Potsdam-Institut für Klimafolgenforschung

Economic evaluation of climate metrics: A conceptual framework

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Motivation

- Change of perspective: an economy-based approach
- Many alternative metrics have been proposed – how can we structure them?
- What are implicit value judgements of alternative metrics?
- What are relevant trade-offs in metric choice?

Framing metrics in economic terms

Overarching question: What is the (marginal) utility of the abatement of a non-CO_2 forcing agent X vs the abatement of CO_2?

$$M_x = \frac{MU_x}{MU_{CO2}} = \frac{AM_x}{AM_{CO2}}$$

By using metrics in an economic context (e.g. emissions trading) explicit or implicit assumptions about the marginal utility of abatement are made

General formulation of a climate metric

Most general form of an absolute metric:

$$AM_x = \int_0^{\infty} \frac{\Delta I}{\Delta E} W(t)\, dt$$

Impact function *I*:
Relation to physical climate parameters

Weighting function:
Aggregation of impacts over time

Basic idea: Make use of this general structure to classify metrics and to reveal implicit assumptions

Examples

Global Warming Potential **(GWP)**

$$AM_{GWP} = \int_0^H \frac{\Delta RF}{\Delta E}\, dt$$

Global Temperature Potential **(GTP)**

$$AM_{GTP} = \frac{\Delta T(t_x)}{\Delta E}$$

Global Damage Potential **(GDP)**

$$AM_{GDP} = \int_0^\infty \frac{\Delta D}{\Delta E}\, e^{-rt}\, dt$$

Special case: cost-effectiveness approach

Global Cost Potential **(GCP)** as metric that allows a prescribed climate target at least costs (cost-effectiveness approach)

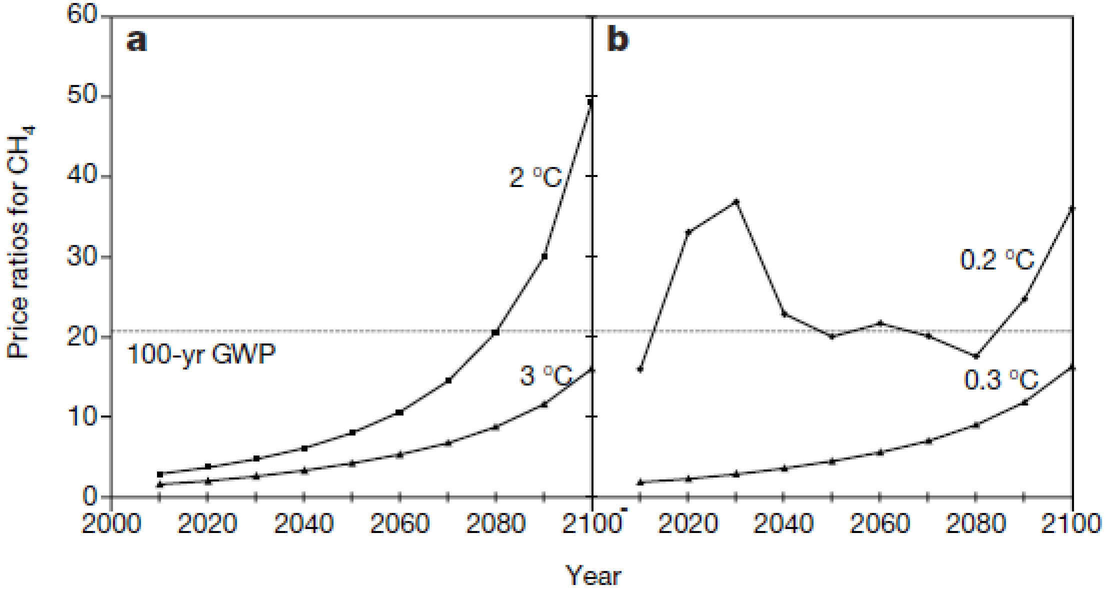
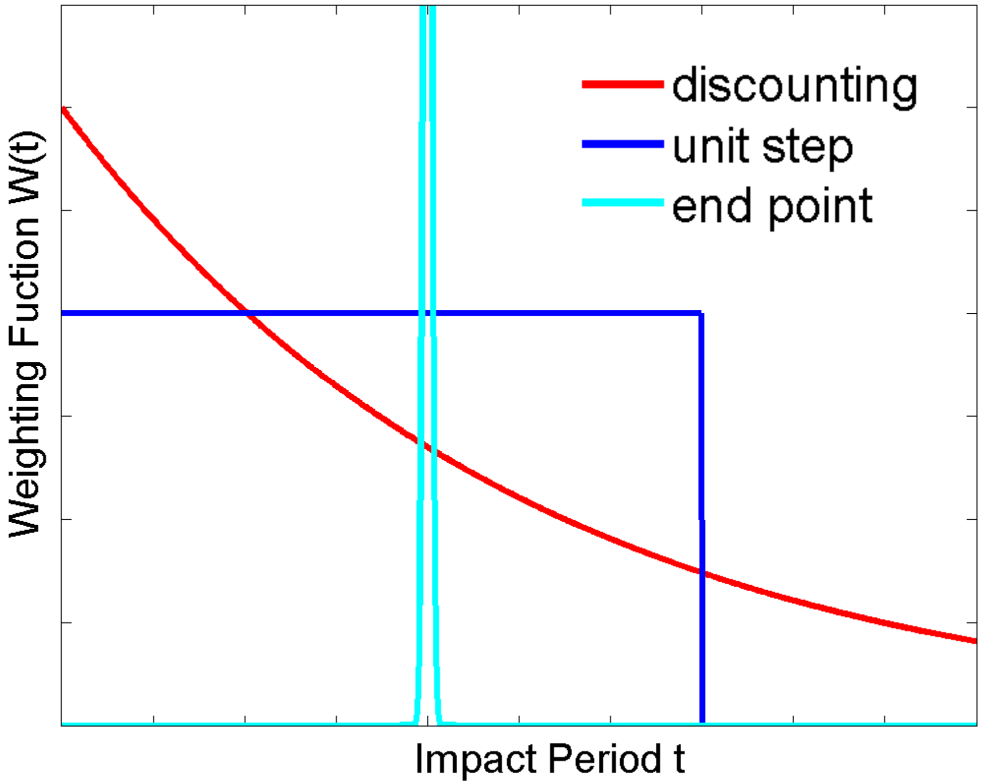


Figure 2 The prices of CH_4 and N_2O relative to that of CO_2 under alternative constraints on absolute and decadal temperature change. **a**, **c**, Prices of CH_4 and N_2O relative to that of CO_2 when the ceiling is on absolute temperature change. **b**, **d**, The corresponding results when a rate of change constraint is added. GWP, global warming potential.

Manne and Richels (2001)

Alternative temporal weighting functions



Discounting:
e.g. GDP, EGWP

Unit Step function
e.g. GWP, MGTP

End point metric
e.g. GTP

Impact functions

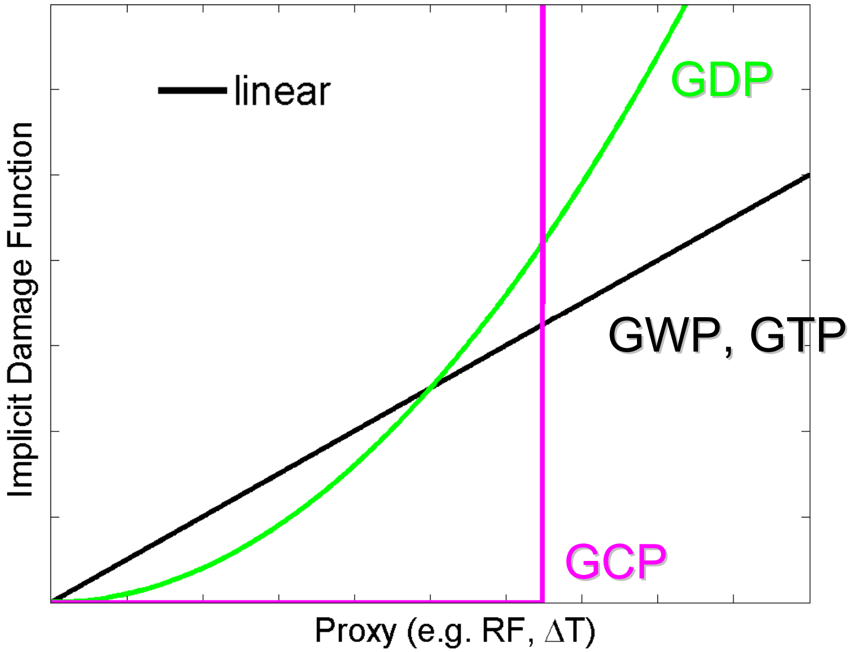
Establish relationship to physical impact proxies

Characterized by

•Physical climate proxy,
e.g. RF, ΔT, ∂T/∂t

•functional relationship between to physical climate proxy

•Background assumptions

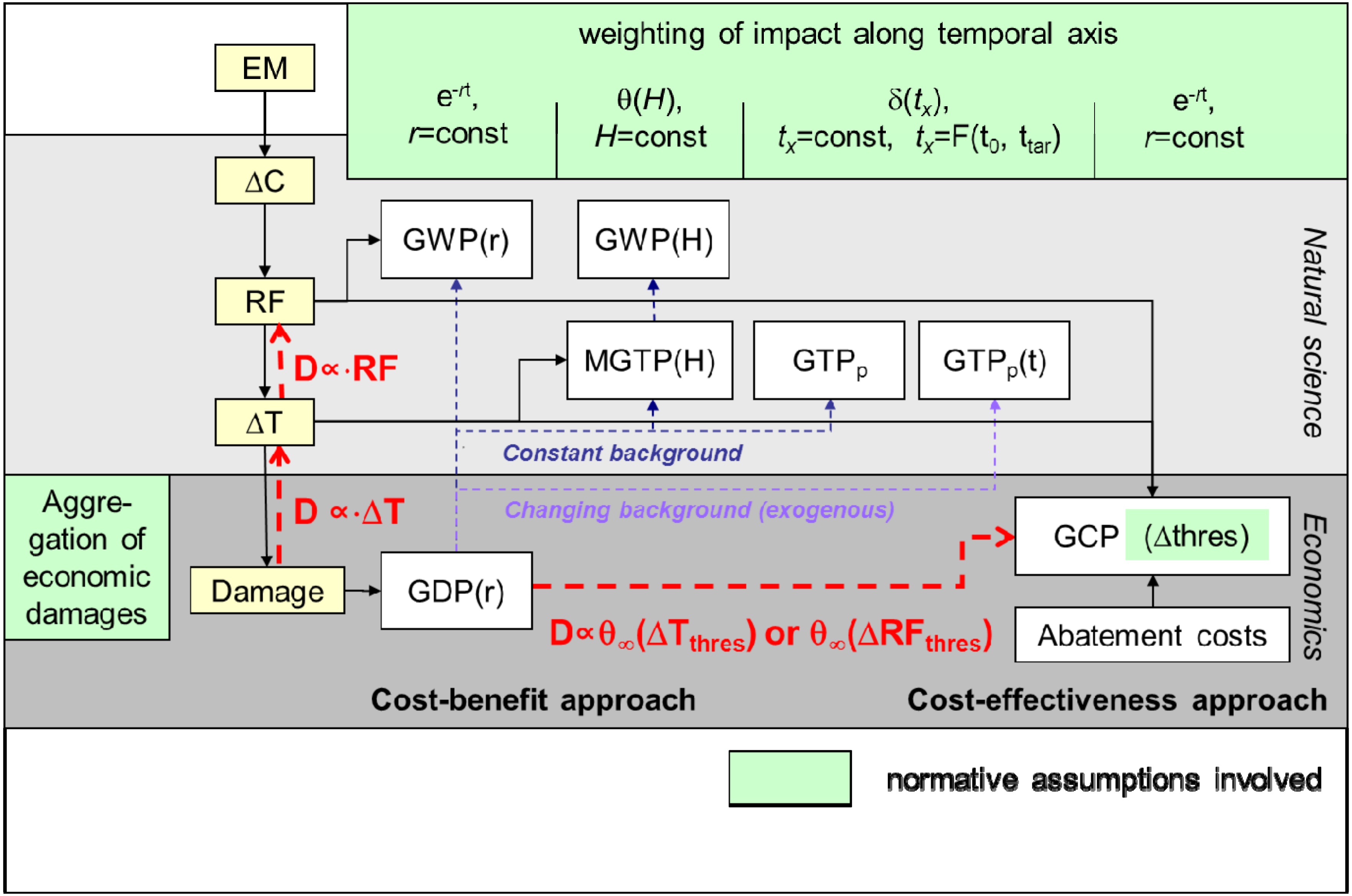


Classification of climate metrics according to conceptual framework

Impact function *I*			Weighting function *W*		
	Implicit Damage function	Atmospheric background $(\vec{C}_{ref}, specification)$	Discounting *dicount rate r*	constant $(\theta - function)$ *time horizon H*	End point *(Dirac function)* *end point tx*
D	$D = f(\Delta T)$	scen, *exogenous*	**GDP**		
ΔT	$D = \theta_{\infty}(\Delta T - \Delta T_{thres})$	const,	**GCP(T)**		
	$D \propto \Delta T$	const, *ref(t* $_0$*)*		**MGTP**	
	$D \propto \Delta T$	scen, *exogenous*			**GTP**
	$D \propto \Delta T$	scen, *historical*		**TEMP**	
ΔRF	$D = \theta_{\infty}(\Delta RF - \Delta RF_{thres})$	scen, *endogenous*	**GCP(RF)**		
	$D \propto \Delta RF$	scen, *ref(Øfuture)*	**GWP(r)**		
	$D \propto \Delta RF$	const, *ref(t* $_0$*)*		**GWP(H)**	
	$D = \gamma \cdot \Delta RF + \omega \cdot \partial RF / \partial t$	const, *ref(t* $_0$*)*	**EGWP**		
	$D \propto \Delta RF$	scen, *historical*		**FEI**	

GDP *Kandlikar 1996, Hammitt 1996*
GCP(T) *Manne & Richels 2001*
GCP(RF) *Van Vuuren et al. 2006*
GTP *Shine et al. 2005, 2007*
MGTP *Gillett and Matthews 2010*
GWP(r) *Lashof and Ahuja 1990,*
GWP(H) *IPCC 1990*
TEMP *Tanaka et al. 2009*
EGWP *Wallis 1994*
FEI *Manning and Reisinger 2011*

Interrelation between selected approaches



Metric choice and uncertainty

Types of uncertainties

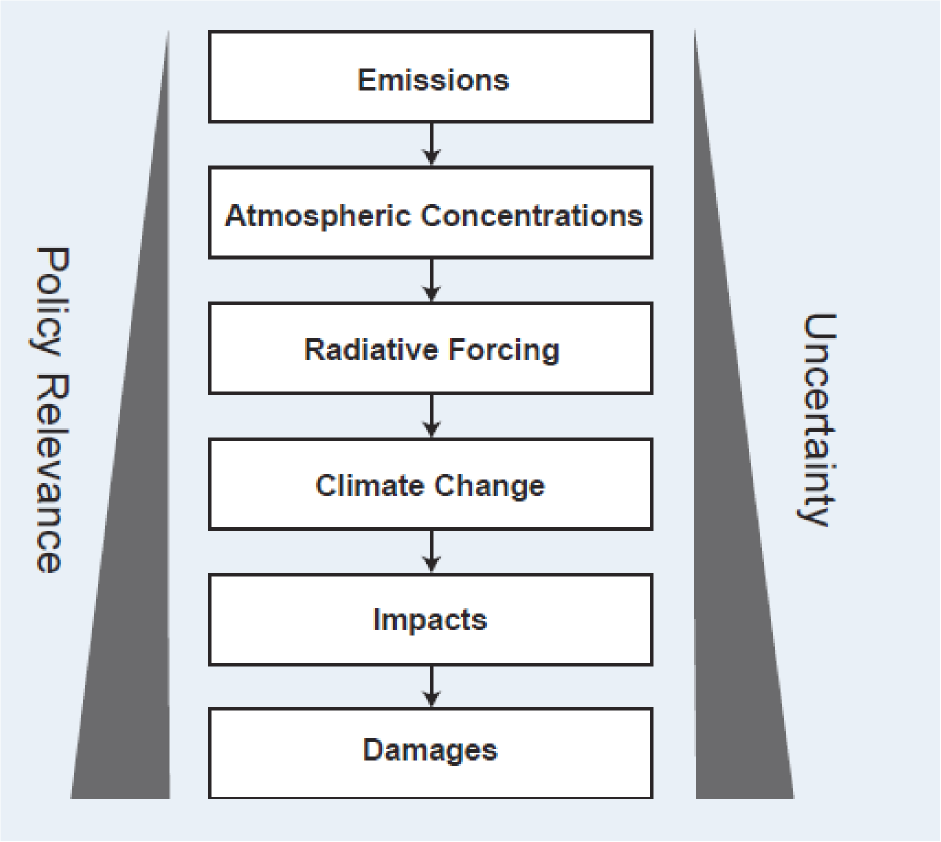
- **Scientific:** **uncertainty in knowledge about chain of impacts**
- **Value-based:** **degree to which normative value judgements are involved**
- **Scenario:** **degree to which metric depends on future state of the world**
- **Structural:** **degree to which real world trade-off is presented**

Qualitative uncertainty assessment of in commonly used metric approaches

Metric approach	*explicit uncertainties*			*implicit uncertainties*
	scientific	value-based	scenario	structural
Global Warming Potential	●	●●	●	●●●●●●
Global Temperature Potential	●●	●●	●●	●●●●
Global Cost Potential (RF)	●●	●●●	●●	●●●
Global Cost Potential (T)	●●●	●●●	●●	●●
Global Damage Potential	●●●	●●●●	●●	●
	Increasing ***operationalizability*** *with decreasing uncertainty*			*Increasing* ***policy relevance*** *with decresing structural uncertainty*
	Implications for policy applications			

→ Trade-off between structural uncertainties on the one hand, and scientifc, value-based, scenario uncertainties on the other hand

Uncertainty



IPCC (2009)

Conclusions

- **Any metric application in economic contexts (e.g. emissions trading) makes explicit or implicit assumptions about the marginal utility of emission abatement of different gases**
- **The impact function and temporal weighting function can be used to categorize alternative metrics and to make value judgements explicit**
- **Most metrics can be constructed as special cases or simplified versions of the Global Damage Potential**
- **There is a trade-off between policy relevance and operatonalizability**