Global Temperature change Potential compared to Global Warming Potential

Background

Global Warming Potential (GWP) has been used to quantify and communicate the relative and absolute contributions to climate change of emissions of different substances, and of emissions from regions/countries or sources/sectors. Thus the Kyoto Protocol uses GWPs to enumerate reductions in greenhouse gas emissions in terms of their equivalence in carbon dioxide emissions. Furthermore, the facility to use GWPs to weight contributions from different emissions of a basket of gases during the performance of a particular activity enables informed choices between technical options and selection of those with minimum overall climate impact.

GWP is defined as the increase in radiative forcing (RF) of the emission of one kilogram of the subject gas, relative to the increase in RF from release of one kilogram of carbon dioxide at the same time. Changes in radiative forcing drive climate change but the relationship is not simple, there are many environmental interactions (including feedbacks), and the calculation of global temperature change resulting from changes in radiative forcing requires complex mathematical models.

Because there are many processes that remove carbon dioxide from the atmosphere, some of which have environmental lifetimes in excess of 10,000 years, GWP is integrated over a specific time horizon and the Kyoto Protocol uses the 100 year values.

Compared to GWP, the Global Temperature change Potential (GTP) goes one step further down the cause-effect chain and is defined as the change in global mean surface temperature at a chosen point in time in response to an emission pulse — relative to that of carbon dioxide. While GWP is integrated in time, GTP is an end-point metric which is based on temperature change for a selected year. Thus GWP integrates the effects up to a chosen time horizon, giving equal weight to all times up to the horizon and zero weight thereafter, but GTP gives the temperature just for one chosen year with no weight on years before or after.

By accounting for the climate sensitivity and the exchange of heat between the atmosphere and the ocean, the GTP includes physical processes that the GWP does not. However, this makes it sensitive to atmospheric modelling assumptions about the climate sensitivity and heat-uptake by the ocean. There are significant uncertainties related to both GWP and GTP and the relative uncertainties are much larger for GTP; there are additional contributions from it being further down the driver-response-impact chain and from the inclusion of climate response.

Uncertainty

For an individual greenhouse gas there are uncertainties in lifetime and radiative efficiency, both of which are discretely measurable values. For the reference gas, carbon dioxide, which does not have a measurable single atmospheric lifetime, the uncertainty is dominated by uncertainties in the impulse response function (IRF) that describes the development in atmospheric concentration that follows from an emission pulse. The IRF is sensitive to model representation of the carbon cycle, pulse size and background carbon dioxide concentrations and climate.

Based on a multi-model study, the uncertainty in the absolute GWP for carbon dioxide is estimated to be ±26% over 100 years. This uncertainty affects all metrics that use carbon dioxide as reference, that is both GWP and GTP, but for GTP there are additional contributions from the parameters describing the ocean heat uptake and climate sensitivity. Consequently, the uncertainty in absolute GTP is ±90% at 100 years.

Values for Greenhouse Gases (particularly Fluorocarbons)

	Lifetime Years	**GWP 100 yrs**	GTP at 20 years	GTP at 50 years	GTP at 100 years
Carbon dioxide	up to 20000	**1**	1	1	1
Methane	12.4	**28**	67	14	4
Nitrous Oxide	121	**265**	277	282	234
CFC-11	45	**4660**	6890	4890	2340
CFC-12	100	**10200**	11500	11000	8450
CFC-13	640	**13900**	11700	14200	15900
CFC-113	85	**5820**	6750	6250	4470
CFC-114	100	**8590**	8190	9020	8550
CFC-115	1020	**7670**	6310	7810	8980
HCFC-22	11.9	**1760**	4200	832	262
HCFC-123	1.3	**79**	95	14	11
HCFC-124	5.9	**527**	1120	121	71
HCFC-141b	9.2	**782**	1850	271	111
HCFC-142b	17.2	**1980**	4390	1370	356
HCFC-225ca	1.9	**127**	170	22	18
HCFC-225cb	5.9	**525**	1110	120	73
HFC-23	222	**12400**	11500	15000	12700
HFC-32	5.2	**677**	1360	145	94
HFC-125	28.2	**3170**	5800	2980	967
HFC-134a	13.4	**1300**	3050	703	201
HFC-143a	47.1	**4800**	6960	5060	2500
HFC-152a	1.5	**138**	174	24	19
HFC-227ea	38.9	**3350**	5280	3440	1460
HFC-236fa	242	**8060**	7400	8400	8380
HFC-245fa	7.7	**858**	1970	245	121
HFC-365mfc	8.7	**804**	1890	262	114
HFC-43-10mee	13.1	**1650**	3720	1070	281
(Z)-HFO-1225ye	8.5days	**0**	0	0	0
(E)-HFO-1225ye	4.9days	**0**	0	0	0
(Z)-HFO-1234ze	10days	**0**	0	0	0
HFO-1234yf	10.5days	**0**	0	0	0
(E)-HFO-1234ze	16.4days	**1**	1	0	0
(Z)-HFO-1336	22days	**2**	2	0	0
HFO-1243zf	7days	**0**	0	0	0
HFO-1345zfc	7.6days	**0**	0	0	0
SF_6	3200	**23500**	18900	23800	28200

The table reproduces the values calculated for GWP and GTP reported by Working Group I in the Fifth Assessment Report of IPCC (available at *http://www.ipcc.ch/report/ar5/wg1/*).

General conclusions concerning comparisons between the metrics are that:

- for gases with atmospheric lifetimes less than a few decades (including most of the useful HFCs), the numerical value of GTP at 100 years is much less than that of the GWP over 100 years,
- similarly, for gases with lifetimes longer than about 250 years, the GTP number at 100 years is greater than the GWP number and
- gases with very short lifetimes (for example, the HFOs) have GWP and GTP values that are zero or very small.

Conclusion

Given that both GWP and GTP are orientated towards providing information for policies, there seems little to be gained and much to be lost by changing from the relatively familiar concept of GWP, which is a specific property of an individual gas and can be used both to rank emissions of individual gases (relative to one another) and to calculate the total climate change impact from all greenhouse gas emissions. The physics underlying the calculation of GWP are well understood for most greenhouse gases, the exception being carbon dioxide, where the range of atmospheric removal processes adds complication and uncertainty. However, since carbon dioxide is the reference gas, changes in understanding of its removal processes affect all greenhouse gas GWPs (and GTPs) similarly.

GTP, on the other hand is highly uncertain and dependent on the vagaries of climate modelling with differing interpretations of synergies and feedbacks. Due to this, the policy relevance of the numbers generated is questionable; the fact that they could be subjected to large changes over time carries the problem that decisions made on the basis of GTP alone could become irrelevant or even counterproductive, exacerbating the consequences for climate. Nor does GTP offer an advantage over GWP when attempting to differentiate technical options; in fact the much greater uncertainty of GTP and its focus on a rather arbitrary end point mitigate against its use in, for example, life cycle analysis.

Unlike GWP, it is not clear that adding GTP weighted emissions together would produce a meaningful result. It is claimed that GTPs could be relevant where the policy is in the form of a target for the increase in temperature. Not only does this place the focus on only one aspect of climate change, it would require a mechanism to link GTP to an actual temperature increase. While this would be possible using the Absolute GTPs for the gas, these are not the numbers that are quoted.

In short, GWP, with its focus on radiative forcing, is a relatively stable parameter that can produce policy relevant results in the form of CO_2equivalent emissions. These values provide "portable" input parameters for climate models so that impacts on, for example, global temperature, precipitation and sea level can be calculated in a way that does not confuse differences in the models with changes in the emissions. Even though the actual values for GTP will place a greater emphasis on carbon dioxide emissions than GWPs do, GTP seems a step too far down the cause-effect chain.