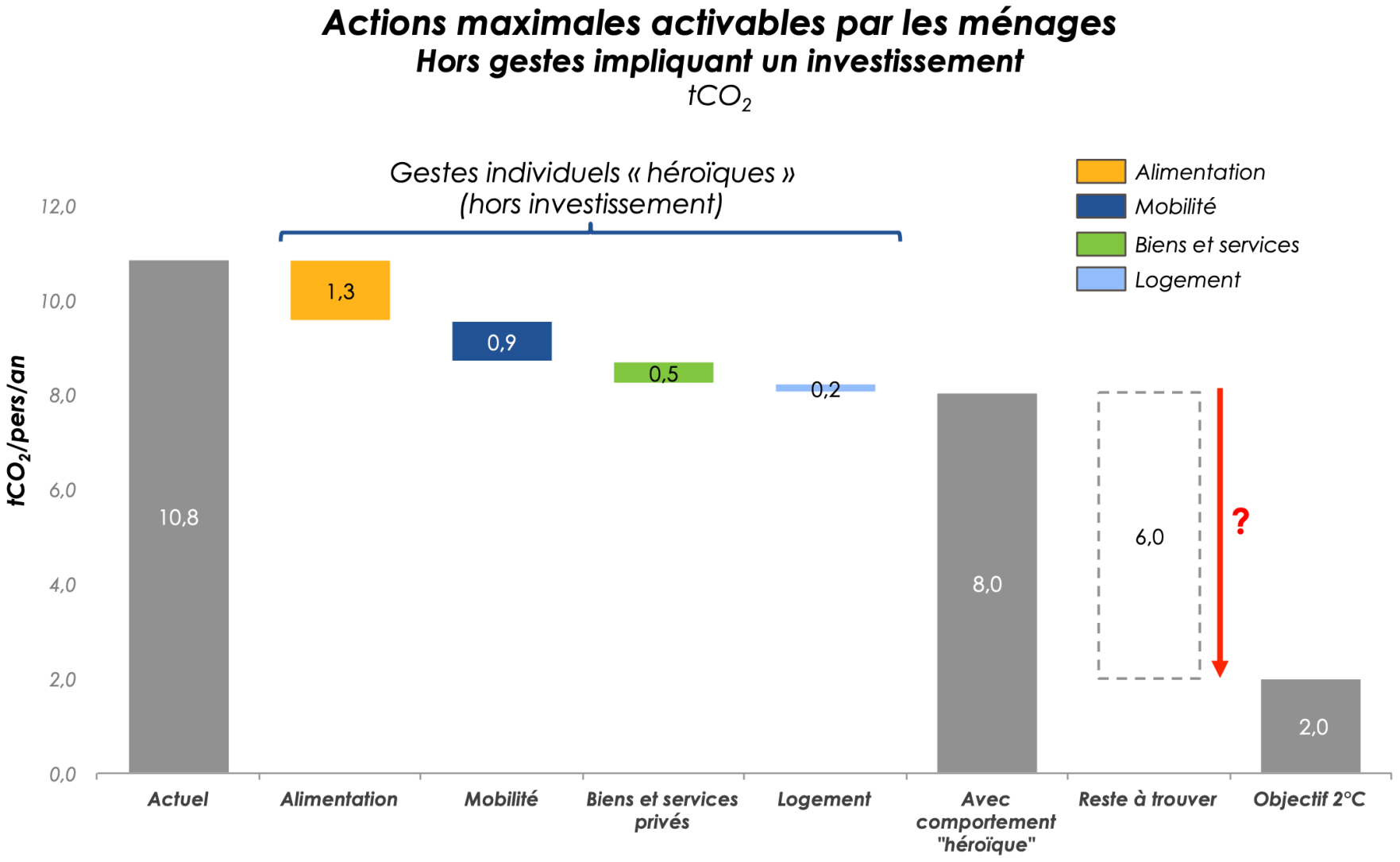
Reducing emissions on an individual scale ?



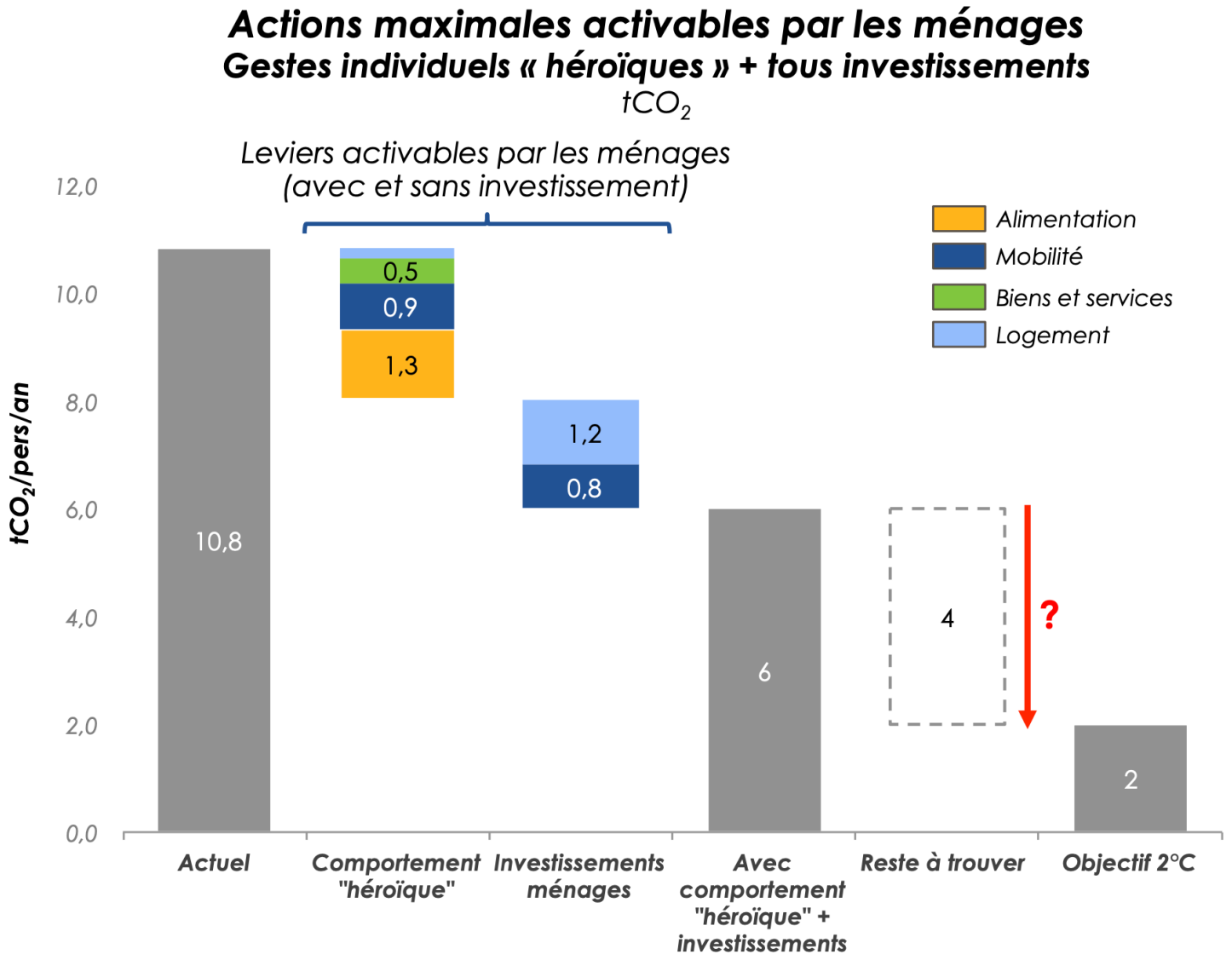
Source : Carbone 4, 2019

Reducing emissions individual or collective responsibility ?



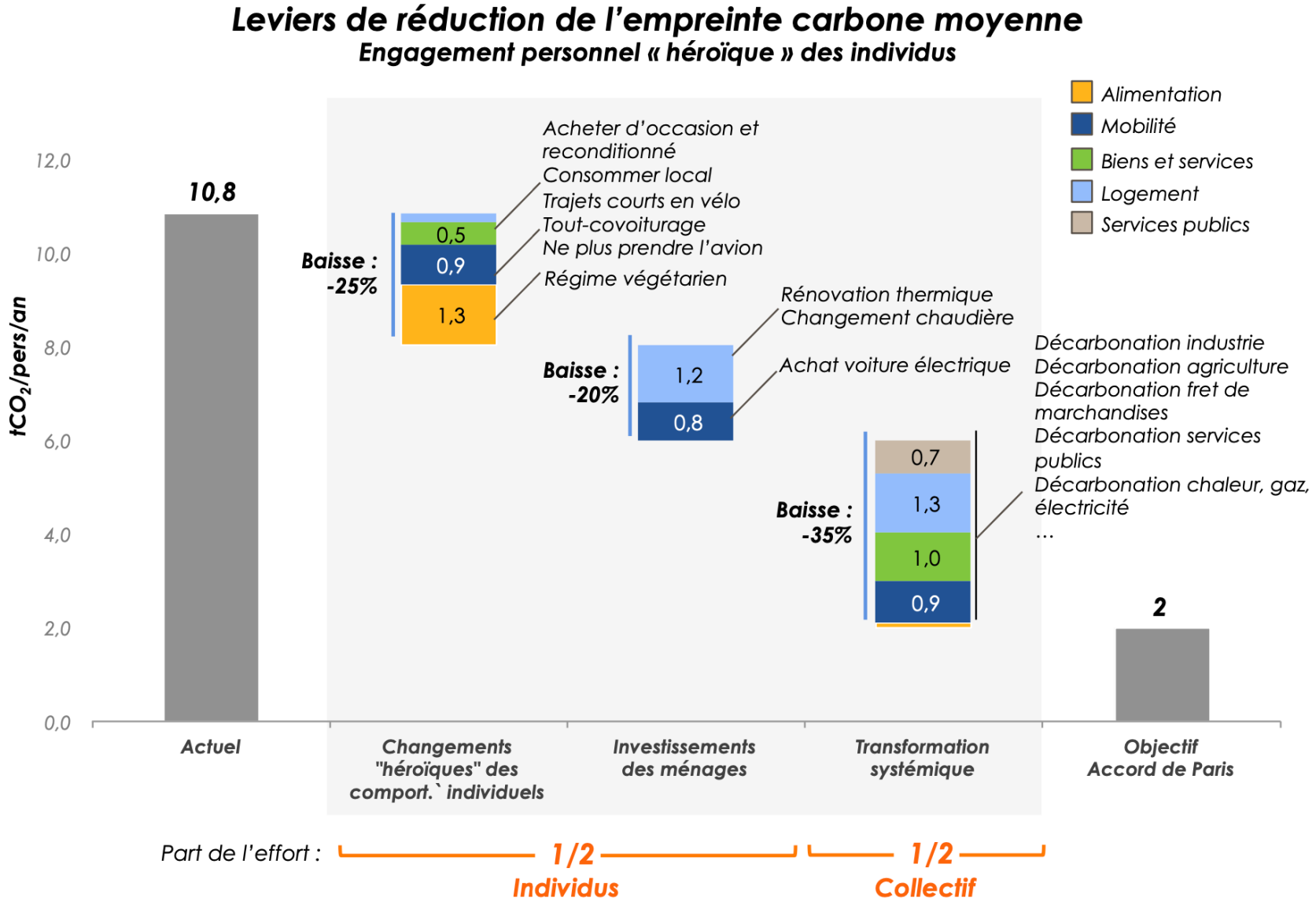
Source : Carbone 4, 2019

Reducing emissions individual or collective responsibility ?



Source : Carbone 4, 2019

Reducing emissions individual or collective responsibility ?



Source : Carbone 4, 2019

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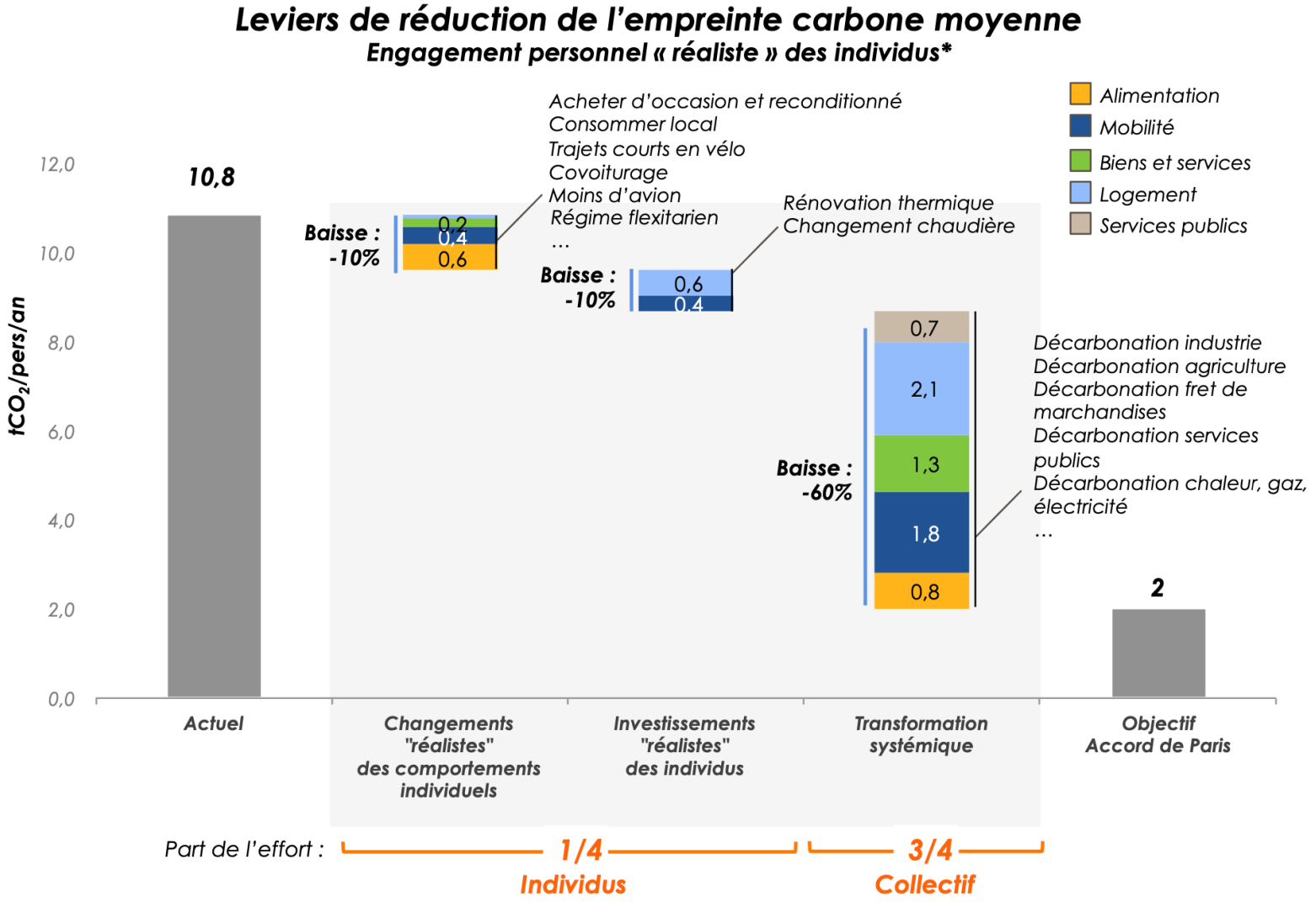
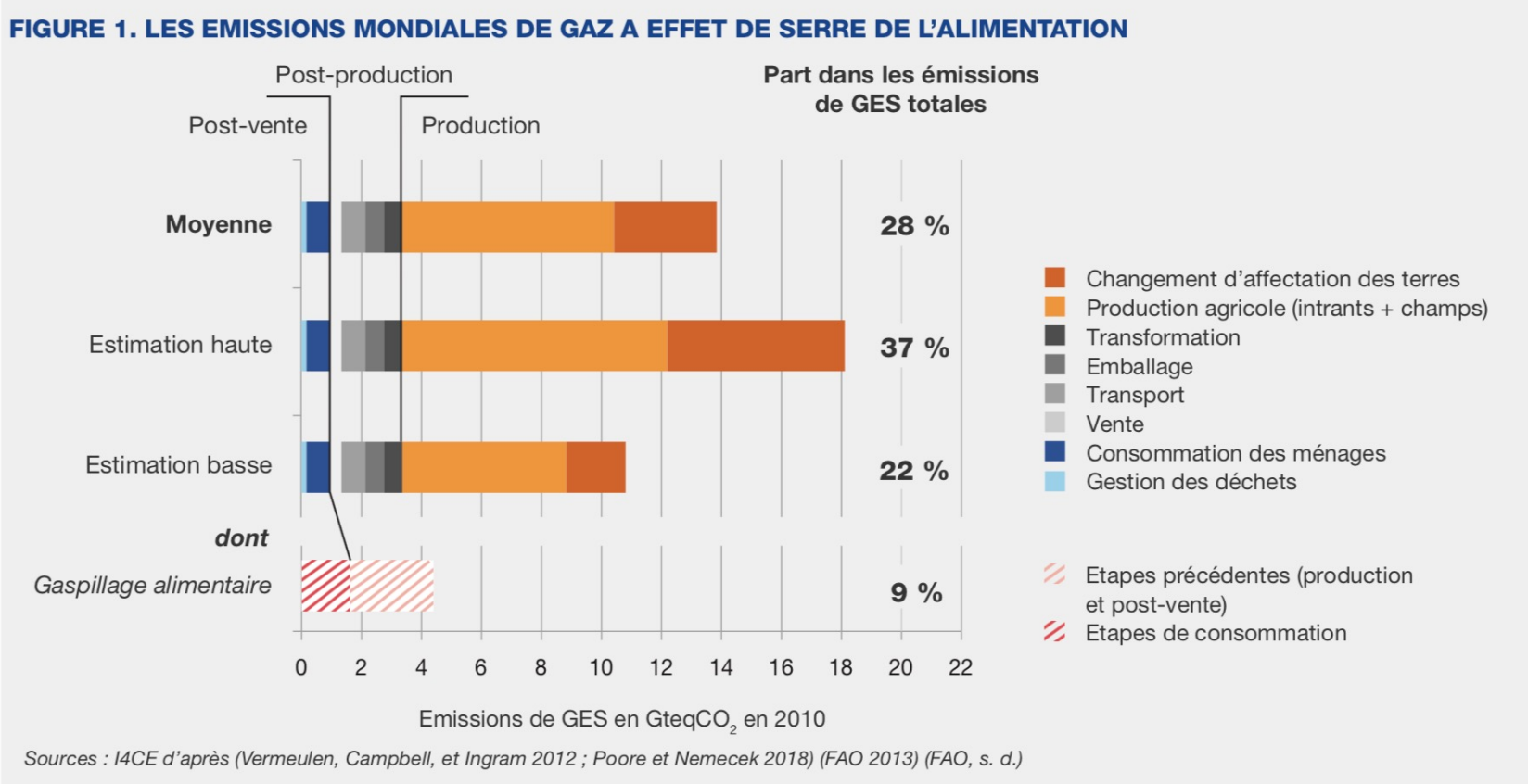


Source : Carbone 4, 2019

Questions ?

Annexes

Food footprint: production, deforestation, transport & processing



Production: ~50%

Deforestation: 20-33%

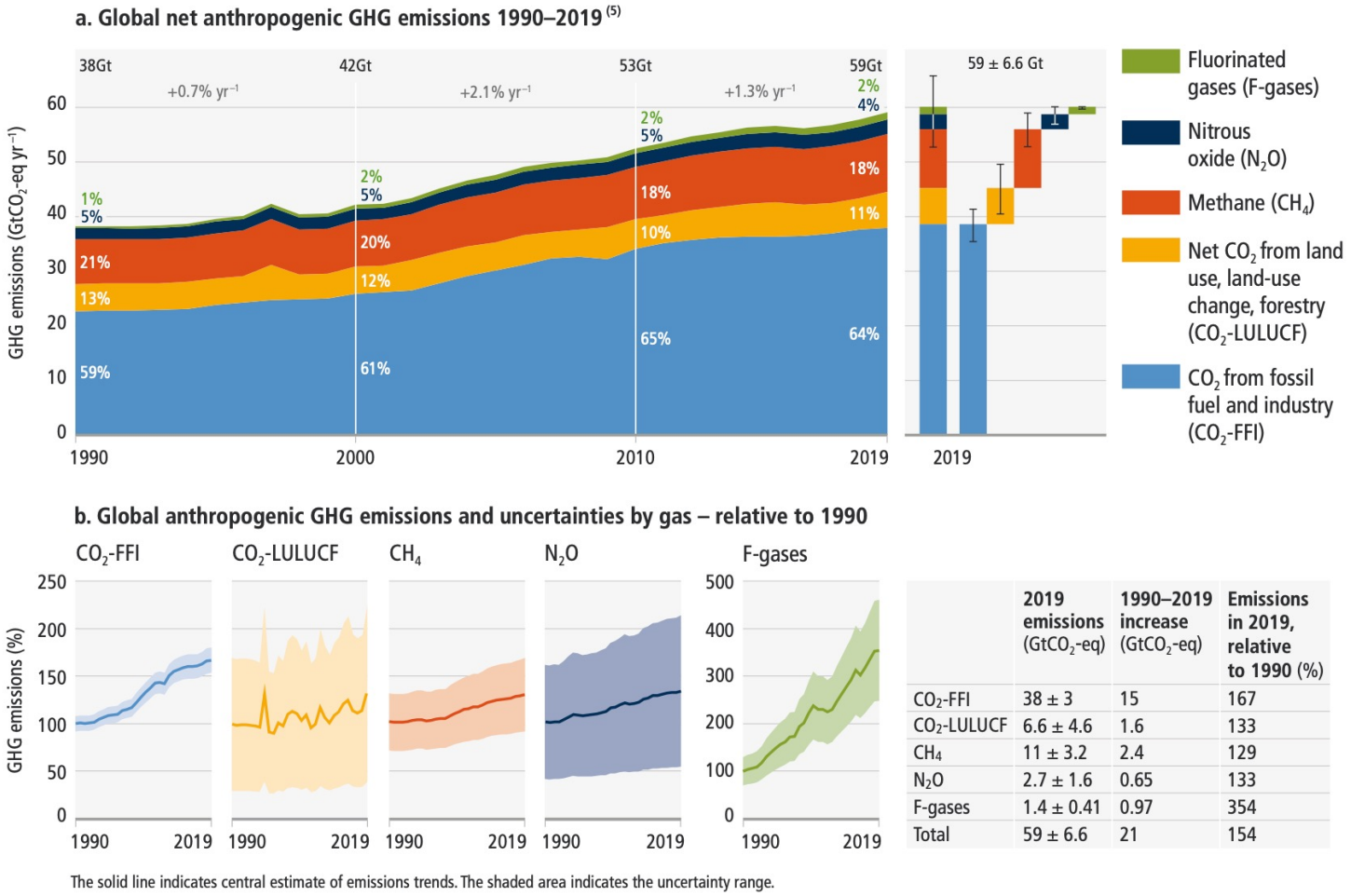
Transport: 4-7 %

Processing + packaging: 7-11%

https://www.i4ce.org/wp-core/wp-content/uploads/2019/02/0225-I4CE2984-PolitiquesAlimentairesEtClimat-Etude24p-web-1.pdf

Time evolution of world GES emission

Global net anthropogenic emissions have continued to rise across all major groups of greenhouse gases.



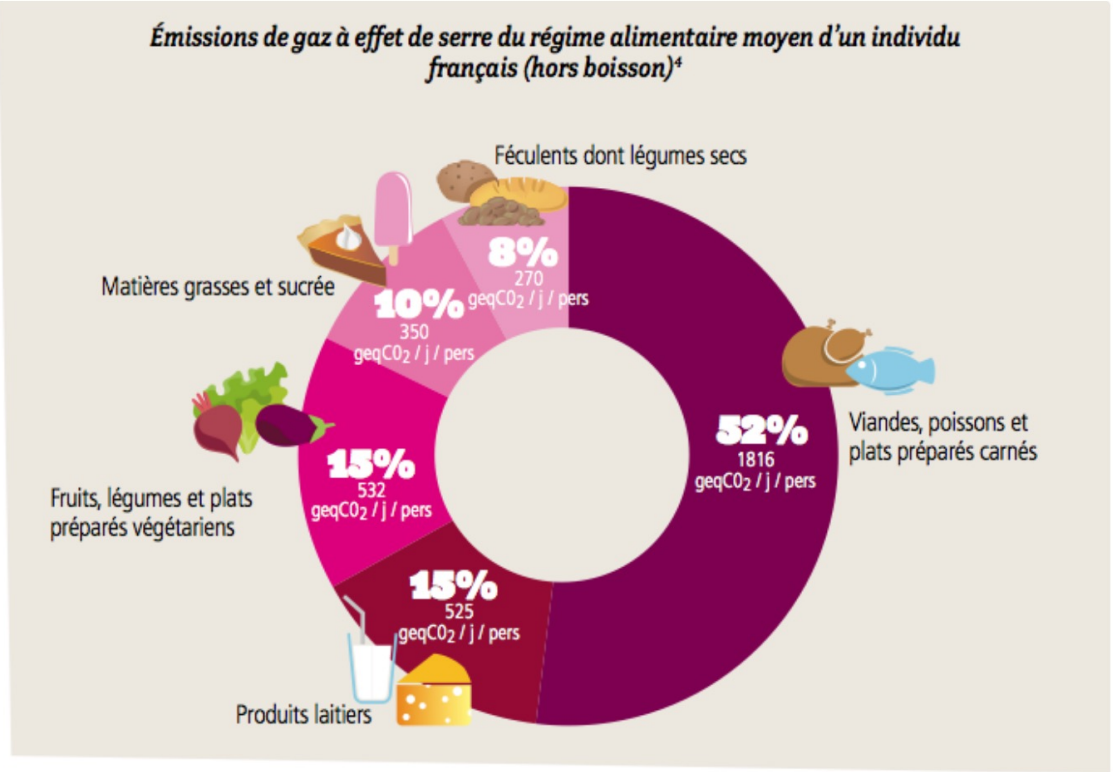
	2019 emissions ($GtCO_2$-eq)	1990–2019 increase ($GtCO_2$-eq)	Emissions in 2019, relative to 1990 (%)
CO_2-FFI	38 ± 3	15	167
CO_2-LULUCF	6.6 ± 4.6	1.6	133
CH_4	11 ± 3.2	2.4	129
N_2O	2.7 ± 1.6	0.65	133
F-gases	1.4 ± 0.41	0.97	354
Total	59 ± 6.6	21	154

The solid line indicates central estimate of emissions trends. The shaded area indicates the uncertainty range.

Figure SPM.1 | Global net anthropogenic GHG emissions ($GtCO_2$-eq yr^{-1}) 1990–2019. Global net anthropogenic GHG emissions include CO_2 from fossil fuel combustion and industrial processes (CO_2-FFI); net CO_2 from land use, land-use change and forestry (CO_2-LULUCF)[9]; methane (CH_4); nitrous oxide (N_2O); and fluorinated gases (HFCs, PFCs, SF_6, NF_3).[6] **Panel a** shows aggregate annual global net anthropogenic GHG emissions by groups of gases from 1990 to 2019 reported in $GtCO_2$-eq converted based on global warming potentials with a 100-year time horizon (GWP100-AR6) from the IPCC Sixth Assessment Report Working Group I (Chapter 7). The fraction of global emissions for each gas is shown for 1990, 2000, 2010 and 2019; as well as the aggregate average annual growth rate between these decades. At the right side of Panel a, GHG emissions in 2019 are broken down into individual components with the associated uncertainties (90% confidence interval) indicated by

IPCC AR6 WGIII FullReport

Food footprint per food type



Livestock (meat, dairy, eggs): 2/3 of tCO_2eq but only 16% of calories..

Source: https://reseauactionclimat.org/poids-alimentation-emissions-gaz-a-effet-de-serre/

Reducing emissions by changing diet

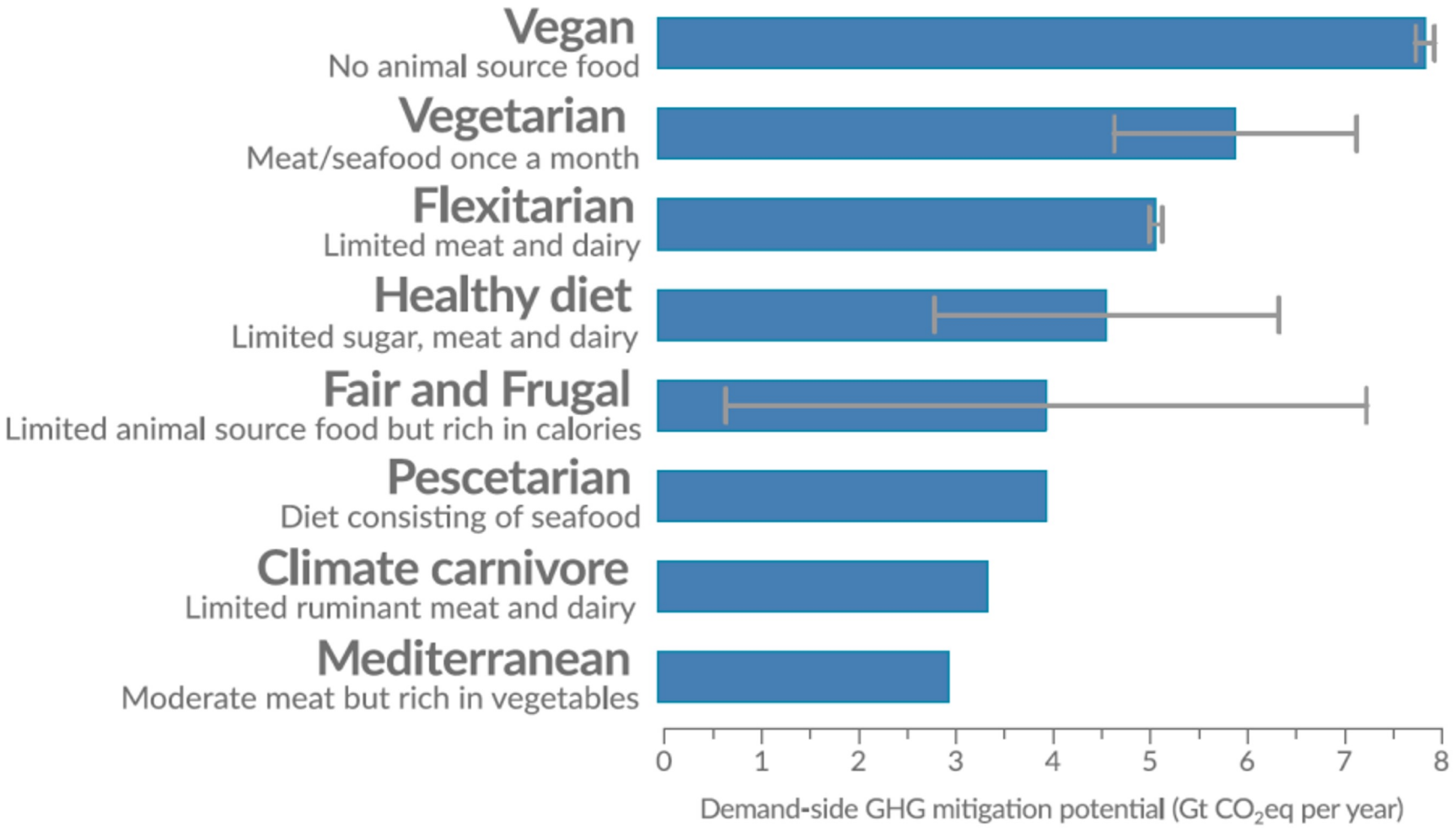


Figure 5.12 | Technical mitigation potential of changing diets by 2050 according to a range of scenarios examined in the literature. Estimates indicate technical potential only and include additional effects of carbon sequestration from land-sparing. Data without error bars are from one study only.

All diets need to provide a full complement of nutritional quality, including micronutrients (FAO et al. 2018).

Vegan: Completely plant-based (Springmann et al. 2016b; Stehfest et al. 2009).

Vegetarian: Grains, vegetables, fruits, sugars, oils, eggs and dairy, and generally at most one serving per month of meat or seafood (Springmann et al. 2016b; Tilman and Clark 2014; Stehfest et al. 2009).

Flexitarian: 75% of meat and dairy replaced by cereals and pulses; at least 500 g per day fruits and vegetables; at least 100 g per day of plant-based protein sources; modest amounts of animal-based proteins and limited amounts of red meat (one portion per week), refined sugar (less than 5% of total energy), vegetable oils high in saturated fat

Source : IPCC, 2019 (SRCCL)

GWP for heating: some examples

Translate energy into CO_2eq :

Electricity: 0.21 kgCO_{2e}/kWh in France for heating

- (NB : it is higher than the average electricity use of 0.08 kgCO_2e/kWh because fossil fuel is used during winter consumption peaks)

0.4 kgCO_{2e}/kWh in Europe

- « Natural gas » (methane): 0.25 kgCO_2/kWh

Old house, 20° : 600 (heat pump) - 1900 (electricity) – 2 300 (gas) kgCO_2eq

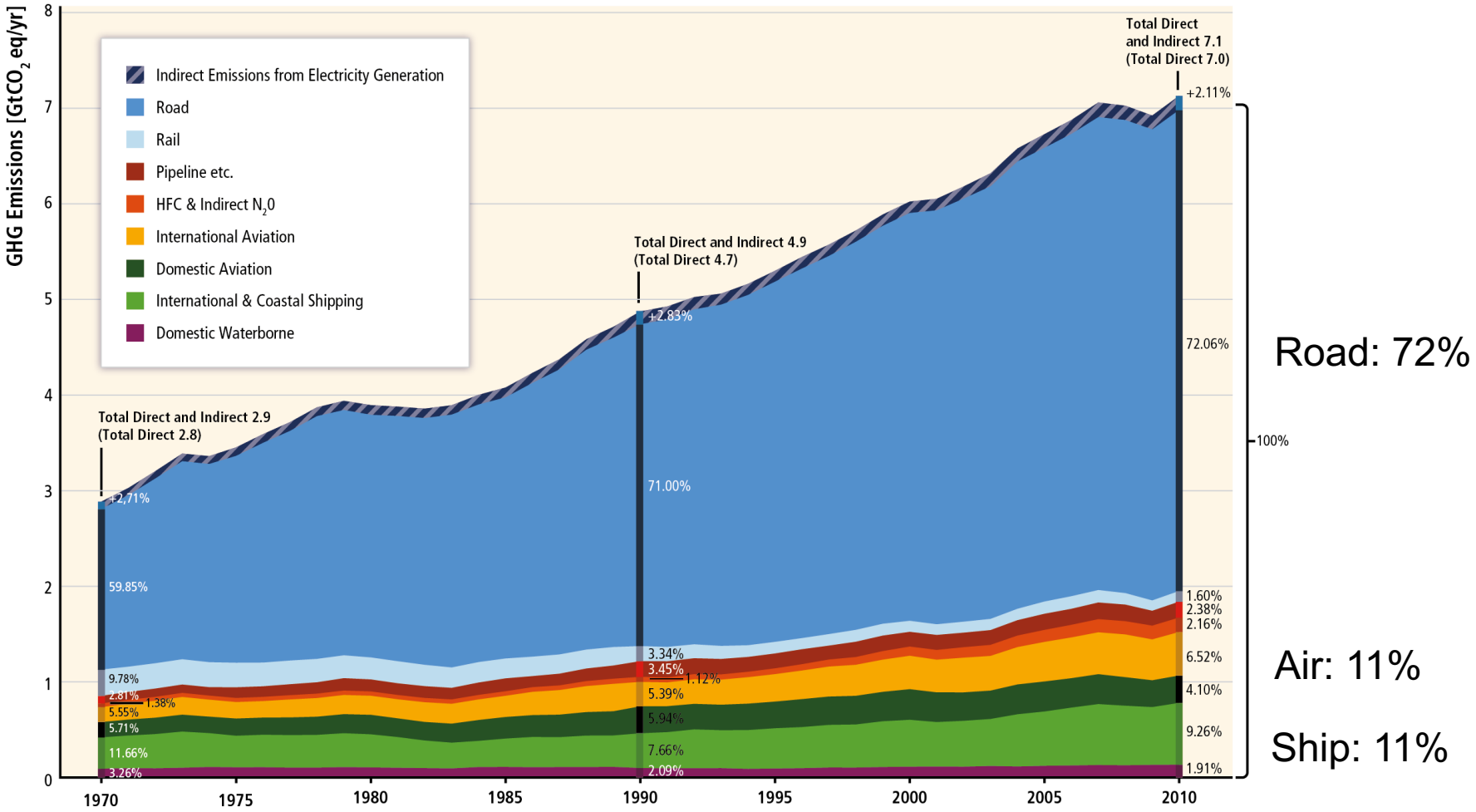
40 m^2 x 3 W/m^2K x 8.7° = 1 044 W x 24x365 = 9 100 kWh

New house, 17° : 200 (heat pump) - 630 (electricity) – 750 (gas) kgCO_2eq

40 m^2 x 1.25 W/m^2K x 6.8° = 340 W x 24x365 = 3 000 kWh

http://bilans-ges.ademe.fr/fr/basecarbone/donnees-consulter/

Footprint of different transport methods (worldwide)



Road: 72%

Air: 11%

Ship: 11%

NB: 10% of the population account for 80% of total motorized travel !

IPCC 2014: https://www.ipcc.ch/report/ar5/wg3/transport/