Projected global warming under a worldwide climate policy following Switzerland's example

Scenario study on request by Greenpeace Switzerland

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1 Introduction and Summary

Switzerland has proposed to reduce greenhouse emissions to at least 20% below its 1990 levels by 2020. Greenpeace Switzerland is concerned that this target is insufficient, given the findings by IPCC that emissions by developed countries need to be reduced to 25-40% below 1990 by 2020 to keep global warming limited to 2°C above pre-industrial. In addition, there is as yet no confirmed Swiss position on a 2050 emission reductions goal for itself. The European Union on the other hand has adopted a goal of 80-95% reductions from 1990 levels by 2050 and a global goal of at least 50% reductions by 2050, and the Alliance of Small Island States and Least Developed Countries are calling for an 85% reduction by this time. In this brief report we analyze if the reduction targets proposed by Switzerland for 2020 are sufficient to put the world on a track to reach the overall goal of keeping global-mean temperature change below 2°C relative to pre-industrial. We analyze a scenario of global emission reductions for the hypothetical case that the Swiss position for 2020 were followed by continuing reductions at the same rates by all developed countries. In this scenario, put forward for evaluation by Greenpeace Switzerland, half of the overall reduction of emissions is achieved through international offsets. Other developed countries are assumed to take on the exact same reduction relative to their own emissions and the policy trend up to 2020 is linearly extended to 2100. The overall reduction of developed countries of 20% below 1990 by 2020 is less than the 25-40% reduction by 2020 required according to IPCC for staying below 2°C. This limited ambition of the developed countries is assumed to lead developing countries to not strengthen their efforts for emission reductions beyond what results from currently planned policy.

In this scenario, global emissions peak at 60 $GtCO_2e$ in the 2050s, a bit earlier and roughly 10$GtCO_2e$ lower than in the business-as-usual scenario used as reference, and drop below 50 $GtCO_2e$ by 2100, which is still above current levels. Although the total emissions in developing countries continue to rise until 2060, while they decrease in developed countries, emissions per head in these two regions only converge by the end of the 21st Century. By 2020, emissions in developed countries are 12 tCO2e/yr per capita on average, while they are 6 tCO2e/yr per head in the developing World. By the 2050s the emissions are respectively 9 and 7 tCO2e/yr per head, and emissions converge to 6 tCO2e/yr per capita in both regions by the end of the Century.

The late peak and modest post-peak decline in emissions in the second half of the 21st Century cause the concentration of greenhouse gases to reach about 750 ppm CO_2-equivalent by 2100. The rate of increase slows gradually, but concentrations are still far from stabilization even at this high a concentration. Since concentrations do not stabilize, let alone start to decrease, global-mean temperatures do not reach a peak in the 21st Century, but are still on their way up by 2100. By then, the probability that 2°C is exceeded is 99% and there is a roughly 1 in 2 chance that global warming will exceed 3°C. The best-estimate global warming in this scenario is 1°C by 2020, 1.8°C by 2050 and 3°C above pre-industrial by 2100. Hence, this emission reduction scenario is not consistent with a position that global warming should be limited to 2°C.

The scenario above can be compared with two scenarios that were discussed at high-level political meetings in the past months: (i) a scenario ultimately leading to a stabilization at an atmospheric concentration of 450 ppm CO_2-equivalent proposed by Lord Stern and (ii) a scenario proposed by AOSIS (Alliance of Small Island States), targeted at bringing global warming back to 1.5°C within the 21st Century, after a peak above this value around the 2050s. Both these scenarios show that geophysical and economic limitations do not prohibit staying below 2°C global warming, but this will require more stringent reductions than present in the scenario based on Switzerland's current position.

2 Global emission pathway following Swiss mitigation position

The scenario evaluated in this report assumes all other developed countries adopt the exact same reduction commitments as the current Swiss government. Although it is extremely unlikely that the developed countries would universally adopt a position brought forward by a single country, evaluating the climate consequences of such a global pathway can be a valuable thought-experiment to illustrate the ultimate implication of a national reduction commitment.

Switzerland has ratified the Kyoto Protocol, which implies that it will have to reduce its annual emissions to an average of 8% below 1990 in the period 2008-2012. For simplicity, we assume all reductions in developed countries are with respect to 1990 industrial emissions (Annex A of Kyoto Protocol) and not relative to the so-called 'base year', which is different from 1990 industrial emissions for a number of countries. Note that for the 2008-2012 period of the Kyoto Protocol, a universal implementation of the Swiss target by all developed countries implies a deeper aggregate emission reduction than the 'real' Kyoto Protocol (-5%).

In the context of the UNFCCC climate negotiations leading up to COP15 in Copenhagen, December 2009, Switzerland has proposed to reduce its emissions further to 20% below 1990 by 2020. Half of this reduction may be achieved by acquiring international offsets. If this position is extended to all developed countries, the international offsets require emission reductions in the developing world, financed by developed countries. Note that the latter requires safeguards against leakage, needs to assure additionality, etc. (see, for example, Sathaye and Andrasko 2007). The scenario assumes the trend of a further 6 percentage points reduction per decade continues up to 2100 for domestic emissions and an equal amount of emissions is reduced by financing emission reductions in developing countries (see Figure 1 and Table 1).

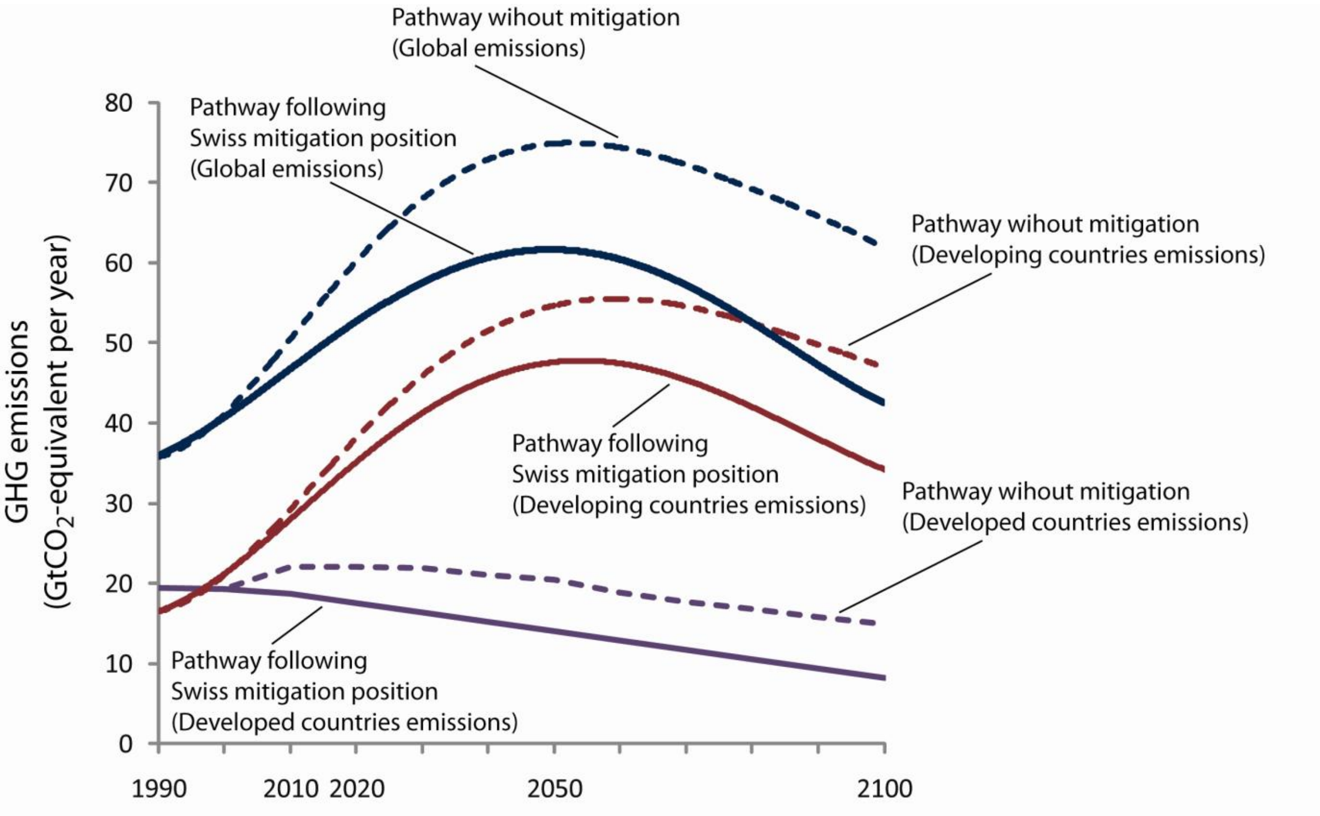

FIGURE 1 CO_2-EQUIVALENT EMISSIONS IMPLIED BY THE GLOBAL PATHWAY CONSISTENT WITH THE SWISS MITIGATION POSITION

The effective reduction by developed countries of 10% below 1990 by 2020, and an equal amount achieved through international offsets, falls short of the 25-40% reduction by developed countries that was estimated as necessary by IPCC (2007) to set the world on a path to stay below 2°C global warming relative to pre-industrial. GP Switzerland requested to extend the scenario with the assumption that this insufficient level of ambition by developed countries would prompt developing countries to not intensify domestic emission reduction policies beyond what is currently planned. The latter was estimated earlier by the authors (Rogelj et al. 2009) as leading to an emission level by 2020 of 4% below business-as-usual (BAU, SRES A1B; IPCC 2000). This reduction in developing countries emissions was included as additional to the reduction through international offsets from 2020 onwards (see Table 1).

Table 1 Emission pathway following Swiss mitigation position

Year	Emission reduction in Switzerland/Industrialized countries - *domestic* (% relative to 1990)	Emission reduction in Switzerland/Industrialized countries - *offsets* (% relative to 1990)	Emission reduction in Developing countries due to Industrialized countries' offsets and Developing countries' domestic policy (% relative to business-as-usual)
1990	+0%	+0%	+0%
2000	-1%	+0%	+0%
2010	-4%	-4%	-3%
2020	-10%	-10%	-9% (incl. -4% from domestic policies)
2050	-28%	-28%	-13% (incl. -4% from domestic policies)
2100	-58%	-58%	-27% (incl. -4% from domestic policies)

In this scenario, only by 2050 will the developed countries come near the range of 25-40% reductions below 1990 and developing countries in the range of 15-30% reduction below BAU, which were estimated as necessary by IPCC for the year 2020 (see Table 1). Although in this scenario the emissions in developing countries will continue to increase over much of the 21st Century, while emissions in developed countries steadily decrease, the average emissions per capita in these two regions converge only by the late 2080s (see Figure 2).

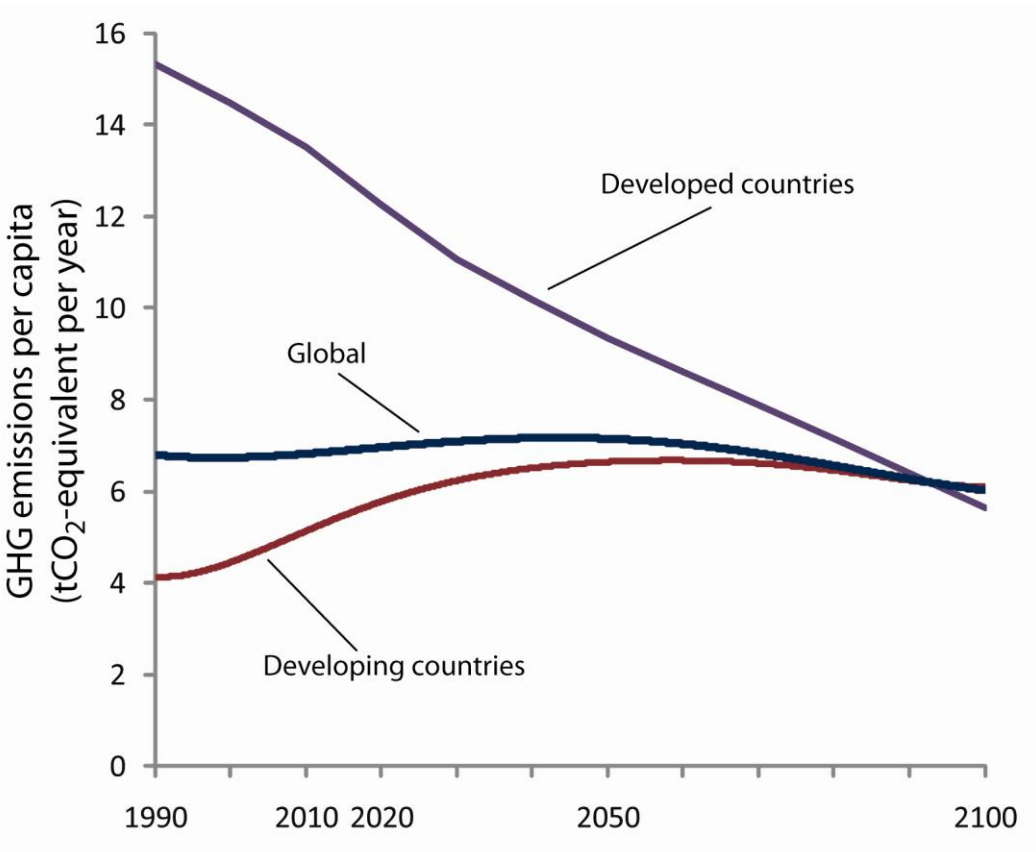

Figure 2 CO_2-equivalent emissions per capita implied by the global pathway consistent with the Swiss mitigation position

The implications of the scenario described above will be compared to those of three other scenarios. The reference, or baseline, scenario is a business-as-usual scenario that does not include any mitigation from developed, or developing countries. This SRES A1B scenario assumes continued globalization of the economy and does not assume a fundamental change in the character of economic development in the direction of enhanced sustainability. At the other side of the scenario spectrum in this report is a scenario consistent with the positions of AOSIS (Alliance of Small Island States) in the UNFCCC process and includes a 45% reduction below 1990 for developed countries by 2020 and an 85% reduction of total global emissions relative to 1990 by 2050 (AOSIS 2009). This scenario is targeted at limiting the peak temperature at a low value, and return as quickly as possible to a temperature change below 1.5°C and a concentration below 350 ppm. The last scenario is a scenario targeted at long-term stabilization at 450 ppm with a reasonable chance to stay below 2°C. This scenario was proposed by Lord Stern in the Greenland Dialogue sessions and is based on considerations of improved emission efficiency of the economies of both developed and developing countries (Stern 2009a; 2009b). Recently published low-emission scenarios show that scale of global emission reductions and reduction rates in the latter two scenarios are technologically and economically feasible (see e.g. Knopf et al. 2008; Rao et al. 2008; van Vuuren et al. 2008). To draw down CO_2 concentrations to lower levels quickly, the scenario based on AOSIS' policy targets includes negative net industrial CO_2 emissions after 2050. The low-emission scenario literature mentioned above shows that the scale of these negative emissions is feasible and requires large-scale carbon capture and storage technology combined with advanced bio-fuel options.

3 Concentrations and temperature change

For the projection of global warming resulting from the scenarios described above, the global CO_2-equivalent emission pathways were further developed into a pathway with emissions for all Kyoto greenhouse gases, as well as aerosols, using the Equal-Quantile-Walk approach (Meinshausen et al. 2006). This is a necessary step, since different greenhouse gases have a very different lifetime in the atmosphere and a different impact on the radiation balance for the same unit of volume, or mass, so a pathway defined in terms of CO_2-equivalent emissions only does not contain sufficient information. The resulting pathway was then used to drive a reduced-complexity climate model (Meinshausen et al. 2008) to obtain probabilistic estimates of future atmospheric greenhouse gas concentrations and global temperature, given uncertainties in our understanding of how the climate system responds to changing concentrations of these gases (Monte-Carlo set-up, see Meinshausen et al. 2009). Unless stated otherwise, all values for concentration and temperature increase given below are 'median' values, meaning under our current understanding we estimate that the uncertain 'real' value has a 50% (1 in 2) probability to lie *above* this median and an equal probability to lie *below* this median.

Concentration

To stabilize concentrations at any level, global emissions eventually need to be reduced to near-zero (Matthews and Caldeira 2007; Weaver et al. 2007). The level at which the concentration stabilizes is largely determined by the cumulative emissions until near-zero emissions are reached. The pathway following the Swiss mitigation position does not approach zero and Figure 3 confirms that the concentrations in this scenario continue to increase until the end of the 21st Century, with only a slight slow-down by that time. The reduction of concentration compared to the business-as-usual scenario is more than 150 ppm, but the gap with the two scenarios aimed at stabilization at 450 ppm, respectively 350 ppm, is much larger by 2100. As mentioned in section 2, the enhanced drop of concentrations in the 350 ppm pathway is caused by negative net industrial CO_2 emissions, through combining carbon capture and storage with bio-fuel options.

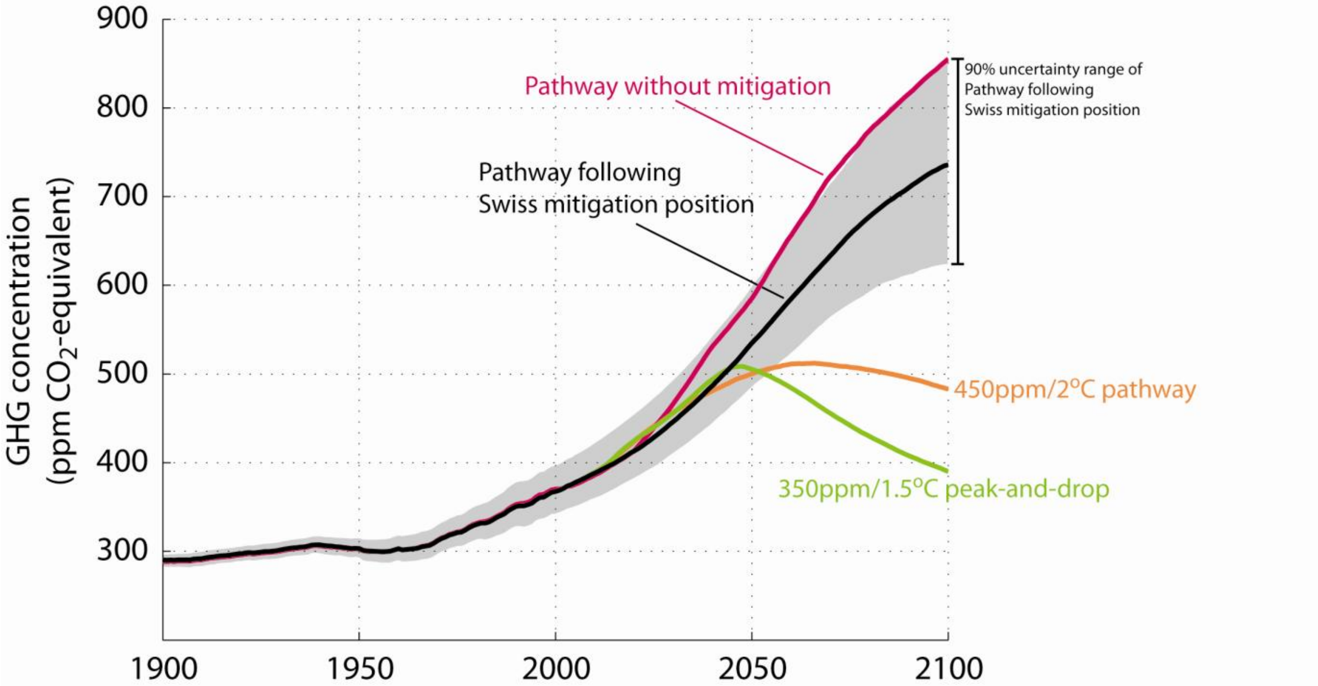

FIGURE 3 GLOBAL CO_2-EQUIVALENT CONCENTRATIONS OF THE FOUR SCENARIOS. THE LINES REPRESENT THE MEDIAN ESTIMATE, WHICH IMPLIES THAT THERE IS A SYMMETRIC 50% CHANCE THAT THE ACTUAL VALUE IS BELOW OR ABOVE THIS LINE. THE BROADER 90% UNCERTAINTY RANGE IS GIVEN AS A GRAY SHADED AREA FOR THE SWISS POSITION PATHWAY ONLY, TO AVOID CONFUSION.

Global-mean temperature change

Since concentrations do not stabilize in the pathway following the Swiss mitigation position, global-mean temperature continues to increase rapidly as well up to the end of the 21st Century, again with only a slight slow-down by that time. There is virtually no chance that global-mean temperature increase will stay below 2°C and the risk of exceeding 3°C is considerable at 50%. Even reaching 4°C above pre-industrial cannot be excluded, since the risk to exceed this very high level is roughly 10%. By contrast, the low-emission scenarios are likely to peak below 2°C. Although Figure 3 shows that the 350ppm/1.5°C pathway peaks at the same concentration level as the 450ppm/2°C pathway, the peaking temperature is lower. The reason is that concentrations drop down more rapidly in the 350ppm/1.5°C scenario and in that case, the long time lags in the climate system prevent the temperature increase to 'catch up' with the peaking concentrations that are already on their way down.

The table in Appendix A summarizes the emissions and global warming implications of the 4 scenarios evaluated in this report.

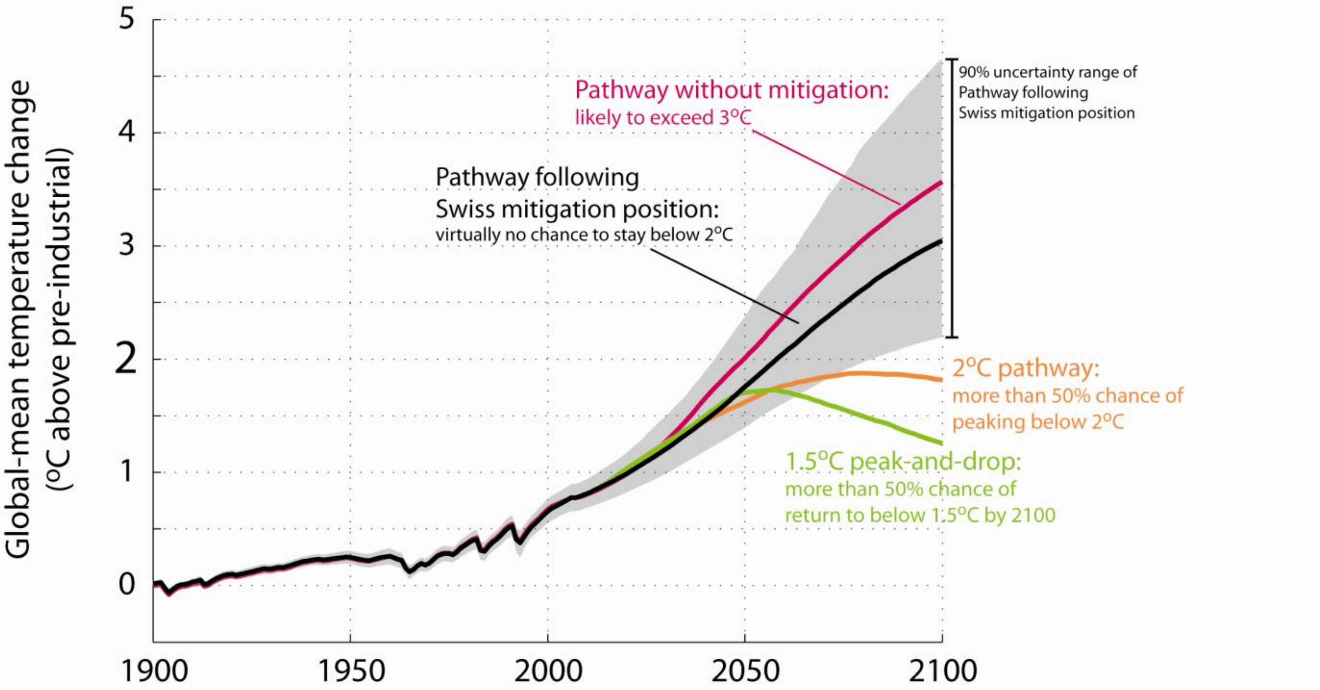

FIGURE 4 GLOBAL-MEAN TEMPERATURE CHANGE RELATIVE TO PRE-INDUSTRIAL OF THE FOUR SCENARIOS. THE LINES REPRESENT THE MEDIAN ESTIMATE, WHICH IMPLIES THAT THERE IS A SYMMETRIC 50% CHANCE THAT THE ACTUAL VALUE IS BELOW OR ABOVE THIS LINE. THE BROADER 90% UNCERTAINTY RANGE IS GIVEN AS A GRAY SHADED AREA FOR THE SWISS POSITION PATHWAY ONLY, TO AVOID CONFUSION.

4 Conclusions

In a global emission scenario, brought forward by Greenpeace Switzerland, that follows from a developed-country-wide implementation of the present Swiss mitigation position absent a strong goal for 2050 emission reductions, there is virtually no chance that global-mean temperature increase will stay below 2°C and the risk of exceeding 3°C is considerable at 50%. These projections show that the ultimate consequence of a worldwide climate policy following Switzerland's example is not consistent with a policy target of keeping global-mean temperature increase below 2°C relative to pre-industrial, let alone the safer level of below 1.5°C called for by the most vulnerable countries. This scenario contrasts starkly with two low-emission pathways evaluated in this report, which represent examples of proposed emission reductions leading global warming to likely stay below 2°C. Comparing the Swiss position scenario with these two low-emission pathways illustrate that it is likely social and political inertia, rather than geophysical laws, that may cause global warming to exceed 2°C above pre-industrial levels.

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See also www.climateanalytics.org and www.primap.org

CLIMATE ANALYTICS GmbH is a non-profit organization established in Potsdam and hosted at Potsdam Institute for Climate Impact Research (PIK) e.V. The team is backed by scientific models to assess and synthesize climate science, and to provide policy and analytical support to negotiators and NGOs at international climate negotiations. A major project carried out by CLIMATE ANALYTICS is the PREVENT-Project "Assessing and preventing dangerous climate change". PREVENT's aim is to provide policy and analytical support for delegations of developing countries, in particular the Least Developed Country Group (LDCs) and Small Island States (SIDS), in the 'post-2012' negotiations. In addition, the project will assist in building in-house capacity within SIDS and LDSs.

Dr. Michiel Schaeffer received his PhD in Dynamic Meteorology at University of Utrecht, The Netherlands, specializing in the interactions between atmosphere, ocean, ecosystems and society. He worked as senior researcher on Earth System science at the National Institute for Public Health and the Environment (RIVM). He is currently affiliated with Environmental System Analysis, Wageningen University and Research Centre (WUR) and is one of the founders of Climate Analytics. Based from 2005 to 2009 in Accra, Ghana and in Kigali, Rwanda, he has worked on building up co-operation with applied scientists and policy makers in the Western and Eastern-African regions on the subject of climate change research and policy applications. Since he moved from Kigali to New York mid-2009, he focuses on bringing together the scientific assessments with the policy applications for all projects that are carried out by Climate Analytics.

APPENDIX A

SUMMARY OF EMISSIONS AND GLOBAL WARMING IMPLICATIONS OF THE FOUR SCENARIOS EVALUATED IN THIS REPORT. TO CALCULATE PER CAPITA EMISSIONS, THE POPULATION PROJECTIONS OF THE BUSINESS-AS-USUAL SCENARIO HAVE BEEN APPLIED TO ALL OTHER SCENARIOS. WORLD TOTAL MAY NOT EQUAL SUM OF INDUSTRIALIZED AND DEVELOPING COUNTRIES DUE TO ROUNDING. FOR THE 450PPM/2°C SCENARIO ONLY GLOBAL EMISSIONS WERE AVAILABLE FROM STERN (2009A; 2009B).

Year	Scenario	GHG emissions ($GtCO_2e/yr$)	GHG emissions per head ($tCO_2e/capita/yr$)	GHG concentration (ppm CO_2-eq)	Global warming (°C above pre-industrial)
2020	**Business-as-usual**	**60 (World)** 22 (Industrialized) 38 (Developing)	**8 (World)** 15 (Industrialized) 6 (Developing)	**415**	**1.0**
	Worldwide Swiss	**52 (World)** 18 (Industrialized) 34 (Developing)	**7 (World)** 12 (Industrialized) 6 (Developing)	**415**	**1.0**
	450ppm/2°C	**44 (World)**	**6 (World)**	**420**	**1.0**
	350ppm/1.5°C	**40 (World)** 11 (Industrialized) 29 (Developing)	**5 (World)** 7 (Industrialized) 5 (Developing)	**420**	**1.0**
2050	**Business-as-usual**	**76 (World)** 20 (Industrialized) 56 (Developing)	**9 (World)** 14 (Industrialized) 8 (Developing)	**560**	**2.0**
	Worldwide Swiss	**63 (World)** 14 (Industrialized) 49 (Developing)	**7 (World)** 9 (Industrialized) 7 (Developing)	**535**	**1.8**
	450ppm/2°C	20 (World)	**2 (World)**	**500**	**1.6**
	350ppm/1.5°C	**5 (World)** 1 (Industrialized) 4 (Developing)	**1 (World)** 1 (Industrialized) 1 (Developing)	**505**	**1.7**
2100	**Business-as-usual**	**62 (World)** 15 (Industrialized) 47 (Developing)	**9 (World)** 10 (Industrialized) 8 (Developing)	**860**	**3.6**
	Worldwide Swiss	**42 (World)** 8 (Industrialized) 34 (Developing)	**6 (World)** 6 (Industrialized) 6 (Developing)	**735**	**3.0**
	450ppm/2°C	**0 (World)**	0 (World)	**480**	**1.8**
	350ppm/1.5°C	**-14 (World)**	-2 (World)	**390**	**1.3**