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Tuning the IPCC GWPs: Time Correction Factors & Time Adjusted Warming Potentials

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Goals

1. Develop a CO_2e metric that includes timing
   - Keeping the 'CO_2e' units to facilitate adoption
2. Develop an easy way for practitioners and policymakers to calculate this new metric

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Background

- Earlier proposals (by me) for time correction, each tailored to different problems and representing different evolutions in my thinking:
  - TCF (time correction factor for amortized upfront emissions, fixed analytical time horizon)
  - pTCF and rTCF (production and recycling time correction factors for amortized emissions, for various analytical time horizons)
  - TAWP (Time-adjusted warming potential yielded CO2e equivalent 'today' for various analytical time horizons)

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GWP Alternatives – the TCF

- A simple scaling
- Rather than a **reference gas** (CO_2), the TCF calculates relative potential based on a **reference time**

$$TCF_{TH_A} = \frac{\int_0^{TH_A} RF_{Total}\,dt}{\sum_{i=0}^{TH_A}\left(\int_i^{TH_A} RF_{Total/TH}\,dt\right)}$$

TH_A = Time Horizon of Amortization

Source: Kendall, A., Chang, B., Sharpe, B. (2009) "Accounting for Time-Dependent Effects in Biofuel Life Cycle Greenhouse Gas Emissions Calculations" *Environmental Science & Technology* 43(18) 7142–7147

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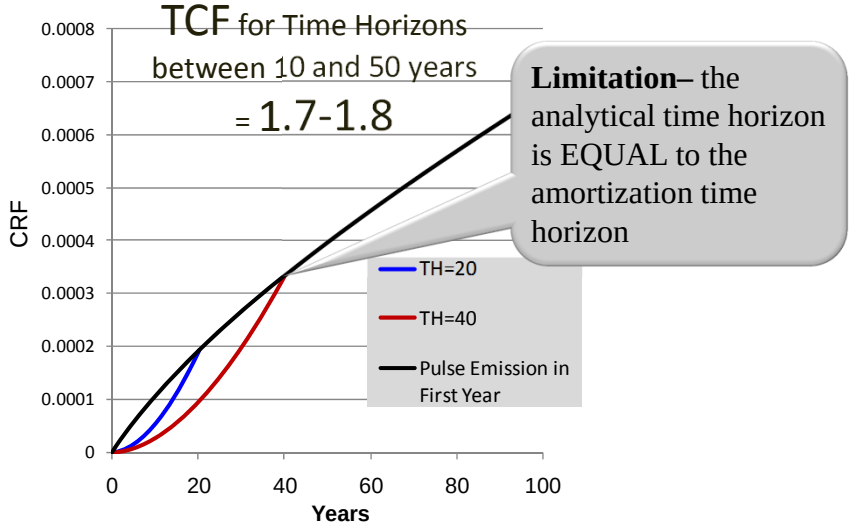
Effect of Applying TCF to Amortized Emissions



Source: Kendall, et al. (2009)

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2nd Generation TCFs – the pTCF and rTCF

- Next-generation Time Correction Factors (TCF) developed with the same principles used to calculate GWP
- In addition to a **reference gas** (CO_2), the TCF calculates relative potential based on a **reference time and any analytical time horizon**

AT = Analytical Time Horizon
TH_A = Time Horizon of Amortization

$$pTCF_{AT} = \frac{\int_0^{AT} RF_{Total}\,dt}{\sum_{i=0}^{TH_A}\left(\int_i^{AT} RF_{Total/TH_A}\,dt\right)}$$

Source: Kendall and Price (2012)

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Implementing a production time correction factor (pTCF) and a recycling time correction factor (rTCF)

$$\frac{gCO_2e}{mile} = \left(\frac{G_{prod} \times pTCF + G_{use} + G_{rec} \times rTCF}{LifetimeVMT} \right)$$

GHG_{prod}= GHG (g CO_2e) emissions attributable at the time of vehicle production
GHG_{use}= GHG (g CO_2e) attributable to vehicle use, such as fuel combustion, assumed to be constant over the service life
GHG_{rec} = GHG (g CO_2e) emissions attributable at the time of vehicle end-of-life (for vehicles dominated by recycling credits)

Source: Kendall and Price (2012)

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Life cycle emissions intensity (g CO_2e/km, g CO_2e/mi shown in parentheses)

	Description	HD 2020 Vehicle				
		Prod	Use	EOL	*Total*	% Use
16-year service life	no time correction	66 (106)	131 (211)	-25 (-39)	172 (278)	**76%**
	100-year time correction	70 (113)	131 (211)	-23 (-37)	178 (287)	**74%**
	30-year time correc			-28)	198 (309)	66%
	30-year time correctio			28)	172 (267)	61%
11-year service life	no time correctio			51)	184 (297)	71%
	100-year time corre			49)	189 (305)	**69%**
	30-year time correction	99 (160)	131 (211)	-26 (-42)	204 (329)	**64%**
	30-year time correction, LCF	99 (160)	105 (169)	-26 (-42)	178 (286)	59%

Conclusion: Timing not important, but life cycle emissions are!

Source: Kendall and Price (2012)

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How about non-amortized emissions?

- The TCFs are tailored to amortized emissions only
- If we are simply concerned with emissions occurring over some time horizon, but want to consider the equivalent CO_2e today…we need a different metric

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Time Adjusted Warming Potential (TAWP)

$$GWP = \frac{\int_0^{AT} RF_i dt}{\int_0^{AT} RF_{CO_2} dt} = \frac{CRF_i}{CRF_{CO_2}}$$

Emission occurring **y** years in the future

$$TAWP = \frac{\int_0^{AT-y} RF_i(t) dt}{\int_0^{AT} RF_{CO_2}(t) dt}$$

Source: Kendall (Accepted)

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How is this useful

- If a tree sequesters approximately 40 kg CO_2 per year for 50 years, how much sequestration credit should it receive?

- Thus when comparing the value of different sequestration credits, timing may play an important role in determining preferences for one strategy over another.

Source: Kendall (Accepted)

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Calculation tool and Current Publications

- A TAWP calculation tool will be available online...
- The 1st and 2nd Generation TCFs, and TAWPs are documented in:
  - Kendall, A., Chang, B., Sharpe, B. (2009) Accounting for Time-Dependent Effects in Biofuel Life Cycle Greenhouse Gas Emissions Calculations. *Environmental Science and Technology*. 43: 7142–7147
  - Kendall, A, Price, L. (2012) Incorporating Time-Corrected Life Cycle Greenhouse Gas Emissions in Vehicle Regulations. *Environmental Science and Technology*. 46: 2557-2563
  - Kendall, A. (Accepted) "Time-adjusted global warming potentials for LCA and carbon footprints" *International Journal of Life Cycle Assessment*. DOI: 10.1007/s11367-012-0436-5