Appendix B

Attachments to the Center for Biological Diversity's Comment Letter on the Draft EIR

4.3 AIR QUALITY

The purpose of the Air Quality section is to address the impacts of the project on ambient air quality and the exposure of people, particularly sensitive individuals, to odors and hazardous pollutant concentrations, including toxic air contaminants. This section evaluates the significance of the increased emissions and exposures associated with the proposed project, and recommends mitigation measures to reduce the emissions and exposures to acceptable levels. The following analysis is derived from the *Air Quality Analysis for the Panorama Planned Development Project* (Tetra Tech EC, Inc., 2008).

This EIR also considers the potential effects of the project on climate change. Emissions of carbon dioxide, an important greenhouse gas, have been calculated and are presented below for the various components of the proposed project (construction, traffic-related emissions, operational emissions). A more detailed analysis of the project's contribution to greenhouse gas emissions is included in Section 5.1: Cumulative Impacts.

Project construction and operation could both result in exceedances of the County's Level "A" thresholds for NO_x and possibly VOCs. In addition, future residents could be exposed to odors, dust, and other air pollutants from nearby agricultural and industrial operations. A number of measures are available to minimize construction-related emissions. Operational emissions can be substantially reduced by eliminating use of wood-burning fireplaces and wood stoves; the passive solar design criterion to be implemented as part of the project proposal would further limit operational emissions. With implementation of these measures, neither short-term nor long-term emissions are considered significant.

The reaction to odors varies from individual to individual. No measures are available to the project proponents to control off-site odor or dust generation. However, provided prospective purchasers of the residences are notified of the potential for off-site odor and dust generation, the potential for impacts would be reduced to an acceptable level.

4.3.1 ENVIRONMENTAL SETTING

CLIMATE AND METEOROLOGY

Shasta County is located at the northern end of the Sacramento Valley Air Basin (SVAB). The SVAB consists of all or part of eleven counties. The SVAB is bounded on the north and west by the Coast Range, and on the east by the southern end of the Cascade Range and the northern end of the Sierra Nevada. These mountain ranges represent a substantial physical barrier to locally created pollution, as well as that transported northward on prevailing winds from the Sacramento metropolitan area.

The climate of the Sacramento Valley Air Basin is dominated by the strength and location of a semi-permanent, subtropical, high-pressure cell over the northeastern

Pacific Ocean, with terrain variations creating various microclimates. The existence of mountains and hills within the basin is responsible, in large part, for the wide variations of rainfall, temperatures, and localized winds that occur throughout the region. Airflow patterns in the basin are predominantly northwesterly in the spring and summer; however, seasonal variations do occur. Calm conditions dominate the winter months. Regional airflow patterns affect air quality by directing pollutants downwind of sources. Localized meteorological conditions, such as light winds and shallow vertical mixing, as well as topographical features, such as surrounding mountain ranges, create areas of high pollutant concentrations by hindering dispersal. Figure 4.3.1: Redding Airport Reporting Station Wind Rose Data shows the wind rose data for the Redding Airport reporting station.

Precipitation is highly variable seasonally. Summer months are often dry, averaging less than one inch in total precipitation per month. Rainfall is most abundant during the winter months and increases with elevation. Annual rainfall is lowest in the valleys, higher in the foothills, and highest in the mountains. Summary climate statistics for the Redding Airport, which lies to the north of the project site, are presented in Table 4.3.1.

Table 4.3.1
Climate Data Summary for the Redding Airport

Mean Maximum Temperature, F	75.3
Highest Mean Maximum Temperature, F	103.4
Lowest Mean Maximum Temperature, F	48.9
Mean Minimum Temperature, F	47.9
Highest Mean Minimum Temperature, F	68.7
Lowest Mean Minimum Temperature, F	26.9
Mean Annual Precipitation, in.	33.52
Predominate Wind Direction[2]	N to NW
Annual Average Wind Speed, mph[2]	7.1
% of Calm Conditions[2]	15.55

Source: Tetra Tech EC, Inc., 2008.
[1] NCDC 1971-2000 Monthly Normal Data, Western Regional Climatic Center
[2] Redding Airport wind data for 1988-1991

The valley is frequently subjected to inversions that, coupled with geographic barriers and high summer temperatures, create a high potential for air pollution problems. Generally, areas below 1,000 feet in elevation within Shasta County experience a moderate to poor capability to disperse pollutants in both the horizontal and vertical wind fields. This is, in large measure, due to relatively stable atmospheric conditions which act to suppress vertical air movement. Extremely stable atmospheric conditions referred to as "inversions" act as barriers to the dispersal of pollutants. In valley locations, at or below 1,000 feet in elevation, such as the project area, inversions create a "lid" under which pollutants are trapped. Dust and other pollutants trapped within these inversion layers will not disperse until atmospheric conditions become unstable. This situation creates concentrations of pollutants at or near the ground surface, and as a result may pose significant health risks for plants, animals, and people.

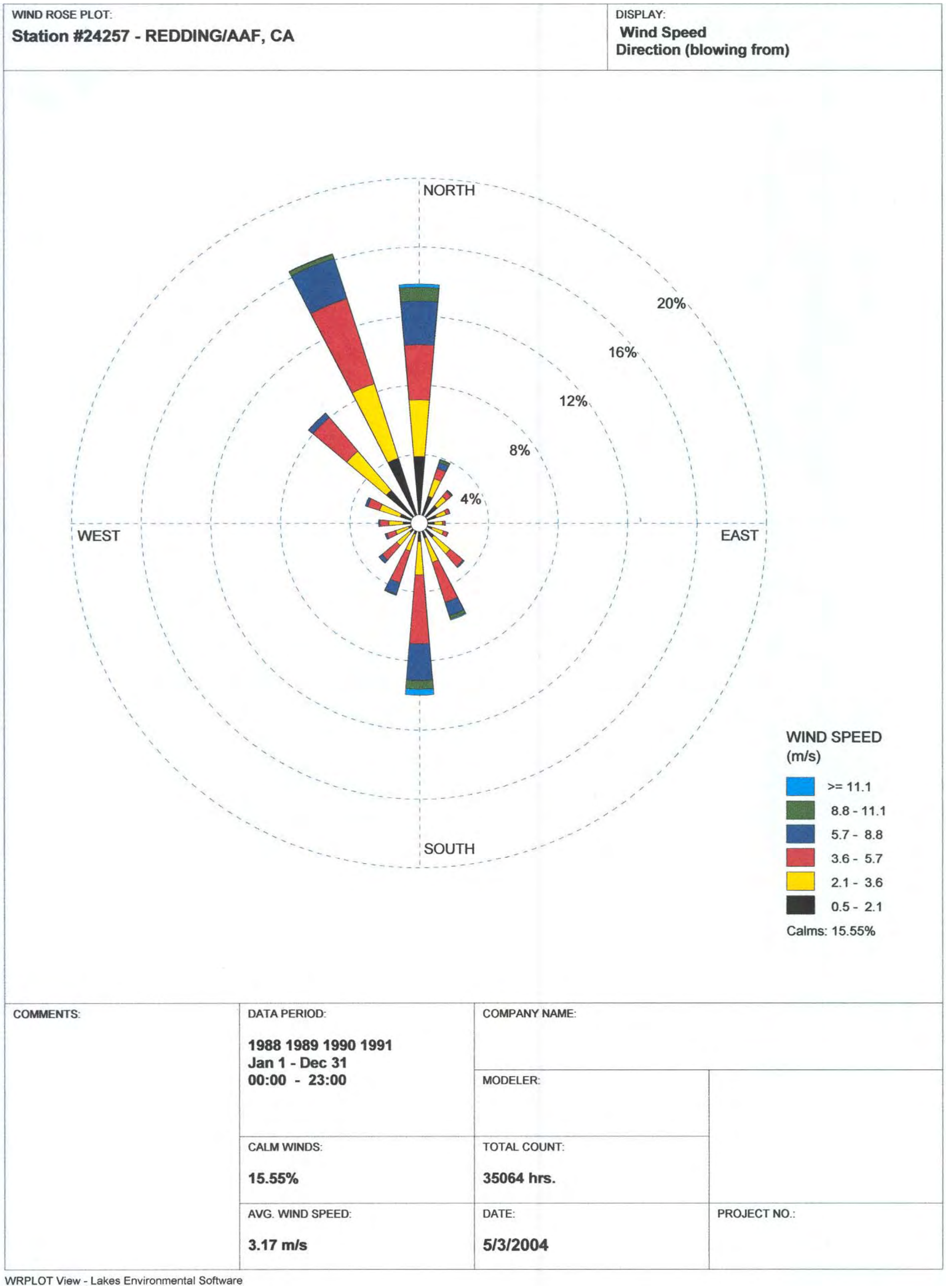

Figure 4.3.1
Redding Airport Reporting Station Wind Rose Data
(Source: Tetra Tech EC, Inc., 2008)

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REGULATORY SETTING

An overview of existing and proposed *Shasta County General Plan* land use classifications and *Shasta County Zoning Plan* designations for the project site is provided in Section 3.4: Panorama Planned Development Regulatory Setting. A discussion of federal, state, and local regulations related to air quality, as well as objectives and policies in the *Shasta County General Plan* that are pertinent to the air quality analysis for the project, are included below.

Federal Regulations

Environmental Protection Agency. At the federal level, the U.S. Environmental Protection Agency (EPA) has been charged with implementing national air quality programs. The U.S. EPA air quality mandates are derived from the federal Clean Air Act (CAA), which was signed into law in 1970. Congress amended the CAA in 1977 and again in 1990. The CAA required the EPA to establish the national ambient air quality standards (NAAQS), and to also establish deadlines for their attainment. Two types of NAAQS have been established: primary standards, which protect public health, and secondary standards, which protect public welfare from non-health-related adverse effects, such as visibility limitations.

The CAA Amendments of 1990 made major changes in deadlines for attaining NAAQS and in the actions required of areas of the nation that exceed these standards. Under the CAA, state and local agencies in areas that exceed the NAAQS are required to develop and implement air pollution control plans designed to achieve and maintain the NAAQS established by EPA. States may also establish their own standards, provided that state standards are at least as stringent as the NAAQS. California has established California ambient air quality standards (CAAQS) pursuant to California Health and Safety Code.

The CAA required states to develop an air quality control plan referred to as the State Implementation Plan (SIP). The SIP contains the strategies and control measures that California uses to attain the NAAQS. The EPA approved the California SIP in September 1996. The SIP became effective on February 7, 1997. Pursuant to the SIP, the State of California will strive for compliance with federal ozone standards by the year 2010. This will be accomplished using a combination of performance standards and market-based programs that will speed the introduction of cleaner technology and expand compliance flexibility.

State Regulations

California Air Resources Board. The California Air Resources Board (CARB) is the agency responsible for coordination and oversight of state and local air pollution control programs and for implementing the California Clean Air Act (CCAA) of 1988. The CCAA requires that all air districts in the state endeavor to achieve and maintain CAAQS by the earliest practical date. The CCAA mandates that districts focus particular attention on reducing emissions from transportation and area-wide emission sources, and the Act provides districts with the authority to regulate indirect sources.

Each district is to achieve a five percent annual reduction, averaged over consecutive three-year periods, in district-wide emissions of each nonattainment pollutant or its precursors. Air districts in violation of CAAQS are required to prepare an Air Quality Attainment Plan (AQAP) that includes measures for attaining the CCAA mandates.

California's Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24). The Energy Efficiency Standards for Residential and Nonresidential Buildings were established in 24 CCR Part 6 in 1978 in response to a legislative mandate to reduce California's energy consumption. The standards are updated periodically to allow for consideration and possible incorporation of new energy efficiency technologies and methods. The current California Energy Commission standards were adopted in January 2008 (California Energy Commission, 2008), and implemented in January 2010.

Local Regulations

Shasta County Air Quality Management District. The project site is located in the jurisdiction of the Shasta County Air Quality Management District (AQMD). The AQMD is designated by law to adopt and enforce regulations to achieve and maintain ambient air quality standards. The AQMD, along with other air districts in the Sacramento Valley Air Basin (SVAB), has committed to jointly prepare the SVAB Air Quality Attainment Plan for the purpose of achieving and maintaining healthful air quality throughout the air basin. The Plan was initially adopted in 1994 and is intended to be updated on a triennial basis. The most recent update occurred in 2006. The triennial updates of the SVAB Air Quality Attainment Plan address the progress made in implementing the AQAP and propose modifications to the strategies necessary to attain the California ambient air quality standard for the 1-hour ozone standard at the earliest practicable date. Like previous updates of the Air Quality Attainment Plan, the 2006 AQAP focuses on adoption and implementation of control measures for stationary sources, area-wide sources, and indirect sources, and addresses public education and information programs. The 2006 AQAP also addresses the effect that pollutant transport has on the north valley area's ability to meet and attain the State standards. Specific AQMD rules or programs applicable to the proposed project include the following.

- Rule 3:16 – Fugitive, Indirect, or Non-Traditional Sources
- Protocol for Review – Land Use Permitting Activities
- Environmental Review Guidelines – Procedures for Implementing CEQA

Shasta County General Plan. The *Shasta County General Plan* includes various objectives and policies to help protect and improve the County's air quality and to help the County attain and maintain federal and state ambient air quality standards. The objectives and policies most applicable to the proposed project are summarized as follows:

Objectives

AQ-1 To protect and improve the County's air quality in accordance with Federal and State clean air laws in order to: (1) safeguard human health, and (2) minimize crop, plant, and property damage.

AQ-2 To meet the requirements of the: (1) Federal Clean Air Act, and (2) the California Clean Air Act as soon as feasible.

AQ-3 To integrate air quality, land use, housing, transportation, and energy planning efforts to achieve the most efficient use of public resources and to create a healthier and more livable environment through reductions in air pollution contaminants.

AQ-4 To reduce traffic congestion, vehicle trips, vehicle miles traveled, and increase average vehicle ridership through more efficient use of infrastructure and support for trip reduction programs.

AQ-6 To promote site designs that encourage walking, cycling, and transit use.

AQ-8 To reduce emissions related to energy consumption and area sources.

Policies

AQ-1a The County shall require builders/developers to limit fireplace installations in new development to low-emitting fireplaces conforming to a maximum emission limit of 7.5 grams per hour of total particulate matter by being equipped with a EPA-certified insert or by being individually certified to meet the above emission standard.

AQ-1b The County will encourage the development of local programs to minimize emissions from residential wood burning.

AQ-1d The County shall require residential development projects and projects categorized as sensitive receptors to be located an adequate distance from existing and potential sources of toxic emissions such as freeways, major arterials, industrial sites, and hazardous material locations.

AQ-2b The County will work to accurately determine and fairly mitigate the local and regional air quality impacts of projects proposed in the unincorporated portions of Shasta County.

AQ-2c Land use decisions, where feasible, should contribute to the improvement of air quality. New projects shall be required to reduce their respective air quality impacts to below levels of significance, or proceed as indicated in Policy AQ-2e.

AQ-2d Shasta County shall ensure that air quality impacts identified during CEQA review are: (1) consistently and fairly mitigated, and (2) mitigation measures are feasible.

AQ-2e Shasta County will cooperate with the AQMD in assuring that new projects with stationary sources of emissions of non-attainment pollutants or their precursors that exceed 25 tons per year shall provide appropriate emission offsets. A comparable program which offsets indirect emissions of these pollutants exceeding 25 tons per year from development projects shall also be utilized to mitigate air pollution impacts. An Environmental Impact Report will be required for all projects that have unmitigated emissions of non-attainment pollutants exceeding 25 tons per year.

AQ-2f Shasta County shall require appropriate Standard Mitigation Measures and Best Available Mitigation Measures on all discretionary land use applications as recommended by the AQMD in order to mitigate both direct and indirect emissions of non-attainment pollutants.

AQ-2g Significance thresholds as proposed by the AQMD for emissions shall be utilized when appropriate for: (1) Reactive Organic Gases (ROG) and Oxides of Nitrogen (NO_x), both of which are precursors of ozone, and (2) inhalable particulate matter (PM_{10}) in determining mitigation of air quality impacts.

AQ-2j The County shall work toward measures to reduce particulate emissions from construction, grading, excavation, and demolition to the maximum extent feasible.

AQ-3a The County shall consider potential air quality impacts when planning the land uses and transportation systems needed to accommodate expected growth.

AQ-3b The County shall work towards creating a land use pattern that encourages people to walk, bicycle, or use public transit for a significant number of their daily trips.

AQ-3c The County shall encourage projects proposing pedestrian- or transit-oriented designs at suitable locations.

AQ-3f Existing town centers and rural community centers should be recognized among the primary pedestrian-oriented commercial and service centers as major contributors in promoting air quality goals in the unincorporated portions of the County.

AQ-3h The County will encourage higher residential densities in areas served by the full range of urban services.

AQ-4b The County's development standards shall require the paving of roads as a part of new development permits to the extent necessary to meet access and air quality objectives. These requirements shall be designed to help mitigate potentially significant adverse air quality impacts created by particulate emissions on both an individual and cumulative basis.

AQ-4c The County will encourage and publicize the use of public transit; ridesharing and van pooling; shortened and combined motor vehicle trips for work, shopping and services; use of bicycles; "pedestrian friendly" design criteria and walking.

AQ-4f The County shall consult as appropriate with transit providers to determine potentially significant project impacts on long-range transit plans to ensure that impacts are adequately mitigated.

AQ-5b The Shasta County Department of Resource Management will consult with the AQMD, where appropriate, when conducting CEQA reviews for all discretionary development applications.

AQ-6a The County shall encourage project sites designed to increase the convenience, safety, and comfort of people using transit, walking, or cycling.

AQ-6b The County shall review all subdivision street and lot designs, commercial site plans and multi-family site plans to identify design changes that can improve access by transit, bicycle, or walking.

AQ-8a The County will encourage new development projects to reduce air quality impacts from area sources and energy consumption requirements for heating and cooling.

AQ-8b The County will encourage use of energy conservation features and low-emission equipment for all new residential and commercial development.

BACKGROUND AIR QUALITY

Pollutants of concern include both criteria pollutants and toxic air contaminants. Criteria pollutants are those regulated by federal and State laws since the 1970s pursuant to the federal and State Clean Air Acts: e.g., ozone, carbon monoxide, suspended particulate matter, oxides of nitrogen, and sulfur dioxide. Toxic air contaminants are identified by State regulation: e.g., particulate matter from diesel-fueled engines, asbestos, chlorinated organic compounds, metals, radon and iodine gas, and other contaminants.

Criteria Pollutants

To date, the national ambient air quality standards (NAAQS) have been established for seven criteria pollutants, as follows: sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), nitrogen dioxide (NO_2), sub 10-micron particulate matter (PM_{10}), sub 2.5-micron particulate matter ($PM_{2.5}$), and lead (Pb). The criteria pollutants are those that have been demonstrated historically to be widespread and have a potential for adverse health impacts. The State of California has also established ambient air quality standards (CAAQS) that further limit the allowable concentrations of certain criteria pollutants.

Each federal or state ambient air quality standard is comprised of two basic elements: (1) a numerical limit expressed as an allowable concentration, and (2) an averaging time that specifies the period over which the concentration value is to be measured. Table 4.3.2 presents the current federal and state ambient air quality standards.

Table 4.3.2
Ambient Air Quality Standards

Pollutant	Averaging Time	California Standards Concentration	National Standards Concentration
Ozone	1 hour	0.09 ppm (180 µg/m^3)	-
	8 hour	0.07 ppm (137 µg/m^3)	0.075 ppm (147 µg/m^3) (3-year average of annual 4th-highest daily maximum)
Carbon monoxide	8 hour	9.0 ppm (10000 ug/m^3)	9 ppm (10000 ug/m^3)
	1 hour	20 ppm (23000 ug/m^3)	35 ppm (40000 ug/m^3)
Nitrogen dioxide	Annual Average	.030 ppm	0.053 ppm (100 µg/m^3)
	1 hour	0.18 ppm (338 µg/m^3)	-
Sulfur dioxide	Annual Average	-	0.03 ppm (80 µg/m^3)
	24 hour	0.04 ppm (105 µg/m^3)	0.14 ppm (365 µg/m^3)
	3 hour	-	0.5 ppm (1300 µg/m^3)
	1 hour	0.25 ppm (655 µg/m^3)	-
Respirable particulate matter (10 micron)	24 hour	50 µg/m^3	150 µg/m^3
	Annual Arithmetic Mean	20 µg/m^3	-
Fine particulate matter (2.5 micron)	Annual Arithmetic Mean	12 µg/m^3	15 µg/m^3 (3-year average)
	24 hour	-	35 µg/m^3 (3-year average of 98th percentiles)
Sulfates	24 hour	25 µg/m^3	-
Lead	30 day	1.5 µg/m^3	-
	Calendar Quarter	-	1.5 µg/m^3

Source: Tetra Tech EC, Inc., 2008.
ppm = parts per million
µg/m^3 = micrograms per cubic meter

Brief descriptions of health effects for the main criteria pollutants are as follows.

Ozone. Ozone is a reactive pollutant that is not emitted directly into the atmosphere; rather, it is a secondary air pollutant produced in the atmosphere through a complex series of photochemical reactions involving precursor organic compounds (POC) and oxides of nitrogen (NO_x). Significant ozone production generally requires POC and NO_x to be present in a stable atmosphere with strong sunlight for approximately three hours. Ozone is a regional air pollutant because it is not emitted directly by sources, rather is formed downwind of sources of POC and NO_x under the influence of wind and sunlight. Short-term exposure to ozone can irritate the eyes and cause constriction of the airways. In addition to causing shortness of breath, ozone can aggravate existing respiratory diseases such as asthma, bronchitis, and emphysema.

Carbon Monoxide. Carbon monoxide is a non-reactive pollutant that is a product of incomplete combustion. Ambient carbon monoxide concentrations generally follow the spatial and temporal distributions of vehicular traffic, and are also influenced by meteorological factors such as wind speed and atmospheric mixing. Under inversion conditions, carbon monoxide concentrations may be distributed more uniformly over an area, out to a particular distance, from vehicular sources. When inhaled at high concentrations, carbon monoxide combines with hemoglobin in the blood and reduces the oxygen-carrying capacity of the blood. This results in reduced oxygen reaching the brain, heart, and other body tissues. This condition is especially critical for people with cardiovascular diseases, chronic lung disease, or anemia, as well as for fetuses.

Particulate Matter (PM10 and PM2.5). PM_{10} consists of particulate matter that is 10 microns or less in diameter (a micron is one-millionth of a meter). Fine particulate matter, $PM_{2.5}$, consists of particulate matter 2.5 microns or less in diameter. Both PM_{10} and $PM_{2.5}$ represent fractions of particulate matter that can be inhaled into the air passages and the lungs and can cause adverse health effects. Particulate matter in the atmosphere results from many kinds of dust- and fume-producing industrial and agricultural operations, combustion, and atmospheric photochemical reactions. Some of these operations, such as demolition and construction activities, contribute to increases in local PM concentrations, while others, such as vehicular traffic, affect regional PM concentrations.

Several studies conducted by the U.S. EPA have shown an association between exposure to particulate matter, both PM_{10} and $PM_{2.5}$, and respiratory ailments or cardiovascular disease. Other studies have related particulate matter to increases in asthma attacks. In general, these studies have shown that short-term and long-term exposure to particulate matter can cause acute and chronic health effects. $PM_{2.5}$, which can penetrate deep into the lungs, causes more serious respiratory ailments. These studies, along with information provided by the U.S. EPA in a 1996 staff report, were used as the basis for evaluating the impacts of the proposed project emissions of PM_{10} and $PM_{2.5}$ on public health.

Nitrogen Dioxide and Sulfur Dioxide. Nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) are two gaseous compounds within larger groups of compounds, oxides of nitrogen (NO_x) and sulfur oxides (SO_x), respectively, that are products of the combustion of fuel. NO_x and SO_x emission sources can elevate local NO_2 and SO_2 concentrations, and both are regional precursor compounds to particulate matter. As described above, NO_x is also an ozone precursor compound and can affect regional visibility. Elevated concentrations of these compounds are associated with increased risk of acute and chronic respiratory disease. Sulfur dioxide and nitrogen oxides emissions can be oxidized in the atmosphere to eventually form sulfates and nitrates, which contribute to acid rain.

Lead. Gasoline-powered automobile engines used to be the major source of airborne lead in urban areas. Excessive exposure to lead concentrations can result in gastrointestinal disturbances, anemia, kidney disease, and in severe cases, neuromuscular and neurological dysfunction. The use of lead additives in motor vehicle fuel has been eliminated in California, and lead concentrations have declined substantially as a result.

Toxic Air Contaminants

"Toxic air contaminants" are air pollutants that are believed to have carcinogenic or adverse non-carcinogenic effects but do not have a corresponding ambient air quality standard. There are hundreds of different types of toxic air contaminants, with varying degrees of toxicity. Sources of toxic air contaminants include industrial processes such as petroleum refining, electric utility and chrome-plating operations, commercial operations such as gasoline stations and dry cleaners, and motor vehicle exhaust.

Toxic air contaminants are regulated under both state and federal laws. Federal laws use the term "Hazardous Air Pollutants" (HAPs) to refer to the same types of compounds referred to as "Toxic Air Contaminants" (TACs) under State law. Both terms encompass essentially the same compounds. For the sake of simplicity, this section will use TACs when referring to these compounds rather than HAPs. Under the 1990 Clean Air Act Amendments, approximately 190 substances are regulated under a two-phase strategy. The first phase involves requiring facilities to install Maximum Achievable Control Technology (MACT); EPA has established MACT standards for a wide variety of industries that emit toxic air contaminants and will develop MACT standards for others over the next several years. Even if MACT is established for a given source category, a facility in that category is subject to MACT only if the TAC emissions are 10 tons per year or more for any substance or 25 tons per year or more for any combination of TACs.

The second phase of control involves determining the residual health risk represented by TAC emissions sources after implementation of MACT standards. The EPA will determine residual risks within eight years after MACT standards for a source category are set. Results of this analysis will be used to determine if the residual risks allow for a reasonable margin of safety for public health.

With respect to State law, in 1983 the State legislature adopted Assembly Bill 1807 (AB 1807), which established a process for identifying toxic air contaminants and provided the authority for developing retrofit air toxics control measures on a statewide basis. In 1992, the State legislature adopted Assembly Bill 2728 to provide a legal framework for the integration of the existing State air toxics programs, including those developed under AB 1807, with the new federal program discussed above. Air toxics in California may also be regulated because of another state law, the Air Toxics "Hot Spots" Information and Assessment Act of 1987, Assembly Bill 2588 (AB 2588). Under AB 2588, toxic air contaminant emissions from individual facilities are required to be quantified by the facility and reported to the local air pollution control agency. The facilities are prioritized by the local agencies based on the quantity and toxicity of these emissions, and their proximity to areas where the public may be exposed. High priority facilities are required to perform a health risk assessment, and if specific risk thresholds are exceeded, they are required to communicate the results to the public in the form of notices and public meetings. Depending on the health risk levels, emitting facilities can be required to implement varying levels of risk reduction measures.

Organic Gases

Volatile Organic Compounds (VOCs) are organic chemical compounds that are in a gaseous form under normal conditions, and readily react with other chemicals, often contributing to the formation of smog. A wide range of carbon-based molecules, such as aldehydes, ketones, and other light hydrocarbons are VOCs. As defined by the U.S.EPA, VOCs are any volatile compound of carbon, excluding methane, carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, ammonium carbonate, and exempt compounds. Common artificial VOCs include paint thinners, dry cleaning solvents, and some constituents of petroleum fuels (e.g., gasoline and natural gas). Many VOCs found around the house, such as paint strippers and wood preservatives, contribute to sick building syndrome.

Reactive Organic Gases (ROG) are, for the most part, the same group of compounds as VOC, with some species being VOC and not ROG and vice versa. Total Organic Gases (TOG) consist of both ROG and VOC.

Air Quality Monitoring Data

The nearest criteria pollutant air quality monitoring sites to the proposed project site are in Redding and Anderson. Ambient monitoring data for these sites for the most recent three-year period is summarized in Table 4.3.3. Exceedances of the state and federal standards for both ozone and PM_{10} have been recorded at the Shasta County monitoring stations during the period noted in Table 4.3.3.

Table 4.3.3
Air Quality Monitoring Data Summary (Highest Monitored Values)

Pollutant	Site	Avg. Time	2005	2006	2007
Ozone, ppm	Redding	8 Hr (4^{th} High)	.084	.08	.07
	Anderson		.08	.073	.075
	Redding	1 Hr	.102	.107	.089
	Anderson		.105	.092	.084
PM_{10}, ug/m^3	Redding	24 Hr	30	54	35
	Anderson		47	53	46
PM_{10}, ug/m^3	Redding	Annual Arithmetic Mean	14.9	17.5	15.2
	Anderson		22.3	23.3	20.1
$PM_{2.5}$, ug/m^3	Redding	24 Hr	20.0	31.0	18.9
$PM_{2.5}$, ug/m^3	Redding	Annual Arithmetic Mean	7.3	8.7	5.6
CO, ppm	-	8 Hr	nd	nd	
CO, ppm	-	1 Hr	nd	nd	
NO_2, ppm	-	1 Hr	nd	nd	
NO_2, ppm	-	Annual	nd	nd	
SO_2, ppm	-	Annual	nd	nd	
SO_2, ppm	-	24 Hr	nd	nd	
Sulfate, ug/m^3	-	24 Hr	nd	nd	

Source: Tetra Tech EC, Inc., 2008.

Table 4.3.4 presents a summary of historical air quality data for the air basin for the period 1985 through 2004.

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Table 4.3.4
Historical Air Quality Summary

Sacramento Valley Air Basin

County: Shasta

OZONE (ppm)	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Peak 1-Hour Indicator	0.115	0.115	0.121	0.122	0.119	0.129	0.119	0.117	0.111	0.111	0.105	0.114	0.118	0.127	0.126	0.125	0.110	0.100	0.118	0.112
Peak 8-Hour Indicator	0.106	0.102	0.105	0.106	0.104	0.107	0.103	0.102	0.098	0.100	0.097	0.102	0.100	0.111	0.110	0.110	0.097	0.088	0.099	0.095
4th High 1-Hr. in 3 Yrs	0.100	0.110	0.120	0.120	0.120	0.110	0.110	0.110	0.110	0.110	0.101	0.110	0.110	0.120	0.120	0.120	0.111	0.098	0.107	0.107
Avg. of 4th High 8-Hr. in 3 Yrs	0.077	0.080	0.091	0.088	0.085	0.093	0.091	0.090	0.083	0.084	0.080	0.087	0.086	0.095	0.095	0.093	0.082	0.078	0.075	0.087
Maximum 1-Hr. Concentration	0.120	0.120	0.130	0.120	0.090	0.130	0.110	0.110	0.110	0.113	0.099	0.110	0.119	0.140	0.116	0.102	0.087	0.098	0.114	0.131
Max. 8-Hr. Concentration	0.105	0.097	0.108	0.105	0.083	0.110	0.095	0.091	0.088	0.105	0.084	0.100	0.107	0.126	0.098	0.087	0.079	0.084	0.096	0.096
Days Above State Standard	10	8	25	5	0	13	12	10	1	7	3	16	8	40	23	3	0	4	9	3
Days Above Nat. 1-Hr. Std.	0	0	2	0	0	1	0	0	0	0	0	0	0	3	0	0	0	0	0	1
Days Above Nat. 8-Hr. Std.	9	9	21	3	0	13	11	10	1	8	0	14	6	45	12	1	0	0	6	2

PM_{10} (ug/m³)	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Max. 24-Hr. Concentration (State)				60	91	80	83	86	91	64	55	51	63	52	75	53	71	58	52	74
Max. 24-Hr. Concentration (Nat)				60	91	80	83	86	91	64	55	51	63	61	81	49	66	60	53	76
Annual Average (State)							28.7		20.1	24.4	25.1	24.3				24.3	24.1	20.8	21.7	23.6
Annual Average (Nat)				26.4		24.9	28.7		20.1	24.4	25.2	24.3	22.2	23.5		23.7	23.7	25.9	21.5	23.5
Calc Days Above State 24-Hr Std							50		7	12	13	6				6	6	6	12	6
Calc Days Above Nat 24-Hr Std				0		0	0		0	0	0	0	0	0	0	0	0	0	0	0

$PM_{2.5}$ (ug/m³)	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Max. 24-Hr. Concentration (State)														50.0	57.0	45.0	49.0	40.0	34.0	26.0
Max. 24-Hr. Concentration (Nat)														50.0	57.0	45.0	49.0	40.0	34.0	26.0
98th Percentile of 24-Hr Conc.															55.0		29.0	38.0	16.0	18.0
Annual Average (State)															12.9		9.2		7.5	
Avg. of Qtrly. Means (Nat)															12.9		9.2	10.5	7.5	7.2

CARBON MONOXIDE (ppm)	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Peak 8-Hr. Indicator	1.1	3.1	3.1		2.4	2.3	2.3	2.7	2.0	2.0										
Max. 1-Hr. Concentration	2.0	5.0	4.0	4.0	4.0	4.0	3.0	3.0	4.0	4.5										
Max. 8-Hr. Concentration	1.1	2.8	2.5	1.8	2.5	2.3	2.0	1.9	2.1	1.7										
Days Above State 8-Hr. Std.	0	0	0	0	0	0	0	0	0	0										
Days Above Nat. 8-Hr. Std.	0	0	0	0	0	0	0	0	0	0										

NITROGEN DIOXIDE (ppm)	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Peak 1-Hr. Indicator		0.091	0.093	0.093	0.090	0.081	0.069	0.069												
Max. 1-Hr. Concentration	0.020	0.090	0.100	0.100	0.080	0.070	0.070	0.050												
Max. Annual Average			0.015				0.012													

SULFUR DIOXIDE (ppm)	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Peak 1-Hr. Indicator																				
Max. Annual Average																				
Max. 24-Hr. Concentration																				

No Monitoring Data Available

Source: Tetra Tech EC, Inc., 2008.

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Table 4.3.5 shows the background air quality values based upon the data presented in Table 4.3.4. The background values represent the average of all the highest values reported for all sites during the most recent three-year period.

Table 4.3.5
Background Air Quality Values

Pollutant and Averaging Time	Background Value, ug/m3
Ozone – 8 Hour	164
Ozone – 1 Hour	214
PM_{10} – 24 Hour	55
PM_{10} – Annual	23.3
$PM_{2.5}$ – 24 Hour	31
$PM_{2.5}$ – Annual	8.7
CO – 8 Hour	nd
CO – 1 Hour	nd
NO_2 – 1 Hour	nd
NO_2 – Annual	nd
SO_2 – 1 Hour	nd
SO_2 – 3 Hour	nd
SO_2 – 24 Hour	nd
SO_2 - Annual	nd

Source: Tetra Tech EC, Inc., 2008.

SHASTA COUNTY AIR QUALITY INFLUENCES

Air quality in Shasta County is influenced by two primary mechanisms: pollutant transport and localized emissions. Transport of pollutants from other areas or regions can have a significant effect on localized air quality. Such transport is especially important with respect to ozone impacts. The northern portion of the SVAB is a recognized transport "couplet", as defined by the State Air Resources Board. The ARB report identifies the transport "couplet" between the broader Sacramento area to the Upper Sacramento Valley as ranging from "inconsequential" to "overwhelming."

Table 4.3.6 presents a summary of the most current emissions inventory for Shasta County.

Table 4.3.6
2006 Emissions Inventory Data for Shasta County (Tons/day)

Source Category	TOG	VOC	CO	NO_x	SO_x	PM_{10}	$PM_{2.5}$
Total Stationary Sources	3.82	2.01	24.97	7.88	0.28	2.15	1.56
Total Area Sources	23.41	8.46	90.85	1.04	0.15	29.1	10.99
Total Mobile Sources	15.32	14.12	99.41	30.61	0.39	1.59	1.32
Total Natural Sources	177.76	166.89	49.47	1.65	0.51	5.09	4.32
County Total	220.3	191.5	264.7	41.2	1.3	37.9	18.2

Source: Tetra Tech EC, Inc., 2008.

4.3.2 THRESHOLDS OF SIGNIFICANCE

Criteria for determining the significance of impacts related to air quality were based on the Environmental Checklist Form in Appendix G of the State CEQA Guidelines (Cal. Code Regs., Title 14, Section 15000 et seq.). An impact related to air quality was considered significant if it would:

- Conflict with or obstruct implementation of the applicable air quality plan.
- Violate any air quality standard or contribute substantially to an existing or projected air quality violation.
- Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or state ambient air quality standard (including releasing emissions which exceed quantitative thresholds for ozone precursors).
- Expose sensitive receptors to substantial pollutant concentrations.
- Create objectionable odors affecting a substantial number of people.

For the purposes of environmental review, Shasta County has defined a substantial contribution to an existing or projected air quality violation as generation of air pollutants in excess of the thresholds shown in Table 4.3.7.

Table 4.3.7
AQMD Air Quality Emission Thresholds (lbs/day)

Level	NO_x	ROG (VOC)	PM_{10}
A	25	25	80
B	137	137	137

Source: Tetra Tech EC, Inc., 2008.

Table Footnotes:

- Apply Standard Mitigation Measures (SMM) to all projects based on potential air quality impacts.
- Apply SMM and appropriate Best Available Mitigation Measures (BAMM) when a project exceeds Level "A" thresholds. The appropriate type and number of BAMM applied to a project will be based on the unique characteristics of the project. BAMM will be selected from a list of measures kept updated by the Shasta County Planning Division (SCPD) and the Shasta County Air Quality Management District (AQMD).
- Apply SMM, BAMM, and special BAMM (when project exceeds Level "B" thresholds) based on their emission reduction potential to lower project emissions below Level "B" thresholds. The AQMD will advise the SCPD of the efficiency of proposed emission measures as part of the effort to reduce project emissions below Level "B" thresholds.
- If application of the above procedures results in reducing project emissions below Level "B" thresholds, the project can proceed with an environmental determination of a Mitigated Negative Declaration assuming other project impacts do not require more extensive environmental review.
- If project emissions cannot be reduced to below Level "B" thresholds, emission offsets will be required. The SCPD may seek the assistance of the AQMD regarding other efforts and measures that could be used to reduce unmitigated emissions exceeding the 137 lbs. per day. If, after applying the emissions offsets, the project emissions still exceed the Level "B" threshold, an EIR will be required before the project can be considered for action by the reviewing authority.

4.3.3 ENVIRONMENTAL IMPACTS AND MITIGATION

Impact AQ-4.3-1 Conflict With or Obstruct Implementation of the Applicable Air Quality Plan *(Less-than-Significant Impact with Mitigation Incorporated)*

Air quality impacts from the proposed residential subdivision project can be categorized as follows:

- Temporary impacts during the construction phases from exhaust emissions from construction-related equipment; fugitive dust due to grading, trenching, and surface preparation activities; and volatile organic gases from painting and road paving activities;
- Traffic-related emissions resulting from vehicle uses as the project phases are sold and occupancy is established; and
- Occupancy-related emissions from fuel use, most notably natural gas use, fireplace and wood stove uses, etc.

Generally, these emissions activities are not subject to the permitting regulations of the AQMD, but are subject to the CEQA review guidelines, and indirect source review provisions of the AQMD rules.

Construction Emissions

For the purposes of this analysis, it was assumed that project construction would extend from 2009 through 2019 (delay of project initiation and/or completion by one to several years would result in the actual air emissions being slightly lower than projected, due to improving engine technologies and more stringent air quality standards). Table 3.6.1: Project Construction Phasing and Corresponding Areas of Disturbance in Section 3.6: Project Construction, presents data with regard to the specific project phases and corresponding areas of disturbance. Phases correspond with the *Tentative Site Plans* (SDS, 2007), included on the Appendices Compact Disc. Two types of emissions are of particular concern during construction: fugitive dust emissions and combustion emissions.

Fugitive dust. Fugitive dust emissions from the construction of the project will result from:

- Dust entrained during site preparation, finish grading/excavation, road bed preparation, etc., at the construction site; and
- Dust entrained during construction equipment travel on paved and unpaved surfaces.

Estimated fugitive dust emissions (PM_{10} and $PM_{2.5}$) are presented in Table 4.3.8.

Combustion emissions. Combustion emissions during construction will result from:

- Exhaust from the diesel construction equipment used for site preparation, grading, excavation, and construction of on-site structures;

- Exhaust from water trucks used to control construction dust emissions;
- Exhaust from diesel-powered welding machines, electric generators, air compressors, and water pumps;
- Exhaust from pickup trucks and diesel trucks used to transport workers and materials around the construction site;
- Exhaust from diesel trucks used to deliver concrete, fuel, and construction supplies to the construction site; and
- Exhaust from automobiles used by workers to commute to the construction site.

Table 4.3.8 presents the results of the construction emissions analysis for each phase (per Table 3.6.1) in terms of lbs/day, including fugitive dust. Combustion emissions are based on a typical mix of equipment used on a daily basis, while fugitive dust emissions are based on the acreage of land disturbance. CO_2 data is presented in units of tons for each construction phase. The *Air Quality Analysis for the Panorama Planned Development Project* (Appendices Compact Disc: Air Quality) contains detailed emissions calculations and the support data and assumptions for each phase.

The following mitigation measures have been included as an integral part of the project construction emissions calculations.

Fugitive dust emissions.

- Use either water application or chemical dust suppressant application to control dust emissions from active construction areas (including on-site roads);
- Use vacuum sweeping and/or water flushing of paved road surfaces to remove buildup of loose material to control dust emissions from travel on the paved access road (including adjacent public streets impacted by construction activities) and paved parking areas; and
- Limit traffic speeds on all unpaved or active site construction areas to 5 mph.

Based on review of the AQMD's Standard Mitigation Measures and Best Available Mitigation Measures and other available technologies, implementation of the following emission controls is recommended:

Fugitive dust emissions.

- Implement all adequate dust control measures in a timely and effective manner during all phases of project development and construction;
- Water all excavated, stockpiled, or graded material to prevent fugitive dust from leaving property boundaries and causing a public nuisance or a violation of an ambient air standard. Watering shall occur at least twice daily with complete site coverage, preferably in the mid-morning and after work is completed each day;

- During initial grading, earth moving, or site preparation, construct a paved (or dust palliative treated) apron, at least 100 feet in length, onto the project site from the adjacent paved road(s);
- Sweep adjacent paved streets (recommend water sweeper with reclaimed water) at the end of each day if substantial volumes of soil materials have been carried onto adjacent public paved roads from the project site;
- Install sandbags or other erosion control measures to prevent silt runoff to roadways;
- Apply Department of Public Works approved non-toxic soil stabilizers (according to manufacturer's specifications) to all inactive construction areas (previously graded areas which remain inactive for 96 hours), in accordance with the Shasta County Grading Ordinance;
- Replant vegetation in disturbed areas as quickly as possible;
- Cover all trucks hauling soil, sand, and other loose materials, or require all trucks to maintain at least two feet of freeboard;
- Use wheel washers or wash off tires of all trucks exiting the construction site; and
- Mitigate fugitive dust emissions from wind erosion of areas disturbed from construction activities (including storage piles) by application of either water or chemical dust suppressant.

Exhaust emissions from the diesel heavy equipment.

- Shut down equipment when not in use to limit engine idling time. Idling time shall be limited to no more than 3 minutes. This idling limit does not apply to circumstances as stated in the California Environmental Protection Agency Air Resources Board Advisory Number 377 (2008) and in Mitigation Measure AQ-4.3-1b;
- Provide regular preventive equipment maintenance to prevent emission increases due to engine problems;
- Use low sulfur and low aromatic fuels meeting California standards for motor vehicle diesel fuel; and
- Use low-emitting gas and diesel engines meeting state and federal emissions standards (Tier I, II, III) for construction equipment.

Other miscellaneous emissions.

- Use low VOC coatings for the architectural coating phase of construction. All coatings must meet the VOC limits per AQMD Rule 3-31;
- Use asphalt mixtures appropriate for the time of year of application, while maintaining compliance with County road design and construction standards;

- Use alternatives to open burning of vegetative material on the project site, unless otherwise deemed infeasible by the AQMD. Among suitable alternatives are chipping, mulching, or conversion to biomasss fuel;
- Provide for temporary traffic control as appropriate during all phases of construction to improve traffic flow as deemed appropriate by the Department of Public Works and/or Caltrans; and
- Schedule construction activities that direct traffic flow to off-peak hours as much as practicable.

Table 4.3.8
Construction Emissions Summary

Phase	NO_x (lbs/day)	CO (lbs/day)	VOC [1] (lbs/day)	SO_x (lbs/day)	PM_{10} [2] (lbs/day)	$PM_{2.5}$ [2] (lbs/day)	CO_2 (tons per const period)
1	31.7	41.1	22.5	0.04	2.2/2.9	2.2/0.42	1240
2	31.7	41.1	22.5	0.04	2.2/3.46	2.2/0.54	830
3	31.7	41.1	24.6	0.04	2.2/8.45	2.2/1.41	830
4	31.7	41.1	24.3	0.04	2.2/8.82	2.2/1.67	830
5	31.7	41.1	25.0	0.04	2.2/10.35	2.2/1.81	830
6	31.7	41.1	21.9	0.04	2.2/2.17	2.2/0.27	830
7	31.7	41.1	21.7	0.04	2.2/2.17	2.2/0.27	830
8	31.7	41.1	22.0	0.04	2.2/3.6	2.2/0.40	830

Source: Tetra Tech EC, Inc., 2008.

[1] VOC includes asphalt off-gassing and structure coating VOC losses.

[2] For PM_{10} and $PM_{2.5}$, two values are presented as V1/V2. V1 is PM from equipment exhaust, while V2 is PM from fugitive dust sources.

Comparison to significance criteria. NO_x emissions are projected to exceed the Level "A" significance thresholds during all phases of construction. VOC emissions are projected to reach but not exceed the Level "A" significance threshold during Phase 3. However, the projections reflect "worst-case" assumptions, and the following should be noted:

- It is highly unlikely that all of the predicted construction equipment would be used each and every day, nor would all of the equipment listed be used for the listed hourly rates each day;
- It is highly unlikely that all of the workers would be on site each and every day, nor would this occur on a supposed "worst case" day; and
- It is highly unlikely that all delivery and support traffic emissions would occur each and every day, nor would all of this activity occur on a supposed "worst case" day.

Nonetheless, without mitigation, the emission thresholds are likely to be exceeded on at least some days. With appropriate mitigations applied, construction emissions are not expected to result in short- or long-term violations of any current ambient air quality standard. In addition, the State Implementation Plan (South Coast Air Quality Management District, 2003), which includes the Shasta County Air Quality Management District, incorporates an emissions allowance for construction projects. This project will be included in the emissions allowance, as will other similar projects within the AQMD boundaries.

Vehicular Emissions
Vehicular emissions resulting from project-generated trips are based upon the following:

- The average single-family dwelling generates 9.57 one-way trips per day (Institute of Transportation Engineers, 2007);
- The average one-way trip travel distance will be 8.25 miles (KD Anderson & Associates, Inc., 2008);
- Composite vehicle emissions factors generated by EMFAC, for the beginning and ending phase years have been averaged to estimate emissions for each phase; and
- Composite vehicle emissions factors generated by EMFAC for the build-out year have been used to estimate emissions upon final build-out.

Table 4.3.9 presents data based on the calculated average travel distances for vehicles entering and leaving the project, as well as vehicle emissions. Results are presented by phase and for the project build-out configuration. Emissions are based on the maximum distance traveled by phase and for full build-out.

Table 4.3.9
Vehicle Travel and Emissions Summary

Phase	Trips/ day	Total VMT[1]/day	Vehicle Emissions Summary (lbs/day)						
			NO_x	CO	VOC	SO_x	PM_{10}	$PM_{2.5}$[2]	CO_2
1	345	2846	2.96	31.4	5.9	0.03	0.11	0.11	2669
2	565	4461	4.85	51.4	9.67	0.05	0.19	0.19	4371
3	1330	10973	11.41	120.9	22.8	0.11	0.44	0.44	10289
4	565	4461	4.85	51.4	9.67	0.05	0.19	0.19	4371
5	699	5767	6.0	63.6	12	0.06	0.23	0.23	5408
6	153	1262	1.31	13.9	2.6	0.01	0.05	0.05	1183
7	163	1345	1.4	14.7	2.8	0.01	0.05	0.05	1261
8	297	2450	2.55	27	5.1	0.02	0.10	0.10	2297
Build-out	4117	33965	18.7	196	22.8	0.34	0.34	0.34	31654
Build-out (tons/yr):			**3.4**	**35.8**	**4.2**	**0.06**	**0.06**	**0.06**	**5777**

Source: Tetra Tech EC, Inc., 2008.
[1] VMT = vehicle miles traveled
[2] CARB-CEIDARS Updated $PM_{2.5}$ fraction inventory indicates that PM2.5 is 0.998 of PM_{10} for gasoline fuel vehicles.

Vehicle emissions do not exceed the Level “A” significance levels on a phase or build-out basis, and are therefore not considered as a significant impact. Likewise, carbon monoxide “hotspot” emissions are not expected to be significant. Carbon monoxide concentrations in Shasta County (Redding/Anderson/Cottonwood region) have historically been very low, and well within compliance with both state and federal ambient air quality standards. Historical CO data over the period 1985-1994 showed that the average annual 1-hour CO concentration in the Redding urban (downtown) area was 3.75 ppm which is 19 percent and 11 percent of the state and federal CO standards, respectively. The 8-hour average concentration during the same period was 2.1 ppm, which represents 23 percent of the current state and federal CO standards. Over the ensuing years, a number of industries in the southern Shasta County area that were significant CO sources have closed and ceased operations. These closures have most likely been offset by increases in traffic-related CO emissions. However, the overall effect in the County is that CO concentrations remain relatively low, and it is not anticipated that CO from project traffic would generate a CO “hotspot.”

Operational Emissions

Operational emissions from the proposed residential development would consist of those from natural gas consumption, wood-burning stoves and fireplaces, landscaping equipment such as lawnmowers, and consumer products. Emissions from each of these sources are discussed individually below, and a summary of overall operational emissions is also presented.

Natural Gas Consumption. Natural gas would be used for home heating and food preparation. Table 4.3.10 presents a summary of estimated emissions from residential natural gas use.

Table 4.3.10
Residential Natural Gas Emissions Summary

Pollutant	EF*	Emissions by Phase (lb/day)								Build-out (lb/dy)	Build-out (tons/yr)
		1	2	3	4	5	6	7	8		
NO_x	80	0.596	0.98	2.3	0.98	1.21	0.27	0.28	0.513	7.12	1.3
CO	20	0.149	0.24	0.58	0.24	0.30	0.066	0.07	0.128	1.78	0.325
VOC	5.3	0.04	0.065	0.152	0.065	0.08	0.018	0.019	0.034	0.472	0.086
SO_x	0.6	0.0045	0.0073	0.029	0.0073	0.0091	0.0020	0.0021	0.0039	0.0534	0.00975
PM_{10}	0.2	0.0015	0.0024	0.0058	0.0024	0.003	0.0007	0.0007	0.0013	0.0178	0.00325
$PM_{2.5}$	0.2	0.0015	0.0024	0.0058	0.0024	0.003	0.0007	0.0007	0.0013	0.0178	0.00325
CO_2	120,000	894	1465	3452	1465	1812	398	422	797	10678	1949

Source: Tetra Tech EC, Inc., 2008.

*EF = Emission Factor (lbs/million standard cubic feet)

The emissions noted in Table 4.3.10 assume the use of currently approved energy saving home heating and cooking systems. Emissions for future phases may be lower due to changes in the design and emissions signatures of such devices. Emissions from the use of natural gas would not exceed the Level “A” significance thresholds on a phase or build-out basis. Therefore, there would be a less-than-significant impact with regard to residential natural gas emissions.

Wood-burning Stoves and Fireplaces. It is possible that a percentage of the homes proposed would supplement their annual heating needs by installing wood stoves or utilizing built-in fireplaces. For purposes of estimating potential emissions from such a scenario, it was assumed that 45 percent of the homes would supplement heating with wood stoves/fireplaces, with fireplaces being used in 22 percent of these residences, and woodstoves in the remaining 78 percent of the residences (Tetra Tech EC, Inc., 2008). An average of 1.48 cords of wood per year would be burned by each user (using Urbemis 9.2.4 (Rimpo and Associates, Inc., 2008)). Table 4.3.11 presents a summary of the estimated emissions from residential wood combustion sources for the purposes of home heating.

Table 4.3.11
Residential Wood Stove/Fireplace Emissions Summary

Phase	NO_x (lbs/day)	CO (lbs/day)	VOC (lbs/day)	SO_x (lbs/day)	PM_{10} (lbs/day)	$PM_{2.5}$ [1] (lbs/day)	CO_2 [2] (lbs/day)
1	0.35	20.89	7.89	0.05	2.89	2.6	0
2	0.57	34.24	12.93	0.08	4.74	4.3	0
3	1.34	80.66	30.46	0.19	11.17	10.1	0
4	0.57	34.24	12.93	0.08	4.74	4.3	0
5	0.70	42.36	16.0	0.10	5.87	5.3	0
6	0.15	9.28	3.51	0.02	1.29	1.2	0
7	0.16	9.87	3.73	0.02	1.37	1.2	0
8	0.30	17.99	6.79	0.04	2.49	2.2	0
Build-out	4.15	249.53	94.24	0.60	34.55	31.1	0
Build-out, tons/yr	**0.76**	**45.54**	**17.20**	**0.11**	**6.39**	**5.75**	**0**

Source: Tetra Tech EC, Inc., 2008.
[1] $PM_{2.5}$ is 90% of PM10, per CARB-CEIDARS fractionation listing.
[2] CO_2 emissions are carbon neutral for this source category, i.e., carbon uptake in the fuel equals carbon release upon combustion.

Given the above assumptions, VOC emissions would exceed the Level "A" significance threshold during Phase 3, as well as on through final build-out. The VOC emissions for all phases and build-out are significantly influenced by the use of fireplaces, which release more emissions than wood stoves. The above calculations are based on the assumption that all wood stoves and fireplaces will meet District Rule 3:23 (EPA Phase II) emissions standards, therefore the only available mitigation measure is to withhold approval of residential designs that includes the use of fireplaces or other similar inefficient wood or biomass combustion devices for home heating purposes. Implementation of Mitigation Measure AQ-4.3-1d would reduce emissions from this source category to zero.

Landscaping Equipment. Estimates of emissions from residential landscaping equipment use are presented in Table 4.3.12. Emissions from residential landscape equipment use would not exceed the Level "A" significance thresholds.

Table 4.3.12
Residential Landscaping Equipment Emissions Summary

Phase	NO_x (lbs/day)	CO (lbs/day)	VOC (lbs/day)	SO_x (lbs/day)	PM_{10} (lbs/day)	$PM_{2.5}$ [1] (lbs/day)	CO_2 (lbs/day)
1	0.02	1.61	0.29	0.0001	0.004	0.004	2.58
2	0.03	2.63	0.48	0.0001	0.007	0.007	4.23
3	0.07	6.20	1.12	0.0003	0.016	0.016	9.96
4	0.03	2.63	0.48	0.0001	0.007	0.007	4.23
5	0.04	3.26	0.59	0.0001	0.009	0.009	5.23
6	0.01	0.71	0.13	0.0	0.002	0.002	1.15
7	0.01	0.76	0.14	0.0	0.002	0.002	1.22
8	0.02	1.38	0.25	0.0001	0.004	0.004	2.22
Build-out	0.22	19.20	3.48	0.0009	0.051	0.050	30.82
Build-out, tons/yr	**0.039**	**3.5**	**0.635**	**0.0002**	**0.009**	**0.009**	**5.625**

Source: Tetra Tech EC, Inc., 2008.
[1] $PM_{2.5}$ fraction is 0.998 of PM_{10}, per CARB-CEIDARS fractionation listing.

Consumer Products. Estimated emissions for VOCs from the use of consumer products such as aerosols are presented in Table 4.3.13. Emissions from consumer product use would not exceed the Level "A" significance thresholds for VOCs.

Table 4.3.13
Summary of Project-Related Consumer VOC Emissions

Phase	lbs/day	tons/yr
1	1.76	0.32
2	2.89	0.53
3	6.8	1.24
4	2.89	0.53
5	3.57	0.65
6	0.78	0.14
7	0.83	0.15
8	1.52	0.28
Build-out	20.04	3.84

Source: Tetra Tech EC, Inc., 2008.

Total Estimated Operational Emissions. Table 4.3.14 presents a summary of the estimated operational emissions (including vehicle emissions), for the build-out scenario.

Table 4.3.14
Post-Construction Emissions Summary

Component	NO_x (lbs/day)	CO (lbs/day)	VOC (lbs/day)	SO_x (lbs/day)	PM_{10} (lbs/day)	$PM_{2.5}$ (lbs/day)	CO_2 (lbs/day)
Vehicle Travel	18.70	196.00	22.80	0.34	0.34	0.34	31,654
Natural Gas Consumption	7.12	1.78	0.472	0.0534	0.0178	0.0178	10,678
Wood Stoves/ Fireplaces	4.15	249.53	94.24	0.60	34.55	31.10	0
Landscaping Equipment	0.22	19.20	3.48	0.0009	0.051	0.05	30.82
Consumer Products	--	--	20.04	--	--	--	--
TOTAL:	30.2	466.5	141.0	1.0	35.0	31.5	42,363

Source: Tetra Tech EC, Inc., 2008.

As shown above, VOC and NO_x would exceed the Level "A" threshold criteria when considering operational and vehicular emissions together. No pollutant emissions would exceed the Level "B" significance threshold. The VOC emissions are primarily influenced by wood stove/fireplace usage, vehicle travel, and consumer product use, while NO_x emissions are primarily influenced by vehicle travel, natural gas consumption, and wood stove/fireplace usage.

With respect to potential mitigation strategies, the following should be noted.

- Rural and semi-rural areas, such as Shasta County (including the small Redding-Anderson urban area), are generally considered to be "NO_x-limited" regions, i.e., regions where the concentrations of ozone depend on the amount of NO_x in the atmosphere. In NO_x-limited regions, controlling NO_x is the preferred strategy to reduce ozone concentrations.
- The lower elevations of Shasta County are probably the most affected by transport of pollutants from the lower Sacramento Valley areas, most notably the Sacramento metropolitan area, as noted above. The Sacramento metropolitan area, like most large urbanized areas, is a VOC-limited area, i.e., an area in which the concentrations of ozone depend upon the amount of VOCs in the atmosphere. Consequently, controlling VOCs in these areas would reduce ozone. In all likelihood, transport from the Sacramento metropolitan area is highly enriched with VOCs, which when mixed with the local contribution of VOCs, results in a much more NO_x-limited environment.

Considering the above analysis, a balanced strategy of controlling both NO_x and VOCs would most likely the best approach for Shasta County, with an emphasis placed on

NO_x reduction strategies. Further, as stated in the *Shasta County General Plan*, new innovative strategies to reduce travel demand need to be considered. Allowing and encouraging mixed-use centers at major arterial intersections or transit stations, increasing residential densities allowed in the Suburban Residential and Urban Residential General Plan designations in areas served by transit, and promoting alternative modes choices for travel are among ways the County can address air quality impacts created by vehicles.

The following mitigation measures are recommended for the above potentially significant construction- and operation-related impacts:

MM AQ-4.3-1a. The following airborne dust control measures shall be required during all construction operations, the grading of roads, and the clearing of land.

- Use either water application or chemical dust suppressant application to control dust emissions from active construction areas (including on-site roads);
- Use vacuum sweeping and/or water flushing of paved road surfaces to remove buildup of loose material to control dust emissions from travel on the paved access road (including adjacent public streets impacted by construction activities) and paved parking areas;
- Limit traffic speeds on all unpaved or active site construction areas to 5 mph;
- Implement all adequate dust control measures in a timely and effective manner during all phases of project development and construction;
- Water all excavated, stockpiled, or graded material to prevent fugitive dust from leaving property boundaries and causing a public nuisance or a violation of an ambient air standard. Watering shall occur at least twice daily with complete site coverage, preferably in the mid-morning and after work is completed each day;
- During initial grading, earth moving, or site preparation, construct a paved (or dust palliative treated) apron, at least 100 feet in length, onto the project site from the adjacent paved road(s);
- Sweep adjacent paved streets (recommend water sweeper with reclaimed water) at the end of each day if substantial volumes of soil materials have been carried onto adjacent public paved roads from the project site;
- Install sandbags or other erosion control measures to prevent silt runoff to roadways;
- Apply Department of Public Works approved non-toxic soil stabilizers (according to manufacturer's specifications) to all inactive construction areas (previously graded areas which remain inactive for 96 hours), in accordance with the Shasta County Grading Ordinance;
- Replant vegetation in disturbed areas as quickly as possible;
- Cover all trucks hauling soil, sand, and other loose materials, or require all trucks to maintain at least two feet of freeboard;

- Use wheel washers or wash off tires of all trucks exiting the construction site; and
- Mitigate fugitive dust emissions from wind erosion of areas disturbed from construction activities (including storage piles) by application of either water or chemical dust suppressant.

MM AQ-4.3-1b. The following mitigation measures shall be implemented to control exhaust emissions from the diesel heavy equipment used during construction of the project phases.

- Provide regular preventive equipment maintenance to prevent emission increases due to engine problems;
- Use low sulfur and low aromatic fuels meeting California standards for motor vehicle diesel fuel;
- Use low-emitting gas and diesel engines meeting state and federal emissions standards (Tier I, II, III) for construction equipment; and
- Shut down equipment when not in use to limit engine idling time. Idling time shall be limited to no more than 3 minutes. This idling limit does not apply to circumstances as stated in the California Environmental Protection Agency Air Resources Board Advisory Number 377 (2008), such as:
  - Idling when queuing;
  - Idling to verify that the vehicle is in safe operation condition;
  - Idling for testing, servicing, repairing, or diagnostic purposes;
  - Idling necessary to accomplish work for which the vehicle is designed (such as operating a crane);
  - Idling required to bring the machine system to operating temperature; and
  - Idling necessary to ensure safe operation of the vehicle.

MM AQ-4.3-1c. The following mitigation measures shall be implemented to control other miscellaneous emissions during construction of the project phases.

- Use low VOC coatings for the architectural coating phase of construction. All coatings must meet the VOC limits per AQMD Rule 3-31;
- Use asphalt mixtures appropriate for the time of year of application, while maintaining compliance with County road design and construction standards;
- Use alternatives to open burning of vegetative material on the project site, unless otherwise deemed infeasible by the AQMD. Among suitable alternatives are chipping, mulching, or conversion to biomasss fuel;
- Provide for temporary traffic control as appropriate during all phases of construction to improve traffic flow as deemed appropriate by the Department of Public Works and/or Caltrans; and

- Schedule construction activities that direct traffic flow to off-peak hours as much as practicable.

MM AQ-4.3-1d. To control VOC and PM_{10} emissions during project operation, the use of fireplaces, wood stoves, or other similar wood- or biomass-combustion devices for home heating purposes shall not be authorized.

With implementation of MM AQ-4.3-1 (a-d), the above potentially significant impacts would be reduced to less-than-significant levels.

Impact AQ-4.3-2 Violate an Air Quality Standard or Contribute to an Existing or Projected Air Quality Violation *(Less-than-Significant Impact with Mitigation Incorporated)*

See analysis under Impact AQ-4.3-1.

With implementation of MM AQ-4.3-1, this potentially significant impact would be reduced to less than significant.

Impact AQ-4.3-3 Result in a Cumulatively Considerable Net Increase of any Criteria Pollutant for which the Project Region is in Non-Attainment *(Less-than-Significant Impact with Mitigation Incorporated)*

Impacts related to greenhouse gases are addressed in Section 5: Additional CEQA-Mandated Impact Analyses.

The residual impacts from the construction phases of the proposed project are not expected to be significant since the emissions, with the exception of NO_x, would be below the Level "A" thresholds, and the mitigation measures proposed are anticipated to result in off-site impacts well below state and federal ambient air quality standards.

The residual impacts from long-term occupancy of the planned development would be in the areas of traffic-related emissions, use of woodstoves/fireplaces for supplemental home heating, and the use of consumer products by the residents of the project. Impacts in these categories are dominated by woodstove/fireplace emissions, which can be mitigated by eliminating the use of wood-burning stoves and fireplaces, as recommended in Mitigation Measure AQ-4.3-1. This would substantially limit both VOC and PM_{10}/$PM_{2.5}$ emissions in the long term. In addition, the project would adhere to the California Energy Commission Efficiency Standards for Residential and Nonresidential Buildings (Title 24), including the incorporation of passive solar design. Design of project buildings shall include features to ensure that project buildings provide 15 percent greater energy efficiency than required under the Title 24 regulations (California Energy Commission) in effect at the time of construction.

MM AQ-4.3-3. Design of project buildings shall include features to ensure that project buildings provide 15 percent greater energy efficiency than required under the Title 24 regulations (California Energy Commission) in effect at the time of construction.

As stated earlier, the County emissions inventory, as well as the SIP emissions inventory, includes current and future year emissions estimates or growth allowance emissions for construction and operation of the planned development (based on population growth, etc.). Therefore, these emissions are accounted for in the normal growth cycle of the County, and are not considered to be cumulatively significant.

With implementation of MM AQ-4.3-1 and MM AQ-4.3-3, impacts resulting in a cumulatively considerable net increase of any criteria pollutant for which the project region is in non-attainment are considered to be less than significant; no additional mitigation is necessary.

Impact AQ-4.3-4 Expose Sensitive Receptors to Substantial Pollutant Concentrations *(Less-than-Significant Impact)*

The property surrounding the proposed development is sparsely populated. The community of Cottonwood lies to the south of the project. The Interstate 5 corridor lies due west of the project site. To the north lies the south-Anderson industrial area. It is highly unlikely the proposed development would be exposed to significant concentrations of toxic air contaminants generated in the Cottonwood town center or along the I-5 corridor. However, emissions of both criteria and toxic pollutants could come from a wide range of sources located in the Anderson industrial area. These pollutants can be generated from sources such as biomass power production, sand and gravel processing operations, lumber processing operations, metal fabricating sources, etc.

The Wheelabrator Shasta Energy Company, Inc., located approximately one-half-mile north of the proposed residential development, is one of the largest stationary sources of criteria pollutants in Shasta County. Wheelabrator Shasta is a biomass energy production facility rated at approximately 50 MW. The primary fuels are biomass wood wastes and mill wood wastes. In 2006, this facility was listed by the Shasta County AQMD in the Top Ten Sources for pollutants such as PM_{10}, NO_x, VOCs, CO, and SO_x. Annual pollutant emissions for 2006 are tabulated in Table 4.3.15.

Table 4.3.15
Wheelabrator Shasta Energy Company, Inc.,
Annual Pollutant Emissions for 2006

Pollutant	Tons/Year
PM_{10}	176.2
CO	2395.3
VOC (ROG)	27.2
NO_x	587.3
SO_x	4.5

Source: Tetra Tech LC, Inc., September 2008.

The emissions noted above (for 2006) are well below the allowable or permitted emissions levels. Impact analyses conducted on the allowable or potential emissions during the original facility siting analysis, as well as follow-on permit modification analyses, clearly indicated that the facility emissions would not cause a violation of any state or federal ambient air quality standard, nor would the emissions cause a worsening of any violation of an existing ambient air quality standard. It is therefore not expected that actual emissions, which are less than permitted emissions, would cause any violations of any current state or federal air quality standard or adversely affect residents of the proposed residential development.

With respect to toxic and/or hazardous air pollutants, the risk prioritization values for Wheelabrator Shasta (for 2003) per the AB 2588 Hot Spots program are as follows: (1) carcinogenic score of 3.97, (2) chronic health effects score of 0.48, and (3) acute health effects score of 0.08. These values are compared to the air district prioritization threshold values which range from 0 to 100, with a score of 0 being the lowest, and a score approaching 100 being the highest. Scores less than 10 are considered to represent low priority sources that do not require public notification of risks under the AB 2588 program guidelines. Residents of the proposed development are not expected to be exposed to significant concentrations of toxic or hazardous air pollutants from the Wheelabrator Shasta facility.

In conclusion, there is no evidence that any single source or group of sources would expose project residents to pollutants concentrations that would be above the normal exposures seen elsewhere in the lower elevation areas of Shasta County. The potential for exposure of sensitive receptors to substantial pollutant concentrations would not be significant.

No mitigation is necessary for the above less-than-significant impact.

Impact AQ-4.3-5 Create Objectionable Odors Affecting a Substantial Number of People *(Less-than-Significant Impact)*

The proposed project, as with most residential developments, is not expected to result in generation of objectionable odors. However, there are two existing odor sources in the vicinity that could affect future residents of the project area: the Wheelabrator Shasta Energy Company and the Shasta Livestock Auction Yard.

Wheelabrator Shasta Energy Company, Inc*.*

Typically, fuels for biomass facilities are stored outside and are rotated into the energy production (combustion) process on a schedule that matches fuel needs with fuel storage times. Odors from outside storage of biomass fuels are generally rare, with the typical odor resembling that of recently cut wood, sawdust, or wood chips. Fuel management practices rarely result in fuel being kept on-site for a duration of time where rotting or malodor production can occur; thus, typically, odors from facilities are not anticipated to result in a significant odor impacts. However, data obtained from the Shasta County AQMD indicates that numerous complaints (including odor complaints) have been received concerning the Wheelabrator Shasta facility (period 5-10-93 through 6-9-08). The complaints regarding odor generation possibly indicate a situation where fuel may not be properly stored, managed, or rotated to the energy process. However, it is not the responsibility of the EIR to mitigate for sources that are currently operating beyond permit conditions and standards.

Given the potential for on-going odor generation, purchasers of the proposed residential lots should be clearly informed of the potential for odor impacts from the energy facility. Such notification can be achieved by placing a notice on the deeds of the residential parcel, as recommended under Mitigation Measure AGR-4.2-3. Although this measure would not reduce odor production or exposure, it would serve as an advisory to odor-sensitive prospective purchasers and minimize the potential for future land use conflicts.

Shasta Livestock Auction Yard

The Shasta Livestock Auction Yard is located on the west side of Locust Street, north of Cattleman Drive. Lands owned by the auction yard extend to within approximately 600 feet of the southwest corner of the proposed residential development. However, livestock are kept only on a small portion of the overall site, in the northwest corner. The livestock holding pens are located approximately 1,500 feet or greater from the closest proposed residential lot.

Odors from livestock operations (all varieties) are primarily generated from the anaerobic decomposition of manure and urine. Recent studies have identified up to 200 different gases produced by livestock operations. The primary odiferous compounds are hydrogen sulfide, methane, and ammonia. Generation of these compounds is highly dependent on the following: (1) moisture content, (2) temperature, (3) pH, (4) oxygen concentrations, and (5) environmental conditions such as season of the year, wind patterns, and precipitation patterns. For large operations, odor and gaseous emissions can be controlled by utilizing ventilation systems, management or “housekeeping” practices, on-site waste management systems, or waste application systems. For large or small operations, location of the facility with established buffer zones between other land uses is also a very effective odor management technique. For small sites such as the Shasta Livestock Auction Yard, buffering, waste management, and housekeeping practices are the most viable options.

The use of buffer zones has been studied extensively as applicable to both large and small operations. As an example, the State of Missouri requires buffer zone distances for animal feeding operations as shown in Table 4.3.16.

Table 4.3.16
Recommended Buffer Distances from Animal Feeding Operations

Facility Class	Size Category Definition	Recommended Buffer Distance (ft.)
Class 1A	≥ 7000 AUEs	3000
Class 1B	3000 – 6999 AUEs	2000
Class 1C	1000 – 2999 AUEs	1000

Source: Missouri Department of Natural Resources, 2008.

An AUE (animal unit equivalent) equals the following: 1 beef cow, 0.5 horse, 0.7 dairy cow, 2.5 swine weighing over 55 lbs., 15 swine weighing less than 55 lbs., 10 sheep, 30 laying hens, 55 turkeys, or 100 broiler chickens. The AUE is evaluated on an annual basis, i.e., 1 beef cow held on site for one year is 1 AUE, whereas 1 beef cow held on site for 1 month is 0.083 AUE.

Data obtained from the management of the Shasta Livestock Auction Yard indicates that a total of approximately 80,000 animals flow through the auction yard in a typical year, and that the average animal hold time on site is 2-3 days (0.00822 AUE per head). For purposes of a conservative analysis, it is assumed that all animals are equivalent to beef cattle; auction yard staff estimates that 99 percent of all the animals held on site are cattle. This results in approximately 660 AUEs, which is synonymous with a Class 1C or smaller facility. Therefore, an appropriate buffer zone would be 1,000 feet. It is unlikely that odors from the auction yard will result in significant impacts to residents of the proposed residential development since the distance to the development boundary is approximately 1,500 feet from the animal holding facility, and no odor-generating activities are conducted on auction yard lands within 1,000 feet of the proposed residential development.

Although odor-related impacts from the Wheelabrator Shasta facility and Shasta Livestock Auction Yard are not considered to be significant, implementation of Mitigation Measure AGR-4.2-3, which calls for a notice on the deeds of all residential lots advising potential purchasers of the proximity of industrial and agricultural uses, would further reduce the potential for conflict. Impacts related to odors are considered to be less than significant.

4.3.4 LEVEL OF SIGNIFICANCE AFTER MITIGATION

With implementation of the above mitigation measures (Mitigation Measure AQ-4.3-1 and Mitigation Measure AGR-4.2-3), air quality impacts associated with the proposed project would be less than significant.

***End of Section*.**

The Emissions Gap Report

Are the Copenhagen Accord pledges sufficient to limit global warming to 2° C or 1.5° C?

A preliminary assessment

November 2010

ADVANCE COPY

Foreword

Achim Steiner,
UN Under-Secretary-General, UNEP Executive Director

Climate change represents one of the greatest challenges but also an inordinate opportunity to catalyse a transition to a low carbon, resource-efficient Green Economy.

This report informs Governments and the wider community on how far a response to climate change has progressed over the past 12 months, and thus how far the world is on track to meet wider goals.

The pledges associated with the Copenhagen Accord of 2009 are the point of departure for this report. What might be achieved in terms of limiting a global temperature rise to 2° C or less in the twenty-first century and in terms of setting the stage for a Green Economy?

And what remains to be done—what is the gap between scientific reality and the current level of ambition of nations? The analysis focuses on where global emissions need to be in around 10 years time to be in line with what the science says is consistent with the 2° C or 1.5° C limits, and where we expect to be as a result of the pledges.

If the highest ambitions of all countries associated with the Copenhagen Accord are implemented and supported, annual emissions of greenhouse gases could be cut, on average, by around 7 gigatons (Gt) of CO_2 equivalent by 2020.

Without this action, it is likely that a business-as-usual scenario would see emissions rise to an average of around 56 Gt of CO_2 equivalent by around 2020. Cuts in annual emissions to around 49 Gt of CO_2 equivalent would still however leave a gap of around 5 Gt compared with where we need to be—a gap equal to the total emissions of the world's cars, buses and trucks in 2005.

That is because the experts estimate that emissions need to be around 44 Gt of CO_2 equivalent by 2020 to have a likely chance of pegging temperatures to 2° C or less.

However, if only the lowest ambition pledges are implemented, and if no clear rules are set in the negotiations, emissions could be around 53 Gt of CO_2 equivalent in 2020—not that different from business as usual—so the rules set in the negotiations clearly matter.

This report, the result of an unprecedented partnership between UNEP and individuals from 25 leading research centres, underlines the complexity of various scenarios.

The Emissions Gap Report emphasizes that tackling climate change is still manageable, if leadership is shown. In Cancun action on financing, mitigation and adaptation need to mature and move forward—supported perhaps by action on non-CO_2 pollutants such as methane from rubbish tips to black carbon emissions.

Above all, Cancun must demonstrate to society as a whole that Governments understand the gaps left by Copenhagen. But at the same time remain committed to counter climate change while meeting wider development goals.

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Three online appendices accompany this report

Appendix 1: Further detail on the four pledge cases and the differences between estimates
Appendix 2: Detailed information about countries' pledges
Appendix 3: Detailed information about the studies reviewed

Available at www.unep.org/publications/ebooks/emissionsgapreport

Glossary

Annex I Target	For the purpose of this report, the quantified economy-wide emission reduction targets submitted by UNFCCC Annex I countries to the Copenhagen Accord's Appendix I.
Conditional Pledge	Pledges made by some countries that are contingent on the ability of national legislatures to enact the necessary laws, ambitious action from other countries, realization of finance and technical support, or other factors.
Copenhagen Accord	The 15th Conference of the Parties to the UNFCCC took note of this agreement in Copenhagen, Denmark in December 2009. The Accord includes two appendices listing Annex I and non-Annex I pledges, which are analysed in this report.
Cumulative Emissions	Sum of annual global greenhouse gas emissions over a period of time. Because many greenhouse gases persist in the atmosphere for a long time, cumulative emissions greatly influence concentrations and therefore temperature.
Double Counting	In the context of this report, double counting refers to a situation in which the same emission reductions are counted towards meeting two countries' pledges.
Emission Pathway	The trajectory of annual global greenhouse gas emissions over time.
Energy and Industry CO_2 Emissions	CO_2 emissions from the energy and industry sectors. These are often referred to in this report when describing emission reduction rates and negative emissions
Feasible Rates of Emission Reduction	The average annual rate of emission reductions assumed feasible given assumptions about technological development, economic costs, and/or socio-political factors.
Global (total) Greenhouse Gas Emissions	Emissions from all sectors and all greenhouse gases
Integrated Assessment Models	Models of climate change that seek to combine knowledge from multiple disciplines in formal integrated representations. As such they describe the full chain of climate change, including relevant linkages and feedbacks between socio-economic and biophysical processes.
Likely Chance	A greater than 66 per cent likelihood. Used to convey the probabilities of meeting temperature limits.
Lenient LULUCF Credits	Credits given for carbon removals from existing forests or other sinks that would have occurred without policy intervention.
Lenient Rules	Pledge cases with maximum Annex I "lenient LULUCF credits" and surplus emissions units.
Medium Chance	A 50 to 66 per cent likelihood. Used to convey the probabilities of meeting temperature limits.

Negative Emissions	Either globally or for a particular sector, the emissions that could occur if, in a given period, the removal of greenhouse gases from the atmosphere as a result of anthropogenic activities is greater than the addition of anthropogenic emissions into it.. Note that in this report negative energy and industry CO_2 emissions are often mentioned.
Non-Annex I Action	For the purpose of this report, those emission reduction actions submitted to the UNFCCC by non-Annex I countries and listed in the Copenhagen Accord's Appendix II.
Offsets	A general term referring to credits that offset the need to reduce emissions elsewhere.
Overshoot Pathway	An emission pathway wherein a selected target (concentration or temperature) is exceeded for a period of time, but is eventually met.
Pledge	For the purpose of this report, pledges include Annex I targets and non-Annex I actions as included in Appendix I and Appendix II, respectively, to the Copenhagen Accord.
Scenario	A description of how the future may unfold based on 'if-then' propositions. A scenario in the context of this report consists typically of a representation of an initial socio-economic situation and a description of the key driving forces and future changes in emissions, temperature or other climate change-related variables.
Strict Rules	Pledge cases in which the impact of "lenient LULUCF credits" (see definition above) and surplus emissions units are set to zero.
Stylized Pathways	These are results from carbon cycle and climate models that are designed to better understand the relationships between emissions and temperatures, but do not explicitly incorporate assumptions about technological, economic or socio-political feasibility of emission reductions.
Surplus Emission Units	After the first commitment period of the Kyoto Protocol (2008-2012), according to Article 3, paragraph 13, Parties holding emission units not required for compliance with their commitments are able to carry over these units for future use or sale. These are called "surplus emission units". There is also the possibility that new surplus emission units will be created in the second commitment period, when targets are set below business-as-usual expectations.
Temperature Limits	Targets for maximum global average temperature increase above pre-industrial levels.
20th-80th percentile range	Results that fall within the 20-80 per cent range of the frequency distribution of results in this assessment.
Unconditional Pledges	Pledges made by countries without conditions attached.

Acronyms

AAU	Assigned Amount Unit
BECCS	Bioenergy combined with Carbon Capture and Storage
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CO_2e	Carbon dioxide equivalent For the purpose of this report, greenhouse gas emissions (unless otherwise specified) are the sum of the basket of greenhouse gases listed in Annex A of the Kyoto Protocol, expressed as carbon dioxide equivalent. The carbon dioxide equivalent of the various gases is computed by using the global warming potentials published in the Second IPCC Assessment Report.
COP	Conference of the Parties to the UN Framework Convention on Climate Change
GDP	Gross Domestic Product
Gt	Gigatonne (1 billion metric tonnes)
IAM	Integrated Assessment Model
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land-Use Change and Forestry
Mt	Megatonne (1 million metric tonnes)
RCPs	Representative Concentration Pathways. RCPs form an important element of the new scenarios used for assessment of climate change.
UNFCCC	UN Framework Convention on Climate Change

Technical Summary

The Emissions Gap Report

Are the Copenhagen Accord Pledges Sufficient to Limit Global Warming to 2° C or 1.5° C?

A Preliminary Assessment

The Copenhagen Accord declared that deep cuts in global emissions are required *"so as to hold the increase in global temperature below 2 degrees Celsius".* The Accord called for an assessment that would consider strengthening the long-term goal including *"temperature rises of 1.5 degrees".* Since December 2009, 140 countries[1] have associated themselves with the Copenhagen Accord. Of these, 85 countries have pledged to reduce their emissions or constrain their growth up to 2020.

The question remains, however, whether these pledges are sufficient to achieve the Accord's temperature limits, or if there will be a gap between what is needed and what is expected as a result of the pledges.

Many scientific groups have identified global emission pathways[2], or emissions trajectories, that are consistent with various temperature limits, while others have estimated global emissions in 2020 based on the Copenhagen Accord pledges. Some groups have calculated both. Not surprisingly, different groups have come up with different estimates. The range of estimates is caused, for example, by the fact that some of the pledges have conditions attached, such as the provision of finance and technology or ambitious action from other countries. This leads to a range of potential outcomes rather than a single estimate.

To understand and interpret the range of results coming from different studies, the United Nations Environment Programme (UNEP), in conjunction with the European Climate Foundation and the National Institute of Ecology, Mexico, convened a six-month preliminary assessment of these studies. This assessment aims to provide policy-makers with an overview of results from various studies, as well as their areas of agreement and disagreement. Individuals from twenty-five groups have contributed to the assessment and co-authored this publication. This report is a summary of that work.

Notably, the 2020 emissions reduction pledges analysed in this report were not decided under a quantitative top-down approach to emissions management — one that starts with temperature limits for which the mitigation effort is distributed among countries by

[1] As of 12 November 2010.

[2] An "emission pathway" shows how emissions change into the future

negotiation. Therefore, at this time we are only analysing the effect of the offers brought forward by countries in the form of pledges under the Copenhagen Accord.[3]

This assessment addresses four main questions:

- What 2020 emission levels are consistent with the 2° C and 1.5° C limits[4]?
- What are the expected global emissions in 2020?
- How big is the "emissions gap"?
- How can the gap be reduced?

Key findings

- Studies show that emission levels of approximately 44 gigatonnes of carbon dioxide equivalent ($GtCO_2e$) (range: 39-44 $GtCO_2e$*) in 2020 would be consistent with a "likely" chance of limiting global warming to 2° C.
- Under business-as-usual projections, global emissions could reach 56 $GtCO_2e$ (range: 54-60 $GtCO_2e$) in 2020, leaving a gap of 12 $GtCO_2e$.
- If the lowest-ambition pledges were implemented in a "lenient" fashion**, emissions could be lowered slightly to 53 $GtCO_2e$ (range: 52-57 $GtCO_2e$), leaving a significant gap of 9 $GtCO_2e$.
- The gap could be reduced substantially by policy options being discussed in the negotiations:
  - By countries moving to higher ambition, conditional pledges
  - By the negotiations adopting rules that avoid a net increase in emissions from (a) "lenient" accounting of land use, land-use change and forestry activities and (b) the use of surplus emission units
- If the above policy options were to be implemented, emissions in 2020 could be lowered to 49 $GtCO_2e$ (range: 47-51 $GtCO_2e$), reducing the size of the gap to 5 $GtCO_2e$. This is approximately equal to the annual global emissions from all the world's cars, buses and transport in 2005 – But this is also almost 60 per cent of the way towards reaching the 2° C target.
- It will also be important to avoid increasing the gap by "double counting" of offsets.
- Studies show that it is feasible to bridge the remaining gap through more ambitious domestic actions, some of which could be supported by international climate finance.

[3] We note that this is a technical report that explores possible outcomes associated with the implementation of the Copenhagen Accord. It is not intended to legitimize the Accord, nor does it constitute an endorsement of a pledge-and-review architecture vis-à-vis a target-based approach for emission reductions. In addition this report is not intended to advocate any particular policy or emissions pathway.

[4] Although the Copenhagen Accord is not explicit about the baseline against which temperature increase should be measured, we have assumed that it is pre-industrial levels.

- With or without a gap, current studies indicate that steep emission reductions are needed post 2020 in order to keep our chances of limiting warming to 2° C or 1.5° C.

** Range here refers to the "majority of results", i.e. their 20th and 80th percentile.*
*** "Lenient" in this report is used to refer to the situation in which LULUCF accounting rules and the use of surplus emission units result in a net increase in emissions*

What 2020 emission levels are consistent with the 2° C and 1.5° C limits?

Box 1: Method for assessing emission levels consistent with temperature limits

In this assessment we examine two groups of pathways: (1) pathways produced by integrated assessment models (IAM), which simulate the energy-economic system including the turnover of energy infrastructure; and (2) "stylized" pathways, produced by other models that do not explicitly model the change in the energy system or feasibility of emission reduction rates. We focus on results from IAMs because they are able to actually describe the system's response to different policies and measures and emission-related targets (see Box 2). However, we also draw on "stylized" scenarios in order to better understand the theoretical rates of emission reduction and magnitude of negative emissions needed to be consistent with particular temperature limits.

A total of 223 emission pathways produced by 15 modelling groups have been analysed[5]. We account for many, but not all, sources of the uncertainty of models and data by compiling results from a number of studies and identifying conclusions that appear robust.

1. The level of human-induced global warming is primarily determined by the cumulative emissions over time, i.e. when emissions peak, at what level, and how fast they decline thereafter*.*

The total stock of greenhouse gases in the atmosphere has a strong effect on climate forcing related to climate change. This stock is determined by the accumulated emissions of greenhouse gases in the atmosphere. It follows that cumulative emissions have a profound influence on the long-term increase of global temperature[6].

An important point is that several different emission pathways can result in the same cumulative emissions over a period of time. But not all pathways are considered equally feasible; some are thought to be constrained by an upper ceiling on the rate of emission reductions due to technological, economic, social and political factors. Hence, the feasibility of reduction rates plays a central role in determining which 2020 emission levels are consistent with temperature limits. Also important are assumptions about the feasibility of "negative emissions", i.e. the net removal of carbon dioxide (CO_2) from the atmosphere through, for example, planting forests or capturing CO_2 from biomass (see Box 3).

Studies show that there is a trade-off between the timing of the peak and the rate of decrease in emissions afterwards – the sooner and lower the peak, the slower the rate of decrease can be afterwards. Conversely, the longer the peak is delayed and the higher it is, the faster emissions must decline afterwards, and/or the stronger the negative emissions over the long term, in order to stay within the temperature limit (see Figure A).

Many recent modelling studies have assumed that it would be unrealistic for global emissions to immediately start decreasing (because of political and economic factors) and therefore have focused on scenarios in which global emissions continue to increase for a few years and then decrease sharply afterwards.

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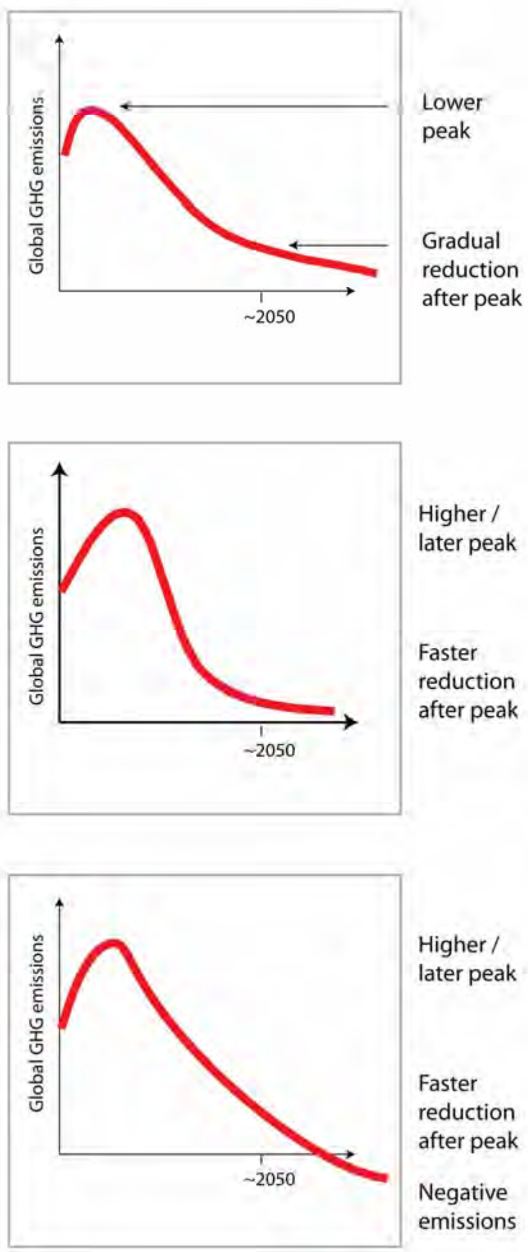
5 Detail on the studies reviewed can be found in Chapters 2 and 3 of the full report.

6 It is important to note that a number of other factors, such as the level of sulphate aerosols and the shape of the pathway, also have a significant influence on the maximum temperature increase.

Figure A: Illustration of different pathway types for the same temperature increase. See Point 1 for explanation.



Box 2: Understanding temperature limits

A temperature increase of 2° C or 1.5° C represents an increase in global average near surface temperature compared with pre-industrial times. This is meant to be an indicator of local climate changes. Importantly, a 2° C or 1.5° C global average increase can translate into much higher temperature changes locally.

There are significant uncertainties in the relationship between temperature, emission pathways, cumulative emissions, and atmospheric concentrations. Therefore, in this assessment, each emission pathway is associated with a range of probabilities for temperature, reflecting uncertainties in the carbon cycle and many other aspects of the climate system. Hence, an emission pathway is associated with probabilities of staying within a range of different temperature changes.

To illustrate, an emission pathway that has a 50 per cent chance of limiting warming to under 2° C, may also have a 5 per cent probability that warming will exceed 3° C and, say, a 10 per cent probability of staying below 1.5° C. Similarly, an emission pathway that has a 66 per cent chance of staying under 2° C, may also have a probability of less than 3 per cent that warming will exceed 3° C and, say, a 20 per cent probability of staying below 1.5° C.

In this assessment we focus on emission pathways that lead to a global average temperature increase of less than 2° C over this century with a "likely" chance (greater than 66 per cent probability) and then explain how they would be different for a "medium" chance (50-66 per cent probability). In addition we examine pathways in which the temperature changes are below 1.5° C by the end of the century, but "overshoots" this value for part of the century.

2. Emission pathways consistent with a "likely" chance of meeting the 2° C limit generally peak before 2020, have emission levels in 2020 around 44 $GtCO_2e$ (range: 39-44 $GtCO_2e$[7]), have steep emission reductions afterwards and/or reach negative emissions in the longer term.

Emission pathways assessed in this report that provide a "likely" (greater than 66 per cent) chance of staying within the 2° C limit, have the following characteristics:

- A peak in global annual emissions[8] before 2020.
- 2020 global emission levels of around 44 $GtCO_2e$ (range: 39-44 $GtCO_2e$).[9]
- Average annual reduction rates of CO_2 from energy and industry between 2020 and 2050 of around 3 per cent (range: 2.2 to 3.1 per cent)[10].
- 2050 global emissions that are 50-60 per cent below their 1990 levels.
- In most cases, negative CO_2 emissions from energy and industry starting at some point in the second half of the century.

[7] All ranges given in this report represent the 20th and 80th percentiles of results, unless otherwise stated. This range has been chosen to reflect the majority of results of the analysis.

[8] Global annual emissions consist of emissions of the "Kyoto basket of gases" coming from energy, industry and land use.

[9] These are rounded numbers. If numbers with one decimal place were shown it would be clear that the upper end of the range is slightly greater than 44 $GtCO_2e$ and the median slightly smaller than 44. The fact that both the median and upper end of the range are 44 indicates that many of the estimates were close to 44.

[10] Throughout this report emission reduction rates are given for carbon dioxide emissions from energy and industry and expressed relative to 2000 emission levels except when explicitly stated otherwise

Accepting a "medium" (50-66 per cent) rather than "likely" chance of staying below the 2° C limit relaxes the constraints only slightly: emissions in 2020 could be 1 $GtCO_2e$ higher, and average rates of reduction after 2020 could be 2.5 per cent per year (range 2.2-3.0 per cent). Nevertheless, global emissions still need to peak before 2020 in the majority of cases.

3. It turns out that the 2020 emission levels with a *"likely"* chance of staying within the 2° C limit can be about the same as those with a *"medium" or lower* chance of meeting the *1.5 °C* target. However, to have a higher chance of meeting the 1.5° C target the emission reduction rates after 2020 would have to be much faster.

In this assessment we have identified some emission pathways that keep the increase in temperature below 1.5° C by 2100, but "overshoot" this limit by a small amount for a few decades prior to 2100. However, the chance of doing so is low (range: 27-35 per cent probability). The emission levels in 2020 of these pathways are about the same as those in Point 2 above, i.e. they are consistent with a likely chance of staying below the 2° C limit throughout the twenty-first century.[11]

In addition, the most ambitious "stylized" pathways show that staying within the 1.5° C limit with overshoot (and with a "medium" or "likely" chance) have emission reduction rates after 2020 that are at the high end or faster than presently found in the IAM literature. Lower emission levels in 2020 would allow slower emission reduction rates after 2020.

These findings should be considered preliminary, however, as few studies have explicitly looked at the question of achieving the 1.5° C target.

4. The range in results stems from uncertainties of assumptions and models used for calculations.

The range in estimates of emission levels comes from model uncertainties including the omission of feedback phenomena in the climate system and (in some models) the impact of aerosols on climate forcing. The uncertainty of key assumptions, such as baseline emissions, also has an influence on calculations.

Box 3. What are feasible emission reduction rates? What are negative emissions?

The behaviour of the climate system dictates that future temperatures will be strongly influenced by emissions throughout the coming decades. Hence, the consistency of 2020 emissions with a given temperature limit can only be judged if emissions after 2020 are taken into account. For that reason it is important to know the feasible rates of emission reductions after 2020. Feasibility refers to whether a particular emission pathway is considered achievable. It depends upon technical, economic, political and social constraints and the extent of mitigation policy. Some of these factors, in particular technological and economic feasibility, can be represented in models such as integrated assessment models (IAM). These include assumptions about the maximum feasible rate of introducing technology, maximum costs of technologies, feasibility of specific system configurations, and limits regarding behavioural changes. Another important factor determining the maximum emissions reduction rate is the typical lifetime of machinery and infrastructure. These lifetimes are important if mitigation strategies aim to avoid premature replacement of capital, which is often considered to be very expensive. Other factors, such as political or social attitudes, might also influence the rate of emission reductions, but they are usually not taken into account by IAMs.

[11] One IAM pathway has been identified that has a "medium" chance of complying with the 1.5° C limit by 2100 (with some overshoot for a few decades) and shows emission reduction rates considered feasible in the IAM literature. See Chapter 2, full report.

There are different views about feasible emission reduction rates. The highest average rate of emission reductions over the next four to five decades found in the IAM literature is around 3.5 per cent per year. This would imply a decarbonisation rate (the rate of decrease in emissions per unit of GDP) of more than 6 per cent per year. Historically (1969-2009), a decarbonisation rate of about 1% has been seen globally. However, it is important to note that expectations about feasibility can change with future developments in technology, attitudes, and economics.

One of many important elements related to the feasibility of emission pathways is negative emissions. Many of the scenarios compiled in this assessment show global negative carbon dioxide (CO_2) emissions (from energy and industry) from mid-century onwards in order to achieve the temperature limits examined here[12].

Global negative CO_2 emissions would occur if the removal of CO_2 from the atmosphere is greater than the emissions into it. This might be achievable through large-scale afforestation efforts, for example. Many models assume a large deployment of bioenergy combined with carbon-capture-and-storage (BECCS) technology in order to achieve negative emissions. The feasibility of large scale bioenergy systems is related to its sustainability, including the availability of sufficient land and water, its impact on biodiversity, and the productivity of biomass.

If negative CO_2 emissions at a significant scale are not possible, then the options for meeting the limits are substantially constrained.

What are the expected global emissions in 2020?

5. Global emissions in 2020 will depend on the pledges implemented and the rules surrounding them. On one hand, emissions in 2020 could be as low as 49 $GtCO_2e$ (range: 47-51 $GtCO_2e$) when countries implement their conditional pledges with “strict” accounting rules. On the other hand, they could be as high as 53 $GtCO_2e$ (range: 52-57 $GtCO_2e$) when countries implement unconditional pledges with “lenient” accounting rules.

As a reference point, without pledges global greenhouse gas emissions may increase from 45 $GtCO_2e$ in 2005 to around 56 $GtCO_2e$ in 2020 (range: 54-60 $GtCO_2e$) according to business-as-usual projections. These results come from thirteen studies that have been reviewed in this assessment.

Results show that the pledges, if implemented, are expected to reduce global emissions in 2020 compared to business-as-usual projections. How much lower will depend on:

i. Whether countries implement their unconditional (lower ambition) or conditional (higher ambition) pledges. Conditions attached to the pledges include, for example, the provision of adequate climate finance and ambitious action from other countries.

ii. The extent to which accounting rules for land use, land-use change and forestry (LULUCF) can be used to weaken the mitigation targets of industrialized countries. This could occur if credit is given for LULUCF activities that would have happened in any case without further policy intervention.

iii. The extent to which surplus emissions units, particularly those that could be carried over from the current commitment period of the Kyoto Protocol, are used to meet industrialized country targets.

12 In this assessment, seventy-five per cent of scenarios with a “likely” chance of staying below 2° C and fifty per cent of the scenarios that have a “medium” chance of staying below 2° C.

For the purposes of this report, we have developed four cases that provide a range of plausible outcomes from the UNFCCC negotiations, each with different combinations of the factors mentioned above. We use the term "lenient rules" to refer to cases in which countries maximise the use of surplus emission units and "lenient LULUCF credits", and thereby weaken mitigation targets.[13] We use "strict rules" for the cases in which they do not[14].

> *Case 1 – "Unconditional pledge, lenient rules"*: If countries implement their unconditional pledges and are subject to "lenient" accounting rules (as explained in the paragraph above), global emissions are expected to be about 53 $GtCO_2e$ in 2020 (range: 52-57 $GtCO_2e$), or about 3 $GtCO_2e$ lower than business-as-usual projections.
>
> *Case 2 – "Unconditional pledge, strict rules"*: If countries implement their unconditional pledges and are subject to "strict" accounting rules (as explained in the paragraph above), global emissions are expected to drop to 52 $GtCO_2e$ (range: 50-55 $GtCO_2e$).
>
> *Case 3 – "Conditional pledge, lenient rules"*: If countries implement their higher ambition, conditional pledges and are subject to "lenient" accounting rules, global emissions are expected to drop to 51 $GtCO_2e$ (range: 49-53 $GtCO_2e$)
>
> *Case 4 – "Conditional pledge, strict rules"*: If countries implement their higher ambition, conditional pledges, and are subject to "strict" accounting rules, global emissions are expected to drop to 49 $GtCO_2e$ in 2020. (range: 47-51 $GtCO_2e$).

Thus, under the most ambitious outcome, the pledges could result in 2020 emissions that are 7 $GtCO_2e$ lower than business-as-usual.

6. Emissions could be lower or higher than these estimates, as a result of other factors. Emissions could be higher if offsets were to be "double-counted" towards both industrialized and developing country pledges or if pledges were to be ineffectively implemented. Emissions could be lower as a result of international climate finance for further mitigation efforts, or if countries were to strengthen their pledges, or if domestic activities went beyond their pledges.

The estimates reflected in the four cases do not take into account all factors that could affect emissions in 2020.

Two factors could increase emissions and lessen the impact of the pledges. If industrialized countries were to use offsets to meet their targets, and the developing countries that supplied the offsets also counted them towards their pledges, then emissions would be higher than estimated in Point 5. This "double counting" of offsets could increase emissions in 2020 by up to 1.3 $GtCO_2e$ in 2020. Similarly, if domestic policies were to be ineffective in meeting the pledges, emissions could be higher in 2020.

There are also factors that could further decrease emissions in 2020. If substantial international funds were to become available as agreed to in the Copenhagen Accord, emissions could be as much as 2.5 $GtCO_2e$ lower in 2020 than in the four cases above.

[13] Credits given for carbon removals from existing forests or other sinks that would have occurred without policy intervention. See Chapter 3, full report for more detail on the "lenient" and "strict" definitions.

[14] Note that surplus emission units and credits given for LULUCF activities do not necessarily weaken mitigation targets.

Similarly, if domestic policies went beyond international pledges or if pledges were strengthened, emissions could be substantially lower.

7. A number of uncertainties lead to a significant range in estimates of expected 2020 emissions.

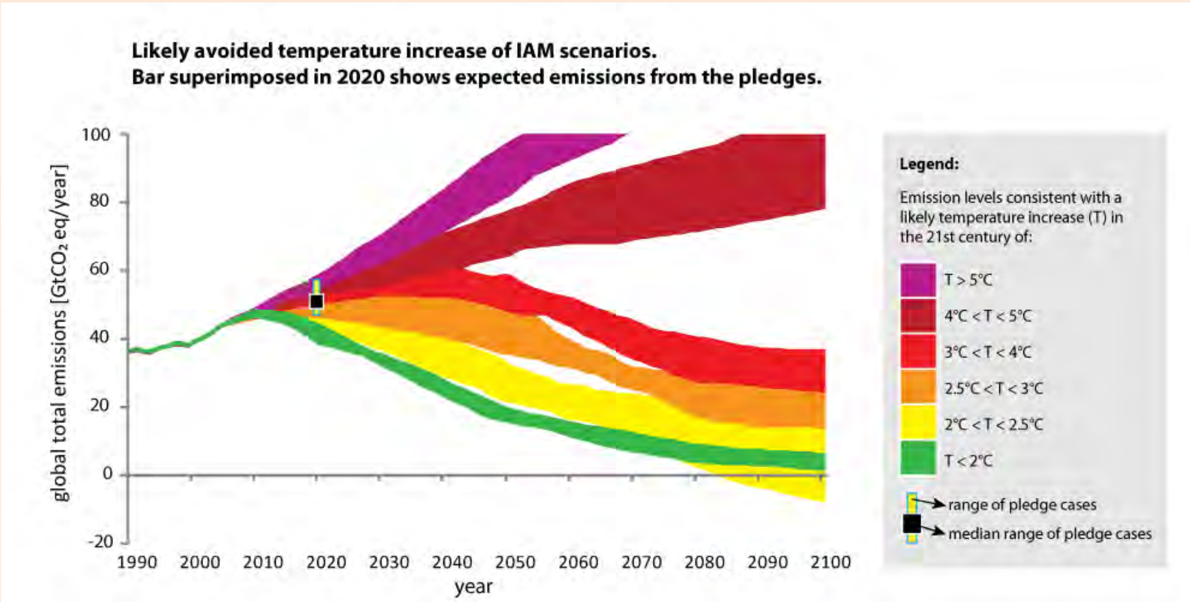
There is a large range between different groups' estimates for 2020 emission levels, even under the same assumptions regarding conditionality of pledges and accounting rules (range: -4 to +8 $GtCO_2e$ around the median estimate, depending on the case). The range of estimates is caused, for example, by differences in the underlying data sets, the treatment of emissions from LULUCF, the estimates of emissions from international transport, and the assumptions made about business-as-usual emissions growth of developing countries.

Box 4. What are the temperature implications of present pledges?

It is not possible to precisely answer the above question because the trend in temperature will strongly depend on the pathway of emissions after 2020. But results from integrated assessment models give us a hint at the range of pathways that could occur between 2020 and 2100. If we start at the level of emissions expected from the Copenhagen Accord pledges in 2020 and then follow the range of these pathways through to 2100, we find that they imply a temperature increase of between 2.5 to 5^{o}C before the end of the century (see Figure B). The lower bound is the case in which emissions are fairly stringently controlled after 2020, and the upper in which they are more weakly controlled. In other words, emission levels in 2020 implied by current pledges do not seem to be consistent with 2° C or 1.5° C temperature limits. To stay within these limits, emission levels would have to be lower in 2020 and then be followed by considerable reductions.

Figure B – Temperature increases associated with emission pathways and compared to the expected emissions from the pledges: Coloured bands show groups of IAM emission pathways that have approximately the same "likely" avoided temperature increase in the twenty-first century. Specifically the coloured bands show the 20th to 80th percentile range of the IAM pathways associated with those temperature increases[15]. Superimposed on top of the pathways is the range of estimated emissions resulting from the Copenhagen Accord pledges. The small black bar shows the range of median estimates from the four pledge cases. The thin blue bar represents the wider range of estimates associated with those four cases (the 20th to 80th percentile range).

[15] The gaps between the coloured bands come about because this report mainly compiled pathways from low greenhouse gas stabilisation scenarios



How big is the "emissions gap"?

8. A "gap" is expected in 2020 between emission levels consistent with a 2° C limit and those resulting from the Copenhagen Accord pledges. The size of the gap depends on the likelihood of a particular temperature limit, and how the pledges are implemented. If the aim is to have a "likely" chance (greater than 66 per cent) of staying below the 2° C temperature limit, the gap would range from 5-9 $GtCO_2e$, depending on how the pledges are implemented.

As a reference point, we saw in Point 2 that to have a "likely" chance of staying below the 2° C temperature limit, global emissions should be around 44 $GtCO_2e$ (range: 39-44 $GtCO_2e$). But according to business-as-usual projections global emissions in 2020 may be around 56 $GtCO_2e$ (range: 54-60 $GtCO_2e$). This leaves a gap of about 12 $GtCO_2e$ (range: 10-21 $GtCO_2e$).

The four pledge cases, each with different assumptions about the future outcome of the UNFCCC negotiations, result in different gaps as follows[16]:

> <u>*Case 1 – "Unconditional pledges, lenient rules"*</u>. The gap would be reduced down to 9 $GtCO_2e$ (range: 8-18 $GtCO_2e$) or about 3 $GtCO_2e$ below business-as-usual.

[16] All cases refer to emission levels consistent with a "likely" chance of staying below 2° C.

Case 2 – "Unconditional pledges, strict rules". The gap would be about 8 $GtCO_2e$ (range: 6-16 $GtCO_2e$), or about 4 $GtCO_2e$ below business-as-usual.

Case 3 – "Conditional pledges, lenient rules". The gap would be about 7 $GtCO_2e$ (range: 5-14 $GtCO_2e$) or about 5 $GtCO_2e$ below business-as-usual.

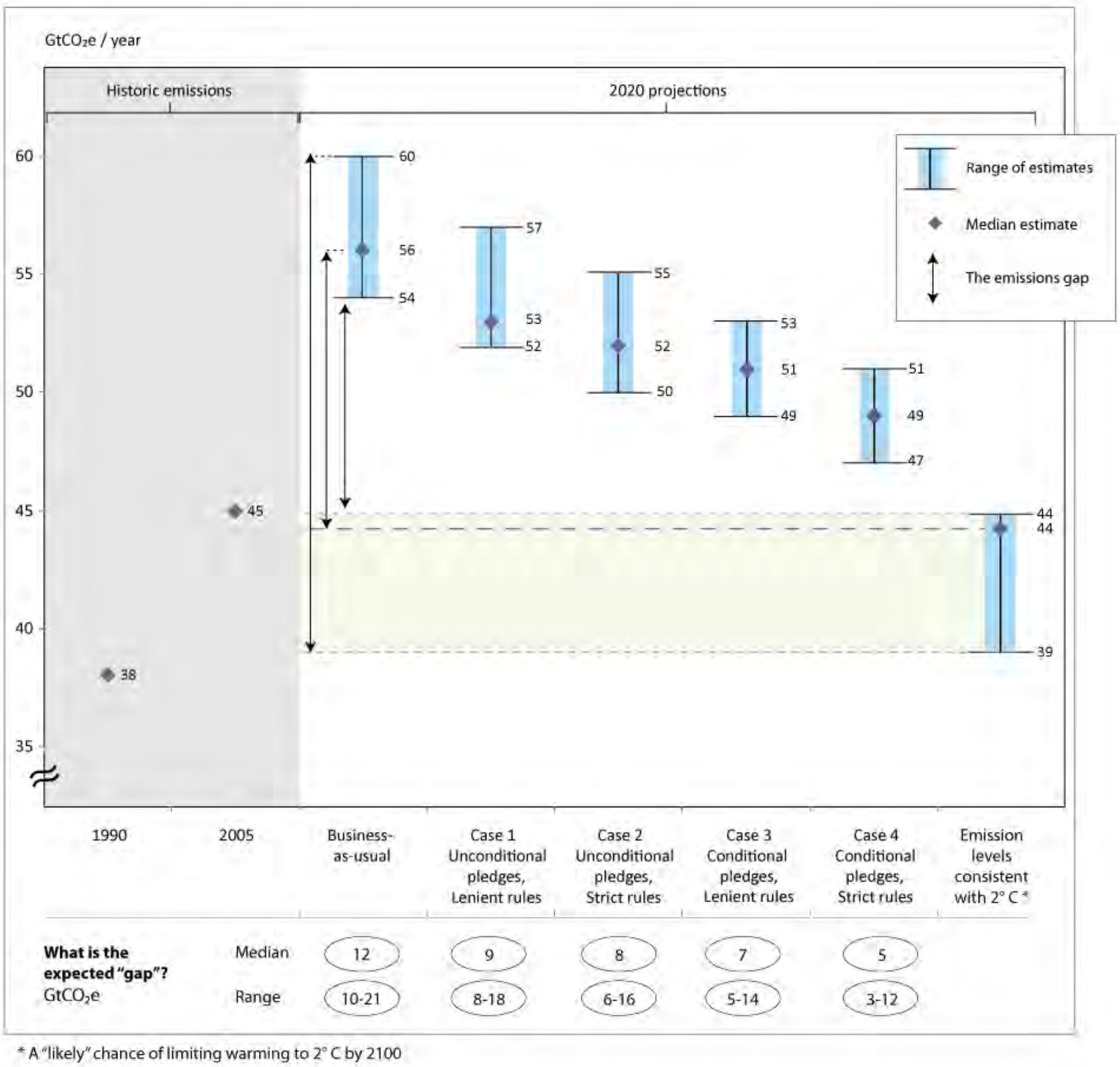
Case 4 – "Conditional pledges, strict rules". The gap would be about 5 $GtCO_2e$ (range: 3-12 $GtCO_2e$). This is about 7 $GtCO_2e$ lower than business-as-usual, and almost 60 per cent of the way to the 2° C levels. Although the gap would be considerably narrower than the business-as-usual case, it would still be as large as the total greenhouse gas emissions from the European Union in 2005 or from global road transport emissions in that year.

These results can be seen in Figure C.

Double-counting of international emission offsets could also increase the gap up to 1.3 $GtCO_2e$. This is a real risk since the Copenhagen Accord does not include rules regarding the use of international offsets.

As a final point here, to have a *"medium"* rather than a *"likely"* chance of staying within the 2° C limit, global emissions in 2020 can be about 1 $GtCO_2e$ higher and the gap also narrows by about 1 $GtCO_2e$.

Figure C: Comparison of expected emissions in 2020 with the emission levels consistent with a "likely" chance of meeting the 2° C limit. The figure compares the expected emissions in 2020 resulting from the four pledge cases with the emission levels consistent with a "likely" chance of meeting the 2° C limit. The median estimates and range of estimates (20th to 80th percentile) are shown. The gap between expected emissions and the 2° C levels is given below in each case.



9. There are considerable uncertainties around the estimates of the gap.

Since the emissions gap is the difference between emission levels for different temperature targets and expected emissions in 2020, the gap also inherits the uncertainties of these two components. The reader will note that the range around median estimates (Figure C) is not symmetric; the lower bound extends about 1-2 $GtCO_2e$ below the median, whereas the upper bound rises 7-9 $GtCO_2e$ above it (for a "likely" chance of staying below 2^oC). One way to interpret this skewed range is that the gap may turn out to be higher rather than lower than the median.

This assessment focuses on the majority (20th – 80th percentile) of emission pathways. But there are obviously also results outside of this range. In the extreme case, if we combine the highest 2°C emission levels with the lowest estimate of expected emissions, the gap disappears. At the opposite extreme, if we combine the lowest 2°C emission levels with the highest estimate of expected emissions, the gap would be greater than 20 GtCO_2e.

How can the gap be reduced?

10. Various international policy actions are available to close the gap.

a) Reducing the gap through higher ambition pledges.

The gap can be reduced by around 2-3 GtCO_2e (with a range of estimates from 2 to 5 GtCO_2e) by moving from the unconditional (lower ambition) pledges to the conditional (higher ambition) pledges.

- Industrialized countries: The majority of this reduction would come from industrialized countries, whose pledges are sometimes conditional on the ambitious action of other countries or on domestic legislation.
- Developing countries: A smaller, but still important, part of the reduction would come from developing countries, whose pledges are sometimes conditional on the adequate provision of international climate finance or technology transfer.

b) Reducing the gap by tightening the rules

The gap can be reduced by around 1-2 GtCO_2e by ensuring that “strict” rules apply to the use of LULUCF credits and surplus emission units.

- LULUCF accounting: If industrialized countries apply “strict” accounting rules to minimise the use of what we refer to as ‘lenient LULUCF credits’[17] , they would strengthen the effect of their pledges and thus reduce the emissions gap by up to 0.8 GtCO_2e.
- Surplus emission units: Likewise, if the rules governing the use of surplus emission units under the Kyoto Protocol were designed in a way that would avoid the weakening of mitigation targets, the gap could be reduced by up to 2.3 GtCO_2e. These include units carried over from the current commitment period and any potential new surpluses created in the next.

We note that policy options (a) and (b) are interdependent and so their benefits cannot necessarily be added together. But we estimate that the two options combined could reduce

[17] Credits given for carbon removals from existing forests or other sinks that would have occurred without policy intervention

emissions by around 4 $GtCO_2e$ in 2020 (with a range of estimates of 4-6 $GtCO_2e$) compared with the least ambitious case (case 1).

In addition, the risk of the gap increasing in size can be avoided if the negotiations set rules regarding international offsets to prevent them from being counted towards both industrialized and developing country pledges. “Double-counting” would increase the gap by up to 1.3 $GtCO_2e$.

11. It is feasible to close the remaining gap through further mitigation actions by countries, some of which could be supported by international climate finance.

If the above measures were to be taken, there might still be a gap of 5 $GtCO_2e$ compared with a 2° C limit. This gap could be closed if countries were to adopt more ambitious actions or pledges. The results from integrated assessment models (IAM) suggest that it is possible to reach emission levels where there is no gap, using mitigation measures that are economically and technologically feasible. .

Analysis also shows that international climate finance in line with the Copenhagen Accord could help achieve some of these reductions in developing countries.

12. Studies show that laying the groundwork for steep rates of emissions reduction from 2020 onwards would be necessary for staying within a limit of 2° C and even more so for 1.5° C, whatever the outcome of the pledges.

The results of the IAM pathways that have a “likely” (greater than 66 per cent) or even “medium” (50-66 per cent) chance of limiting temperature increase to 2° C show average annual emission reduction rates of greater than 2 per cent per year after 2020. Achieving this over the long-term would be unprecedented because, on the contrary, global emissions have almost continuously grown since the industrial revolution.

The higher the emissions in 2020, the faster the rate of decline required thereafter to meet temperature targets. Therefore, if targets are to be met, it will be essential to lay the groundwork now for such rates of reduction. This can be done, for example, by avoiding lock-in of high carbon infrastructure with long life-spans and developing and introducing advanced clean technologies.

1. Introduction

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1.1. COPENHAGEN, TEMPERATURE LIMITS AND PLEDGES

Following the 15th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change, forty-two[18] industrialized countries submitted quantified economy-wide emission targets for 2020. In addition, forty-three[19] developing countries submitted nationally appropriate mitigation actions for inclusion in the Appendices to the 2009 Copenhagen Accord.[20] These pledges[21] have since become the basis for analysing the extent to which the global community is on track to meet long-term temperature goals as outlined in the Copenhagen Accord:

> *(Para 1)…To achieve the ultimate objective of the Convention to stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, we shall, recognizing the scientific view that the increase in global temperature should be below 2 degrees Celsius, on the basis of equity and in the context of sustainable development, enhance our long-term cooperative action to combat climate change.*
>
> *(Para 2)…We agree that deep cuts in global emissions are required according to science, and as documented by the IPCC Fourth Assessment Report with a view to reduce global emissions so as to hold the increase in global temperature below 2 degrees Celsius, and take action to meet this objective consistent with science and on the basis of equity.*
>
> *(Para 12)…We call for an assessment of the implementation of this Accord to be completed by 2015, including in the light of the Convention's ultimate objective. This would include consideration of strengthening the long-term goal referencing various matters presented by the science, including in relation to temperature rises of 1.5 degrees Celsius.*

This publication aims to assess the following questions: are countries' pledges of action collectively consistent with and, if implemented, likely to achieve the 2° C and 1.5° C temperature goals? If not, how big is the gap between emission levels consistent with these temperature goals and the emissions expected as a result of the pledges?

Notably, the 2020 emission reduction pledges were not decided through a quantitative top-down approach to emissions management, i.e. one that would begin with agreed-upon temperature limits and then be followed by negotiation to distribute the burden of emission reductions necessary to meet these limits. Therefore, at this time we can only analyse the

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[18] http://unfccc.int/home/items/5264.php

[19] http://unfccc.int/home/items/5265.php

[20] http://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf#page=4

[21] For the purposes of this report, pledges include Annex I targets and non-Annex I actions.

emerging "global deal" on climate change by summing pledges from the bottom up—in other words, based on offers already brought forward voluntarily by countries.

Box 1a: Understanding temperature limits

A warming limit of 2° C or 1.5° C refers to the increase in global annual average near surface temperature compared with pre-industrial times. This temperature is intended to be an indicator for local changes in a wide range of observable quantities, such as precipitation. It is important to note that a 2° C global average rise can translate into much larger (or smaller) temperature changes in different latitudes and elevations. Moreover, undesirable impacts will generally be driven by local climate changes (e.g. changes in rainfall patterns) and often by changes in extremes in different seasons rather than by annual average temperature values.

There are significant uncertainties in the relationship between temperature, emission pathways, cumulative emissions, and atmospheric concentrations. Therefore, in this assessment, each emission pathway is associated with probabilities of staying within a range of temperature limits. These probabilities reflect the uncertainties in the carbon cycle as well as many other aspects of the climate system. To illustrate, an emission pathway that has a 50 per cent chance of limiting warming to under 2° C may also have a 5 per cent probability that warming will exceed 3° C and, say, a 10 per cent probability of staying below 1.5° C. If we then consider an emission pathway that has a 66 per cent chance of being under 2° C, it may also have a probability of less than 3 per cent that warming will exceed 3° C, and, say, a 20 per cent probability of staying below 1.5° C.

Therefore, it is not possible to guarantee that a particular emission pathway will achieve a temperature limit of 2° C or 1.5° C, and probabilities of achievement are used instead. In this assessment we focus on two temperature limits, 2° C and 1.5° C; and two probabilities of meeting them – a "likely" chance (probability greater than 66 per cent) and a "medium" chance (probability between 50-66 per cent).

1.2. SCOPE OF THE REPORT

This report addresses many of the key issues raised by the Copenhagen Accord. For example, the emission pathways consistent with temperature limits and the expected emissions in 2020 based on current pledges. Furthermore, it examines whether there is a gap between emission levels consistent with temperature limits and expected emissions, and furthermore, the increases in temperature consistent with such a gap in emissions. Outside the scope of the report are issues related to the comparability and equity of pledges.

1.3. A MULTI-DIMENSIONAL CHALLENGE

In assessing these issues we are confronted with a series of highly complex issues, which result from both scientific and political factors.

In **Chapter 2**, we focus on the likelihood of various emission pathways staying within temperature limits. For these pathways we identify the period in which emissions peak, the level of emissions in 2020, and the corresponding emission reduction rates after 2020. Results include emission pathways from integrated assessment models (IAM) and carbon cycle and climate models. Also discussed are current views about the feasibility of emission reductions and negative emissions, as well as factors determining long-term temperature, including cumulative emissions.

Chapter 3 reviews estimates of global emission levels in 2020 based on country emission pledges. Among the factors influencing these estimates are whether pledges are independent of, or conditional on, other countries' actions, financing or technological support. For industrialized countries, key factors include: the accounting procedures for emissions or uptake of carbon from land use, land-use change and forestry (LULUCF); the potential for international climate finance, as agreed in the Copenhagen Accord to enable further emission reductions; the carry-over of emission reduction units from the first commitment period of the Kyoto Protocol (2008-2012); and the potential double counting of offsets with emission reductions from non-Annex I countries' actions. Emission estimates are also influenced by the uncertainty of base year emissions and by assumptions needed for filling in sectoral or other gaps in the emission estimates of various groups.

The pledges of industrialized countries are fairly easy to convert into emission estimates because they are usually related to historic emissions. However, more assumptions are needed to make this conversion for developing countries because their pledges have usually been pegged to economic, demographic or other projections.

Chapter 4 builds upon the previous two chapters by examining a possible "emissions gap" in 2020 between emission levels consistent with temperature limits and expected emissions resulting from the pledges. It then goes on to explore policy options for narrowing the size of the gap.

Chapter 5 goes a step further by reporting on possible long-term temperature changes following from current pledges.

The online version of the report[22] contains three appendices with additional information about emission pledge calculations in this report. Appendix 1 provides detail on the differences between the four pledge cases described in Chapter 3 and the uncertainties around them. Appendix 2 provides a country-by-country analysis of the pledges of the largest emitting countries. Appendix 3 compares the findings of modelling groups that have assessed country pledges.

[22] www.unep.org/publications/ebooks/emissionsgapreport

2. Which emission pathways are consistent with a 2° C or 1.5° C temperature limit?

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2.1 INTRODUCTION

This chapter identifies future emission pathways that are consistent with a 2° C or 1.5° C temperature limit. Many scenarios and pathways for annual global emissions of greenhouse gases have been published in the scientific literature to explore possible long-term trends in climate change. This literature has been used in this report to understand the kind of pathways consistent with the goal of limiting global temperature increase to less than 2° C or 1.5° C above pre-industrial levels.

Among the different studies of future emission pathways, two main types can be identified. The first type is produced by integrated assessment models (IAM), which simulate both future climate and future socio-economic systems, including the emissions of greenhouse gases from industry and power generation, agriculture, forestry and other land use activities (see for example Clarke et al. 2009, Edenhofer et al. 2010, van Vuuren et al. 2007). IAMs take into account assumptions about technological and economic constraints and so, to some extent, provide a view on what are "feasible" emission reductions. The second type of pathway, described here as "stylized", explores more directly the relationship between emissions and temperature, for example by making assumptions about the timing and magnitude of peak emissions and rates of reduction[23] following the peak. These are pathways produced by models that do not explicitly simulate change in the energy system or feasibility of emission reduction rates. "Stylized" pathways are designed to better understand the temperature outcomes resulting from emission pathways computed by carbon cycle and climate models, without making assumptions about how those emissions are produced (see for example Lowe et al. 2009, Meinshausen et al. 2009).

Although both approaches provide important insights and findings, only results from IAMs are used here for quantitative analysis, unless otherwise stated.

Scenarios published by IAMs in the literature mostly look into optimal pathways to achieve a certain long-term target and not into the question of what emission range in 2020 would achieve a temperature limit. For this reason, we have assembled a large set of scenarios computed with various objectives in mind, and have tested them to see if they are consistent with temperature limits. The combination of these scenarios provides insight into the full range of 2020 emissions consistent with long-term temperature limits. It is possible that other feasible pathways will be identified by modelling groups, once they begin to run their models to explore the full 2020 emissions range.

[23] Throughout this report emission reduction rates are given for carbon dioxide emissions from energy and industry and expressed relative to 2000 emission levels except when explicitly stated otherwise.

Although IAM studies have paid little explicit attention to the question of the range of 2020 emissions consistent with temperature limits, there are some studies of stylized pathways that have done this (Bowen and Ranger 2009, Meinshausen et al. 2009).

In our quantitative assessment of IAM results we have attempted to take the differences between studies (in terms of uncertainties of various input assumptions and different approaches) into account by re-analysing the results of these studies using a common set of assumptions about base year emissions, coverage of non-CO_2 gases, carbon cycle assumptions and interpretation of climate goals (as explained in Box 2a). These re-analysed pathways have been evaluated in terms of their consistency with a 2° C and 1.5° C limit. An important factor here is that projections of the future climate all contain uncertainty (Meehl et al. 2007). This means that when discussing the possibility of satisfying a particular temperature limit, it is necessary to express the result in terms of a probability. As explained in Box 2a, the MAGICC model (Meinshausen et al. 2008) has been used here to take into account some of this uncertainty.

2.2 WHAT DETERMINES LONG-TERM TEMPERATURE?

Many greenhouse gases emitted by human activities have long atmospheric residence times and alter the Earth's energy balance. In addition, the average temperature of the Earth typically adjusts only slowly to changes in the energy balance (Lowe et al. 2009, Solomon et al. 2009). These slow-change processes imply that decision makers need to take into account long-term effects of current and near term emissions (National Research Council 2009). This is even more important as many impacts of climate change are potentially adverse and/or irreversible (at least on time scales of relevance to society).

A number of recent studies have shown that one of the strongest predictors of temperature increase within the twenty-first century is the cumulative emissions of greenhouse gases[24], especially CO_2 (Allen et al. 2009, IPCC 2007b, Matthews and Caldeira 2008, Matthews et al. 2009, Meinshausen et al. 2009, Van Vuuren et al. 2008). Cumulative emissions are determined by the annual emissions over time. In ambitious mitigation scenarios, the following factors play an important role in determining the cumulative emissions:

- the year in which global emissions peak
- the emission level at the peak
- the pathway of global annual emissions after the peak.

For the same cumulative emissions, a higher and/or later emissions peak means faster reductions after the peak than for earlier and/or lower peaks in emissions.

However, all three factors are bounded by feasibility considerations, including economic and/or technological constraints (see Section 2.3). For instance, there are constraints on how fast high-carbon energy infrastructure can be replaced with low-carbon infrastructure (for example, coal-fired power plants with renewable energy production).

[24] The shape of the emission pathway of short-lived greenhouse gases and forcing agents has more influence on the degree of temperature change than long-lived agents. Different emission pathways of short-lived gases (even if they have similar cumulative emissions) influence the temperature increase in different ways (Shine et al. 2005). The assessments in this study include the combined effects of both short and long-lived greenhouse gases and forcing agents.

As a consequence, there is a limited range of 2020 emissions that are consistent with a 2° C or 1.5° C limit, given current assumptions about the feasibility of emission pathways post 2020.

In addition, the probability of exceeding a particular temperature level varies according to the cumulative emissions level—for a higher degree of confidence in staying within a particular temperature limit, a lower cumulative emissions level is required. Pathways with later or higher peaks also reduce, or even eliminate, the “margin of error”, should future advances in climate science or additional evidence of the risks of climate change convince citizens and policymakers that more ambitious targets for limiting climate change are needed (Lowe et al. 2009).

2.3 CURRENT ESTIMATES OF FEASIBILITY

The implications of 2020 emission levels for long-term temperature outcomes depend importantly on how much and how fast it is considered feasible to reduce emissions before, and particularly beyond 2020. Feasibility (i.e. considerations on whether a particular emission pathway is possible to achieve) is a subjective concept that has to take into account several factors: technological, economic, political and social. Technological feasibility refers to whether technologies exist, and can be scaled-up fast enough, to produce enough low-carbon energy to meet demand. Economic feasibility refers to whether or not the cost of doing so is considered prohibitively high. Political feasibility includes factors, such as whether the assumed extent of participation in emission reduction efforts across countries (or economic sectors) is plausible and whether the time required to develop institutions that would facilitate this participation is reasonable. Finally, social feasibility refers to whether measures to control emissions would be acceptable to society, for example after taking into account their implications for equity or for non-climate environmental consequences.

IAMs can account for several of these factors by representing inertia of technological and social systems. Examples include assumptions about the maximum feasible technology penetration rates, maximum cost, feasibility of specific system configurations, and maximum speed of behavioural changes.

The results of IAMs are, therefore, helpful in informing our view on feasibility and, hence, are the primary source of quantitative information used in this assessment. However, it should be noted that they do not set “hard laws” on feasibility. On the one hand, they are based on our *current* understanding of technological and economic constraints, which could change; therefore the range of emission pathways considered feasible could shrink or expand over time. For instance, the models do not include the possibility of the development of “game-changing” new technologies currently unforeseen. On the other hand, feasibility also depends on societal and political factors that are not typically considered in IAMs (Bosetti et al. 2010, Ha-Duong et al. 1997, Ha-Duong and Treich 2004). Recently, IAM studies have explored the influence of participation of different countries in model comparison studies (Clarke *et al.* 2009) and this could reduce the range of pathways considered feasible.

One important factor determining the maximum emission reduction rate is the lifetime of machinery and infrastructure: this can be decades or even centuries for building stock and urban infrastructure; around 40 years for power stations; 20 to 40 years for manufacturing equipment; up to 20 years for heating devices; and 10 to 20 years for passenger vehicles, but much longer for transport infrastructure (Philibert 2007). These lifetimes are critically important, if mitigation strategies aim to avoid premature replacement of capital and the high costs associated with it. For illustration, carbon dioxide emissions from energy and industry would decline by about 3 per cent per year if no new emission-producing infrastructure were to be built (adapted from Davis et al. 2010). In the assessed IAM literature on mitigation scenarios, the highest average rate of total emission reduction over the next 4 to 5 decades is about 3.5 per cent per year (den Elzen et al. 2010)[25].

To put this in context, a global CO_2 emission reduction rate of 3 per cent would require a rate of decrease in emissions per unit of GDP (or decarbonization rate) of almost 6 per cent for an assumed annual rate of global GDP growth of 3 per cent. Ranger et al. (2010) show that there is very little precedent for such high rates of emission reductions amongst the top 25 emitters. The global decarbonization rate over the 1969-2009 period was 1 per cent on average, although this was in the absence of strong international climate policies. In a society that places the highest possible priority on reducing emissions, the normal capital turnover rate could possibly be increased. However, some studies suggest that higher annual reduction rates of up to about 6 per cent per year are possible for a limited time in certain circumstances, but only when the conditions have been put in place for rapid investment in decarbonization of the energy sector (e.g. Edenhofer et al. 2009). The feasibility of achieving emission reduction rates of 3 per cent or more per year for CO_2 emissions from energy and industry is highly uncertain, given political and societal constraints and the fact that emission reductions are not likely to be distributed evenly across nations.

Lastly, it should be noted that most of the pathways consistent with the temperature limits in this report include negative global emissions of CO_2 from energy and industry beginning in the 2060s and 2070s. Understanding the feasibility of negative emissions is therefore crucial for assessing the chances of meeting the 2° C and 1.5° C temperature limits: if negative emissions of a significant scale are not possible, then our options for meeting the targets are significantly constrained. Global net negative emissions occur when the removal of CO_2 from the atmosphere due to anthropogenic activities is greater than the anthropogenic emissions into it. One way to achieve this (and assumed by many IAMs) is through the implementation of bioenergy combined with carbon capture and storage (BECCS). This involves using large amounts of biomass to generate energy, and then capturing and safely storing underground or elsewhere CO_2 released by combustion. Since biomass takes up CO_2 from the atmosphere in the course of its growth, and since the CO_2 taken up is stored underground, BECCS in effect removes CO_2 from the atmosphere (Azar et al. 2010). Direct air capture of CO_2 and other technologies may also lead to negative emissions, but are currently not included in IAMs. The feasibility of large scale bioenergy systems, whether used in conjunction with CCS or not, is related to factors such as availability of land and water, impacts on biodiversity, and biomass productivity.

2.4 WHAT EMISSION PATHWAYS AND EMISSION LEVELS IN 2020 ARE CONSISTENT WITH 2° C AND 1.5° C LIMITS?

This section explains how the re-analysed IAM pathways relate to 2020 emission levels, and how these levels relate to the subsequent evolution of pathways that are consistent with the 2° C and 1.5° C temperature limits. Findings from "stylized" pathways are also discussed, because they add to our understanding of emission pathways consistent with temperature

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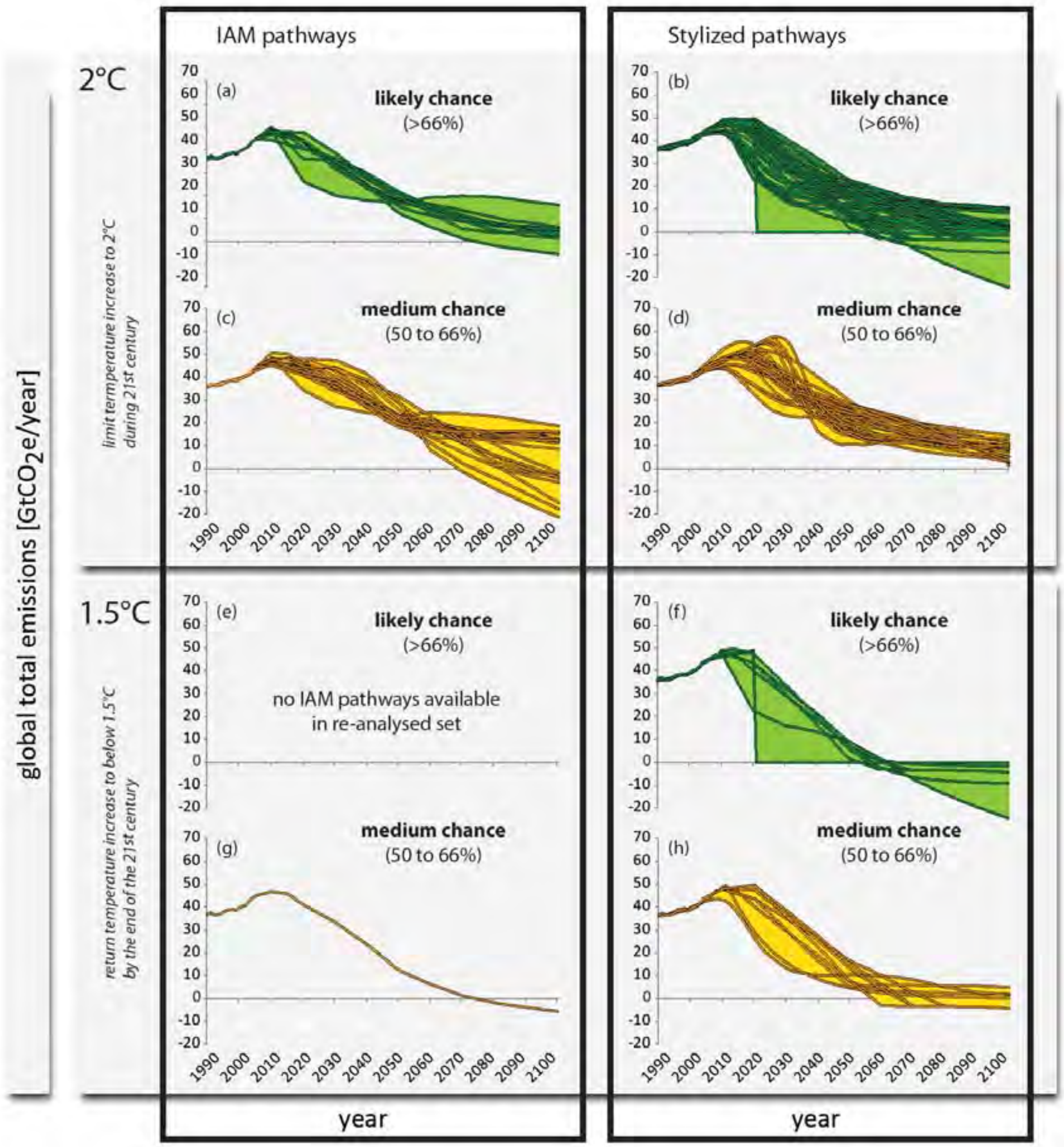
[25] In our set of re-analysed IAM pathways, the fastest reduction rate of energy and industrial emissions is 3.6 per cent (O'Neill et al. 2009). In this report, we usually refer to reduction rates of energy and industrial carbon dioxide emissions, rather than *total* emission reduction rates.

limits. It is shown that expected levels of global emissions in 2020 carry important information for policymakers about the feasibility, scale and magnitude of actions required afterwards to limit global temperature increase.

Figure 1: Overview of global greenhouse gas emissions in $GtCO_2e$/year of IAM emission pathways (panels a, c, e and g at the left) and "stylized" emission pathways (panels b, d, f and h at the right). These are pathways that have been re-analysed in this assessment and that meet the 1.5° and 2° C temperature limits with a particular probability. The area in between the pathways is shaded for clarity. Green pathways meet the temperature limits with a "likely" chance (greater than 66 per cent) (panels a, b, e and f) and orange/yellow pathways with a "medium" chance (50 to 66 per cent) (panels c, d, g and h). The methods used to produce the Figure are detailed in Box 2a. Note that these are global *total* emissions (land use, energy and industry). Later in the chapter we refer to negative emissions of CO_2 from energy and industry only, hence the discrepancy between the number of pathways showing negative emissions in this chart and in Table 1



Box 2a: Method for identifying emission pathways

For the purpose of this assessment we collected a total of 223 emission pathways. Of these 126 were IAM emission pathways published by 15 modelling groups[26], of which 113 explored low greenhouse gas concentration targets while taking into account some assumptions about technological and socio-economic inertia, whereas the remaining 13 represent scenarios without strong mitigation policy. These IAM pathways had varied rates of emission reductions across regions, sectors and gases in order to minimise costs. Of the 223 pathways, 97 were “stylized” pathways[27] which did not make assumptions about technological and economic feasibility, but identified the emission pathways that corresponded to particular temperature targets based on carbon cycle and climate models.

We have evaluated the probability of each of the pathways meeting a 2° C and 1.5° C limit. In order to make results more comparable, we have adjusted the pathways so that they have the same emission levels in 2000 and 2005. Emissions for these years were taken from the multi-gas emissions inventory developed as part of the “Representative Concentration Pathways” (RCPs) scenario exercise (Granier et al. submitted, Meinshausen et al. submitted). When a particular pathway lacked the emissions of a particular substance (e.g. sulphate aerosols, organic carbon, black carbon or atmospheric ozone precursors), these data were taken from the RCP3-PD scenario (van Vuuren et al. submitted). It should be noted that the RCP-3PD scenario assumes strong environmental policies and this is consistent with the aim of this report to identify mitigation pathways that stay within a 2° C or 1.5° C limit. Ozone depleting substances controlled by the Montreal Protocol are assumed to follow a gradual phase-out during the twenty-first century.

The temperature calculations of the harmonised emission pathways were made more comparable by using a single model MAGICC 6.3 (Meinshausen et al. 2009, Meinshausen et al. 2008) to calculate the probabilistic temperature outcome up to 2100 for each emission pathway.

A joint probability distribution of the most important climate response uncertainties has been used, with climate sensitivity uncertainties closely reflecting the estimate provided by the IPCC (IPCC 2007c)[28].This distribution gives the probability of a particular response of temperature to emissions. Because a probability distribution rather than a single number is used for the climate sensitivity factor, temperature outcomes are expressed in terms of probabilities, for example, “emission pathways with a medium chance of staying below a 2° C limit”. The emission pathways were put into different categories according to temperature limits (1.5° and 2° C), their probability of meeting the limit (50-66 per cent, greater than 66 per cent), the assumed technologies (e.g. negative emissions or not), and whether they are “stylized” or IAM pathways.

We also performed a sensitivity analysis by analysing 11 recalibrated versions of the climate model to explore alternative values of the climate sensitivity distribution that have been published (see Meinshausen et al. 2009). For emission pathways that give around a “medium” chance of meeting a 2° C limit during the twenty-first century, the sensitivity studies lead to a spread in the median projected temperature of only ±0.2° C.

It is important to note that although we have harmonised the pathways for comparability, some uncertainties remain, for example, about future levels of anthropogenic aerosols, soot and organic carbon.

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26 Studies underlying the IAM emission pathways can be found in the literature (Clarke et al. 2007, Clarke et al. 2009, Edenhofer et al. 2009, Edenhofer et al. 2010, Fujino et al. 2006, IPCC 2007a, O'Neill et al. 2009, Riahi et al. 2007, Smith and Wigley 2006, van Vuuren et al. 2007, Wise et al. 2009).

27 Studies underlying the “stylized” pathways are found in the literature (Bowen and Ranger 2009, den Elzen et al. 2007, Lowe et al. 2009, Meinshausen et al.2009, Ranger et al. 2010, Rogelj et al. 2010a, Rogelj et al. 2010b, Schaeffer and Hare 2009), as well as the methodology used in this report for possible complementary pathways (Meinshausen et al. 2006).

28 The climate sensitivity distribution used for the analysis throughout this report is the “illustrative default” case as described in Meinshausen et al. (2009).

The climate model used in this study has previously been validated and shown to credibly reproduce observed climate changes when driven by historic emissions or forcings. However, like other climate models it does not include all of the physical processes that could affect the real climate in future. For instance, there is no treatment of extra carbon release from melting permafrosts.

Our quantitative assessment of IAM pathways found a notable number and range of emissions that are consistent with the temperature limits of interest in this report, even after re-analysis. In the text we focus on the median and range of the "majority of results", with the range corresponding to the 20th to 80th percentile of outcomes. Results at either end of this range are not necessarily invalid or incorrect, and are also discussed in the text.

Assessment of the pathways consistent with 2° C

Of all IAM emission pathways that were included in our quantitative assessment, 9 were found to have a "likely" chance (greater than 66 per cent) of limiting warming to less than 2° C above pre-industrial levels. The results of our quantitative assessment (Table 1) show that the majority of emission pathways with a "likely" chance of meeting the 2° C limit show the following characteristics:

- A peak in global greenhouse gas emissions before 2020 and in general earlier in the decade;
- 2020 global greenhouse gas emission levels of 44 $GtCO_2e$ (median), with a range[29] of 39-44 $GtCO_2e$[30];
- Average annual reduction rates of CO_2 emissions from energy and industry between 2020 and 2050 of around 3 per cent (range of 2.2-3.1 per cent)
- 2050 global emissions that are 50-60 per cent below their 1990 levels; and
- In most cases, negative CO_2 emissions from energy and industry beginning in the 2060s to 2070s[31].

A further 18 IAM pathways were found to have a "medium" chance (50-66 per cent) of staying below a temperature increase of 2° C. The 2020 emission levels are similar (median 45 $GtCO_2e$, range 42-46), while the emission reduction rate between 2020 and 2050 is lower (2.5 compared with 3 per cent per year), Half of these "medium" chance pathways involve net negative CO_2 emissions from energy and industry, beginning between the mid-2050s and mid-2070s[32].

[29] Ranges here, and in the following text, refer to the "majority of results", that is, between the 20th and 80th percentile of results, unless otherwise specified.

[30] Note, these are rounded numbers. If numbers with one decimal place were shown it would be apparent that the upper end of the range is above slightly above 44 and the median slightly below. The fact that both the median and the upper end of the range round to 44 indicates that many of the estimates were close to 44.

[31] 2 of the 9 scenarios do not rely on negative CO_2 emissions from energy and industry to meet the 2° C limit and are associated with low 2020 emission levels of 26 and 36 $GtCO_2e$. Note that Figure 1 does not depict this level of negative emissions since that figure shows global *total* emissions rather than CO_2 emissions from energy and industry, which are described here.

[32] Note that Figure 1 does not depict this level of negative emissions since that figure shows global *total* emissions rather than CO_2 emissions from energy and industry, which are described here.

In general, “medium” chance pathways for 2° C differ from “likely” chance pathways either by having higher emission levels in 2020 but the same rates of emission reductions afterwards, or having the same emission levels in 2020 but slower reduction rates afterwards. “Likely” chance pathways also rely more often on negative emissions.

The re-analysed set of “stylized” pathways (not included in Table 1) shows that, if emissions ranged up to 50 $GtCO_2e$ in 2020, average reduction rates of up to 4 per cent per year would be needed in the 2020-2050 period to meet the 2° C limit (Rogelj et al. 2010b, Schaeffer and Hare 2009)[33]. The high end of these reduction rates is currently not found in the IAM literature. These pathways also require large negative emissions in the second half of this century to meet the temperature limit.

Another important message from analysing IAM emission pathways is that they suggest that it is economically and technologically feasible to achieve substantial emission reductions. This implies that it is possible to reach emission levels consistent with a 2° C target (i.e. approximately 44 $GtCO_2e$ in 2020).

To have a higher confidence of staying below a 2° C limit, it seems essential to deploy negative emission technologies (to reduce CO_2 from energy and industry) in the second half of the century, that is, unless emission levels are significantly below 44 $GtCO_2e$ in 2020.

Assessment of the pathways consistent with 1.5° C

None of the IAM or “stylized” pathways in this assessment lead to temperature increases below 1.5° C throughout this century. One IAM study published by Magné et al. (2010) depicts an emission pathway with a “medium” chance of achieving the 1.5° C target by the end of the century and has 2020 emissions of 41 $GtCO_2e$. These results suggest that after a small (0.1° C) transient overshoot of the temperature limit of about half a century, the temperature increase by the end of the twenty-first century could be brought back to below 1.5° C with a “medium” chance. In general, the IAM pathways that meet the 2° C limit with a “likely” chance also meet the 1.5° C target by 2100 but with a lower probability of 30 per cent (range 27-35 per cent for the 20th-80th percentile) and with a median temperature peak at some point in the twenty-first century of between 1.6° C and 1.7° C.

A few studies have used stylized pathways to explore the achievement of a 1.5° C limit in more detail (Ranger et al. 2010, Schaeffer and Hare 2009). The stylized pathways included in this assessment suggest that limiting warming to 1.5° C by 2100 (with a “medium” to “likely” chance) means 2020 emission levels of 40 to 48 $GtCO_2e$ (20th-80th percentile range), and reduction rates of 3 to 5 per cent per year in the 2020-2050 period (Schaeffer and Hare 2009). These pathways would also employ negative CO_2 emissions in the second half of this century. As discussed in Section 2.3, the feasibility of achieving such high emission reduction rates is difficult to assess and they are not found in the current literature of IAM results.

[33] In the literature, two studies of “stylized pathways” have explicitly focused on the question of emission pathways consistent with the 2° C limit (Bowen and Ranger 2009 and Meinshausen et al. 2009).

Table 1: Re-analysis results of IAM pathways with 2° C characteristics.

2° C pathways	Number of pathways	Peak year period*	2020 total emission levels ($GtCO_2e$)**		Average energy and industry CO_2 reduction rate from 2020 to 2050 (% of 2000 levels / yr)		Decade in which global energy and industry CO_2 emissions turn negative	
			Median	Range***	Median	Range***	Median	Range***
"Likely" chance (greater than 66 per cent) of staying below 2° C during twenty-first century								
Without negative CO_2 emissions from energy and industry	2	2010-20	**31**	26-36	**0.9**	0.6-1.2	**N/A**	N/A
With negative CO_2 emissions from energy and industry	7	2010-20	**44**	41-{44-44}-48	**3.0**	2.8-{2.9-3.2}-3.2	**2070**	2050-{*2060-2070*}-2080
Full IAM set	9	2010-20	**44**	26-{39-44}-48	**3.0**	0.6-{2.2-3.1}-3.2	**N/A**	N/A
"Medium" chance (50 to 66 per cent) of staying below 2° C during twenty-first century								
Without negative CO_2 emissions from energy and industry	9	2010-20	**44**	34-{42-45}-48	**2.4**	0.8-{2.2-2.7}-3.1	**N/A**	N/A
With negative CO_2 emissions from energy and industry	9	2010-20	**45**	41-{42-46}-48	**2.5**	1.3-{2.3-3.2}-3.6	**2060**	2050-{*2050-2060*}-2070
Full IAM set	18	2010-20	**45**	34-{42-46}-48	**2.5**	0.8-{2.2-3.0}-3.6	**N/A**	N/A

* Because IAM pathways provide emissions data only for 5-year or 10-year increments, the encompassing period in which the peak in global emissions occurs is given. The peak year period given here reflects the 20th-80th percentile range. Note that pathways with a "likely" chance show peaks earlier in the decade, whilst those with a 'medium' chance are spread across the whole decade.
** For comparison: the median of current (2010) emissions in the harmonised IAM set is 48 $GtCO_2e$.

*** Range is presented as the (minimum value - {20th percentile - 80th percentile} - maximum value). Only minimum, maximum and median values are given for the subsets with very few pathways

Results from low and high ends of emissions range in 2020

In the text we have focused on the "majority of results" of the re-analysed IAM pathway set (the median and 20th to 80th percentile range). However, results outside this range are also valid and provide useful information.

We first consider the *high end* of the range of expected emissions in 2020 represented by results from van Vuuren et al. 2007 for a "likely" chance to stay below a 2°C limit, and O'Neill et al. 2009 for a "medium" chance. At this end of the range emissions are 48 $GtCO_2e$. For a "likely" chance to achieve the temperature target, average reduction rates between 2020 and 2050 (of CO_2 emissions from energy and industry) are 3.2 per cent per year, and for a medium chance 3.6 per cent per year[34]. These set the upper range of emissions and reduction rates.

[34] The seemingly counterintuitive difference in reduction rates is explained by the different shape of the post 2020 emission pathways. Van Vuuren et al. (2007) show emissions declining shortly after 2020 and hence have a lower rate of reduction with a high likelihood of limiting temperature increase than O'Neill et al. (2009), which decline later but faster and deeper.

The *low end* of the range shows that relatively low emission reduction rates between 2020 and 2050 are sufficient to reach the temperature limit, if 2020 emission levels are at the low end of the range. Some pathways, for example in Barker and Scrieciu (2010) and Clarke et al. (2009), indicate 2020 emission levels of 26-36 $GtCO_2e$. These results suggest that it may be technologically and economically feasible to reduce global emissions by 2020 by substantially more than the majority of IAM pathways assume.

Box 2b. Overshooting of 2° C Temperature limits

Model results show that temperature trends could overshoot and then drop again below temperature limits as a result of natural "sinks" acting to gradually reduce the atmospheric burden of the greenhouse gases over time. However, since this process occurs slowly, it is expected that once temperatures overshoot a target, they will take decades to drop below the target (Lowe et al. 2009). This process could be accelerated if negative CO_2 emissions were achieved as discussed earlier (Azar et al. 2006, Azar et al. 2010).

Overshoot pathways often arise in three different contexts: (1) deliberate policy choice to minimise mitigation costs; (2) failure to meet certain emission targets or goals; or (3) late participation by all major emitters in global mitigation efforts (Clarke et al. 2009, van Vliet et al. 2009). While deliberate overshoot may minimise mitigation costs over time, it does run the risk of lock-in of further fossil fuel use and thereby limiting the rate at which emissions can decline in subsequent years.

In the assessed IAM pathway set, four pathways have a temporary temperature overshoot before dropping below 2° C again. [35]. All of these pathways have global negative CO_2 emissions to help achieve the target. In these pathways the constraint on 2020 emissions is relaxed slightly, and the peak is postponed to 2020 and beyond.

Delayed action may have economic benefits (as noted above), but also has risks associated with the higher, albeit temporary, temperatures. These include higher mitigation costs over the long term and later and larger damages from climate change impacts. Huntingford and Lowe (2007) argue that there are significant risks from exceeding temperature limits during overshoot scenarios, due to uncertainty about so-called tipping points. An additional risk of overshooting temperature limits is that positive feedbacks, not known in advance, might result in a larger temperature increase than anticipated.

2.5 GAPS IN KNOWLEDGE AND FURTHER WORK

The ability to assess pathways consistent with specific temperature limits depends on understanding both the climate system and the global energy system, as well as the ways in which each responds to change over time.

Important uncertainties exist in our understanding of the climate system. We have accounted for some of this uncertainty by examining the probability of meeting particular temperature limits. Future shifts in the underlying probability distributions, as a result of improved understanding of parameters and/or feedbacks in the climate system, could change the expected probability with which a certain pathway would meet a specified temperature limit. There is also much uncertainty around the issue of how rapidly temperatures may be reduced after overshooting, and the reversibility of associated climate system changes.

[35] In addition to the 27 of the 126 IAM pathways that are able to meet the 2° C limit during the twenty-first century without a temperature overshoot and with a probability higher than 50 per cent.

Our understanding of the feasibility of pathways is also incomplete. Many of the pathways assessed here were not designed to specifically investigate the limits to feasible emission reductions, and none of the studies were designed explicitly to explore the full range of emissions in 2020 that would be consistent with long-term temperature limits. Research specifically targeted to address these questions would improve our understanding of which pathways can feasibly achieve temperature targets.

In addition, emission pathways now considered infeasible could become feasible if variables such as population growth rate, consumption of energy, aerosol emissions, economic growth and technological developments turn out to be different from the assumptions used in current studies. Other factors could also make emission pathways feasible such as the willingness of society to take “extreme” action by retiring energy infrastructure before the end of its useful lifetime, or by making significant lifestyle changes. Similarly, the pathways thought to be feasible in this report could in practice be unachievable, if, for example, participation in mitigation efforts was limited across sectors and countries, or if technological and socio-economic barriers were more severe than expected.

Given these uncertainties, it will be crucial over time to re-evaluate the emission pathways consistent with particular temperature limits and to inform the policy community accordingly.

3. What are the expected global emissions in 2020?

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3.1 INTRODUCTION

Nearly 140 countries have associated themselves with the Copenhagen Accord and over 80 countries, representing about 80 per cent of global emissions, have appended targets (Annex I countries) and/or mitigation actions (non-Annex I countries). The aim of this chapter is to assess the published analyses and to explore what these targets and actions (collectively referred to as "pledges")[36] are likely to lead to in terms of 2020 emissions[37]. Three appendices to this Chapter are available online[38]. Appendix 1 provides detail on the differences between the four cases and the uncertainties around them. Appendix 2 provides a country-by-country analysis of the pledges of the largest emitting countries. Appendix 3 compares the modelling groups' findings and details the adjustments made to their data to ensure consistent comparisons. Chapter 4 then goes on to combine these results with those of the previous chapter on emission pathways in order to assess the extent to which these pledges are consistent with a 2° C or 1.5° C pathway.

Estimating 2020 emissions, based on countries' pledges or submissions to the Copenhagen Accord, is not a simple task. This Chapter explains in detail that it involves *inter alia*: information on the historical, current and future growth of countries' emissions; interpretations in the cases in which countries have submitted a range of pledges; assumptions on the precise meaning of those pledges where countries have not been specific; and uncertainties in the underlying data used by modelling groups.

Therefore, we separate the emission estimates that are driven by distinct policy choices, either nationally or in the negotiations, from what is driven by different modelling assumptions. We first present the results of this analysis and then move on to explore the modelling uncertainties around them.

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36 Please note that the pledges incorporated in the Copenhagen Accord in early 2010 have not changed through the 2010 negotiations' cycle

37 Whilst this assessment focuses on the pledges submitted to the Copenhagen Accord, in one instance, for Indonesia, modelling groups have analysed a conditional pledge announced by the President but not included in the Copenhagen Accord submission. The impact of that pledge is included in the two conditional pledge cases presented in this Chapter.

38 www.unep.org/publications/ebooks/emissionsgapreport

3.2 GLOBAL AGGREGATE EMISSIONS RESULTING FROM THE PLEDGES

For this assessment, the analyses of 13 modelling groups have been reviewed[39]. Of these, nine groups have performed a global analysis and four have focused on either Annex I or a subset of other countries. These groups have made different assumptions about how the conditionality of pledges plays out in global emissions. Hence, adjustments have been made to the various estimates, in order to facilitate a meaningful comparison. The adjustments made are briefly explained in Box 3a and detailed in the appendices available online[40]. The aim has been to construct a set of pledge cases with estimates of different 2020 emission levels.

Box 3a: Explanation of the four pledge cases and calculation method

In this chapter we have constructed four distinct pledge cases that could result from different policy choices of Governments or from different outcomes of the negotiations. These four cases are combinations of the following two interdependent factors:

Unconditional versus conditional pledges: We have distinguished between countries' unconditional and conditional pledges. Several industrialized countries have made pledges conditional on actions from other countries or the passing of domestic legislation, and developing countries' pledges are often conditional on finance or technology transfer. We have made common assumptions as to whether a country's pledge is deemed conditional or not (detailed in Appendix 2) and applied that to all modelling groups' estimates. We have then summed the estimates to create a global total, which also includes international transport emissions. Note that where a country does not have an unconditional pledge (e.g. Canada, Japan, US and South Africa) the business-as-usual estimate for that country is assumed for the unconditional case reflected in Figure 2. [41]

"Lenient" versus "strict" rules: We have adjusted these results to take into account the maximum[42] impact of two unresolved issues in the negotiations: LULUCF accounting and the use of surplus emissions units. These issues have the potential to displace mitigation action in other sectors and thus lead to higher global emissions in 2020. The adjustments made are based on a review of existing literature and are reflected in the two "lenient" pledge cases (the "strict rules" cases do not include any impact from these issues). Specifically, for LULUCF accounting we have applied a maximum expected impact of 4.2 per cent of 1990 Annex I emissions annually in 2020 (approximately 0.8 $GtCO_2e$). We assumed that credits of this magnitude would be given for carbon removals from existing forests or other sinks that would have occurred without further policy interventions (see Box 3b). For surplus emissions units, we have made two adjustments: the first for the expected impact of surplus emissions units "carried over" or "banked" from the first commitment period and used in the next. We have applied the maximum expected impact of 1.3 $GtCO_2e$ on 2020 emissions. The second adjustment is to account for any new surplus units that are expected to be generated in the next commitment period as a result of the pledges from Russia, Ukraine and Belarus remaining above business-as-usual. The expected impact of these depends on the modelling assumptions of each

[39] Namely: Climate Action Tracker (CAT) by Ecofys, Climate Analytics and PIK; Climate Interactive (the C-ROADS model); Climate Strategies; FEEM (the WITCH model); IIASA (the GAINS model); Grantham Research Institute (LSE); OECD (the ENV-linkages model); PBL Netherlands Environmental Assessment Agency (the FAIR model); Peterson Institute for International Economics (PIIE); Project Catalyst; the AVOID research programme (led by the Met Office Hadley Centre); UNEP Risoe; and the World Resources Institute (WRI).

[40] www.unep.org/publications/ebooks/emissionsgapreport

[41] Given that these countries are implementing and/or planning some domestic policies, this is a very cautious assumption (e.g. for the USA see Bianco and Litz (2010)).

[42] A maximum impact is taken in order to show an upper bound for what 2020 emissions could be under these cases.

group and ranges up to 1 $GtCO_2e$ in 2020.[43] A more detailed description of these issues and adjustments is available in Appendix 1.

In order to make consistent comparisons across modelling groups, we have had to adjust the global emission estimates of some groups to ensure that all sectors and countries are covered. In the case where data were missing (e.g. international transport emissions), we have added the median value of other modelling groups' data. In addition, in order to ensure a consistent comparison with the results from Chapter 2 we have harmonised the data for the same 2005 emissions used in that chapter. These adjustments result in slightly different emission levels for each of the groups compared with those included in their publications. Appendix 3 provides more detail on the differences between modelling groups' findings and the adjustments made.

In Figure 2 we show median results for each case to reflect the clustering of results from modelling groups. In the text we report the 20th and 80th percentile range to reflect the majority of the results.

To estimate emissions expected in 2020 we have to make assumptions about the policy choices of governments. Since these choices are uncertain we specify four different cases, each giving a different combination of choices (Box 3a). The results for emissions are as follows (and are summarised in Figure 2):

As a reference point, without pledges global greenhouse gas emissions may increase from 45 $GtCO_2e$ in 2005 to around 56 $GtCO_2e$ in 2020 (with a range[44] of 54-60 $GtCO_2e$) according to business-as-usual projections.

– *Case 1 – "Unconditional pledges, lenient rules"*: this case would occur if countries stick to their lower-ambition pledges and are subject to "lenient" accounting rules. By this we mean that Annex I countries maximise the use of surplus emission units and "lenient LULUCF credits" (see Box 3b) to meet their targets.. In this case, the median estimate of emissions in 2020 is 53 $GtCO_2e$ per year, with a range of 52-57 $GtCO_2e$.

– *Case 2 – "Unconditional pledges, strict rules"*: This case would occur if countries stick to their lower-ambition pledges and are subject to "strict" accounting rules. By this we mean that the use of surplus units and "lenient LULUCF credits" is assumed to be zero. In this case, the median estimate of emissions in 2020 is 52 $GtCO_2e$, with a range of 50-55 $GtCO_2e$.

– *Case 3 – "Conditional pledges, lenient rules"*: This case would occur if countries moved to their higher-ambition pledges (as conditions are either met or relaxed), but are subject to "lenient" accounting rules (as explained in case 1 above). This case was included because some of the more ambitious pledges of Annex I countries are conditional on some use of these credits or carry-over of surplus units (e.g. European Union, Russia). In this case, the median estimate of emissions in 2020 is 51 $GtCO_2e$, with a range of 49-53 $GtCO_2e$.

– *Case 4 – "Conditional pledges, strict rules"*: This case would occur if countries moved to their higher-ambition pledges, and are subject to "strict" accounting rules

[43] Note that in computing the emissions for the "lenient" cases we have applied the adjustments noted in this box for LULUCF accounting and surplus emission units. H owever, if those adjustments resulted in Annex I emissions being higher than their business-as-usual projections then we capped emissions at that level. Hence the adjustments noted in this box are not additive.

[44] Henceforth, in this chapter all ranges refer to the 20th-80th percentile, unless otherwise specified.

(as explained in case 2 above). In this case, the median estimate of emissions in 2020 is 49 $GtCO_2e$, with a range of 47-51 $GtCO_2e$.

It is worth noting that there is the possibility of higher global emissions if international offsets are counted towards both industrialized and developing countries' pledges (the so-called "double counting" of offsets). It should also be noted that in some countries the impact of existing domestic policies or national plans could lead to lower emissions than the conditional pledges submitted to the Copenhagen Accord. International climate finance could also leverage further mitigation and lower emissions. All these issues have been analysed and found to have a significant effect on 2020 emissions. However, they are not included in any of these cases but are discussed as additional factors in Section 3.4 below.

From the analysis of these four cases it is interesting to note that the international policy options being discussed in the UNFCCC negotiations, and inherent in these cases, can significantly reduce the level of emissions in 2020. The most ambitious of the cases (case 4) is expected to be 7 $GtCO_2e$ lower than business-as-usual emissions (range of 6-9 $GtCO_2e$ lower).

For Annex I countries, in the least ambitious case ("unconditional pledges, lenient rules"), emissions are estimated to be 6 per cent above 1990 levels (range of 1-12 per cent above) or equivalent to business-as-usual emissions in 2020. In fact, in many cases the use by Annex I countries of surplus units and "lenient LULUCF credits" provides more overall emission units than needed. This could result in higher emissions after 2020 if those units were to be banked for use in the following period.

In the most ambitious case ("conditional pledges, strict rules"), Annex I emissions in 2020 are expected to be 16 per cent below 1990 levels (range of 15-18 per cent below) and 20 per cent below business-as-usual emissions (range of 17-26 per cent).

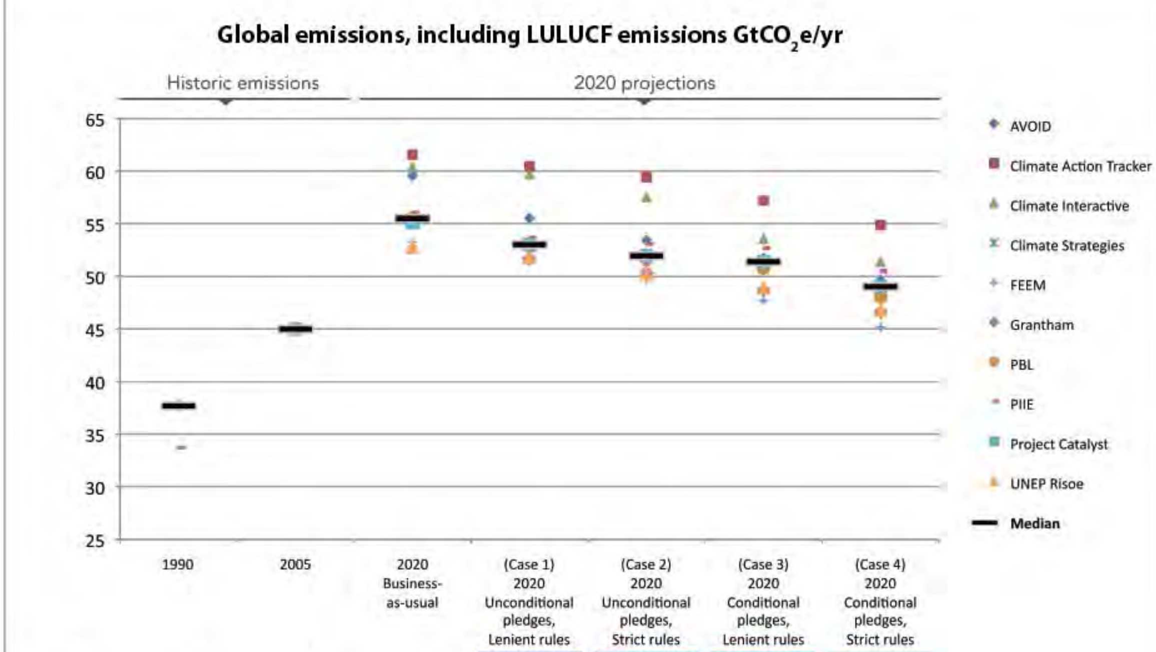
For non-Annex I countries, in the least ambitious case ("unconditional pledges") emissions are estimated to be 7 per cent lower than business-as-usual emissions (range of 6-8 per cent lower). In the most ambitious case ("conditional pledges"), non-Annex I emissions are 9 per cent lower than business-as-usual (range of 8-9 per cent lower).

This implies that the aggregate Annex I countries' emission goals are less ambitious than the 25-40 per cent reduction by 2020 (compared with 1990) suggested in the IPCC Fourth Assessment Report (IPCC 2007a). Collectively the non-Annex I countries' goals are less ambitious than the 15-30 per cent deviation from business-as-usual which is also commonly used as a benchmark (den Elzen and Höhne 2008, 2010). Whilst these values are helpful as a benchmark, it should be noted that, as described in chapters 2 and 4, various other emission pathways are consistent with the 2° C and 1.5° C temperature limits.

The cases presented in Figure 2 will be taken forward into the next chapter, which compares global emissions projections for 2020 with the emission pathways associated with limiting temperature rise to 2° C or 1.5° C. There are many possible combinations of the uncertainties considered in the preceding section that may lead to different 2020 emissions. However, the four cases presented above represent a reasonable summary of the potential low and high ambition outcomes that may be associated with the pledges.

Several options exist for policymakers to influence the final global 2020 emission level by delivering on their highest announced ambition and ensuring that accounting rules do not displace mitigation, and by finding ways to deliver further ambition either domestically, through finance or in sectors not currently covered.

Figure 2. Global emissions resulting from the four pledge cases, as found by different modelling groups



	1990	2005	2020 Business-as-usual	(Case 1) 2020 Unconditional pledges, Lenient rules	(Case 2) 2020 Unconditional pledges, Strict rules	(Case 3) 2020 Conditional pledges, Lenient rules	(Case 4) 2020 Conditional pledges, Strict rules
n[3]	4	9	9	9	9	9	9
High	37.9	45.0	61.6	60.6	59.4	57.2	54.9
80th	37.8	45.0	59.9	57.1	55.1	53.0	50.9
Median	37.7	45.0	55.5	53.0	51.9	51.4	49.0
20th	36.1	45.0	54.3	51.8	50.3	48.8	46.7
Low	33.7	45.0	52.8	51.4	49.7	47.7	45.2

All emissions in this figure and chapter refer to $GtCO_2e$ (gigatonnes or billion tonnes of carbon dioxide equivalent)—the global warming potential-weighted sum of the six Kyoto greenhouse gases, that is, CO_2, CH_4, N_2O, HFCs, PFCs and SF_6, including LULUCF CO_2 emissions.
n = number of studies; High = maximum of full range; Low = minimum of full range; 20th-80th = 20th and 80th percentile values of the range
1. The data presented in the table have been harmonised to a common emissions level in 2005 (45 $GtCO_2e$) in order to make these data more comparable to results in Chapter 2.
2. The range in 1990 emissions stems from the use of different data sources and assumptions especially for non-Annex I countries.
3. In the set of studies examined in this report, nine modelling groups have analysed the impact of pledges at the global level, while four have analysed only a subset of countries.

3.3 ANALYSIS OF DIFFERENCES BETWEEN ESTIMATES

The range between modelling groups' estimates can be split into three categories:

1) Differences between the four pledge cases,
2) Differences between estimates for the same pledge case, and
3) Other factors that could affect emissions

More detail on each of these issues and, where appropriate, the sources of estimates can be found online[45] in Appendix 1. Figure 3 summarises the impact of these differences on the emissions of the four pledge cases, together with the further uncertainties described in the next section.

1) Differences between the four pledge cases

The four cases presented in Figure 2 are characterised by different assumptions on the conditionality of both Annex I and non-Annex I countries' pledges, LULUCF accounting rules and on the use of surplus units from the first commitment period and the possible creation of new surplus in the future. An overview of the impact of these assumptions is provided below – Appendix 1 has more details:

<u>Unconditional versus conditional pledges</u>

If countries were to move from unconditional to conditional pledges global emissions would be around 2-3 $GtCO_2e$ lower (with a range of estimates of 2-5 $GtCO_2e$). This breaks down as follows (numbers in parentheses show the annual 2020 emission reductions associated with moving from case 1 to 3 or from case 2 to 4 in Figure 2):

- <u>Conditionality of Annex I (industrialized) countries (0 to -2.7 $GtCO_2e$)</u>[46]: A significant number of Annex I countries have made pledges that are conditional on the actions of others or on the passing of domestic legislation. In some instances, countries also have unconditional pledges that will be implemented even if those conditions are not met.
- <u>Conditionality of non-Annex I (developing) countries (0 to -0.7 $GtCO_2e$)</u>[47]: As was the case for the Annex I countries, some non-Annex I countries have included a range in their submissions, with the upper end of the range often being conditional on climate finance.

<u>"Lenient" versus "strict" rules</u>

If the rules in the negotiations regarding the use of LULUCF credits and surplus emission units were to be set in a "strict" rather than "lenient" manner, emissions could be around 1-2 $GtCO_2e$ lower. This breaks down as follows (numbers in parentheses show the maximum possible increase in annual 2020 emissions reflected in the "lenient" cases)

- <u>LULUCF accounting rules (0 to +0.8 $GtCO_2e$)</u>: The accounting rules that determine the extent to which LULUCF activities in Annex I countries could be used to meet their respective targets for the period after 2012 are still being negotiated. Most proposals in the negotiations would limit the number of "lenient LULUCF credits" by using historical or reference level baselines (see Box 3b).

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[45] www.unep.org/publications/ebooks/emissionsgapreport

[46] 2.7 $GtCO_2e$ is the median estimate of the studies. It does not exactly match the 2-3 $GtCO_2e$ reflected in the median estimate of Figure 2 due to the distribution of the sample for global emissions. See Appendix 1 for details.

[47] 0.7 $GtCO_2e$ is the median estimate of the studies. It does not exactly match the 1-2 $GtCO_2e$ reflected in the median estimate of Figure 2 due to the distribution of the sample for global emissions. See Appendix 1 for details.

– Surplus emission units

- Carry-over of surplus units from the first commitment period (0 to +1.3 $GtCO_2e$): Surplus emission units can arise due to some countries exceeding their targets in the first commitment period. Countries with surplus units can also "bank" them and use them for meeting their target in a following commitment period post-2012, or sell them to other countries for their compliance.

- Creation of new surplus units in a possible second commitment period: (0 to +1.0 $GtCO_2e$)[48]: Further surplus emission units can occur through some countries being allocated emission units significantly above the estimated business-as-usual level in a possible second commitment period. These units can be used by countries to meet their targets, or sell to other countries for their compliance.

It should be noted that the above issues are interdependent and will result in different emission reductions depending on the order in which they are implemented. Hence the numbers presented above cannot simply be added together and are, therefore, not easily traceable to the median results reflected in Figure 2 above[49]. In the reviewed studies, the total impact from these options (if taken together) would be a reduction in global emissions of 4 $GtCO_2e$ (reflected in the move from Case 1 to 4 in the table), with a full range across studies of 3-8 $GtCO_2e$.

Box 3b: Further explanation of LULUCF accounting in "lenient" and "strict" rules

LULUCF accounting systems should provide credits for proven CO_2 removals from new or enhanced sinks as a result of further policy intervention. Credits for such activities would result in CO_2 removals from the atmosphere that could contribute to meeting, and thus should be counted towards, targets[50].

The "strict" rules cases developed in this chapter reflect situations in which LULUCF credits such as those described above are provided. For calculation purposes, the quantity of LULUCF credits is set to zero in these cases – although some credits could occur. This is accurate because the resulting target emission level is the same and therefore it is not necessary to estimate the possible quantity of these LULUCF credits.

In the "lenient" case, on the other hand, we assume that credits are given for CO_2 removals by sinks that are expected to occur anyway in the absence of additional policy (e.g. from forests existing prior to 1990). Given that these direct-human induced emission removals are anyway part of the baseline emissions,[51] the use of such credits would increase the estimate of 2020 global emissions. In this assessment we call such credits *"lenient LULUCF credits"*. Specifically, we assume that "lenient LULUCF credits" of up to 0.8 $GtCO_2e$ per year in 2020 could be generated in the "lenient" cases shown in Figure 2. See Appendix 1 for details.

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[48] Note that only some modelling groups have analyzed this, so for many groups the assumed impact of this is zero. These groups assume that no extra units are assigned for targets above business-as-usual. However, of the six modelling groups that did analyse this, estimates suggest that it could have as much as a +1 $GtC0_2e$ impact in 2020 (in the conditional pledge cases) – see Appendix 1 for more detail.

[49] The distribution of the sample also complicates this, making it difficult to trace the numbers back to Figure 2.

[50] For the same emission target these credits would allow correspondingly higher emissions in other sectors compared to the situation in which such LULUCF credits were not used to meet the target. In this case, from a global accounting sense, the final net emission level would be the same, assuming that target is met (i.e. would have a "net-zero" effect on the target)

[51] Or are considered by carbon cycle models as CO_2-uptake by the terrestrial biosphere in response to elevated CO_2 concentrations

2) Differences between estimates for the same pledge case

Figure 2 shows that there is sometimes a large difference between modelling groups' estimates of the same cases. The main reasons for these differences are described below and, where possible, the uncertainty that each implies for 2020 global emissions. Numbers in parentheses give the range of 2020 emission estimates in Figure 2 that could be attributed to each of these reasons.

– LULUCF emissions (±4 $GtCO_2e$): Global emissions from LULUCF are subject to a high level of uncertainty, which the IPCC estimates to be ±4 $GtCO_2e$. There is particular uncertainty around anthropogenic emissions from peat lands. Lastly there is an uncertainty around how modelling groups treat the LULUCF emissions from Annex I countries, in particular. LULUCF emission uncertainty may be partially reflected in the range of estimates from different modelling groups.

– Baseline emissions (-3.4 to +2.4 $GtCO_2e$): Modelling groups have used different assumptions regarding non-Annex I countries' business-as-usual emission projections and Annex I countries' base year emissions (e.g. whether LULUCF CO_2 is included or not). Moreover, the quantification of emission reductions due to carbon intensity targets (measured as improvement in emissions per unit of GDP) poses additional uncertainties.

– Non-covered sectors and countries (-1.1 to +2.7 $GtCO_2e$): There is often a significant range in the emissions estimates for sectors not included under national pledges, such as emissions from international aviation and maritime transport (bunkers) and for countries without pledges. The results from different studies will vary, since some have explored the impact of mitigation policies of only a subset of countries.

3) Other factors that could affect emissions

There are_a number of other factors not reflected in the range of estimates under each of these cases, but which could have a large impact on 2020 emissions. Modelling groups have generally not factored these issues into their central estimates for emissions resulting from the pledges—although many of the groups have estimated the impact of these issues separately. These factors include the following. Numbers in parentheses give the maximum annual 2020 emissions impact on the four cases:

– Double counting of offsets (0 to +1.3 $GtCO_2e$): The potential for double counting of offsets towards both industrialized and developing country pledges, is a major source of uncertainty not reflected in Figure 2. This could occur if industrialized countries use offsets to meet their targets and that these same offsets also counted towards developing country pledges. A simple estimate of the risk of double counting can be made by assuming that 33 per cent of the deviation of Annex I emissions from business-as-usual is covered by offsets and that all of those are also counted towards non-Annex I goals. This would lead to emissions being around 1.3 $GtCO_2e$ higher (as compared to the "conditional pledge, strict rules" case)[52]

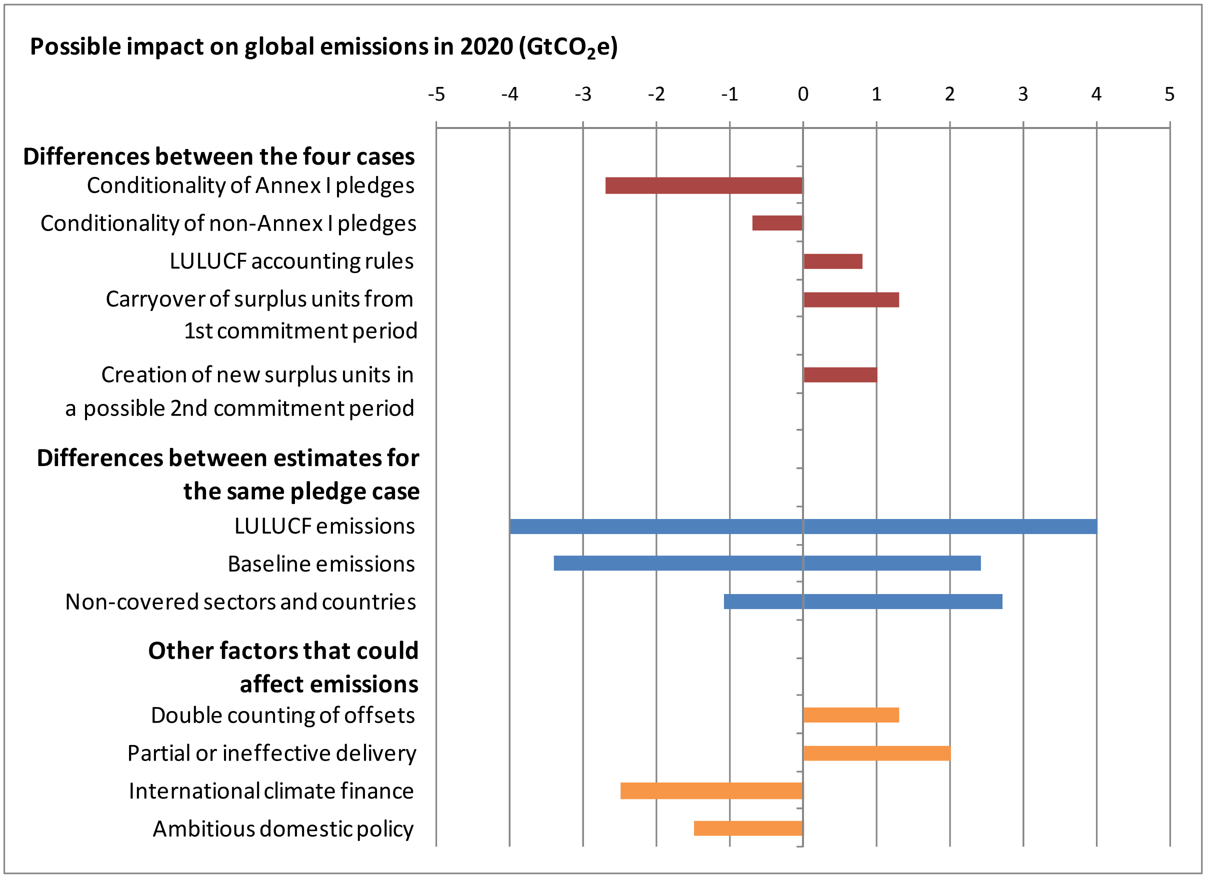
– Partial or ineffective delivery (0 to +2.0 $GtCO_2e$): Any failure to carry out policies would undermine national efforts and lead to higher 2020 emissions; this would push countries' emissions back towards business-as-usual. Conversely, well-designed policies that spur innovation and investment could mean that goals are exceeded. All analyses covered in Figure 2 assume that countries will meet their targets. A crude assessment of the risk of partial implementation can be made by assuming that a certain proportion of the deviation from global business-as-usual is not delivered. Using 25 per cent would lead to estimates of 2020 emissions around 2.0 $GtCO_2e$ higher than in Figure 2 (as compared to the "conditional pledge, strict rules" case).

– International climate finance (0 to -2.5 $GtCO_2e$): International climate finance could leverage further emission reductions beyond the conditional pledges of countries or in countries that have not yet specified mitigation actions. The upper bound of -2.5 $GtCO_2e$ is found by a study that assumes that 25 per cent of Copenhagen Accord financing in 2020 will be used for additional mitigation actions (Carraro and Massetti, 2010).

– Ambitious domestic policy (0 to -1.5 $GtCO_2e$): Certain countries have domestic plans that include mitigation actions that some analysts estimate to be more ambitious than the Copenhagen Accord pledges. The three modelling groups that have analysed this issue estimate that this could lead to emissions being up to 1.5 $GtCO_2e$ lower than the Copenhagen Accord pledges would suggest.

[52] Note also that if offset credits are provided for activities that are not "additional" to expected baselines, even higher total emissions would result.

Figure 3: Summary of the maximum impact of differences and uncertainties on global 2020 emissions. There is a strong interaction between these factors and the effects are therefore not additive. Hence, no estimate of their total impact is given.



Box 3c: Under what circumstances would the Copenhagen Accord pledges lead to a peak in global emissions before 2020?

Most of the emission pathways consistent with a likely chance of meeting the 2º C limit show emissions peaking before 2020 (see Chapter 2). Hence, peaking is an important indicator of whether pledges are consistent with the 2º C limit.

Making an assessment of whether global emissions peak between now and 2020 requires understanding of where the emissions will be in 2020, as well as their trajectory in the interval between now and then. If the emissions in 2020 are close to or below current levels, then it is possible that emissions will peak over this period. Estimates of current (2009) emission levels are around 48 $GtCO_2e$ (Manning et al. 2010). Since only the most ambitious of the pledge cases comes close to current levels, we expect that this pledge case is the one most likely to result in a peak in emissions before 2020. By contrast, the least ambitious pledge case ("unconditional pledges, lenient rules") results in a strong increase in emissions and is therefore the least likely to peak before 2020.

It should be noted that, it is also possible that emissions could peak before 2020, but still remain significantly above current levels in 2020. This could occur, for example, if the emission reduction policies are only introduced or start to take significant effect towards the end of this decade. However, it is difficult to assess the likelihood of this from the pledges alone.

4. What is the emissions gap?

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4.1 INTRODUCTION

This section assesses the potential "emissions gap" between expected emissions based on country pledges and emission levels in 2020 consistent with 2° and 1.5° C limits. For this purpose, we build upon the results in chapters 2 and 3.

As pointed out in Chapter 2, the emission levels consistent with temperature limits depend on the desired likelihood of meeting particular limits, the feasible pace of emission reductions post 2020, and the availability of technology to achieve, for example, negative emissions (Chapter 2, Table 1).

It was explained in Chapter 3 that expected emissions in 2020 depend on whether unconditional or conditional pledges are followed and on the outcome of a number of issues under negotiation, in particular that of LULUCF accounting and surplus emission units (Chapter 3, Figure 2). Given the uncertainty of both expected emissions and emission levels consistent with temperature limits, we do not make a single estimate of the potential gap. Instead, we assess the likely range of the gap based on combinations of assumptions about both expected emissions and emission levels corresponding to temperature targets[53].

4.2 FINDINGS FOR 2° C

Table 2 summarises the gaps that result from four different interpretations of how the pledges are followed, and for a "likely" (greater than 66 per cent) and a "medium" (50-66 per cent) chance of staying below 2° C.

In Chapter 2 it was shown that emission levels of 44 $GtCO_2e$ in 2020 (range of 39-44 $GtCO_2e$)[54] are consistent with a "likely" chance of limiting global warming to 2° C.

In Chapter 3, four pledge cases or possible negotiation outcomes were identified. Here we compare the gap in 2020 between expected emissions based on these cases and emission levels identified in Chapter 2. As a reference point, business-as-usual emissions in 2020 would result in a gap of 12 $GtCO_2e$ (range of 10-21 $GtCO_2e$).

– *Case 1 – "Unconditional pledges, lenient rules"*. Countries implement their lower-ambition pledges and maximise the use of "lenient LULUCF credits"[55] and surplus emissions units to meet their goals. In this case, the gap is 9 $GtCO_2e$ with a range of

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53 However, it is important to note that the results in Chapter 2 do not take into account some other important sources of uncertainty, such as the effects in the future of different potential levels of anthropogenic aerosols—these may also affect the assessment of the gap.

54 As in previous chapters, this and following ranges refer to the 20th and 80th percentile of results, unless otherwise specified.

55 Credits given for carbon removals from existing forests or other sinks that would have occurred without policy intervention and are likely to be included in the baseline of models.

8-18 $GtCO_2e$. The unconditional pledges would thus reduce the gap by about 20 per cent compared to business-as-usual.

– *Case 2 – "Unconditional pledges, strict rules".* Countries implement their lower-ambition pledges but do not use "lenient LULUCF credits" and surplus emission units to meet their goals. In this case, the gap narrows to 8 $GtCO_2e$ (range of 6-16 $GtCO_2e$). Compared to business-as-usual, this is equivalent to achieving about 30 per cent of the overall mitigation effort towards 2° C by 2020.

– *Case 3 – "Conditional pledges, lenient rules".* Countries implement their higher-ambition pledges and make maximum use of "lenient LULUCF credits" and surplus emissions units. In this case, the gap is reduced to 7 $GtCO_2e$ (range of 5-14 $GtCO_2e$). Compared to business-as-usual, this is equivalent to achieving about 35 per cent of the overall mitigation effort towards 2° C by 2020.

– *Case 4 – "Conditional pledges, strict rules".* Countries not only implement their higher-ambition pledges, but also do not use "lenient LULUCF credits" and surplus emission units to meet their goals. The result is a further narrowing of the gap to 5 $GtCO_2e$ (range of 3-12 $GtCO_2e$). This corresponds to the smallest gap assessed in Table 2, and is equivalent to reducing the overall mitigation effort towards 2° C by almost 60 per cent compared to business-as-usual in 2020. As a point of reference, the remaining gap is about the level of emissions in the European Union in 2005 or from the world's road transport in that same year.

Hence, moving from (lower-ambition) unconditional pledges to (higher-ambition) conditional pledges narrows the gap by about 2 to 3 $GtCO_2e$—the majority of this reduction would come from industrialized countries, whose pledges are sometimes conditional on the ambitious action of other countries or on domestic legislation. A smaller, but still important, part of the reduction would come from developing countries, whose pledges are sometimes conditional on the adequate provision of international climate finance or technology transfer.

In addition, the gap can be reduced by around 1 to 2 $GtCO_2e$ by ensuring that "strict" rules apply to the use of LULUCF credits and surplus emission units. If industrialized countries apply "strict" accounting rules to minimise the use of what we refer to as "lenient LULUCF credits", they would strengthen the effect of their pledges and thus reduce the emissions gap by up to 0.8 $GtCO_2e$. Likewise, if the rules governing the use of surplus emission units under the Kyoto Protocol were designed in a way that would avoid the weakening of mitigation targets, the gap could be reduced by up to 2.3 $GtCO_2e$. These include units carried over from the current commitment period and any potential new surpluses created in the next. See Chapter 3 for more details[56].

There are also a number of important factors, mentioned in Chapter 3, that could increase or decrease the gap and that are not included in these cases. The double counting of international offsets towards both industrialized and developing countries' goals could reduce the overall amount of mitigation and thus increase the gap by up to 1.3 $GtCO_2e$. Conversely, the implementation of ambitious existing national plans, beyond what is included in the Copenhagen Accord, could narrow the gap by up to 1.5 $GtCO_2e$ (as compared to the fourth pledge case).

[56] Note that the 0.8 and 2.3 $GtCO_2e$ numbers indicate the maximum possible impact expected from these issues and cannot simply be added together. The median impact of moving from "lenient" to "strict" accounting rules is found to be 1-2 $GtCO_2e$. See Chapter 3 for more details.

To have a *"medium"* rather than a *"likely"* chance of staying below 2° C, the emission levels for the pledge cases can be about 1 $GtCO_2e$ higher, and the corresponding gap 1 $GtCO_2e$ lower for all pledge cases (Table 2).

Explanation of the range of results of the emissions gap for 2° C

The range of the gap presented for the different cases in Table 2 is based on the "majority of results" (20th to 80th percentile) across both the pledges and the 2° C emission levels. The upper bound estimate of the gap combines low 2° C emission levels (20th percentile) with high emissions from pledges (80th percentile). As explained in Chapter 2, emission levels consistent with the 2° C limit tend to be lower in 2020 when followed by comparatively slower emission reduction rates thereafter, or when negative emissions are not achieved over the long run.

Conversely, at the low end of the gap range we find a combination of higher 2° C emission levels in 2020 and low expected emissions as a result of the pledges. Emission levels that are consistent with 2° C tend to be higher in 2020 when reduction rates are comparatively high after 2020 (3.1 per cent per year) and/or it is assumed that negative emissions take effect over the long run. Under these conditions, emissions can afford to be higher in 2020, since they will be reduced more quickly afterwards.

The size of the gap is therefore strongly dependent on expectations about emission reduction rates after 2020 and the prospects for negative emissions later in the century. Both depend, of course, on the rate of technological development.

In addition, the reader will note that the range around median estimates is not symmetric; the lower bound extends by about 1-2 $GtCO_2e$ below the median, whereas the upper bound rises 7-9 $GtCO_2e$ above it (for a "likely" chance). This is found for all the pledge cases examined and arises because of the skewed distribution of pledge estimates with a more pronounced tail on the upper bound. One interpretation of this skewed range is that the gap may in reality tend to be on the higher side of the median.

This chapter has so far focused on the "majority of results" (20th to 80th percentile of estimates). Results outside this range indicate that emission levels for a "likely" chance of staying below 2° C could be as high as 48 $GtCO_2e$ (Chapter 2), while at the same time expected emissions under case 4 ("conditional pledges, strict rules") could, according to one estimate, be as low as 45 $GtCO_2e$ in 2020. Under these conditions, no gap exists. On the other hand, looking at the other end of the range, we find 2° C emission levels for a "likely" chance of staying below the 2° C limit can range as low as 26 $GtCO_2e$, while the highest estimate of emissions under case 1 of the pledge cases ("unconditional pledges, lenient rules") is 61 $GtCO_2e$, resulting in a gap as high as 35 $GtCO_2e$.

4.3 FINDINGS FOR 1.5° C

There is no emission pathway in the assessed IAM literature of Chapter 2 that achieves the 1.5° C limit with a "likely" (greater than 66 per cent) chance and only one study in this literature depicts an emission pathway consistent with a medium (50-66 per cent) chance of meeting the 1.5° C limit (Magné et al. 2010). The IAM pathways assessed that meet the *2° C* limit with a "likely" chance suggest, however, that after a small (0.1-0.2° C) transient overshoot of the 1.5° C target, the temperature increase by the end of the twenty-first century could drop below 1.5° C, *but with a lower probability.* These pathways reach the 1.5° C target in the long-term with a median probability of 30 per cent (range of 27-35 per cent).

Reaching 1.5° C with these lower probabilities would thus leave a similar emissions gap in 2020 as the one for a "likely" chance for 2° C. However, having a "likely" chance of reaching the 1.5° C target would require higher rates of emission reductions after 2020 (and correspondingly high rates of technological development and deployment) than those reported in the IAM literature.

Table 2. The global gap (in $GtCO_2e$ per year) between emission levels for staying below 2° C (with a "likely" (greater than 66 per cent) and a "medium" (50-66 per cent) chance) and expected emissions as a result of the Copenhagen Accord pledges. All estimates in this table are derived from the results of chapters 2 and 3. Values in bold correspond to medians, and numbers in brackets correspond to 20th to 80th percentile of estimates. Numbers in italics give the adjusted 2020 emission levels for expected emissions from the pledges and emission levels from the pathways.

Pledge case	"Likely" chance (>66%) to stay below 2°C *(2020 emissions: 44 [39-44])*		"Medium" chance (50 to 66%) to stay below 2°C *(2020 emissions: 45 [42-46])*	
Business as usual *2020 emissions: 56 [54-60])*	**12**	[10-21]	**11**	[8-18]
Unconditional pledge, Lenient rules *(2020 emissions: 53 [52-57])*	**9**	[8-18]	**8**	[6-15]
Unconditional pledge, Strict rules *(2020 emissions: 52 [50-55])*	**8**	[6-16]	**7**	[4-13]
Conditional pledge, Lenient rules *(2020 emissions: 51 [49-53])*	**7**	[5-14]	**6**	[3-11]
Conditional pledge, Strict rules *(2020 emissions: 49 [47-51])*	**5**	[3-12]	**4**	[1-9]

4.4 CONCLUSIONS

We have seen in this chapter that a global emissions gap is likely between expected emissions as a result of the pledges and emission levels consistent with the 2° C limit in 2020. But our analysis of options for implementing the Copenhagen Accord pledges has also shown that this gap could be narrowed through any of the following policy options[57]:

1. *Implement conditional pledges:* If all countries were to move to their conditional (high ambition) pledges, it would significantly narrow the 2020 emissions gap towards 2° C. The gap would be reduced by about 2 to 3 $GtCO_2e$, with most of the emission reductions coming

[57] Note that options 1 and 2 are non-additive as their impact depends on the order in which they are implemented. We find that the median impact of these two options together is 4 $GtCO_2e$ in 2020 (shown by moving from the "unconditional pledges, lenient rules" case to the "conditional pledges, strict rules" case) with a 20th to 80th percentile range across groups of 4-6 $GtCO_2e$

from industrialized countries and a smaller, but important, share coming from developing countries. This would require that conditions on those pledges be fulfilled. These conditions include expected actions of other countries as well as the provision of adequate financing, technology transfer and capacity building. Alternatively it would imply that conditions are relaxed or removed.

2. *Minimise the use of "lenient LULUCF credits" and surplus emission units*: If industrialized countries applied strict accounting rules to minimise the use of "lenient LULUCF credits" and avoided the use of surplus emissions units for meeting their targets, they would strengthen the effect of their pledges and thus reduce the emissions gap in 2020 by about 1 to 2 $GtCO_2e$ (with up to 0.8 $GtCO_2e$ coming from LULUCF accounting and up to 2.3 $GtCO_2e$ from surplus emissions units[58]).

3. *Avoid double-counting of offsets:* Double-counting of offsets could lead to an increase of the gap of up to 1.3 $GtCO_2e$, depending on whether countries implement their unconditional or conditional pledges (there is likely to be greater demand for offsets in the higher-ambition, conditional case). Hence avoiding double-counting could be an important policy option.

4. *Implement measures beyond current pledges:* The scenarios assessed in Chapter 2 indicate that it is technically possible to reduce emissions beyond present national plans in 2020. These scenarios show that the gap could be closed, and that emission levels consistent with 2° C could be achieved through the implementation of a wide portfolio of mitigation measures, including energy efficiency and conservation, renewables, nuclear, carbon capture and storage, non-CO_2 emissions mitigation, hydro-electric power, afforestation and avoided deforestation.

5. *Lay the groundwork for faster emission reduction rates after 2020:* Emission pathways consistent with a 2° C temperature limit are characterized by rapid rates of emission reductions post 2020 (of greater than 2.2 per cent per year). Such reduction rates on a sustained time-scale would be unprecedented historically. Therefore it is critical to lay the groundwork now for faster post 2020 emission reductions, for example, by avoiding lock-in of high-carbon infrastructure with long lifespans, or by developing and demonstrating advanced clean technologies.

[58] Note that the 0.8 and 2.3 $GtCO_2e$ numbers indicate the maximum possible impact expected from these issues and cannot simply be added together. The median impact of moving from "lenient" to "strict" accounting rules is found to be 1-2 $GtCO_2e$. See Chapter 3 for more details.

5. Twenty-first century temperature projections associated with the pledges

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5.1 INTRODUCTION

In the previous chapter (Chapter 4), it has been shown that, in the majority of cases, there is a gap between the 2020 emission levels expected as a result of the current pledges and the emission levels that would be consistent with either a 2° C or 1.5° C limit. For a "likely" chance of meeting the 2° C limit, the size of the gap can range between 5 and 9 $GtCO_2e$ (range of 3-18 $GtCO_2e$) depending on the pledge case under consideration.

There is also widespread interest in the implications of 2020 pledges for long-term temperature change. Because future temperature increase is highly dependent upon cumulative emissions after 2020, it is not possible to link unambiguously current pledges with a future temperature outcome or likelihood without making assumptions about post 2020 emission levels. However, it is possible to compare 2020 emissions with IAM scenarios associated with different levels of future warming. Each of these IAM scenarios result in an emission pathway consistent with assumptions about technological and economic development. These emission pathways then lead to different levels of temperature increase in the twenty-first century. Superposition of the 2020 pledge estimates on the IAM pathways provides insight into possible long term temperature trends consistent with the pledges.

5.2 PLEDGES IN 2020 AND TWENTY-FIRST CENTURY TEMPERATURES

In Figure 4, a set of 126 IAM emission pathways (see Box 2a) have been assembled that give rise to a range of likely future temperatures from below 2° C to more than 5° C. Since the emission pathways have all been generated by IAM models, the rates of decline in annual emissions in each of these scenarios are constrained by assumptions about technological and/or economic feasibility embedded in these models. Superimposed on these pathways is a bar representing the range of 2020 expected emissions derived from the pledge cases in Chapter 3.

Figure 4 shows that the range of 2020 emission levels resulting from the pledges tends to be consistent with the IAM pathways that have a likely temperature increase ranging from 2.5° C to 5° C. This is consistent with the findings in chapters 2, 3 and 4. This broad range of temperatures results from a variety of assumptions about post 2020 policy, technological and economic development.

As discussed in previous chapters, this does not mean that current pledges preclude meeting the 2° C limit. However, achieving this goal from the level of emissions resulting from the pledges would involve faster rates of decline, or greater negative emissions than included in most of the scenarios in Chapter 2. This could involve factors not assumed in the

IAM scenarios considered in this report such as development of new technologies or higher economic expenditures.

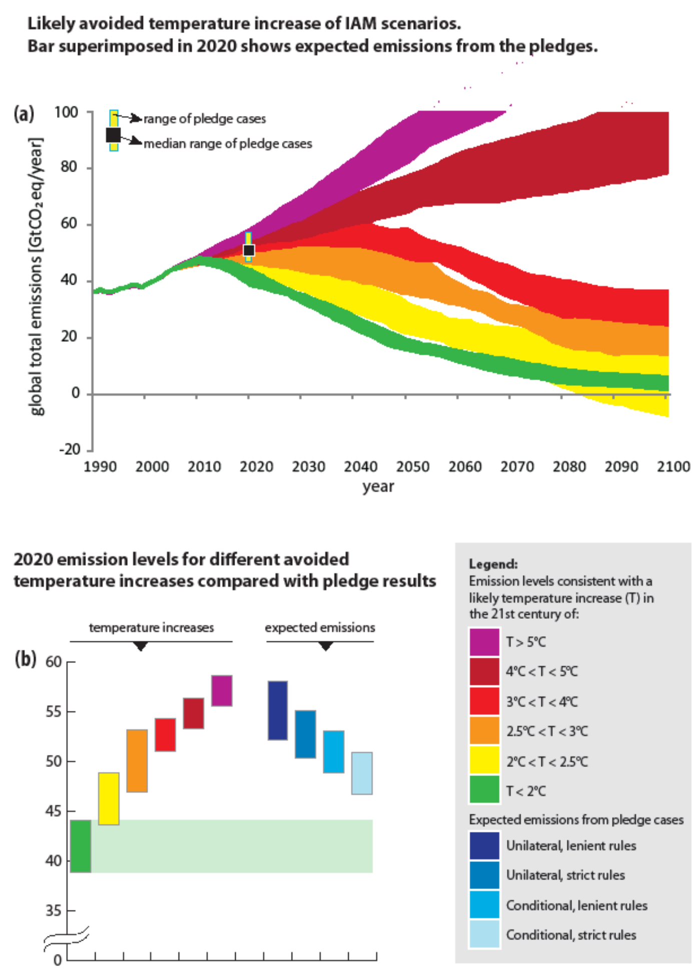
One clear implication of Figure 4 is that a "likely" chance of meeting a 2° C or 1.5° C limit will require attention to two factors:

- Implementing and strengthening 2020 emissions pledges: Implementation of the "conditional pledges, strict rules" case would bring emissions in 2020 to about 49 $GtCO_2e$ (range of 47-51 $GtCO_2e$) compared with the 44 $GtCO_2e$ (range of 39-44 $GtCO_2e$) that would give a "likely" chance of meeting the 2° C limit. Hence, strengthening the pledges would be needed in order to close the gap when considering the majority of results.

- Laying the policy and investment groundwork for faster and deeper reductions in post 2020 emissions: Since all the pathways that have a "likely" chance of achieving temperature limits show strong declines in emissions after 2020 it will be important to achieve faster and deeper emission reductions post 2020.

These conclusions also hold for a "medium" chance of meeting the 2° C limit.

Figure 4: Temperature increases associated with emission pathways and compared to the expected emissions from the pledges
(a) Coloured bands show IAM emission pathways over the twenty-first century. The pathways were grouped based on ranges of "likely" avoided temperature increase in the twenty-first century. Emission corridors were defined by, at each year, identifying the 20th to 80th percentile range of emissions and drawing the corresponding coloured bands across the range. Wide gaps are visible between the coloured bands because most of these scenarios aim for low greenhouse gas emission targets and because only the 20th to 80th percentile of results are shown. The small black bar represents the range of the median estimates of the pledge cases from Chapter 3 in 2020. The thin blue bar represents the range from the 80th percentile of the "unconditional pledges, lenient rules" case to the 20th percentile of the "conditional pledges, strict rules" case.
(b) The coloured bars on the left hand side of this panel show the range (20th to 80th percentile) of 2020 emission levels from the IAM pathways consistent with a "likely" chance of avoiding different temperature increases—as shown in panel (a). The right hand side of panel (b) compares these emissions corridors with the 20th to 80th percentile ranges of expected emissions resulting from the four pledge cases developed in Chapter 3.



5.3 CONCLUSIONS

The majority of results in this report show that emissions in 2020 expected from the Copenhagen Accord pledges are higher than emission levels consistent with a “medium” or “likely” chance of staying below 2° C and 1.5° C. At the same time they also show that the range of 2020 emission levels from the Copenhagen Accord pledges tends to be consistent with the IAM pathways that have “likely” temperature increases of 2.5° C to 5° C up to the end of the twenty-first century.

However, this does not mean that a 2° C goal is infeasible. The IAM literature shows that it remains possible to meet the temperature limits reviewed here, but the emission reduction rates required post 2020 are at the high end of what is currently assumed in the IAM literature to be technologically and economically feasible. The IAM literature also shows that options might be limited after 2020: a full range of low-emission technologies would have to be available and broad participation in global efforts to reduce emissions would be needed (Calvin et al. 2009, Clarke et al. 2009, Krey and Riahi 2009, van Vliet et al. 2009). Pathways capable of meeting the 2° C and 1.5° C limits require significant effort to develop technologies for achieving negative CO_2 emissions from energy and industry starting shortly after mid-century.

Commencing with such fast rates of emission reduction in 2020 and maintaining them for decades will require significant changes in underlying infrastructure and policy. Thus, if it is desired to meet temperature targets, two things appear to be required: first, countries would have to increase the ambition of their 2020 pledges; and second, society would have to put in place the policy, research, and investment processes to support and sustain such a rapid decline in emissions. Rapid rates of emission reduction will also require sustained global effort and cooperation, since action by only a small subset of countries will not be enough to reach temperature targets (Calvin et al. 2009, Clarke et al. 2009, Clarke and Weyant 2009, Krey and Riahi 2009, van Vliet et al. 2009).

In order to bring emissions in line with IAM pathways that meet a 2° C limit, there is a need to not only implement current pledges fully, but also to raise the ambition of those pledges and lay the groundwork for faster and deeper reductions of post 2020 emissions. Going further in the short term and achieving stronger cuts to lower levels in 2020 would leave open more possibilities to meet temperature limits and would allow more flexibility in choosing a post 2020 pathway for global emissions.

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EDITORIAL

Reductions of greenhouse gas emissions in Annex I and non-Annex I countries for meeting concentration stabilisation targets

An editorial comment

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Abstract The IPCC Fourth Assessment Report, Working Group III, summarises in Box 13.7 the required emission reduction ranges in Annex I and non-Annex I countries as a group, to achieve greenhouse gas concentration stabilisation levels between 450 and 650 ppm CO_2-eq. The box summarises the results of the IPCC authors' analysis of the literature on the regional allocation of the emission reductions. The box states that Annex I countries as a group would need to reduce their emissions to below 1990 levels in 2020 by 25% to 40% for 450 ppm, 10% to 30% for 550 ppm and 0% to 25% for 650 ppm CO_2-eq, even if emissions in developing countries deviate substantially from baseline for the low concentration target. In this paper, the IPCC authors of Box 13.7 provide background information and analyse whether new information, obtained after completion of the IPCC report, influences these ranges. The authors concluded that there is no argument for updating the ranges in Box 13.7. The allocation studies, which were published after the writing of the IPCC report, show reductions in line with the reduction ranges in the box. From the studies analysed, this paper specifies the "substantial deviation" or "deviation from baseline" in the box: emissions of non-Annex I countries as a group have to be below the baseline roughly between 15% to 30% for 450 ppm CO_2-eq, 0% to 20% for 550 ppm CO_2-eq and from 10% above to 10% below the baseline for 650 ppm CO_2-eq, in 2020. These ranges apply to the whole group of non-Annex I countries and may differ substantially per country. The most important factor influencing these ranges above, for non-Annex I countries, and in the box, for Annex I countries, is new information on higher baseline emissions (e.g. that of Sheehan, Climatic Change, 2008, this issue). Other factors are the assumed global emission level in 2020 and assumptions on

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land-use change and forestry emissions. The current, slow pace in climate policy and the steady increase in global emissions, make it almost unfeasible to reach relatively low global emission levels in 2020 needed to meet 450 ppm CO_2-eq, as was first assumed feasible by some studies, 5 years ago.

1 Introduction

The level of ambition for reductions by developed countries (Annex I countries) and developing countries (non-Annex I countries), in a future international agreement on climate change, is one very important element in the current climate negotiations. The Ad-Hoc Working Group on Further Commitments for Annex I countries under the Kyoto Protocol (AWG-KP), agreed on the wording of the level of its ambition. At a preparatory meeting in August 2007, it noted the usefulness of the contribution of Working Group III to the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC), which states that emissions need to peak within the next 10 to 15 years and that emissions must be reduced to well below half of the 2000 level by the middle of the twenty-first century, in order to stabilise their concentrations in the atmosphere at the lowest level assessed by the IPCC. In addition, AWG-KP recognised that Annex I countries need to reduce their emissions within a range of 25% to 40% below 1990 levels in 2020, in order to reach the lowest stabilisation levels assessed by the IPCC. The reduction range of −25% to −40% refers to Box 13.7 of the Working Group III report of the IPCC AR4 (Table 1) (Gupta et al. 2007). Agreement on this formulation was possible under the Kyoto Protocol because (1) it is only a recognition of this range and not a decision on it and (2) the USA did not take part in this agreement, as it has not ratified the Kyoto Protocol.

At the Conference of the Parties (COP) 13 in Bali in December 2007, the issue of the reduction range for the Annex I was discussed again, this time with all countries, including the USA. Initial drafts by the EU called for the same wording as already agreed to under the Kyoto Protocol. The Box 13.7 of the IPCC report received large attention, including by the media. But in the end, agreement could not be reached on the reduction percentages in the negotiations under the Convention and, instead, it called for "deep cuts in global emissions" and a reference to the IPCC AR4 was included in a footnote.

The conference also agreed to complete the negotiation process on comparable mitigation commitments or actions by all developed countries and nationally appropriate mitigation actions by developing countries by the end of 2009.

In this paper the authors of Box 13.7 provide more details on the studies that were used to prepare the ranges and they analyse whether new information, obtained after completion of the IPCC report, influences these ranges. A first question is how the ranges were derived and whether new allocation studies would change the results (Section 2). A second question concerns the possibility of quantifying what is termed as "substantial deviation from the baseline" for non-Annex I countries and what the important determinants are. One important assumption is the reductions by the Annex I countries, but an even more important assumption is the baseline that was chosen (Section 3). Different baselines were tested, including those with rapid growth in emissions, in particular in the developing countries, as presented by

Table 1 IPCC Box 13.7: The range of the difference between emissions in 1990 and emission allowances in 2020/2050 for various GHG concentration levels for Annex I and non-Annex I countries as a group

Scenario category	Region	2020	2050
A—450 ppm CO_2-eq[a]	Annex I	−25% to −40%	−80% to −95%
	Non-Annex I	Substantial deviation from baseline in Latin America, Middle East, East Asia and Centrally-Planned Asia	Substantial deviation from baseline in all regions
B—550 ppm CO_2-eq	Annex I	−10% to −30%	−40% to −90%
	Non-Annex I	Deviation from baseline in Latin America and Middle East, East Asia	Deviation from baseline in most regions, especially in Latin America and Middle East
C—650 ppm CO_2-eq	Annex I	0% to−25%	−30% to −80%
	Non-Annex I	Baseline	Deviation from baseline in Latin America, Middle East, and East Asia

Source: Gupta et al. (2007, Section 13.3.3.3). The aggregate range is based on multiple approaches to apportion emissions between regions (contraction and convergence, Multi-Stage, Triptych and intensity targets, among others). Each approach makes different assumptions about the pathway, specific national efforts and other variables. Additional extreme cases—in which Annex I or non-Annex I undertake all reductions—are not included. The ranges presented here do not imply political feasibility, nor do the results reflect cost variances.

[a]Only the studies aiming at stabilisation at 450 ppm CO_2-eq assume a (temporary) overshoot of about 50 ppm (see den Elzen and Meinshausen 2006b).

Sheehan (2008). Also important are assumptions on the required global emission level and on CO_2 emissions from land use, land-use change and forestry (LULUCF).

2 Main assumptions underlying the studies quoted in the IPCC report

Several studies have analysed the level of commitment of different regions and countries and the timing of participation, which are required to ensure meeting the long-term concentration stabilisation targets, using different post-2012 regimes for differentiation of future commitments (allocation schemes). This has been summarised in Box 13.7 by IPCC AR4 (Gupta et al. 2007). Table 2 presents the main assumptions of the sixteen studies used and quoted in the IPCC analysis and two additional unquoted studies (i.e. Höhne et al. 2003; Leimbach 2003), which influence the results:

- *Allocation calculations for CO_2 only or all greenhouse gases (GHGs):* Some calculations were based on all GHGs and some only on CO_2. The share of non-CO_2 gases is usually higher in developing counties
- *Baseline:* The baseline emissions are a major determinant for the results, as more reductions are necessary if baseline emissions are higher
- *Kyoto implementation:* For the short term it is important whether studies have assumed that the Kyoto protocol targets are implemented or not.

Table 2 Main assumptions of the studies quoted by the IPCC and more recent studies (in chronological order) underlying Box 13.7

	Allocation calculations	Baseline scenario[a]	Assumptions on meeting Kyoto targets in 2008–2012	Allocation schemes covered[b]	Global emission target (excl. LULUCF CO_2) in 2020/2050 (%-compared to 1990 levels), for CO_2-eq concentration (ppm), IPCC categories		
					A—450	B—550	C—650
Studies used quoted in IPCC report							
Berk and den Elzen (2001)	CO_2	IPCC* A1	Annex I incl. USA	MS, CC, HR	+10/−20		
Blanchard et al. (2002)	CO_2	IPCC** A1	Annex I excl. USA; FSU BAU[c]	CC, HR, EI			+50/NI
Winkler et al. (2002)	CO_2	IPCC B1	Not considered; base-year 2000	HR, AP, EI	0		
Criqui et al. (2003)	CO_2-eq	CPI 2003	Annex I excl. USA & Australia	MS, CC		+35/−20	+50/+35
Höhne et al. (2003) *(not quoted)*	CO_2-eq	IPCC A2	Annex I incl. USA; FSU BAU[c]	MS, CC, EI, TY, other		+27/NI	
Leimbach (2003) *(not quoted)*	CO_2	Own	Not included; base-year 2000	CC			[40; 75]/+25
WBGU (2003)	CO_2	IPCC**	Annex I incl. USA	CC	+20/−60	+30/+5	
Bollen et al. (2004)	CO_2	IPCC A1	Annex I excl. USA & Australia	CC		+30/NI	+50/NI
Groenenberg et al. (2004)	CO_2	IPCC A1	Not included; base-year 1995	TY	+15/NI	[20; 30]/+5	[35; 60]/+50
Böhringer and Löschel (2005)	CO_2	DOE ref.	Annex I excl. USA & Australia	Other			+50
den Elzen and Lucas (2005)	CO_2-eq	CPI 2003	Annex I excl. USA & Australia	MS, CC, EI, TY, other		+35/−20	+50/+35
den Elzen et al. (2005b)	CO_2-eq	CPI 2003	Annex I excl. USA & Australia	MS, CC, HR		+35/−20	+50/+35
Höhne et al. (2005) (Höhne 2005)	CO_2-eq	IPCC all*	Annex I incl. USA; FSU BAU[c]	MS, CC, EI, TY, other	+10/−40	+30/−10	+50/+45
Michaelowa et al. (2005)	CO_2	Own	Annex I excl. USA & Australia	MS			+30[d]/NI
Böhringer and Welsch (2006)	CO_2	IPCC** A1	Not included; base-year 2000	CC		[30; 35]/−15	

den Elzen and Meinshausen (2006a, b)[e]	CO_2-eq	CPI 2003	Annex I excl. USA & Australia	MS, CC	[20; 30]/ [−30;−50]	+40/[−10; 10]	
Persson et al. (2006)	CO_2	IPCC A1	Annex I excl. USA	CC		+36	
Studies published after IPCC AR4							
den Elzen et al. (2007a)[e,f]	CO_2-eq	CPI 2003	Annex I excl. USA & Australia	Other	[20; 30]/ [−30;−50]	+40/[−10; 10]	
den Elzen et al. (2008b)[e]	CO_2-eq	IPCC B2***	Annex I excl. USA & Australia	MS, CC	+20/−35	+35/−5	
den Elzen et al. (2008a)[e]	CO_2-eq	IPCC B2***	Annex I excl. USA & Australia	TY	+20/−35	+35/−5	
Höhne et al. (2006)[f]	CO_2-eq	IPCC* all	Annex I excl. USA; FSU BAU[c]	Other, CC		+35/−25	+50/+35
Vaillancourt and Waaub (2006)	CO_2	Own	Not included; base-year 2000	Other			+57/+65
Höhne et al. (2007)[f]	CO_2-eq	IPCC* all	Annex I excl. USA; FSU BAU[c]	MS, CC, HR, TY, other	+10/−40	+30/−10	+50/+45
Baer et al. (2008)	CO_2	WEO 2007[g]	Annex I excl. USA	Other	+10/−80		
Timilsina (2008)	CO_2	Own	Annex I excl. USA; FSU BAU[c]	EI			+46/NI
Number of studies					11	16	14

NI Not included

[a]Own: scenario based on own assumptions; IPCC*: IMAGE implementation of IPCC SRES 2001 scenarios (IMAGE-team 2001); IPCC**: IIASA (1998) implementation; CPI: common POLES-IMAGE baseline (van Vuuren et al. 2003, 2006); DOE reference scenario (DOE 2003); Update IPCC B2***: updated IMAGE/TIMER implementation of the IPCC-SRES B2 scenario (van Vuuren et al. 2007), which roughly follows the reference scenario of the World Energy Outlook (WEO) 2004 (IEA 2004)

[b]The abbreviations of the schemes are given in Table 3

[c]The emissions of the former Soviet Union (FSU) and Eastern European countries are assumed to equal the baseline or business-as-usual (BAU) emissions (which are far below their Kyoto targets)

[d]For the period 2013–2017

[e]Assuming a (temporary) overshoot of about 50 ppm

[f]Uncertainty ranges presented in this study also include uncertainties in scenarios, but this effect is limited, and not included in Fig. 1

[g]Reference scenario of the WEO 2007 (IEA 2007)

- *The assumed allocation scheme covered:* Some studies in Table 2 focus on one scheme, whereas others include a wide range of about ten schemes (see for example, den Elzen and Lucas 2005).
- *Global emission limits:* Many global emission pathways can lead to the same long-term concentration stabilisation level. Pathways with higher emissions in the earlier part of the century have lower emissions in the later part of the century. Therefore, it is important which global emission level in 2020 and 2050 was chosen from a possible range that represents one long-term stabilisation level (i.e. 450, 550 and 650 ppm CO_2-eq).

Table 2 (bottom part) also shows the seven new allocation studies that became available after the finalisation of the IPCC report. In fact, the first four of these studies were already included in the calculations of the presented reduction ranges, but at the last moment of publication of the IPCC AR4 report, their citations were excluded, as these studies were still unpublished, at the time.

Figure 1 presents the resulting emission reduction targets for the Annex I and non-Annex I countries as a group, which are mainly based on information provided by the authors of the studies or, for some studies, are derived from detailed information in the papers themselves. The figure also presents the adopted IPCC AR4 reduction ranges (Gupta et al. 2007). The IPCC AR4 based these ranges on the outcomes of all studies mentioned in Table 2 (except for Leimbach 2003; Vaillancourt and Waaub 2006; Höhne et al. 2007; Baer et al. 2008; Timilsina 2008). We listed all studies that were available to us. Outliers that provide substantially different results compared to other studies were excluded and more weight was given to the more recent multi-gas studies. We did not make judgements on the way the studies allocated emission reductions across regions and countries.

A brief overview of the studies is given below.

The study by Berk and den Elzen (2001) is one of the first, quantifying post-2012 CO_2 emission allocations for meeting long-term concentration stabilisation targets, based on three regimes, i.e. Multi-Stage, Contraction & Convergence (C&C) and Berk and den Elzen's implementation of the Brazilian proposal (see Table 3). The study assumed that all Annex I countries would meet their Kyoto targets (the USA had not rejected ratification), a low global emission target of only 10% above 1990 levels, by 2020, and 20% below 1990 levels, by 2050. Based on its low short-term emission this study is clustered under the lowest IPCC 450 ppm CO_2-eq category (Table 2).The Annex I countries, as a group, need to reduce their emissions from about 30% to 45% below 1990 levels, which is at the lower end of the IPCC AR4 range (see Fig. 1). The reductions for the non-Annex I countries, as a group, range from 15% to 35% below the baseline emissions. Later, den Elzen (2002) also included Triptych regime calculations and an extensive sensitivity analysis. Similar work has been done by Blanchard (2002), focussing on stabilisation at 550 ppm CO_2 concentration (about 650 ppm CO_2-eq). Winkler et al. (2002) also calculated the CO_2 emission allowances of the key developing countries, using three allocation schemes, and assuming global CO_2 emissions returning to 1990 levels by 2020, and using the lowest IPCC SRES B1 scenario.