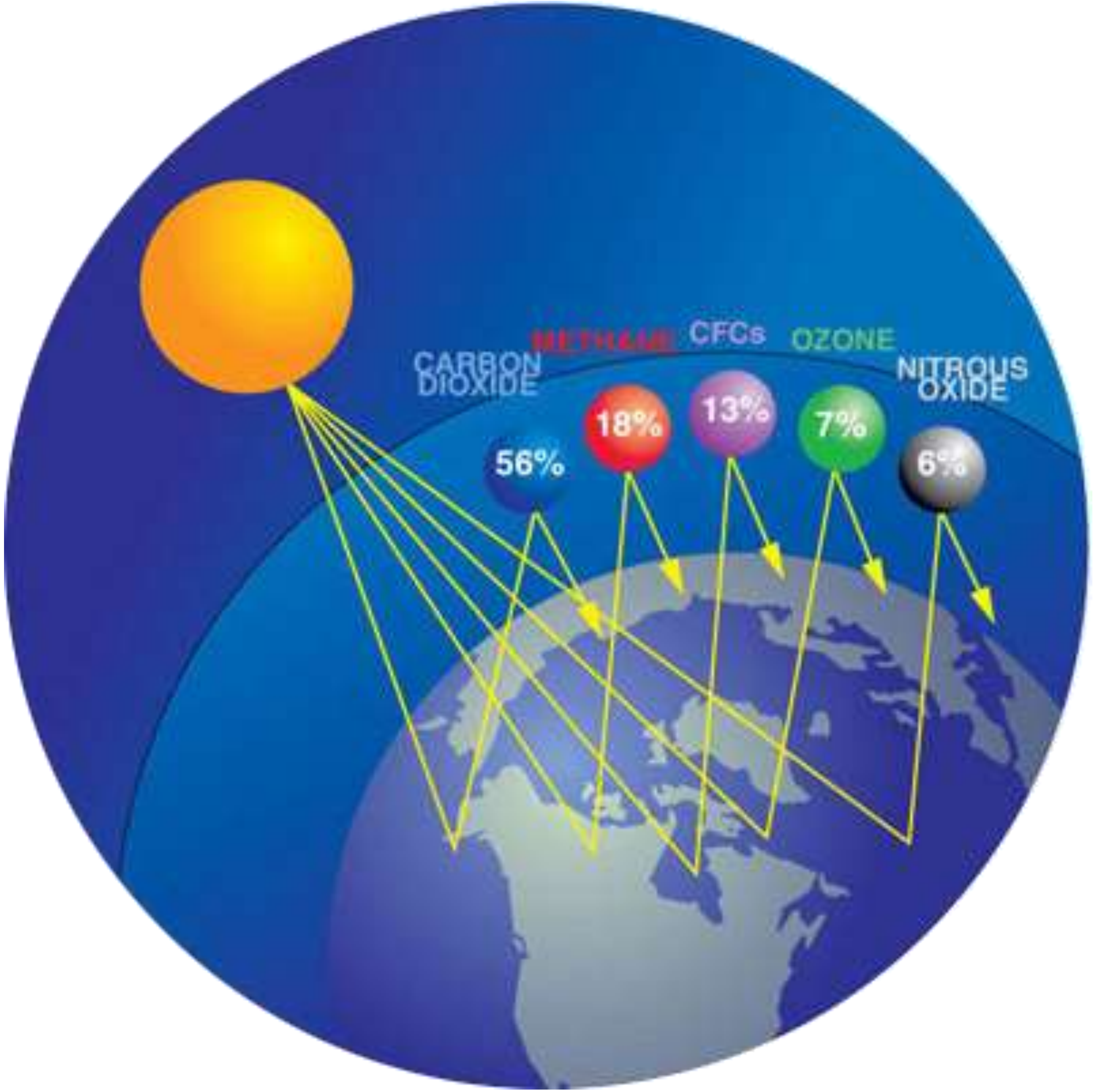
Livestock and Climate

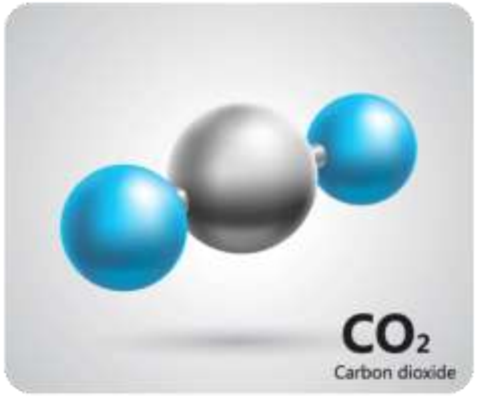
Frank Mitloehner, Ph.D.
Professor & Air Quality Specialist
Department of Animal Science
fmmitloehner@ucdavis.edu

UC DAVIS
CLEAR Center



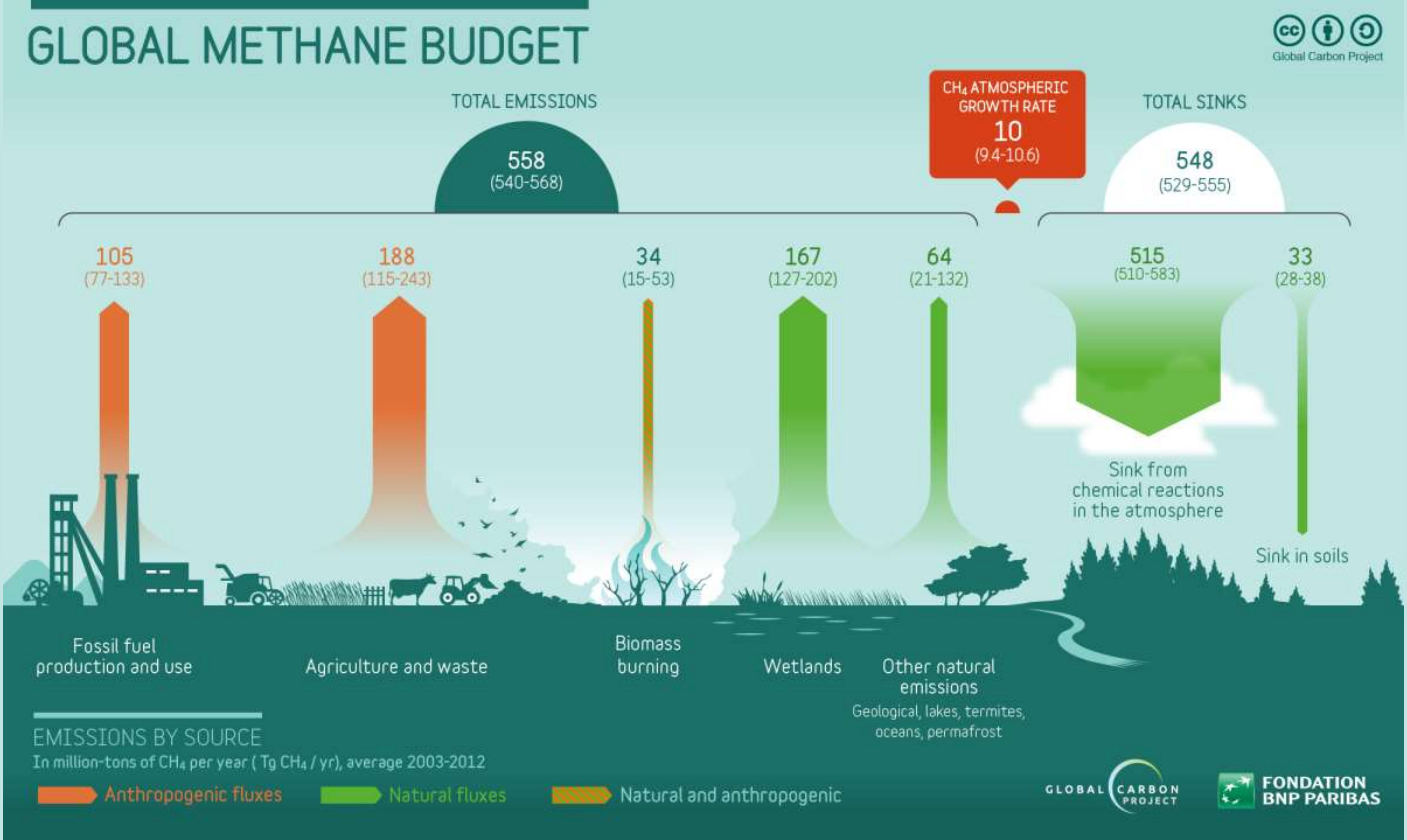
UC DAVIS
CLEAR Center

Global Warming Potential (GWP_{100}) of Main Greenhouse Gases



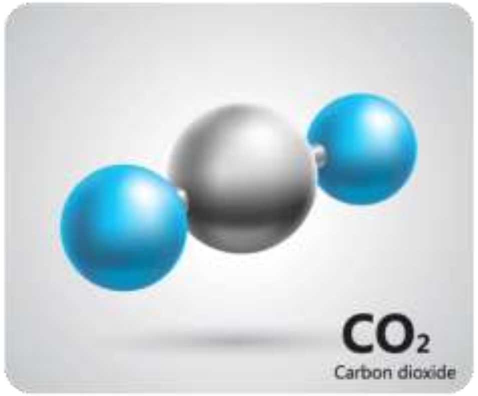
Carbon Dioxide (CO_2)	1
Methane (CH_4)	28
Nitrous Oxide (N_2O)	265

UCDAVIS CLEAR Center


GLOBAL METHANE BUDGET
Global Carbon Project
TOTAL EMISSIONS
558
(540-568)
CH4 ATMOSPHERIC GROWTH RATE
10
(9.4-10.6)
TOTAL SINKS
548
(529-555)
105
(77-133)
188
(115-243)
34
(15-53)
167
(127-202)
64
(21-132)
515
(510-583)
33
(28-38)
Sink from chemical reactions in the atmosphere
Sink in soils
Fossil fuel production and use
Agriculture and waste
Biomass burning
Wetlands
Other natural emissions
Geological, lakes, termites, oceans, permafrost
EMISSIONS BY SOURCE
In million-tons of CH4 per year (Tg CH4 / yr), average 2003-2012
Anthropogenic fluxes
Natural fluxes
Natural and anthropogenic
GLOBAL CARBON PROJECT
FONDATION BNP PARIBAS

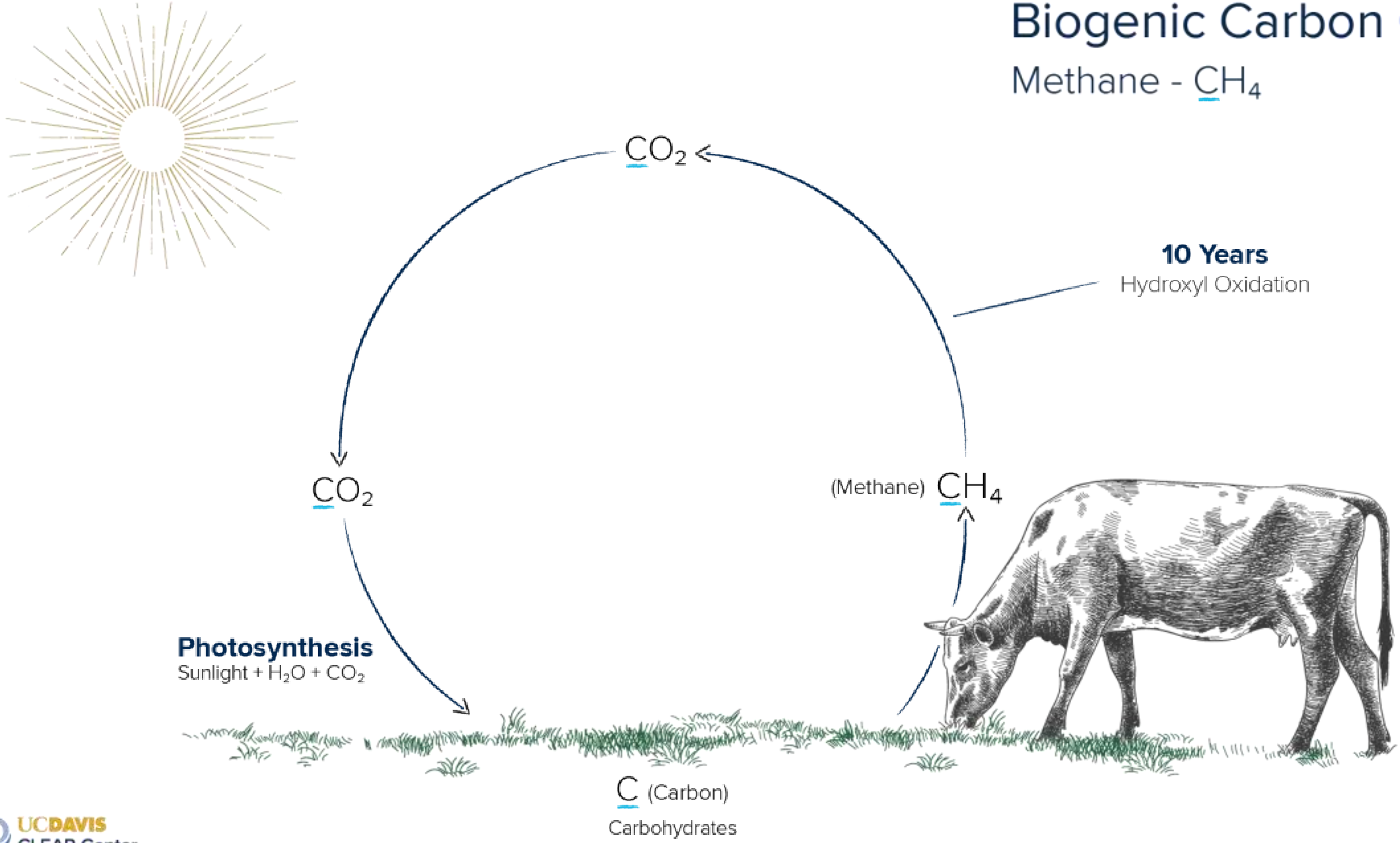
Half-Life of Main Greenhouse Gases in Years

Carbon Dioxide (CO_2)	1,000
Methane (CH_4)	10-12
Nitrous Oxide (N_2O)	110



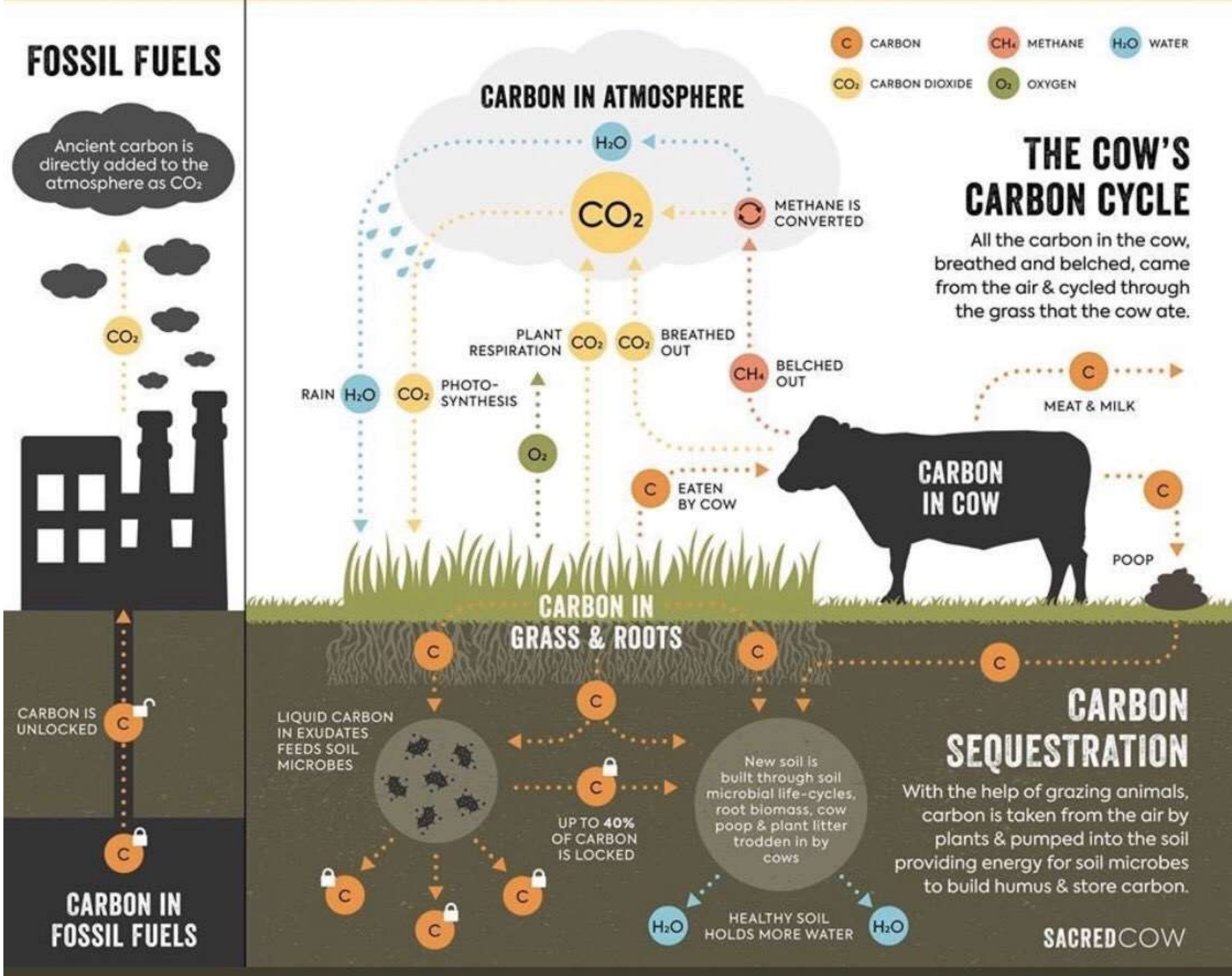
Biogenic Carbon Cycle

Methane - CH_4

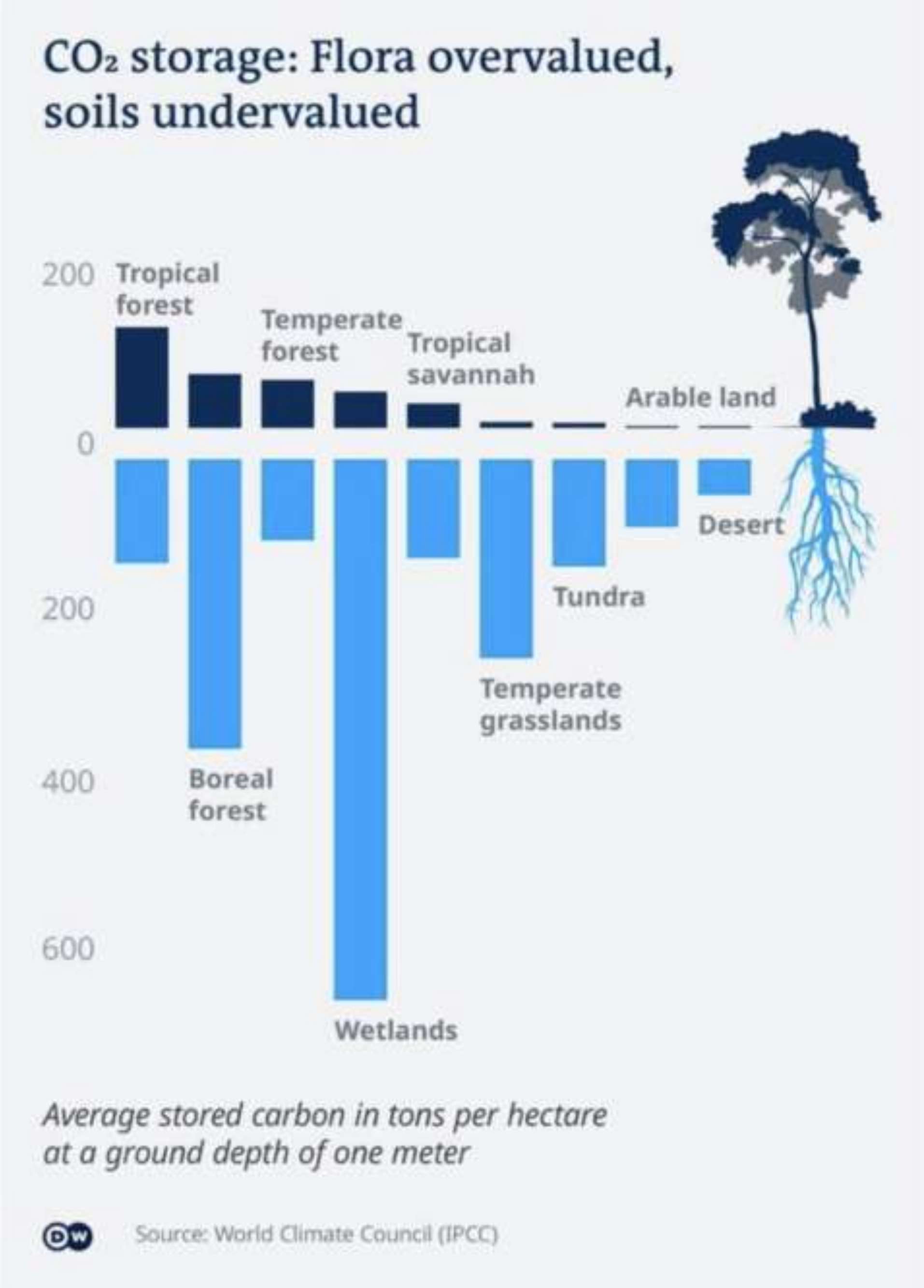


UC DAVIS
CLEAR Center

Fossil vs. Biogenic Carbon



Via:
@sustainabledish
sacredcow.info



UCDAVIS CLEAR Center

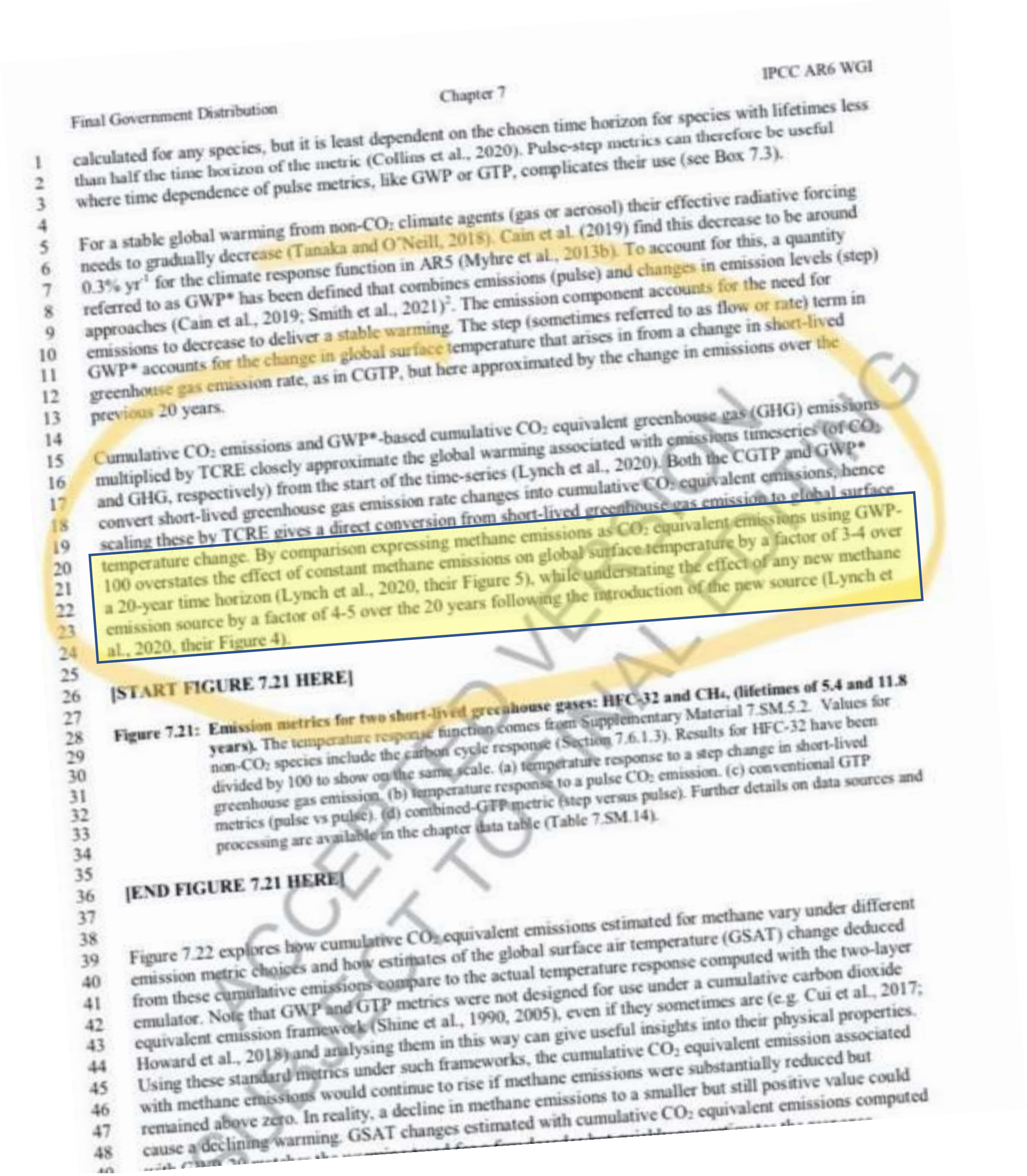
GWP* - A new way to characterize short-lived greenhouse gases

- GWP100 overestimates methane's warming impact of constant herds by a factor of 4, and overlooks it's ability to induce cooling when CH_4 emissions are reduced.

- GWP* is a new metric out of the University of Oxford that assesses how an emission of a short-lived greenhouse gas affects temperature.

- GWP* accounts for methane's short lifespan, including its atmospheric removal.

UC DAVIS
CLEAR Center



calculated for any species, but it is least dependent on the chosen time horizon for species with lifetimes less than half the time horizon of the metric (Collins et al., 2020). Pulse-step metrics can therefore be useful where time dependence of pulse metrics, like GWP or GTP, complicates their use (see Box 7.3).

For a stable global warming from non-CO_2 climate agents (gas or aerosol) their effective radiative forcing needs to gradually decrease (Tanaka and O'Neill, 2018). Cain et al. (2019) find this decrease to be around 0.3% yr^{-1} for the climate response function in AR5 (Myhre et al., 2013b). To account for this, a quantity referred to as GWP* has been defined that combines emissions (pulse) and changes in emission levels (step) approaches (Cain et al., 2019; Smith et al., 2021)[2]. The emission component accounts for the need for emissions to decrease to deliver a stable warming. The step (sometimes referred to as flow or rate) term in GWP* accounts for the change in global surface temperature that arises in from a change in short-lived greenhouse gas emission rate, as in CGTP, but here approximated by the change in emissions over the previous 20 years.

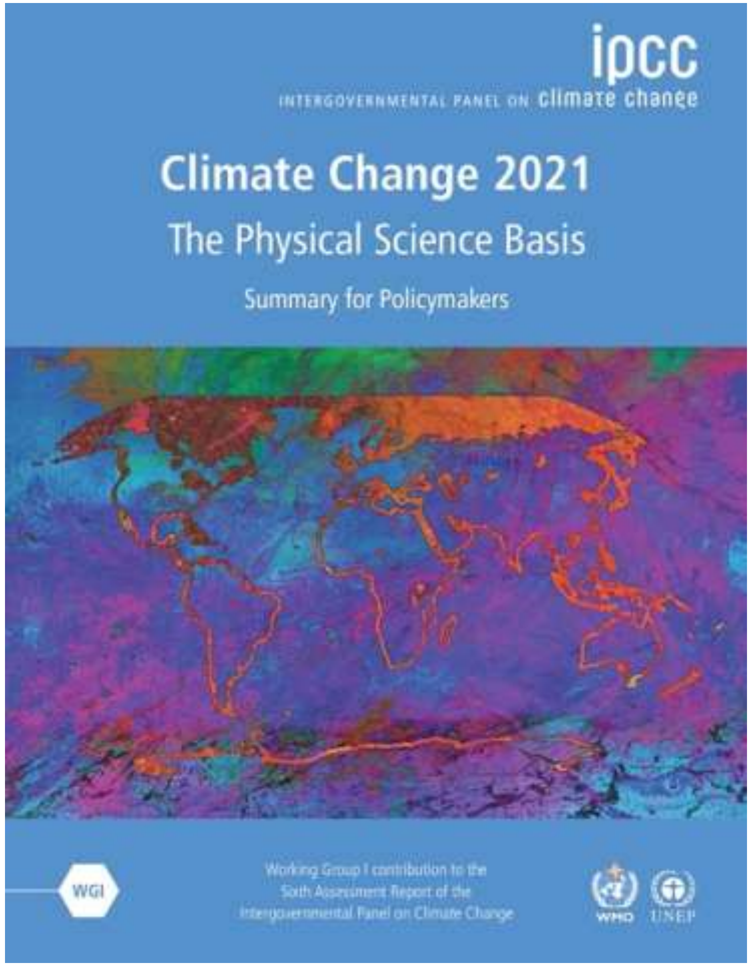
Cumulative CO_2 emissions and GWP*-based cumulative CO_2 equivalent greenhouse gas (GHG) emissions multiplied by TCRE closely approximate the global warming associated with emissions timeseries (of CO_2 and GHG, respectively) from the start of the time-series (Lynch et al., 2020). Both the CGTP and GWP* convert short-lived greenhouse gas emission rate changes into cumulative CO_2 equivalent emissions, hence scaling these by TCRE gives a direct conversion from short-lived greenhouse gas emission to global surface temperature change. By comparison expressing methane emissions as CO_2 equivalent emissions using GWP-100 overstates the effect of constant methane emissions on global surface temperature by a factor of 3-4 over a 20-year time horizon (Lynch et al., 2020, their Figure 5), while understating the effect of any new methane emission source by a factor of 4-5 over the 20 years following the introduction of the new source (Lynch et al., 2020, their Figure 4).

[START FIGURE 7.21 HERE]

Figure 7.21: Emission metrics for two short-lived greenhouse gases: HFC-32 and CH_4, (lifetimes of 5.4 and 11.8 years). The temperature response function comes from Supplementary Material 7.SM.5.2. Values for non-CO_2 species include the carbon cycle response (Section 7.6.1.3). Results for HFC-32 have been divided by 100 to show on the same scale. (a) temperature response to a step change in short-lived greenhouse gas emission. (b) temperature response to a pulse CO_2 emission. (c) conventional GTP metrics (pulse vs pulse). (d) combined-GTP metric (step versus pulse). Further details on data sources and processing are available in the chapter data table (Table 7.SM.14).

[END FIGURE 7.21 HERE]

Figure 7.22 explores how cumulative CO_2 equivalent emissions estimated for methane vary under different emission metric choices and how estimates of the global surface air temperature (GSAT) change deduced from these cumulative emissions compare to the actual temperature response computed with the two-layer emulator. Note that GWP and GTP metrics were not designed for use under a cumulative carbon dioxide equivalent emission framework (Shine et al., 1990, 2005), even if they sometimes are (e.g. Cui et al., 2017; Howard et al., 2018) and analysing them in this way can give useful insights into their physical properties. Using these standard metrics under such frameworks, the cumulative CO_2 equivalent emission associated with methane emissions would continue to rise if methane emissions were substantially reduced but remained above zero. In reality, a decline in methane emissions to a smaller but still positive value could cause a declining warming. GSAT changes estimated with cumulative CO_2 equivalent emissions computed



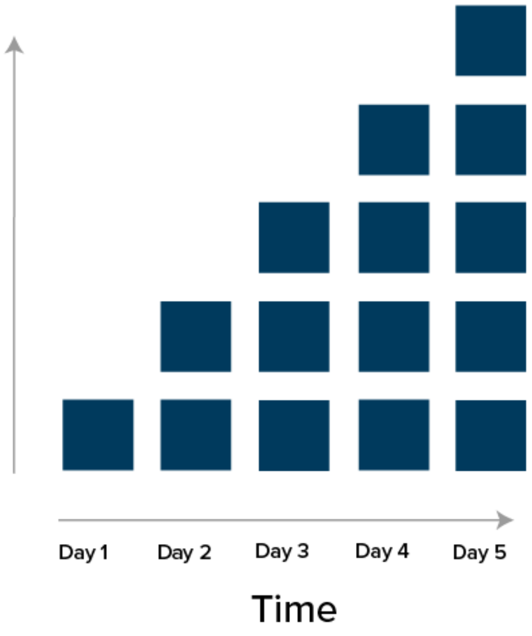
Read the page here: bit.ly/ipcc_ch7

UC DAVIS CLEAR Center

= Pulse of CO_2

Stock Gas
Carbon dioxide (CO_2)

Atmospheric Concentration

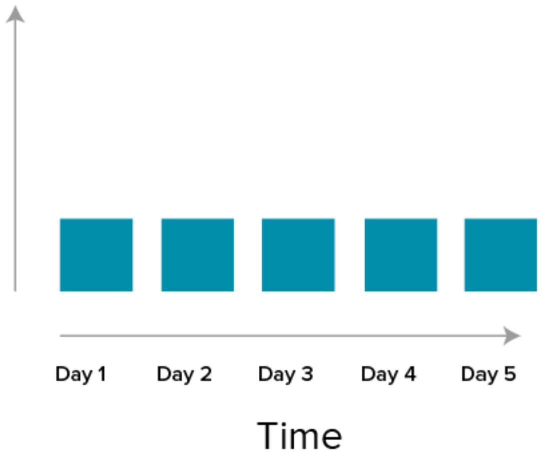


Stock gases will accumulate over time, because they stay in the environment.

= Pulse of CH_4

Flow Gas
Methane (CH_4)

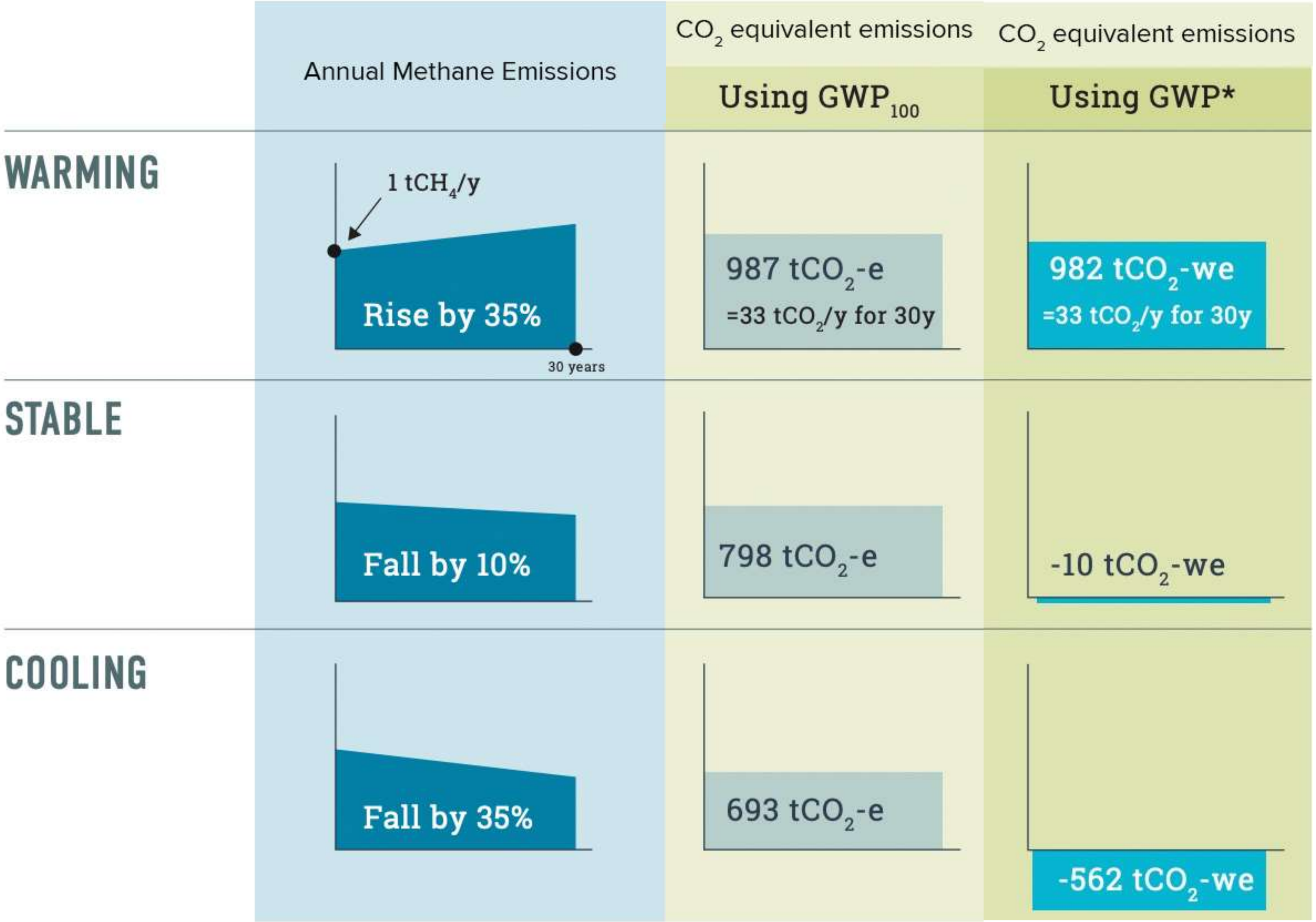
Atmospheric Concentration



Flow gases will stay stagnent, as they are destroyed at the same rate of emission.

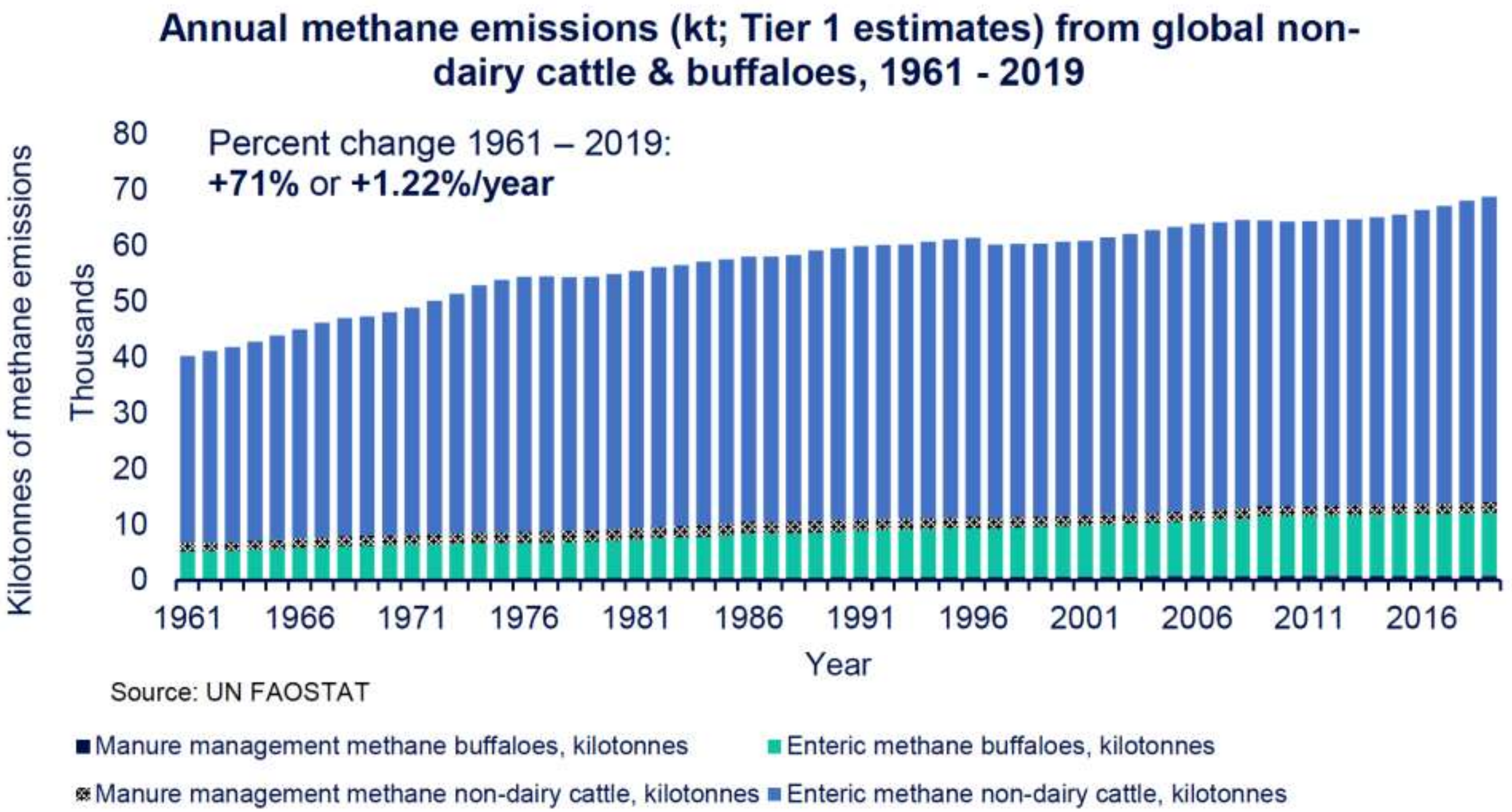
UCDAVIS CLEAR Center

Based on research by Myles R. Allen, Keith P. Shine, Jan S. Fuglestvedt, Richard J. Millar, Michelle Cain, David J. Frame & Adrian H. Macey.
Read more here: https://rdcu.be/b1t7S



Cain, M., Allen, M. & Lynch, J. *Oxford Martin Programme on Climate Pollutants* (2019). Read more at: https://www.oxfordmartin.ox.ac.uk/downloads/academic/201908_ClimatePollutants.pdf.

UC DAVIS CLEAR Center



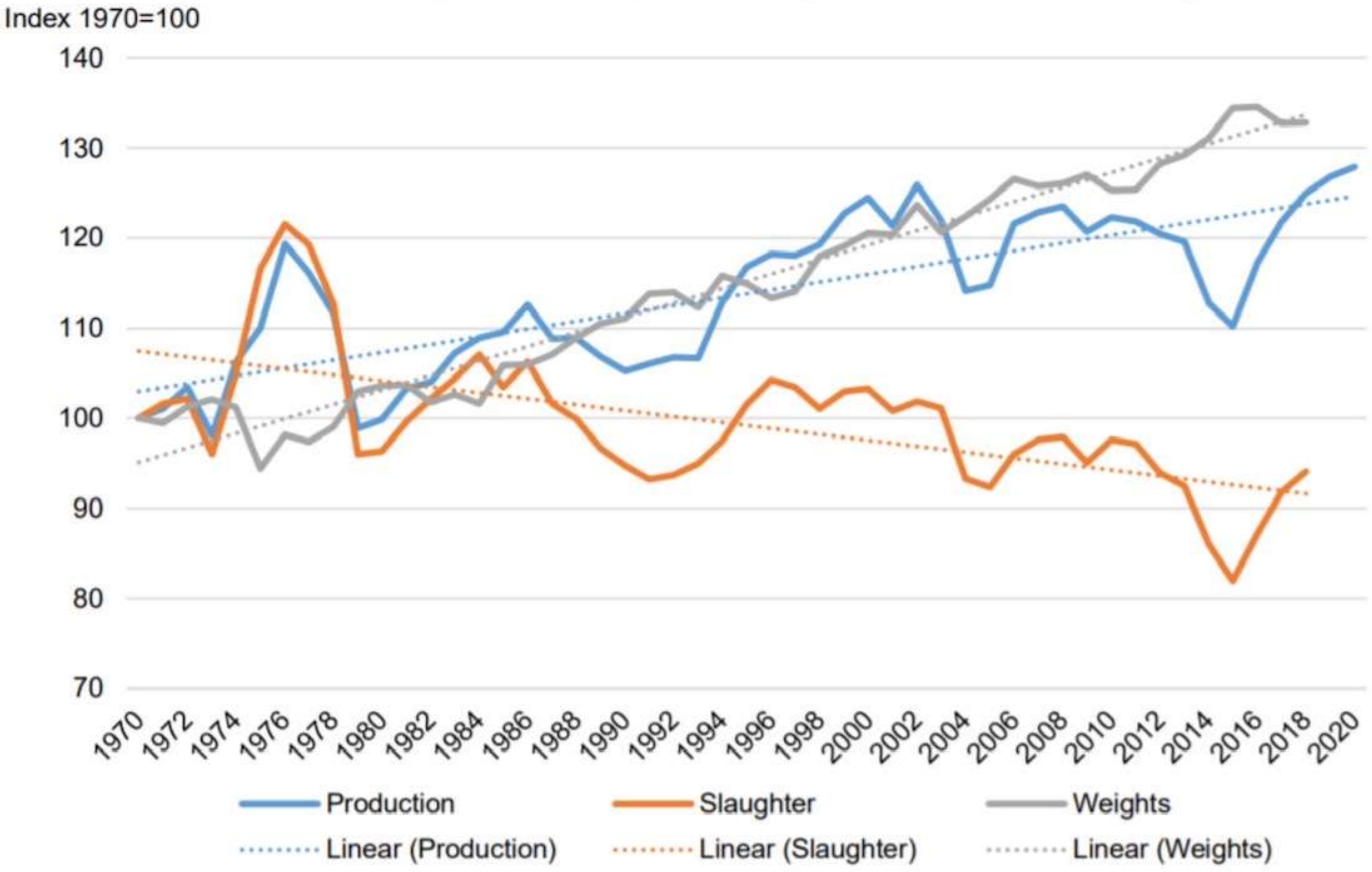
From 1961 to 2017, global cattle and buffalo meat production grew by 144% (UN FAOSTAT, 2022), and methane emissions from both manure and enteric sources grew 71% from 1961 to 2019.

UC DAVIS CLEAR Center

US Beef Trends

- In 1970, the U.S. had 140 million head of beef.
- By comparison, today there are 90 million head.
- In both 1970 and 2010, 24 million tons of beef were produced.

UCDAVIS CLEAR Center



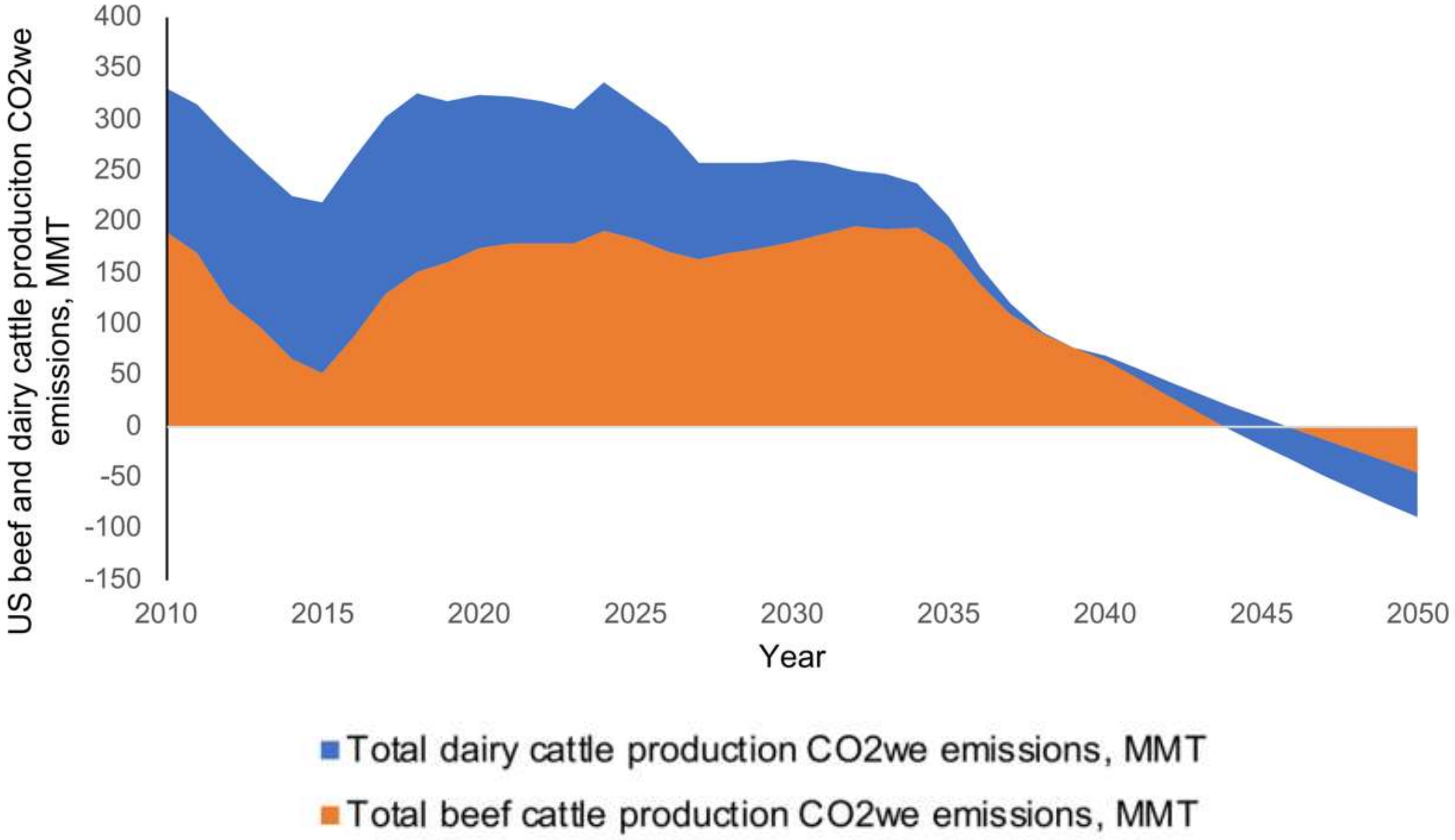
Source: Calculations by USDA, Economic Research Service based on data from USDA, National Agricultural Statistics Service.

For over 50 years, US cattle weights have propelled beef production as cattle slaughter decreased

UCDAVIS CLEAR Center

U.S. cattle sectors can be climate neutral by 2044 with 18% to 32% in methane reductions

- Business-as-usual won't cut it and will require development and adoption of new innovations.
- Reducing enteric emissions is critical. Innovations such as feed additives and developing low-methane emitting breeding strategies are being researched.
- Dairy digesters have reduced 30% of California's methane reduction goals.



Read the white paper at: bit.ly/clearpaper

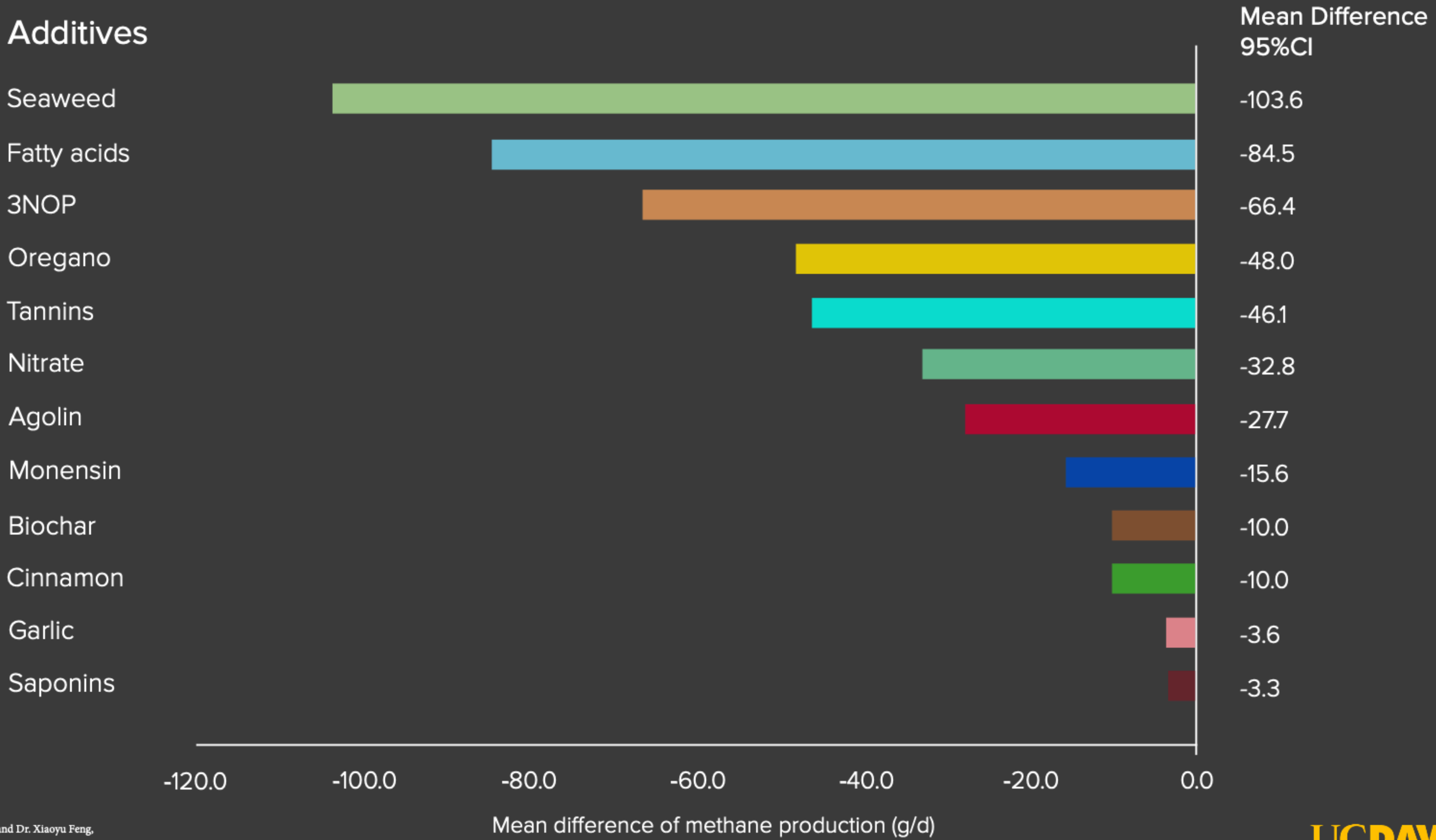
UCDAVIS CLEAR Center

Since 2015 California dairies have reduced greenhouse gases by 2 million metric tons – **a 30% reduction.**

UC DAVIS CLEAR Center

UC DAVIS
CLEAR Center

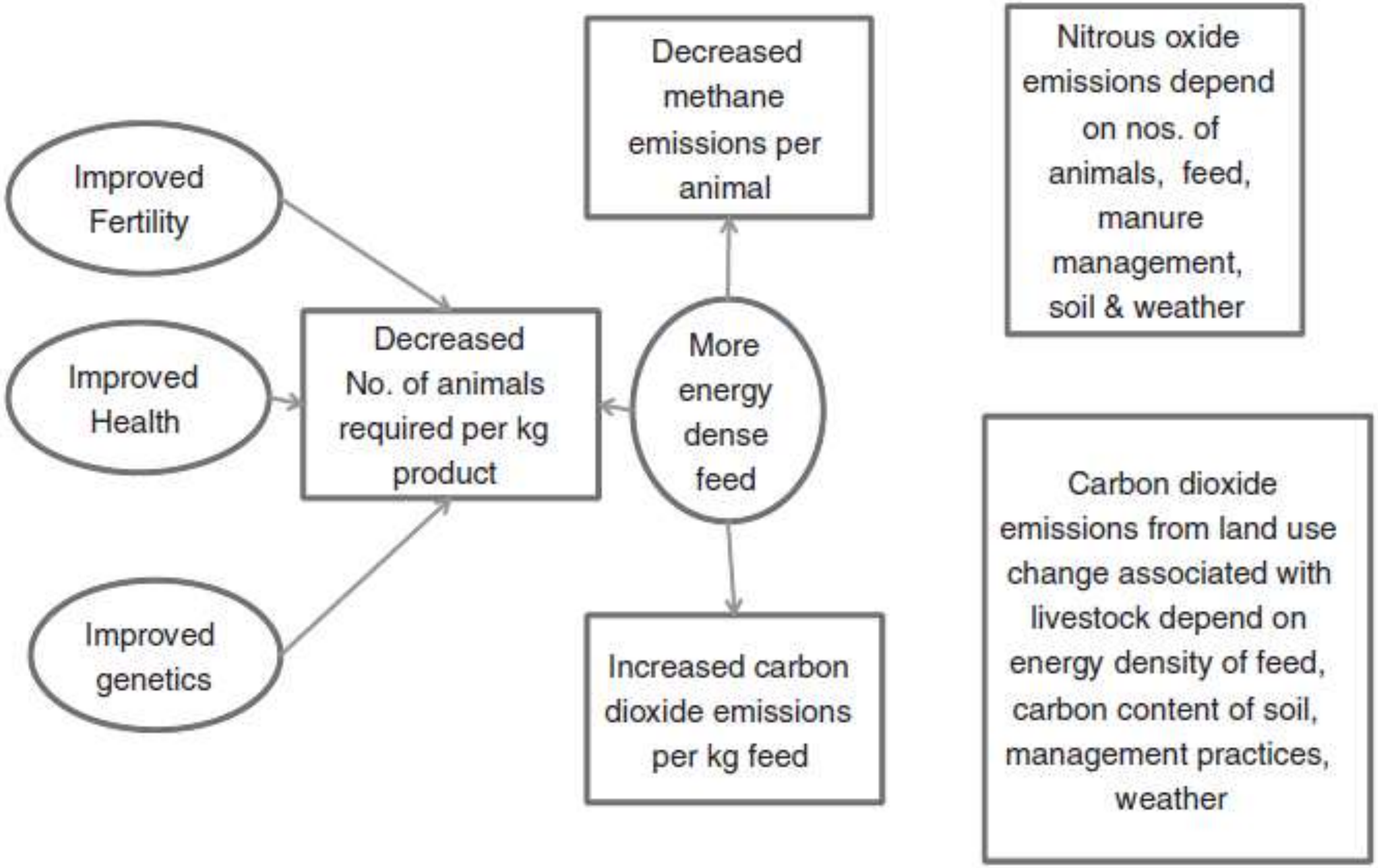
Methane Reductions from Feed Additives



Created based on the work of Dr. Ermias Kebreab and Dr. Xiaoyu Feng, University of California, Davis.
https://ww2.arb.ca.gov/sites/default/files/2020-12/17RD018.pdf

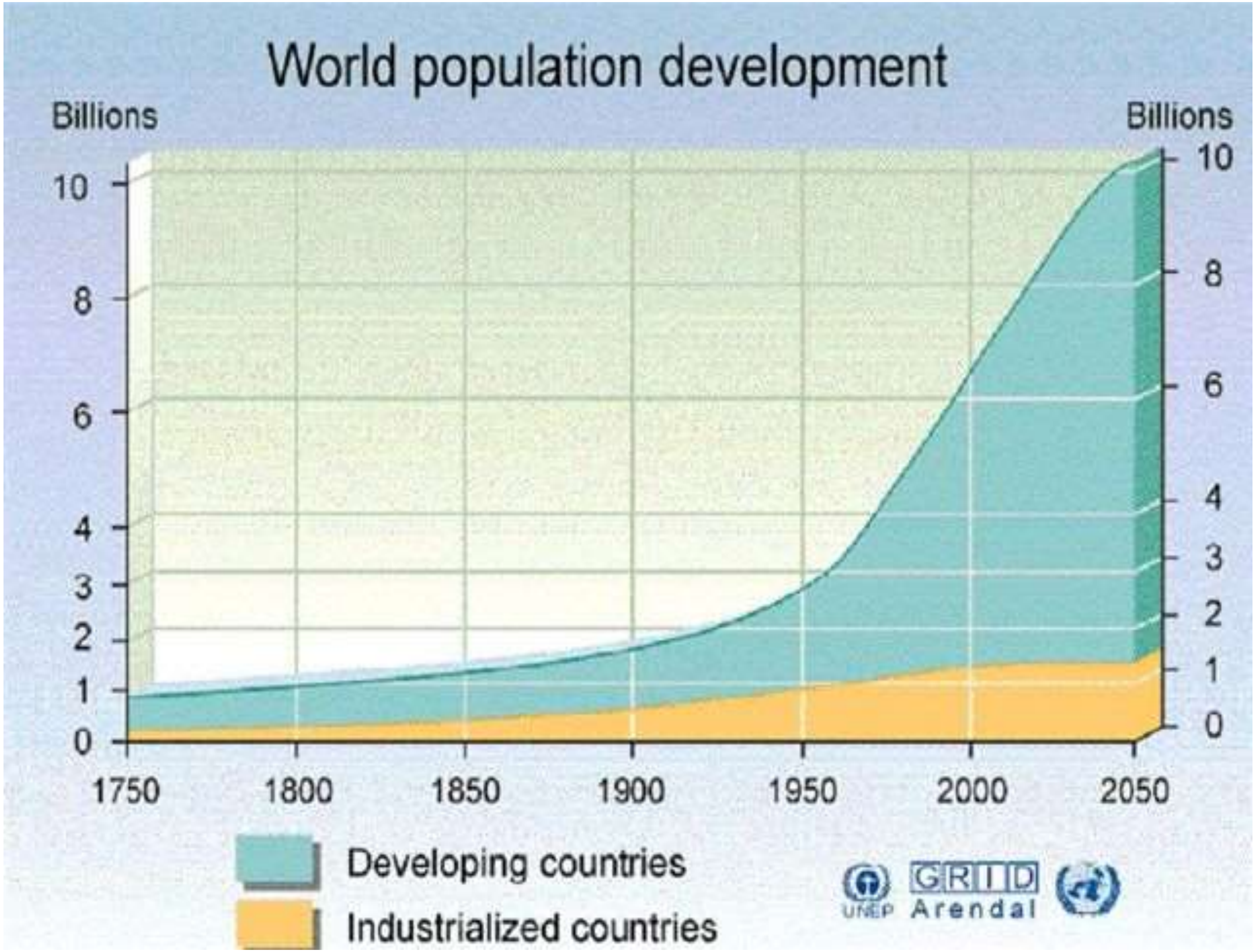
UC DAVIS
UNIVERSITY OF CALIFORNIA

Mitigation: Interventions to improve productivity

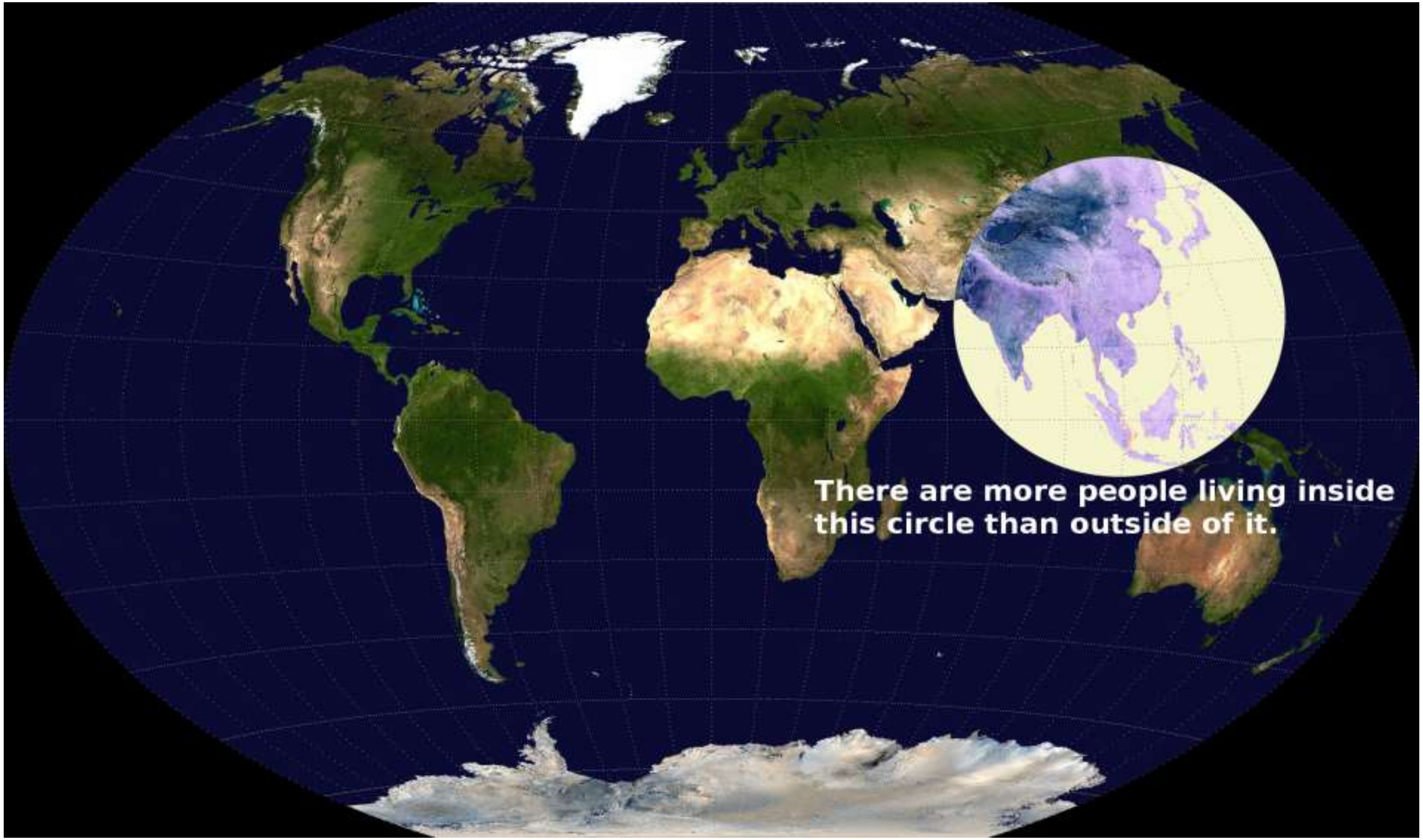


Gill et al. (2010)

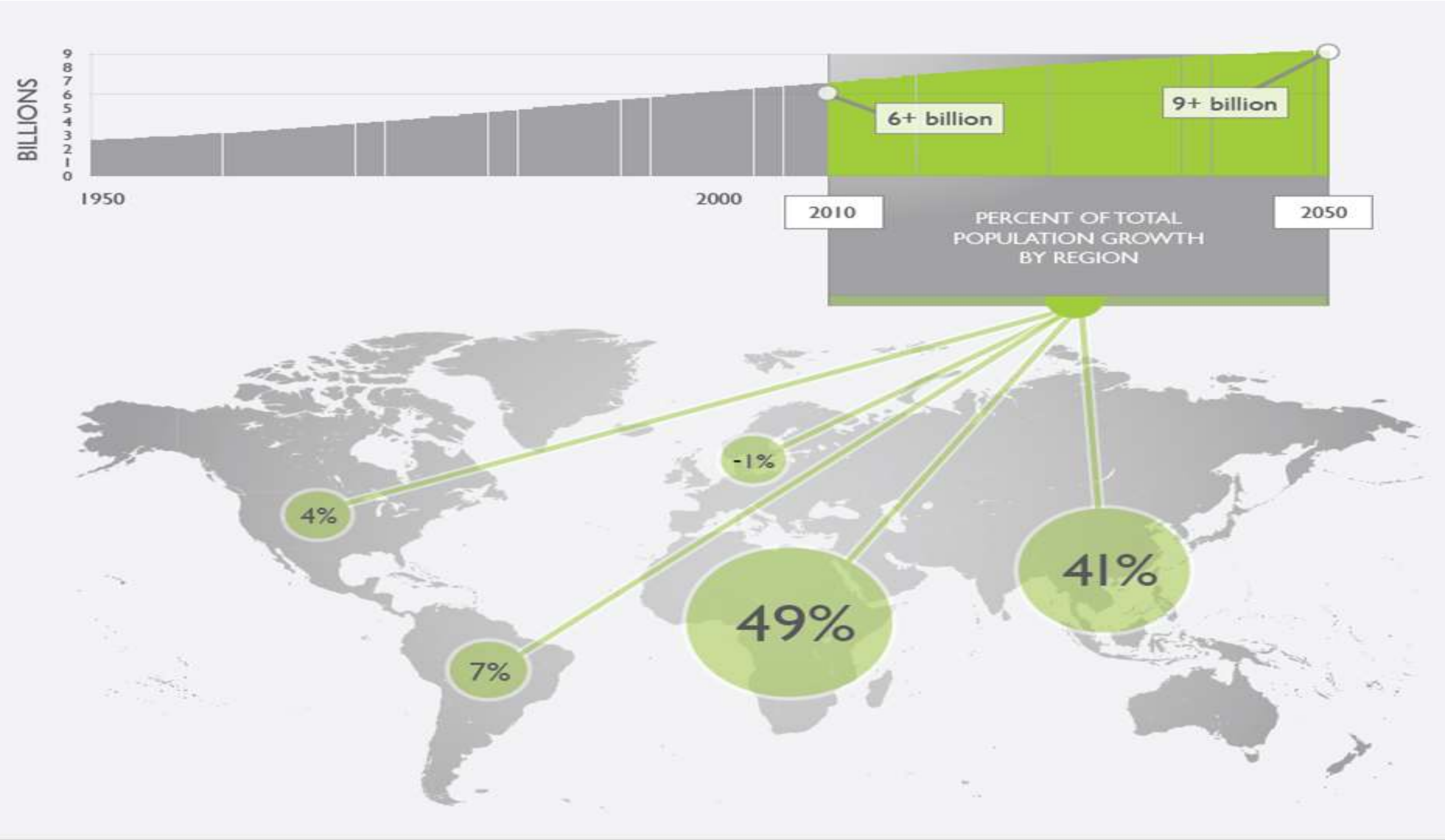
UCDAVIS CLEAR Center



UCDAVIS
CLEAR Center

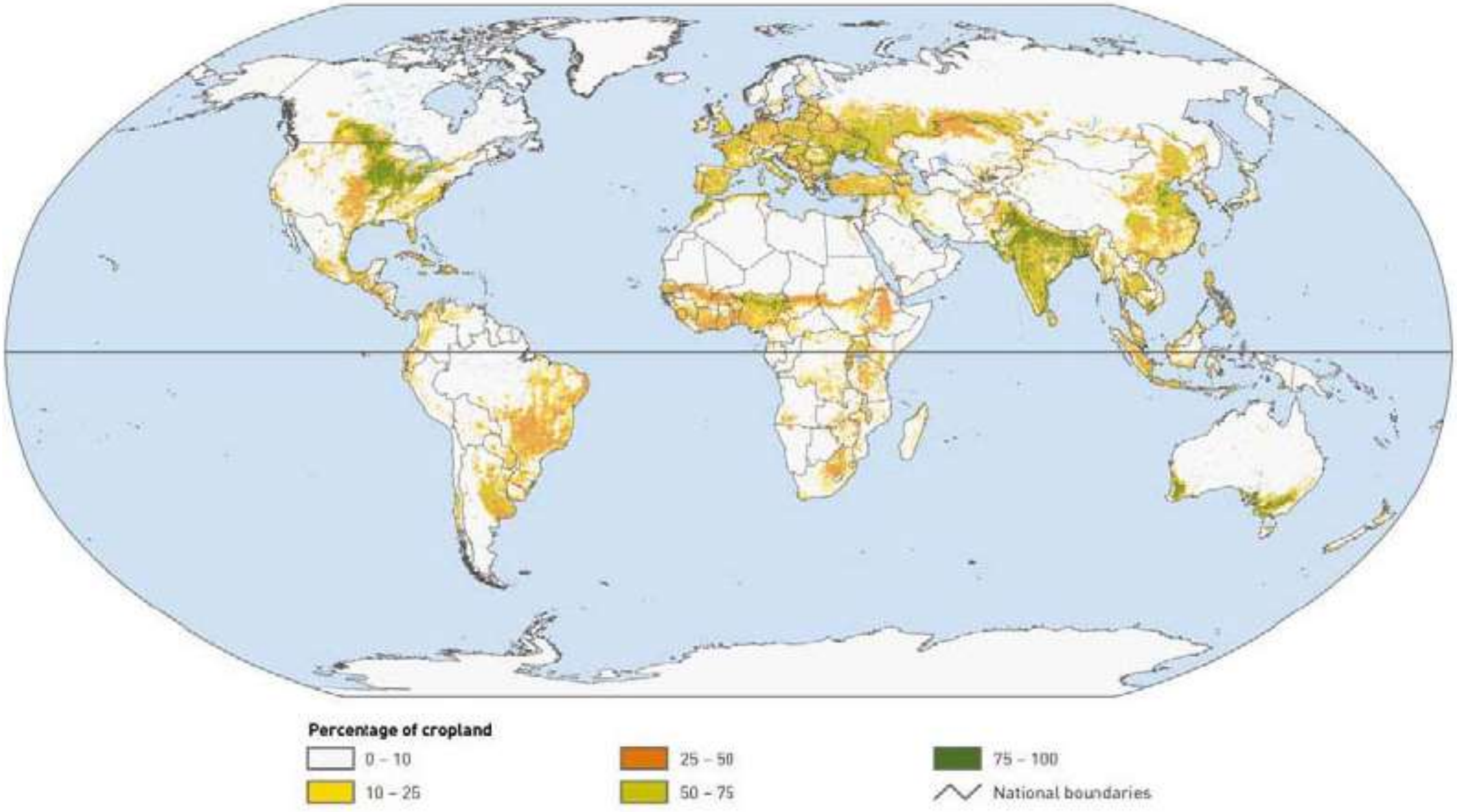


UCDAVIS
CLEAR Center



UCDAVIS
CLEAR Center

Distribution of cropland

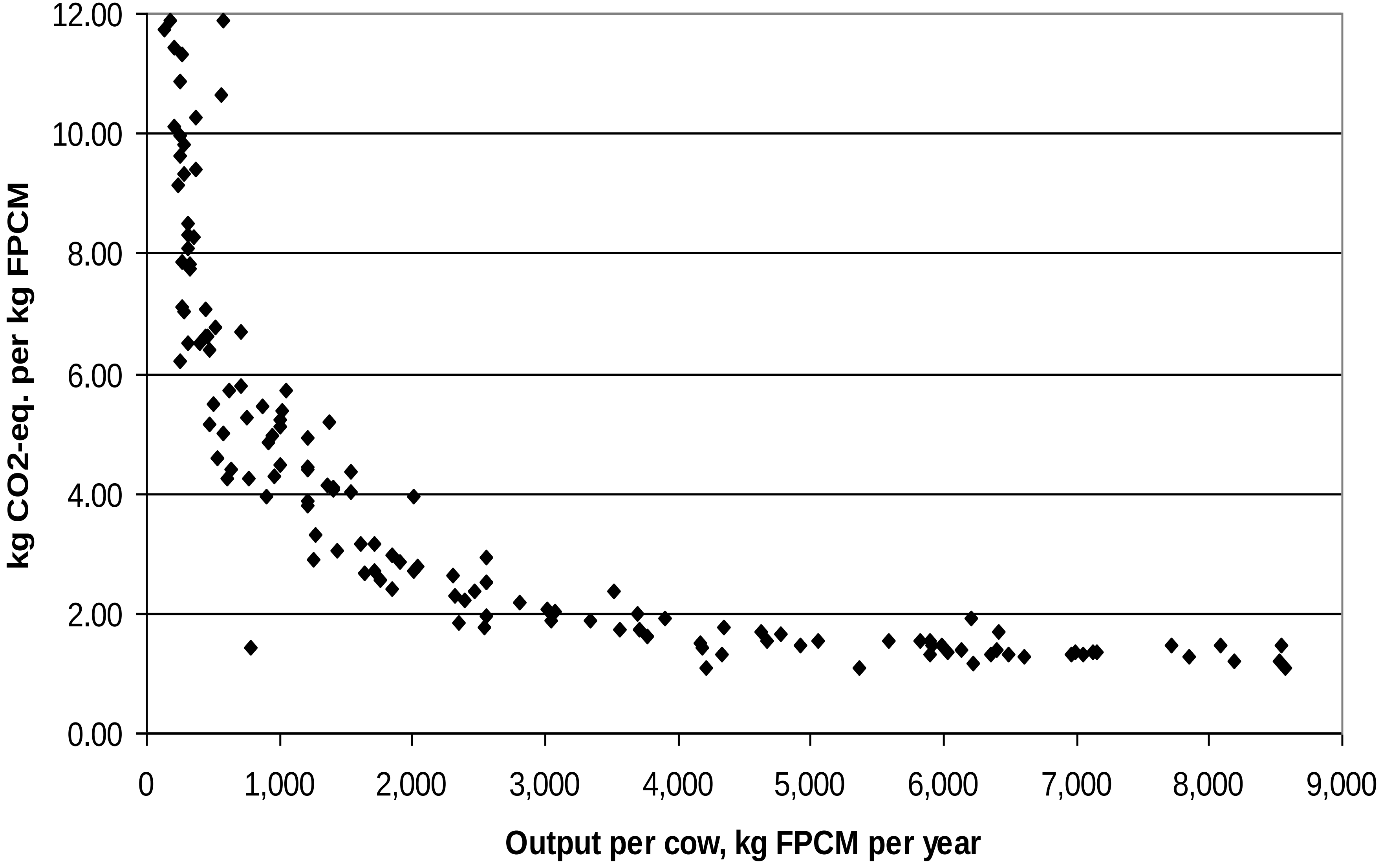


Source: FAO, 2006f.

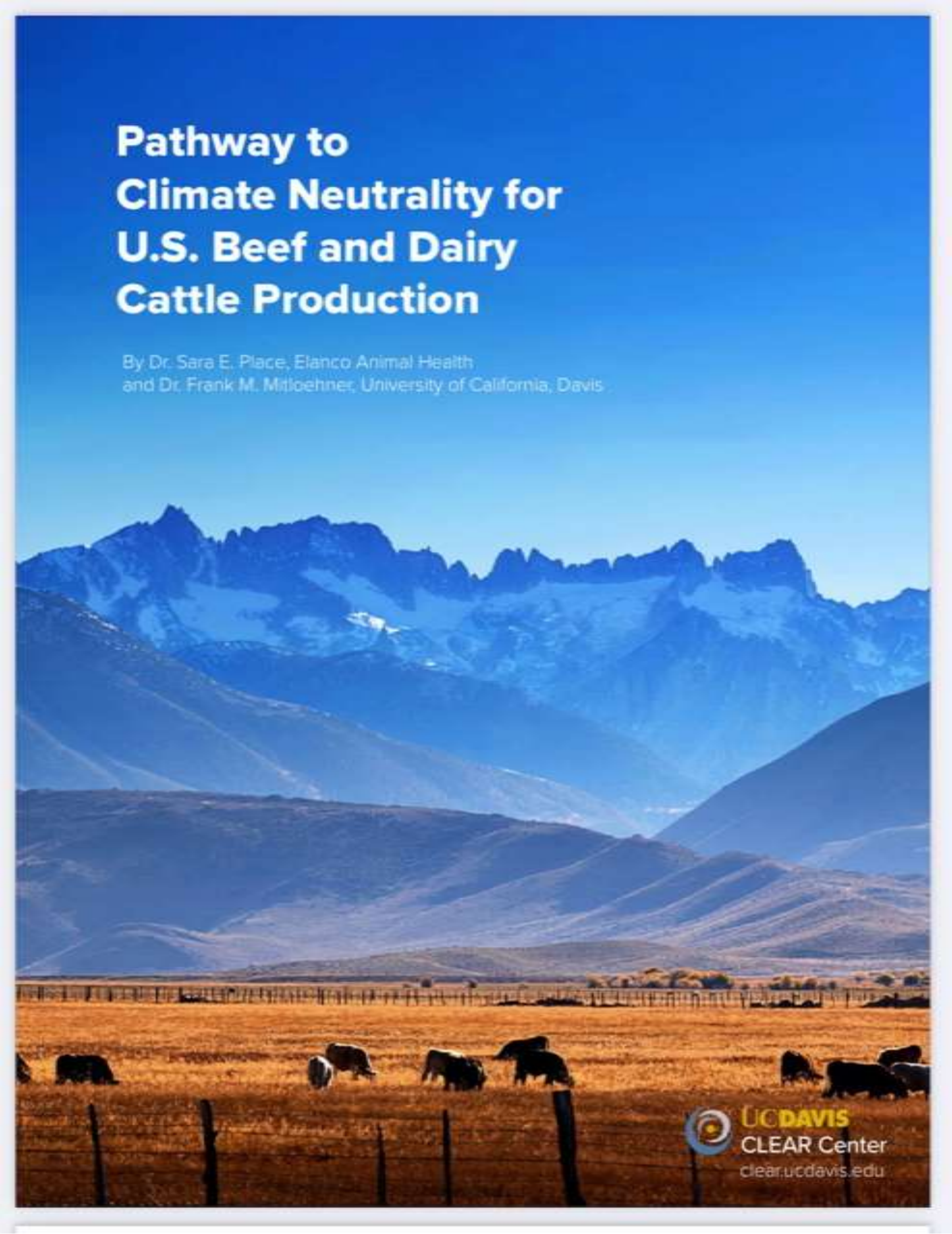
UCDAVIS CLEAR Center

FAO (2006)

Relationship between total greenhouse gas emissions and milk output per cow



H. Steinfeld, 2015



White Paper with the Chief Sustainability Officer of Elanco Animal Health - bit.ly/clearpaper

Rethinking Methane video - bit.ly/RethinkingMethaneVideo

UCDAVIS
CLEAR Center

Read my blog

clear.ucdavis.edu/blog

UCDAVIS
CLEAR Center

Follow us on Twitter

@GHGGuru

@UCDavisCLEAR

UC DAVIS CLEAR Center

Thank you

clear.ucdavis.edu

UCDAVIS
CLEAR Center