

THE CARBON CONUNDRUM: *TECHNICAL LIMITATIONS AND OPPORTUNITIES*

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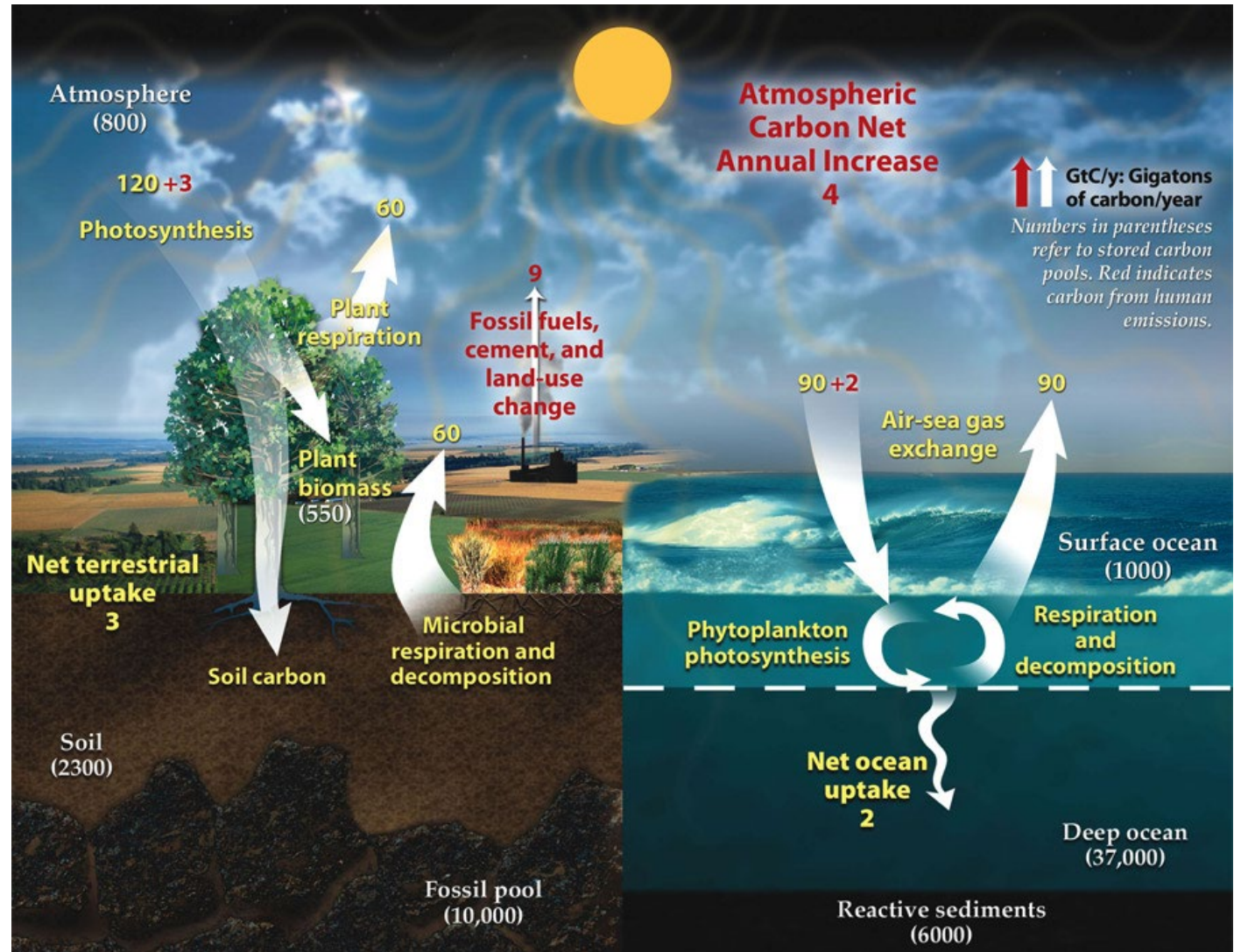
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CARBON AND CLIMATE CONCERNS

Carbon cycle

- Sources = 219
- Sinks = 215
- Balance = 4, accumulated in atmosphere

Results in concern over GHG emissions

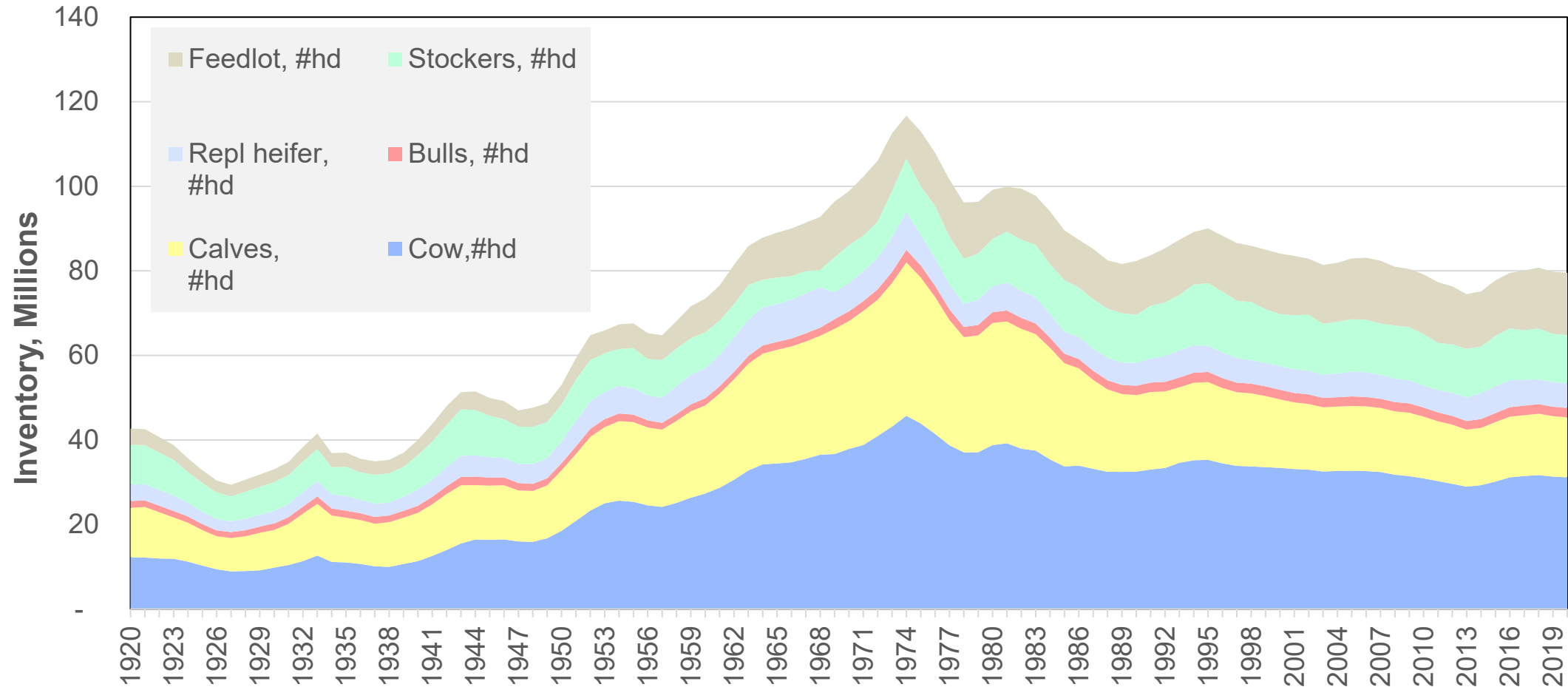


LIMITATION 1: EMISSIONS ESTIMATION

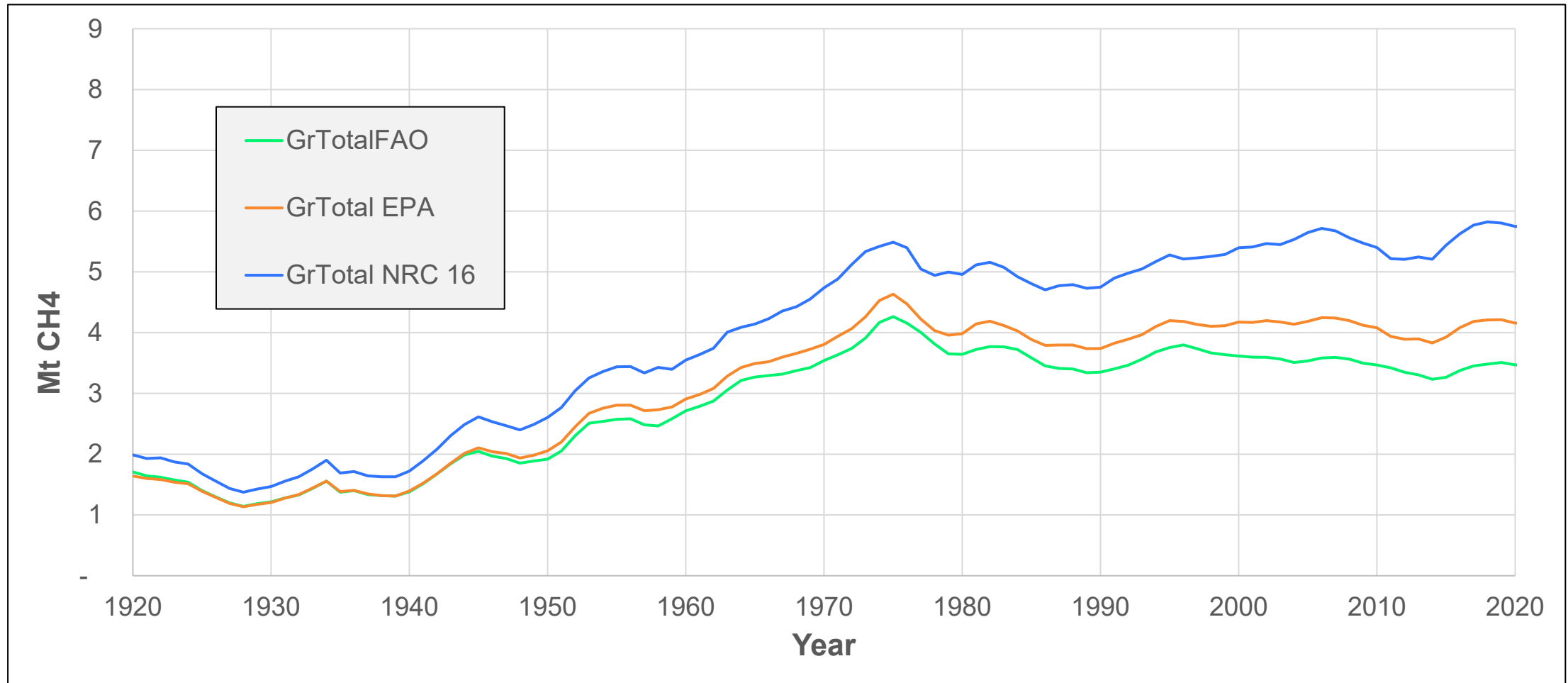
Three “Tiers” defined by IPCC (2006, 2019)

- **Tier 1**
 - Uses a country- or region-specific emissions factor (kg/hd/yr)
 - Multiplied by country-level livestock inventory
- **Tier 2**
 - Inventory by class
 - Estimates of intake (or GE requirements)
 - Requires animal BW, productivity data
 - Ym factors (methane yield as a % of GE intake)
- **Tier 3**
 - Requires detailed animal and diet data
 - Uses equations or models to estimate methane yield

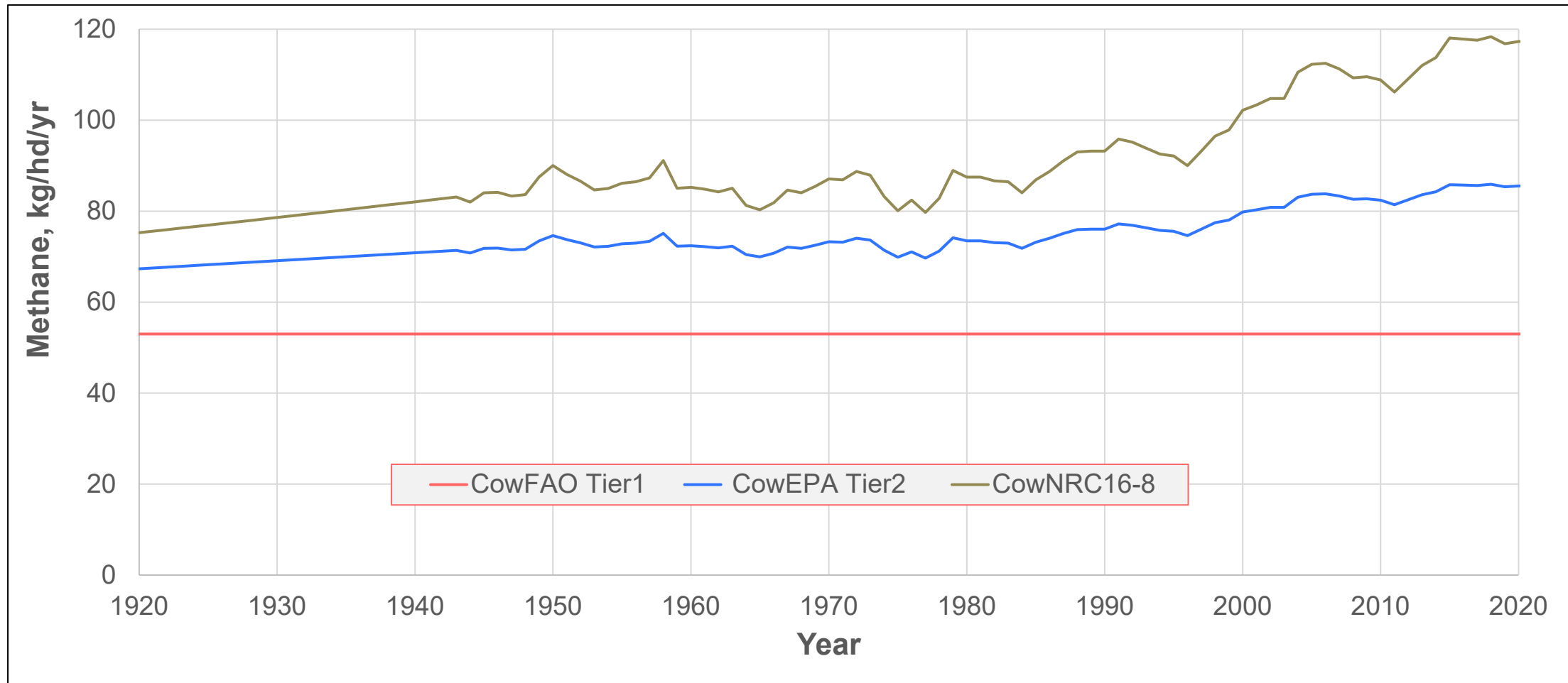
US BEEF CATTLE INVENTORY



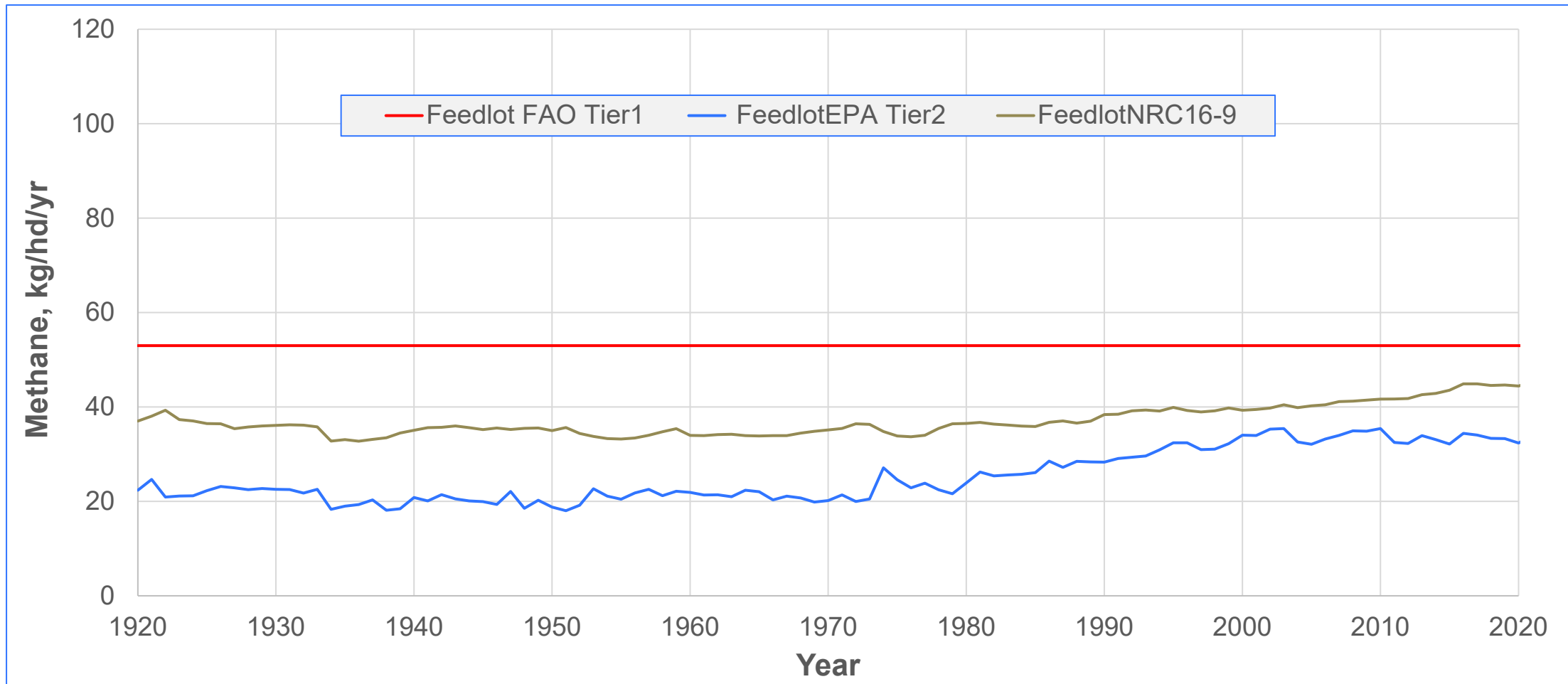
METHANE EMISSIONS BY TIER METHOD



METHANE EMISSIONS FACTORS, COWS



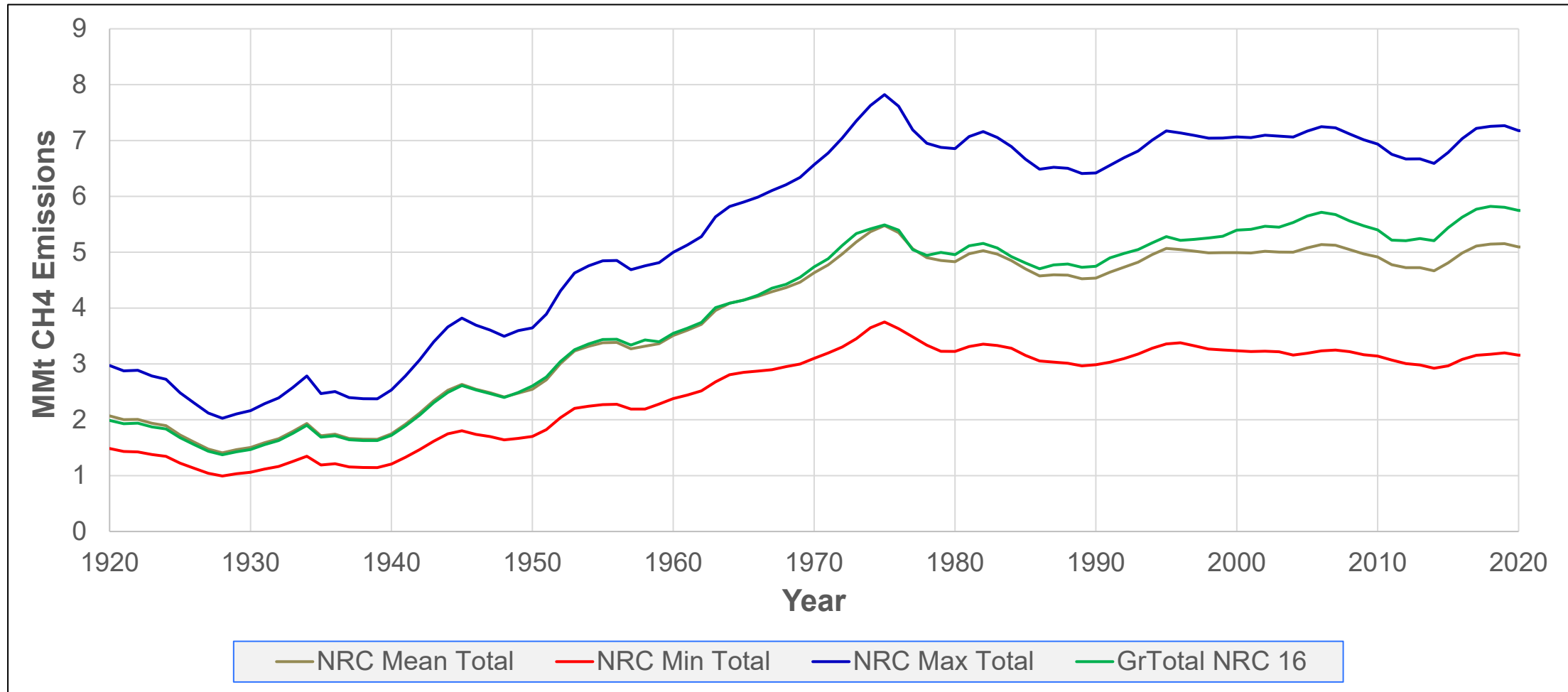
METHANE EMISSIONS FACTORS, FEEDLOT



NON-CONSTANT EMISSIONS FACTORS...

Region	Type	Emissions Factor			Relative Values (NA)	
		<u>2006</u>	<u>2019</u>	<i>% Change</i>	<u>2006</u>	<u>2019</u>
N. Am.	All beef	53	64	20.8%	0.0%	0.0%
W. Europe	Bulls, Calves, Grow	57	52	-8.8%	7.5%	-18.8%
E. Europe	Beef	58	58	0.0%	9.4%	-9.4%
Oceania	Other	60	63	5.0%	13.2%	-1.6%
Latim Am.	Beef	56	56	0.0%	5.7%	-12.5%
Asia	Beef	47	54	14.9%	-11.3%	-15.6%
Africa	Multi-purpose	31	52	67.7%	-41.5%	-18.8%
India	Non-dairy	27	46	70.4%	-49.1%	-28.1%
Mid. East	Non-dairy	31	60	93.5%	-41.5%	-6.3%

TIER 3 - A BETTER ESTIMATOR?



TECHNICAL LIMITATION 2: ASSESSING METHANE IMPACT

Potency of methane

- Based on radiative efficiency (molar)
- Pulse dose impact relative to pulse dose impact of CO₂, translated to mass

Temperature impacts

- Driven primarily by concentration in atmosphere
- Change in concentration is not a linear accumulation of emissions

ASSESSING METHANE IMPACT

A Sample of Metrics...

- **“Radiative forcing”**
 - ✓ Energy disruption caused by a unit addition of a given gas
 - ✓ Each is different
- **Global Warming Potential (GWP_H)**
 - ✓ RF of a pulse emission of a given gas over specified time (H)
 - ✓ Expressed relative to the same mass of CO_2
 - ✓ NOT temperature
- **Global Temperature Potential (GTP_H)**
 - ✓ Model based, predicts temperature change at time H
 - ✓ More direct than GWP, but more uncertain
 - ✓ Time sensitive

ASSESSING METHANE IMPACT

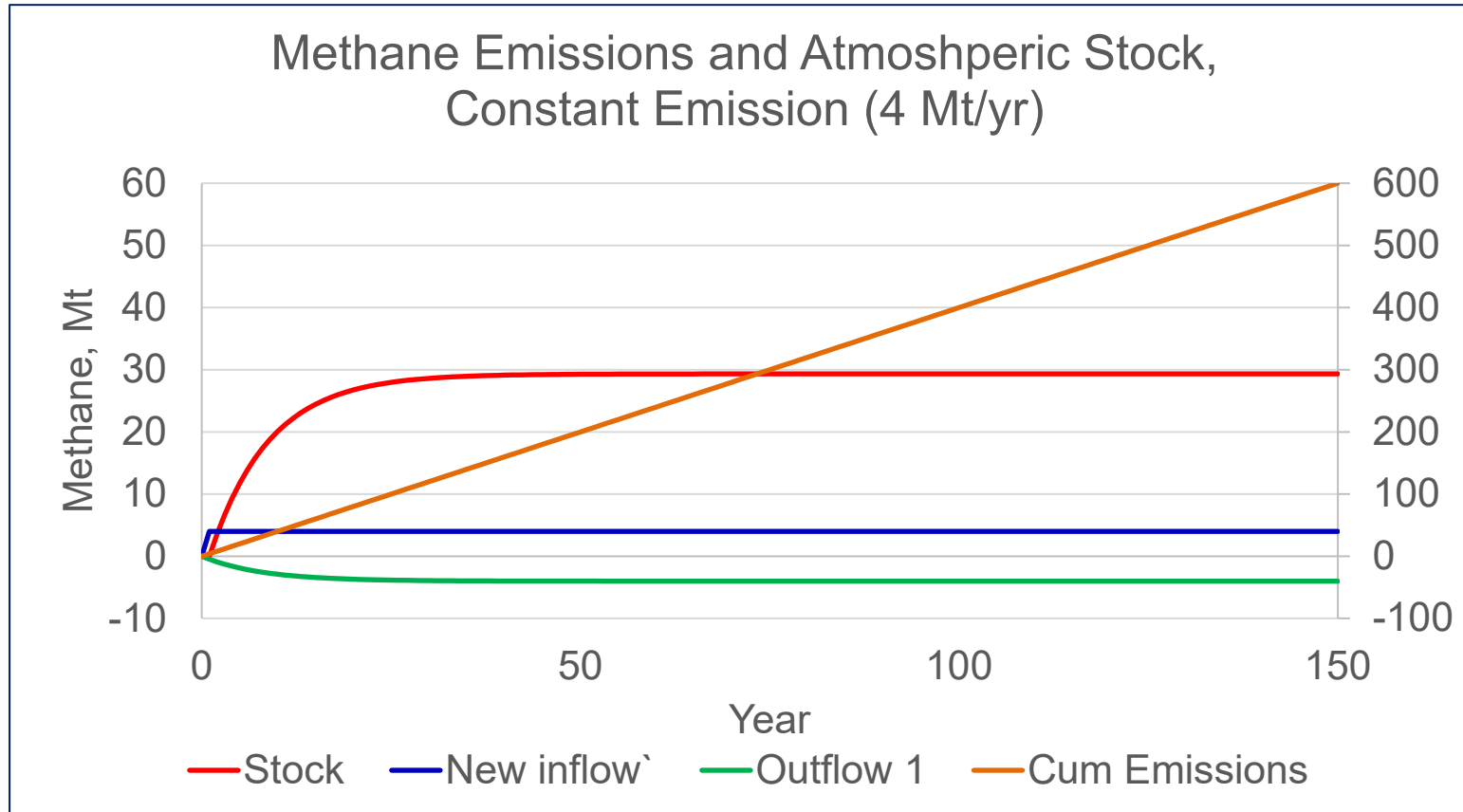
Metrics evaluate emissions, not atmospheric concentrations

- Assumes that emissions are the driving force
- Creates time-based distortion
 - ✓ Especially for gases with atmospheric life < H

GWP₁₀₀ has become the de facto standard

- Used for emissions reporting
- Changes as atmosphere changes
- This is the one you likely associate with 'CO₂ equivalents'
- Has been widely critiqued, esp. for short-lived gases

Cumulative emissions not the same as atmospheric concentration...



...and a metric based solely on emissions of methane will overestimate its effects

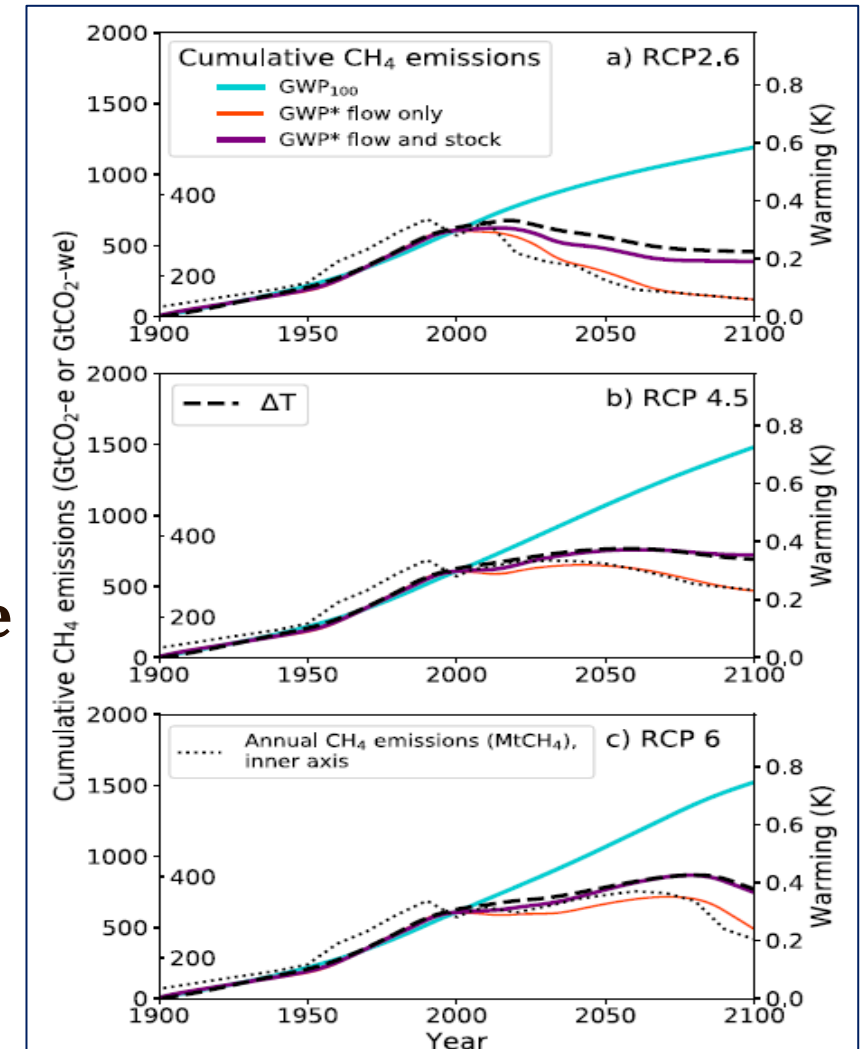
GWP* (*GWP-STAR*)

A better metric?

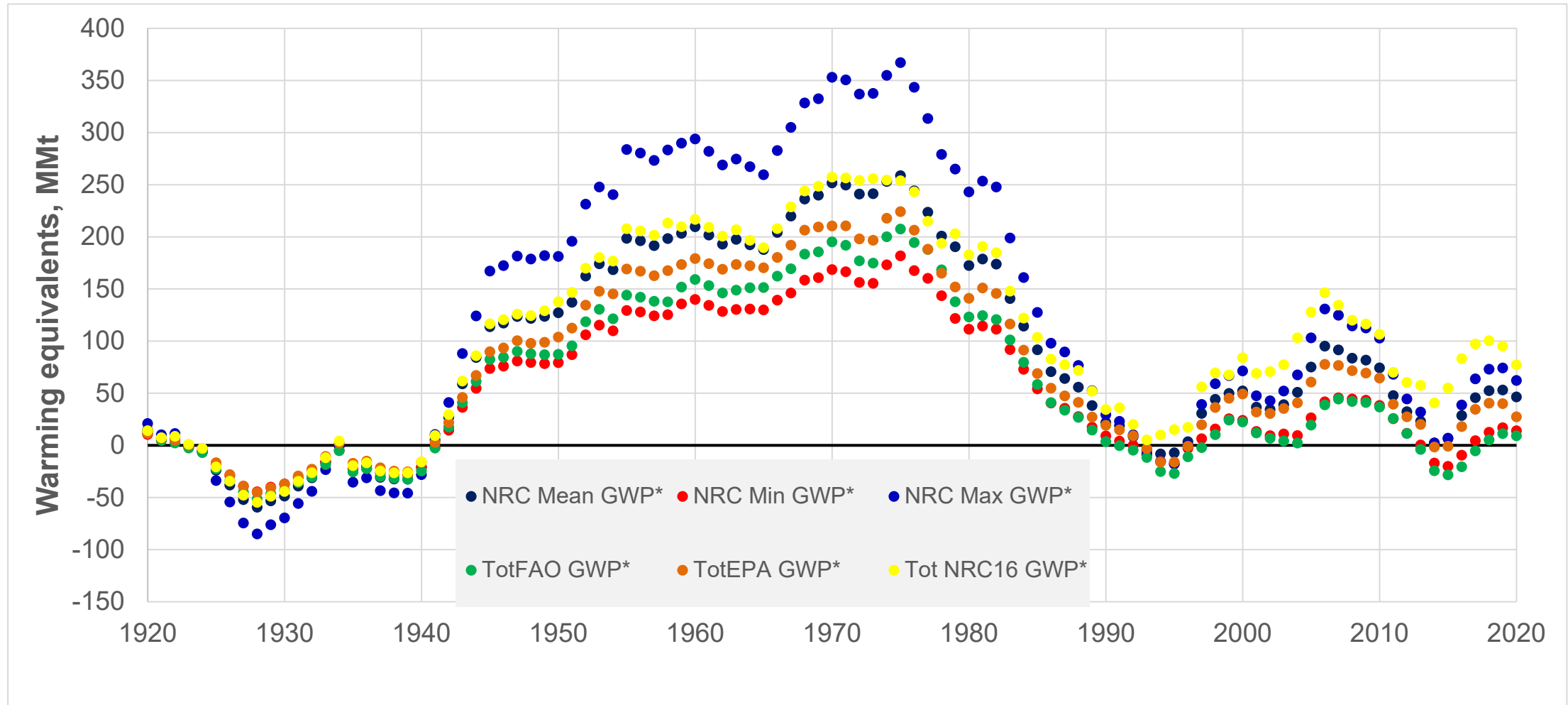
- Designed to account for decay of short-lived gases?
- Results in better approximation of *temperature* effects
- Uses GWP₁₀₀ to make translation straightforward
- Expressed as ‘warming equivalents’
- Designed to estimate effect of ‘new’ emissions that are ongoing

Based on the *change* in emissions rate over time

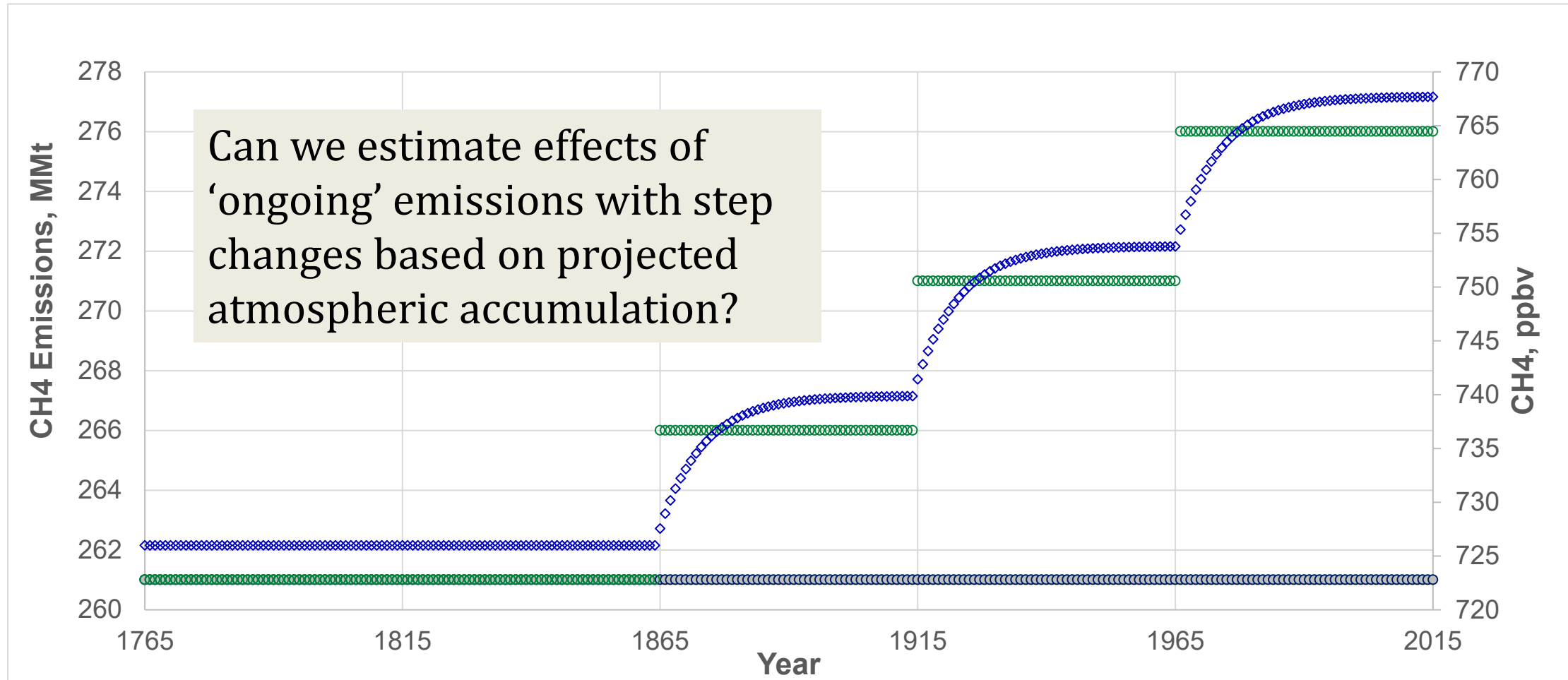
$$E_{Co2-w.e.} = \left(r \times \frac{\Delta E_{slcp}}{\Delta t} \times H + s \times E_{slcp} \right) \times GWP_H$$



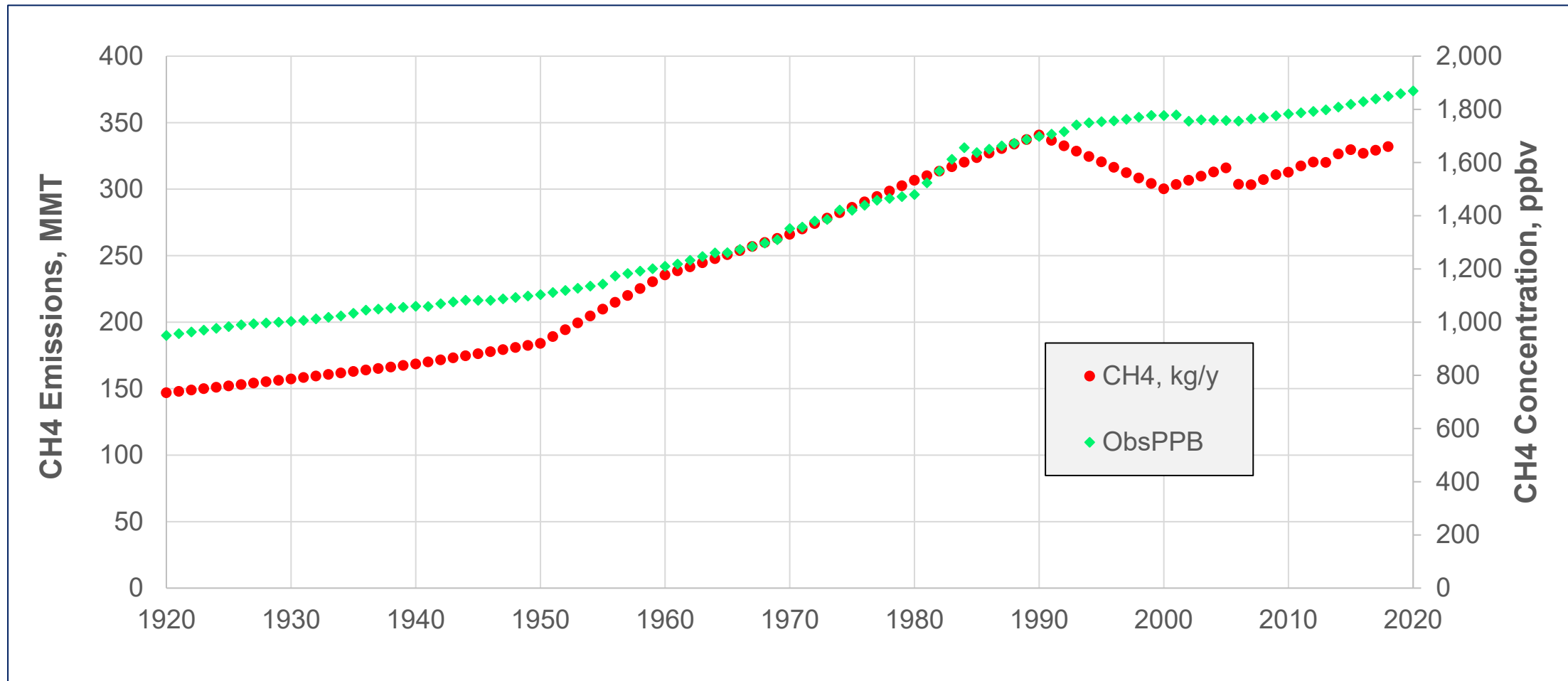
HOW MUCH MITIGATION IS REQUIRED?



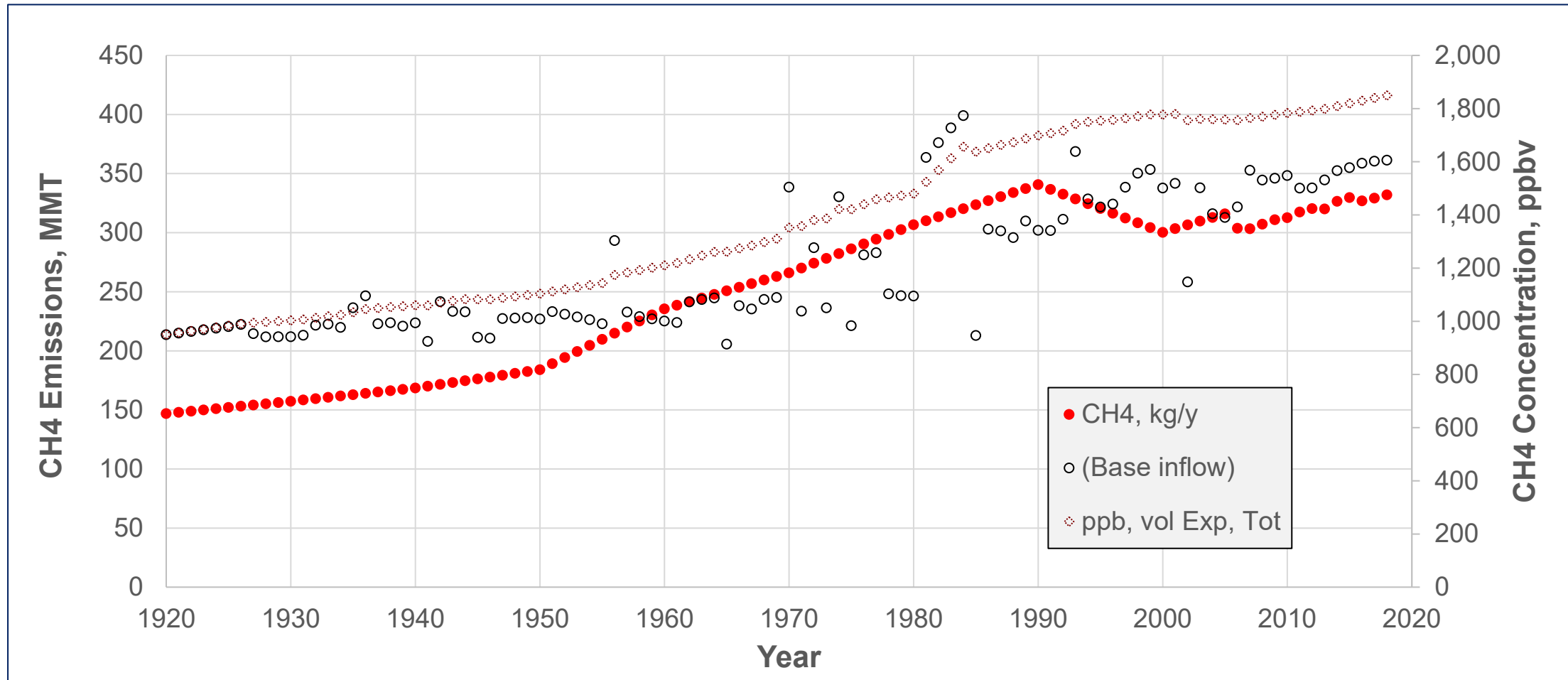
METHANE EMISSIONS AND EQUILIBRIUM



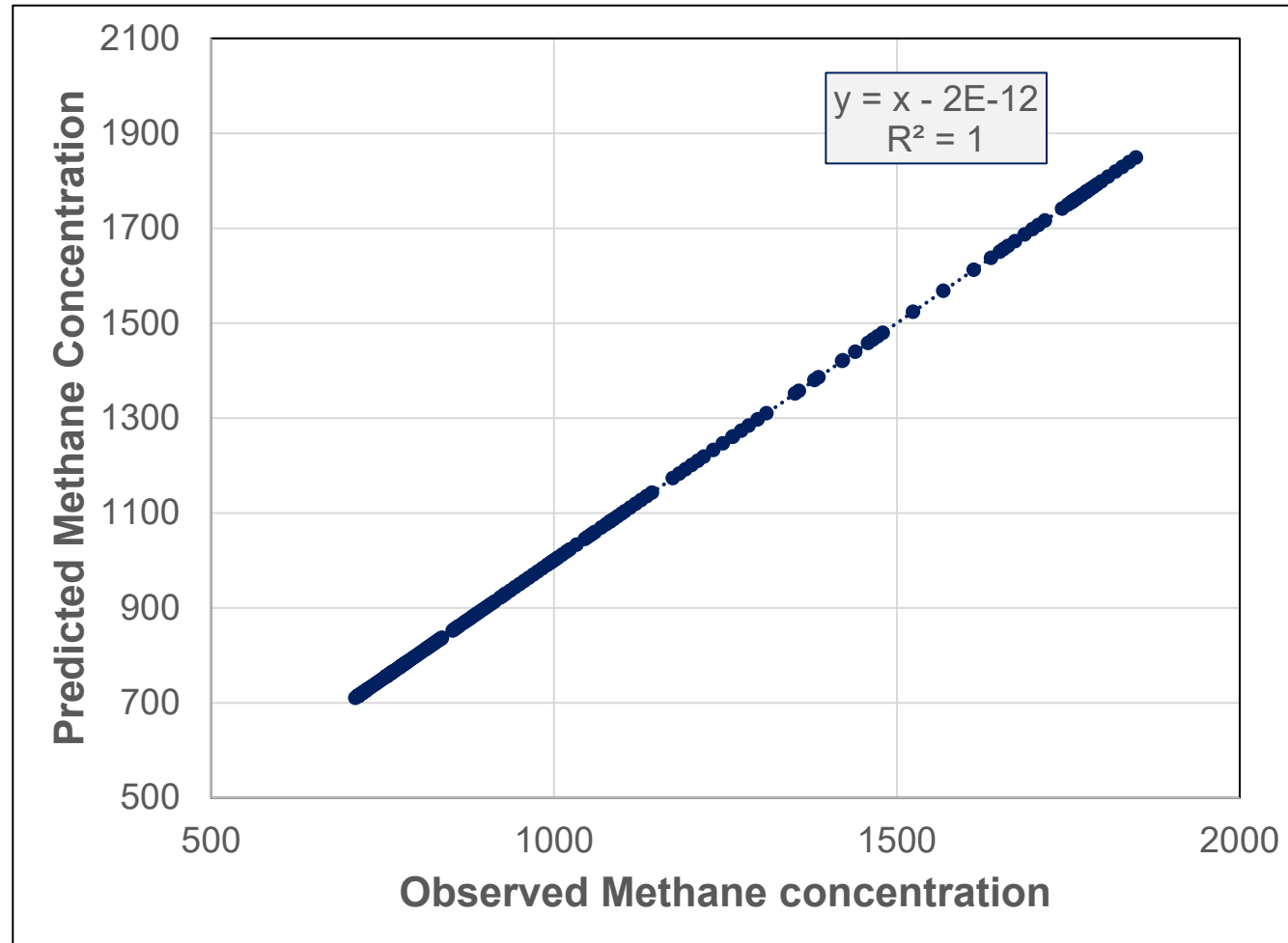
METHANE EMISSIONS (RCP) AND ACCUMULATION



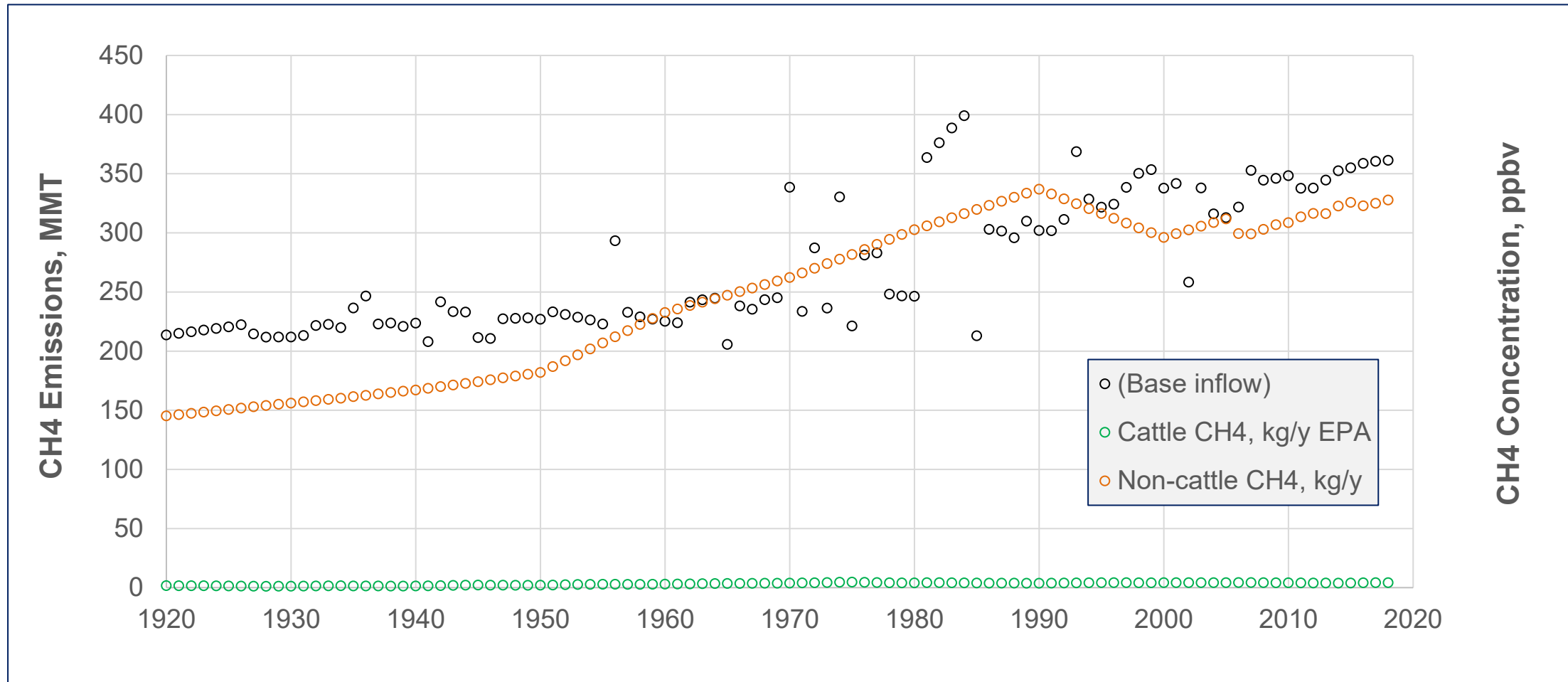
METHANE EMISSIONS AND ACCUMULATION



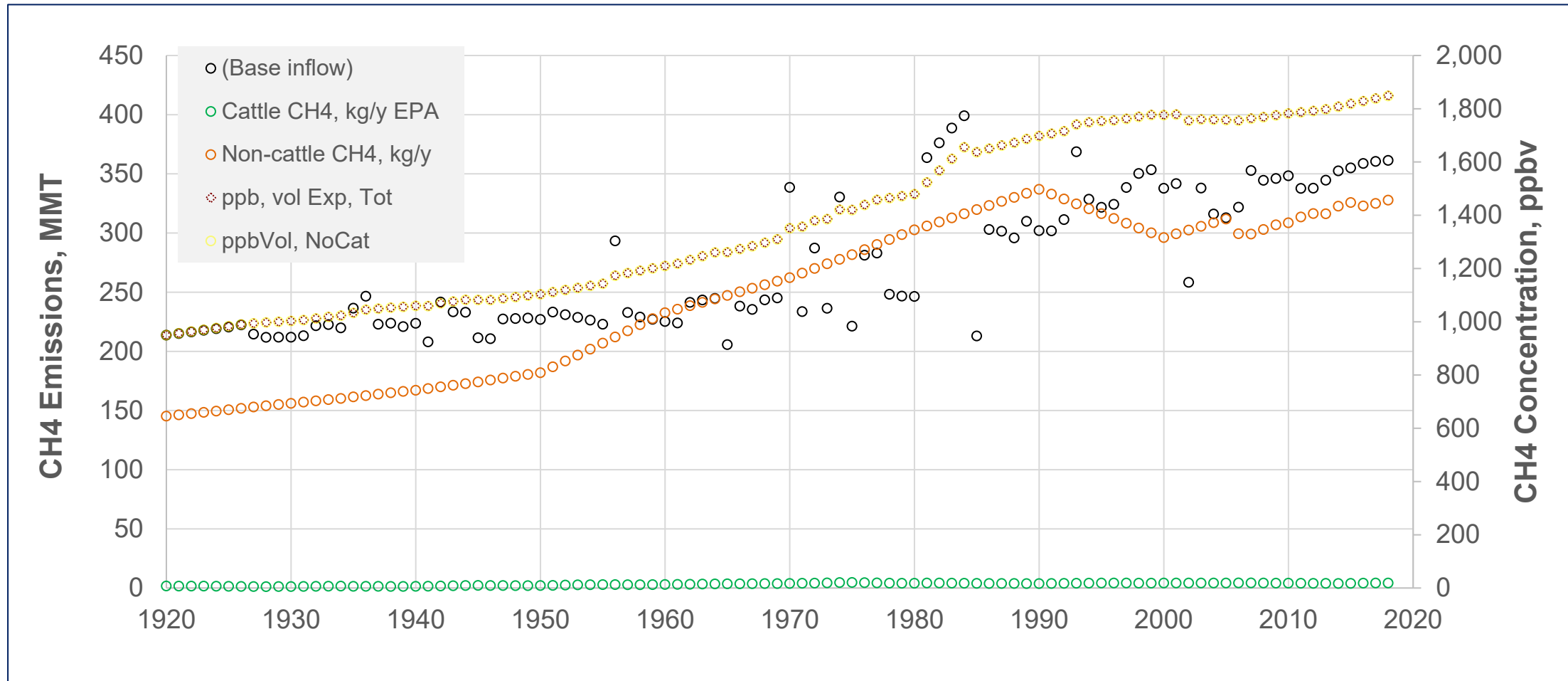
METHANE ACCUMULATION MODEL



METHANE EMISSIONS AND ACCUMULATION



METHANE EMISSIONS AND ACCUMULATION



OPPORTUNITIES

Better definition of total emissions

- Better characterization of beef systems
- Clearer prioritization of mitigation efforts

Better assessment of emissions impact

- Improved understanding of gap to climate neutral
- Appropriate characterization of beef systems

Direct modeling of warming effects

- Atmospheric accumulation versus emissions
- Clearer understanding of the sustainability of systems and tradeoffs

THANKS!