Annex B: Definitions, Units & Conventions

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Table of Contents

This annex on Definitions, Units and Conventions provides background information on material used in the Working Group III Contribution to the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (WGIII AR6). The material presented in this annex documents metrics and common data sets that are typically used across multiple chapters of the report. In few instances there are no updates to what was adopted by WGIII during the production of the Fifth Assessment Report (AR5), in which case this annex refers to Annex II of AR5[1].

The annex is composed of three parts: Part I introduces standards metrics and common definitions adopted in the report; Part II presents methods to derive or calculate certain quantities used in the report; and Part III provides more detailed background information about common data sources. While this structure may help readers to navigate through the annex, it is not possible in all cases to unambiguously assign a certain topic to one of these parts, naturally leading to some overlap between the parts.

Part I: Definitions and units

A.B.1 Regional classifications

In this report there are three different levels of regional classifications used to present results of analysis. These levels are High (5 regions), Intermediate (10) and Low (21). The high level classification is virtually identical to RC5 (Regional Categorisation 5) in WGIII AR5; the low level classification corresponds most closely to the 22 UN M49 (Standard Country or Area Codes for Statistical Use) intermediate regions. The regional classifications are presented below. Throughout the report it will be noted explicitly when individual chapters deviate from the classification set out below.

A.B.1.1. Low level of regional classification

Western Africa: Cabo Verde, Côte d'Ivoire, Ghana, Nigeria, Saint Helena, Ascension and Tristan da Cunha, Benin, Burkina Faso, Gambia (the), Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger (the), Senegal, Sierra Leone, Togo

Eastern Africa: British Indian Ocean Territory (the), French Southern Territories (the), Kenya, Mauritius, Mayotte, Réunion, Seychelles, Zimbabwe, Burundi, Comoros (the), Djibouti, Eritrea, Ethiopia, Madagascar, Malawi, Mozambique, Rwanda, Somalia, South Sudan, Uganda, Tanzania, United Republic of, Zambia

Southern and middle Africa: Botswana, Eswatini, Namibia, South Africa, Lesotho, Cameroon, Congo (the), Equatorial Guinea, Gabon, Angola, Central African Republic (the), Chad, Congo (the Democratic Republic of the), Sao Tome and Principe

Northern Africa: Algeria, Egypt, Libya, Morocco, Tunisia, Western Sahara, Sudan (the)

Middle East: Bahrain, Iran (Islamic Republic of), Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Palestine, State of, Syrian Arab Republic, United Arab Emirates (the), Yemen

Caribbean: Anguilla, Antigua and Barbuda, Aruba, Bahamas (the), Barbados, Bonaire, Sint Eustatius and Saba, Virgin Islands (British), Cayman Islands (the), Cuba, Curaçao, Dominica, Dominican Republic (the), Grenada, Guadeloupe, Jamaica, Martinique, Montserrat, Puerto Rico, Saint Barthélemy,

[1] Krey, et al (2014).

Saint Kitts and Nevis, Saint Lucia, Saint Martin (French part), Saint Vincent and the Grenadines, Sint Maarten (Dutch part), Trinidad and Tobago, Haiti, Turks and Caicos Islands (the), Virgin Islands (U.S.)

Meso America: Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama

South America: Argentina, Bolivia (Plurinational State of), Bouvet Island, Brazil, Chile, Colombia, Ecuador, Falkland Islands (the) [Malvinas], French Guiana, Guyana, Paraguay, Peru, South Georgia and the South Sandwich Islands, Suriname, Uruguay, Venezuela (Bolivarian Republic of)

USA & Canada: United States of America (the), Canada

Greenland, Bermuda & others: Bermuda, Greenland, Saint Pierre and Miquelon

Eastern Asia: China, China Hong Kong Special Administrative Region, China Macao Special Administrative Region, Korea (the Republic of), Korea (the Democratic People's Republic of), Mongolia

India & Sri Lanka

Rest of Southern Asia: Maldives, Pakistan, Afghanistan, Bangladesh, Bhutan, Nepal

South-East Asia: Brunei Darussalam, Indonesia, Malaysia, Philippines (the), Singapore, Thailand, Viet Nam, Cambodia, Lao People's Democratic Republic (the), Myanmar, Timor-Leste

Developing Pacific: Fiji, New Caledonia, Papua New Guinea, Solomon Islands, Vanuatu, Guam, Marshall Islands (the), Micronesia (Federated States of), Nauru, Northern Mariana Islands (the), Palau, United States Minor Outlying Islands (the), Kiribati, American Samoa, Cook Islands (the), French Polynesia, Niue, Pitcairn, Samoa, Tokelau, Tonga, Wallis and Futuna, Tuvalu

Northern and western Europe: Åland Islands, Denmark, Estonia, Faroe Islands (the), Finland, Iceland, Ireland, Isle of Man, Latvia, Lithuania, Norway, Svalbard and Jan Mayen, Sweden, United Kingdom of Great Britain and Northern Ireland (the), Austria, Belgium, France, Germany, Liechtenstein, Luxembourg, Monaco, Netherlands (the), Switzerland, Guernsey, Jersey

Southern and eastern Europe: Andorra, Cyprus, Croatia, Gibraltar, Greece, Holy See (the), Italy, Malta, Portugal, San Marino, Slovenia, Spain, Bulgaria, Czechia, Hungary, Poland, Romania, Slovakia, Turkey, Albania, Bosnia and Herzegovina, Montenegro, Serbia, Ukraine

Australia & New Zealand

Asia-Pacific Developed (others): Japan, Christmas Island, Cocos (Keeling) Islands (the), Heard Island and McDonald Islands, Norfolk Island

Eurasia: Belarus, Russian Federation (the), Republic of North Macedonia, Moldova (the Republic of), Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan

International shipping

International Aviation

A.B.1.2. High and intermediate levels of regional classification

For country mapping to each of the high and intermediate regions see low level of regional classification mappings section A.B.1.1. above and their aggregation in Table A.B.1. below.

Table: A.B.1 | Description of regions

WGIII AR 6		
High Level (5)	**Intermediate level (10)**	**Low Level (21)**
Developed Countries	North America	USA & Canada
		Greenland, Bermuda + others
	Europe	Northern and western Europe
		Southern and eastern Europe
	Asia-Pacific Developed	Australia & New Zealand
		Asia-Pacific Developed (others)
Eastern Europe and West-Central Asia	Eurasia	Eurasia
Latin America and Caribbean	Latin America and Caribbean	Caribbean
		Meso America
		South America
Africa and Middle East	Africa	Western Africa
		Eastern Africa
		Southern and middle Africa
		Northern Africa
	Middle East	Middle East
Asia and developing Pacific	Eastern Asia	Eastern Asia
	Southern Asia	India & Sri Lanka
		Rest of Southern Asia
	South-East Asia and developing Pacific	South-East Asia
		Developing Pacific
Shipping & Aviation		International shipping,
		International Aviation

A.B.2. Standard units and unit conversions

The following sections introduce standard units and unit conversions used throughout this report.

A.B.2.1. Standard units

Standard units of measurements include Système Inter-national (SI) units, SI-derived units, and other non-SI units as well the standard prefixes for basic physical units.

Table: A.B.2 | Système Inter-national (SI) units

Physical Quantity	Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Thermodynamic temperature	kelvin	K
Amount of Substance	mole	mol

Table: A.B.3 | Special names and symbols for certain SI-derived units.

Physical Quantity	Unit	Symbol	Definition
Force	Newton	N	kg m s^2
Pressure	Pascal	Pa	kg m^–1 s^–2 (= N m^–2)
Energy	Joule	J	kg m^2 s^–2
Power	Watt	W	kg m^2 s^–3 (= J s^–1)
Frequency	Hertz	Hz	s^–1 (cycles per second)
Ionizing Radiation Dose	sievert	Sv	J kg^-1

Table: A.B.4 | Non-SI standard units.

Monetary units	Unit	Symbol
Currency (Market Exchange Rate, MER)	constant US Dollar 2015	USD_{2015}
Currency (Purchasing Power Parity, PPP)	constant International Dollar 2015	$Int\$_{2015}$
Emission- and Climate- related units	**Unit**	**Symbol**
Emissions	Metric tonnes	t
CO_2 Emissions	Metric tonnes CO_2	tCO_2
CO_2-equivalent Emissions	Metric tonnes CO_2-equivalent	tCO_2eq
Abatement Costs and Emissions Prices/Taxes	constant US Dollar 2015 per metric tonne	USD_{2015}/t
CO_2 concentration or Mixing Ratio (μmol mol–1)	Parts per million (10^6)	ppm
CH_4 concentration or Mixing Ratio (μmol mol–1)	Parts per billion (10^9)	ppb
N_2O concentration or Mixing Ratio (μmol mol–1)	Parts per billion (10^9)	ppb
Radiative forcing	Watts per square meter	W/m^2
Energy-related units	**Unit**	**Symbol**
Energy	Joule	J
Electricity and Heat generation	Watt Hours	Wh
Power (Peak Capacity)	Watt (Watt thermal, Watt electric)	W (W_{th}, W_e)
Capacity Factor	Percent	%
Technical and Economic Lifetime	Years	yr
Specific Energy Investment Costs	US Dollar 2015 per kW (peak capacity)	USD_{2015}/kW
Energy Costs (e. g., LCOE) and Prices	constant US Dollar 2015 per GJ or US Cents 2015 per kWh	USD_{2015}/GJ and $USct_{2015}$/kWh
Passenger-Distance	passenger-kilometer	p-km
Payload-Distance	tonne-kilometer	t-km
Land-related units	**Unit**	**Symbol**
Area	Hectare	ha

Note that all monetary and monetary-related units should be expressed in constant US Dollar 2015 (USD_{2015}) or constant International Dollar 2015 ($Int\$_{2015}$).

Table: A.B.5 | Prefixes for basic physical units.

Multiple	Prefix	Symbol	Fraction	Prefix	Symbol
1E+21	zeta	Z	1E-01	deci	d
1E+18	exa	E	1E-02	centi	c
1E+15	peta	P	1E-03	milli	m
1E+12	tera	T	1E-06	micro	µ
1E+09	giga	G	1E-09	nano	n
1E+06	mega	M	1E-12	pico	p
1E+03	kilo	k	1E-15	femto	f
1E+02	hecto	h	1E-18	atto	a
1E+01	deca	da	1E-21	zepto	z

A.B.2.2. Physical units conversion

Table: A.B.6 | Conversion table for common mass units (IPCC, 2001).

To:		kg	t	lt	St	lb
From:	multiply by:					
kilogram	kg	1	1.00E-03	9.84E-04	1.10E-03	2.20E+00
tonne	t	1.00E+03	1	9.84E-01	1.10E+00	2.20E+03
long ton	lt	1.02E+03	1.02E+00	1	1.12E+00	2.24E+03
short ton	st	9.07E+02	9.07E-01	8.93E-01	1	2.00E+03
Pound	lb	4.54E-01	4.54E-04	4.46E-04	5.00E-04	1

Table: A.B.7 | Conversion table for common volumetric units (IPCC, 2001).

To:		gal US	gal UK	bbl	ft³	l	m³
From:	multiply by:						
US Gallon	gal US	1	8.33E-01	2.38E-02	1.34E-01	3.79E+00	3.80E-03
UK/Imperial Gallon	gal UK	1.20E+00	1	2.86E-02	1.61E-01	4.55E+00	4.50E-03
Barrel	bbl	4.20E+01	3.50E+01	1	5.62E+00	1.59E+02	1.59E-01
Cubic foot	ft³	7.48E+00	6.23E+00	1.78E-01	1	2.83E+01	2.83E-02
Liter	l	2.64E-01	2.20E-01	6.30E-03	3.53E-02	1	1.00E-03
Cubic meter	m³	2.64E+02	2.20E+02	6.29E+00	3.53E+01	1.00E+03	1

Table: A.B.8 | Conversion table for common energy units (NAS, 2007; IEA, 2012).

To:		TJ	Gcal	Mtoe	Mtce	MBtu	GWh
From:	multiply by:						
Tera Joule	TJ	1	2.39E+02	2.39E-05	3.41E-05	9.48E+02	2.78E-01
Giga Calorie	Gcal	4.19E-03	1	1.00E-07	1.43E-07	3.97E+00	1.16E-03
Mega Tonne Oil Equivalent	Mtoe	4.19E+04	1.00E+07	1	1.43E+00	3.97E+07	1.16E+04
Mega Tonne Coal Equivalent	Mtce	2.93E+04	7.00E+06	7.00E-01	1	2.78E+07	8.14E+03
Million British Thermal Units	MBtu	1.06E-03	2.52E-01	2.52E-08	3.60E-08	1	2.93E-04
Giga Watt Hours	GWh	3.60E+00	8.60E+02	8.60E-05	0.000123	3.41E+03	1

A.B.2.3. Monetary unit conversion

To achieve comparability across cost und price information from different regions, where possible all monetary quantities reported in the WGIII AR6 have been expressed in constant US Dollar 2015 (USD_{2015}) or constant International Dollar 2015 ($Int\$_{2015}$), as suitable.

To facilitate a consistent monetary unit conversion process, a simple and transparent procedure to convert different monetary units from the literature to USD2015 was established which is described below.

In order to convert from year X local currency unit (LCU_X) to 2015 US Dollars (USD_{2015}) two steps are necessary:

1. in- /deflating from year X to 2015, and

2. converting from LCU to USD.

In practice, the order of applying these two steps will lead to different results. In this report, the conversion route LCU_X -> LCU_{2015} -> USD_{2015} is adopted, i. e., national/regional deflators are used to measure country- or region-specific inflation between year X and 2015 in local currency and current (2015) exchange rates are then used to convert to USD_{2015}.

To reflect the change in prices of all goods and services that an economy produces, and to keep the procedure simple, the economy's GDP deflator is chosen to convert to a common base year. Finally, when converting from LCU_{2015} to USD_{2015}, official 2015 exchange rates, which are readily available, but on the downside often fluctuate significantly in the short term, are adopted for currency conversion in the report.

In order to be consistent with the choice of the World Bank databases as the primary source for gross domestic product (GDP) and other financial data throughout the report, deflators and exchange rates from the World Bank's World Development Indicators (WDI) database (World Bank, 2019) is used.

To summarize, the following procedure has been adopted to convert monetary quantities reported in LCU_X to USD_{2015}:

1. Use the country- / region-specific deflator and multiply with the deflator value to convert from LCU_X to LCU_{2015}. In case national / regional data are reported in non-LCU units (e. g., USD_X or $Euro_X$), which is often the case in multi-national or global studies, apply the corresponding currency deflator to convert to 2015 currency (i. e., the US deflator and the Eurozone deflator in the examples above).

2. Use the appropriate 2015 exchange rate to convert from LCU_{2015} to USD_{2015}.

Part II: Conventions

A.B.3. Levelised cost metrics

Across this report, a number of different metrics to characterize cost of climate change mitigation are employed. To facilitate a meaningful economic comparison across diverse options at the technology level, the metric of 'levelised costs' is used throughout several chapters of this report in various forms. More specifically, the adopted metrics are the levelised cost of energy (LCOE), the levelised cost of conserved energy (LCCE), and the levelised cost of conserved carbon (LCCC). These metrics are used throughout the WGIII AR6 to provide a benchmark for comparing different technologies or practices of achieving the respective output. Each comes with a set of context-specific caveats that need to be taken into account for correct interpretation. Various literature sources caution against drawing too strong conclusions from these metrics. Annex II in AR5, namely section A.II.3.1., includes a detailed discussion on interpretations and caveats.

A.B.3.1. Levelised cost of energy

The levelized cost of energy (LCOE) can be defined as the unique break-even cost price where discounted revenues (price x quantities) are equal to the discounted net expenses (Moomaw et al., 2011), which is expressed as follows:

$$\sum_{t=0}^{n} \frac{E_t * LCOE}{(1+i)^t} = \sum_{t=0}^{n} \frac{Expenses_t}{(1+i)^t} \qquad (1)$$

where $LCOE$ are the levelized cost of energy, E_t is the energy delivered in year t (which might vary from year to year), Expenses cover all (net) expenses in the year t, i is the discount rate and n the lifetime of the project.

solving for $LCOE$:

$$LCOE = \frac{\sum_{t=0}^{n} \frac{Expenses_t}{(1+i)^t}}{\sum_{t=0}^{n} \frac{E_t *}{(1+i)^t}} \qquad (2)$$

The lifetime expenses comprise investment costs I, operation and maintenance cost $O\&M$ (including waste management costs), fuel costs F, carbon costs C, and decommissioning costs D. In this case, levelized cost can be determined by (IEA, 2010):

$$LCOE = \frac{\sum_{t=0}^{n} \frac{I_t + O\&M_t + F_t + C_t + D_t}{(1+i)^t}}{\sum_{t=0}^{n} \frac{E_t *}{(1+i)^t}} \qquad (3)$$

Assuming energy E provided annually is constant during the lifetime of the project, one can rewrite (3) as follows:

$$LCOE = \frac{\text{CRF} \cdot \text{NPV (Lifetime Expenses)}}{E} = \frac{\text{Annuity (Lifetime Expenses)}}{E} \qquad (4)$$

where $CRF = \frac{i}{1-(1-i)^{-n}}$ is the capital recovery factor and NPV the net present value of all lifetime expenditures (Suerkemper et al., 2011). For the simplified case, where the annual costs are also assumed constant over time, this can be further simplified to ($O\&M$ costs and fuel costs F constants):

$$LCOE = \frac{\text{CRF} \cdot \text{I+O\&M+F}}{E} \qquad (5)$$

Where I is the upfront investment, $O\&M$ are the annual operation and maintenance costs, F are the annual fuel costs, and E is the annual energy provision. The investment I should be interpreted as the sum of all capital expenditures needed to make the investment fully operational discounted to $t = 0$. These might include discounted payments for retrofit payments during the lifetime and discounted decommissioning costs at the end of the lifetime. Where applicable, annual $O\&M$ costs have to take into account revenues for by-products and existing carbon costs must be added or treated as part of the annual fuel costs.

A.B.3.2. Levelised cost of conserved energy

The levelized cost of conserved energy (LCCE) annualizes the investment and operation and maintenance cost differences between a baseline technology and the energy-efficiency alternative, and divides this quantity by the annual energy savings.

The conceptual formula for $LCCE$ is essentially the same as Equation (4) above, with ΔE meaning in this context the amount of energy saved annually (Suerkemper et al., 2011):

$$LCCE = \frac{CRF.NPV(\Delta Lifetime\ Expenses)}{\Delta E} = \frac{Annuity(\Delta Lifetime\ Expenses)}{\Delta E} \quad (6)$$

In the case of assumed annually constant $O\&M$ costs over the lifetime, one can rewrite (6) as follows:

$$LCCE = \frac{CRF \cdot \Delta I + \Delta O\&M}{\Delta E} \quad (7)$$

where ΔI is the difference in investment costs of an energy saving measure (e.g., in USD) as compared to a baseline investment; $\Delta O\&M$ is the difference in annual operation and maintenance costs of an energy saving measure (e.g., in USD) as compared to the baseline in which the energy saving measure is not implemented; ΔE is the annual energy conserved by the measure (e.g., in kWh) as compared to the usage of the baseline technology; and CRF is the capital recovery factor depending on the discount rate i and the lifetime of the measure n in years as defined above. It should be stressed once more that this equation is only valid if $\Delta O\&M$ and ΔE are constant over the lifetime. As $LCCE$ are designed to be compared with complementary levelized cost of energy supply, they do not include the annual fuel cost difference. Any additional monetary benefits that are associated with the energy saving measure must be taken into account as part of the $O\&M$ difference.

A.B.3.3. Levelised cost of conserved carbon

The levelized cost of conserved carbon can be used for comparing mitigation costs per unit of avoided emissions and comparing these specific emission reduction costs for different options.

The conceptual formula for $LCCC$ is essentially similar to Equation (6) above, with ΔC is the annual reduction in GHG emissions, which can be expressed as follows:

$$LCCC = \frac{CRF.NPV(\Delta Lifetime\ Expenses)}{\Delta C} = \frac{Annuity(\Delta Lifetime\ Expenses)}{\Delta C} \quad (8)$$

In the case of assumed annually constant $O\&M$ costs over the lifetime, one can rewrite (8) as follows:

$$LCCC = \frac{CRF \cdot \Delta I + \Delta O\&M - \Delta B}{\Delta C} \quad (9)$$

where ΔI is the difference in investment costs of a mitigation measure (e.g., in USD) as compared to a baseline investment; $\Delta O\&M$ is the difference in annual operation and maintenance costs (e.g., in USD) and ΔB denotes the annual benefits, all compared to a baseline for which the option is not implemented. Note that annual benefits include reduced expenditures for fuels, if the investment project reduces GHG emissions via a reduction in fuel use. As such $LCCC$ depend on energy prices. An important characteristic of this equation is that $LCCC$ can become negative if ΔB is bigger than the sum of the other two terms in the numerator.

A.B.4. Growth rates

A.B.4.1. Emissions growth rates

In order to ensure consistency throughout the reported growth rates for emissions in AR6, this section establishes the convention for calculating these rates following exactly from the method proposed in Le Quéré et al (2018).

In order to report the emissions annual growth rate in percent per year for adjacent years, one can use the following equation:

$$r = \frac{(E_{FF}(t_0-1) - E_{FF}(t_0))}{E_{FF}(t_0)} * 100 \quad (10)$$

where E_{FF} stands for fossil CO2 emissions.

When relevant a leap-year adjustment in required in order to ensure valid interpretation of annual growth rates in the case of adjacent years. A leap-year affects adjacent years growth rate by approximately 0.3% yr^{-1} $\left(\frac{1}{365}\right)$ which causes growth rates to go up approximately 0.3% if the first year is a leap year, and down 0.3% if the second year is a leap year.

The relative growth rate of E_{FF} over time periods of greater than one year are derived as follows. Starting from:

$$E_{FF}(t+n) = E_{FF}(t) * (1+r)^n \quad (11)$$

solving for r:

$$r = \left(\frac{E_{FF}(t+n)}{E_{FF}(t)}\right)^{1/n} - 1 \quad (12)$$

A.B.4.2. Economic growth rates

As for calculating economic growth rates (e.g. GDP), number of different methods exist, all of which lead to slightly different numerical results. If not stated otherwise, the annual growth rates shown, have been derived using the *Log Difference Regression* technique *or Geometric Average* techniques which can be shown to be equivalent.

The Log Difference Regression growth rate r_{LD} is calculated the following way:

$$r_{LD} = e^B - 1 \quad \text{with } \beta = \frac{1}{T-1}\sum_{t=2}^{T} \Delta ln X_t \quad (13)$$

The Geometric Average growth rate r_{GEO} is calculated as shown below:

$$r_{GEO} = \left(\frac{X_T}{X_1}\right)^{\frac{1}{T-1}} - 1 \quad (14)$$

Other methods that are used to calculate annual growth rates include the Ordinary Least Square technique and the Average Annual Growth Rate technique.

A.B.5. Decades

In order to undertake a timeseries calculation that includes a decade, the 10-year period should be defined following this example: from 1st of Jan 2001 to 31st of December 2010, that is 2001-2010.

In order to compare or contrast two different decades, for instance comparing 2000 and 2010 cumulative CO2 emissions, in such case the year 2000 runs from 1st of January to 31st of December and similarly the year 2010 runs from 1st of January to 31st of December.

A.B.6. Social discount rates

(placeholder for the next submission)

A.B.7. Primary energy accounting

Annex II of AR5, namely section A.II.4, includes a detailed discussion of the three alternative methods that are predominantly used to report primary energy from non-combustible energy sources, i.e. nuclear energy and all renewable energy sources except biomass. The method adopted in AR6 is the *direct equivalent method* which counts one unit of secondary energy provided from non-combustible sources as one unit of primary energy, i. e., 1 kWh of electricity or heat is accounted for as 1 kWh = 3.6 MJ of primary energy. This method is mostly used in the long-term scenarios literature, including multiple IPCC reports (IPCC, 1995; Nakicenovic and Swart, 2000; Morita et al., 2001; Fisher et al., 2007; Fischedick et al., 2011), because it deals with fundamental transitions of energy systems that rely to a large extent on low-carbon, non-combustible energy sources.

A.B.8. Indirect primary energy use and co2 emissions

(placeholder and will be updated before LAM3).

A.B.9. The concept of risk

The concept of risk is a key aspect of how the IPCC assesses and communicates to decision-makers the potential adverse impacts of, and response options to, climate change. AR6 will include a Guidance[2] for authors on the concept of risk in order to ensure a consistent and transparent application across Working Groups.

The aim in this section below of Annex B is to summarise the Guidance briefly with focus on issues related to WGIII, i.e. with focus on mitigation. We invite reviewers to comment briefly on the section below and more extensively on the Guidance.

A.B.9.1. The definition of risk

Risk: the potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as *human responses to climate change*. Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and

[2] Reisinger et al., 2019.

cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species.

In the context of climate change responses, risks result from the potential for such responses not achieving the intended objective(s), or from potential trade-offs with, or negative side-effects on, other societal objectives, such as the Sustainable Development Goals. Risks can arise for example from uncertainty in implementation, effectiveness or outcomes of climate policy, climate-related investments, technology development or adoption, and system transitions.

A.B.9.2. DO's and DON'T's

DO:

- use risk where you're explicitly considering potential adverse outcomes and the uncertainty relating to those outcomes.
- use risk to improve the ability for decision-makers to understand and manage risk

Don't:

- use risk as simple substitute for probability/chance.
- use risk to describe physical hazards.
- use risk as generic term for 'anything bad that may happen in future'.

A.B.9.3. Examples of application in the context of mitigation

Food security

Climate-related risk to food security arises from multiple drivers that include both climate change impacts, responses to climate change and other stressors.

In the context of responses to climate change, drivers of risk include the demand for land from climate change responses (both adaptation and mitigation), the role of markets (e.g. price spikes related to biofuel demand in other countries), governance (how are conflicts about access to land and water resolved) and human behaviour more generally (e.g. trade barriers, dietary preferences).

Given the multitude of drivers, it will be difficult for any statement to describe "the" risk to food security. To be useful, most statements will have to be relative to some factors remaining unchanged, and to focus on the effect of specific changes. Such assumptions are important for analytical robustness. Nonetheless, it will be important to state any such assumptions clearly.

Transition risk in the investment and finance literature

Transition risks typically refer to risks associated with transition to a low carbon economy, which can entail extensive policy, legal, technology, and market changes to address mitigation and adaptation requirements related to climate change. Depending on the nature, speed, and focus of these changes, transition risks may pose varying levels of financial and reputational risk to organizations. The following risk-related terms appear frequently in finance and investment literature:

- Risk related to an asset losing its value: the potential for loss of investment in infrastructure.
- Risk related to losing some or all of the principal of an investment (or invested capital)
- Solvency risk: the risk from reduction in credit ratings due to potential adverse consequences of climate change or climate policy. This includes liquidity risk or the risk of not being able to access funds. Another example is suffering a downgraded credit rating.
- Risk of lower than expected return on investment.

- Liability risk: Lack of response to climate change creates risk of liability for failure to accurately assess risk of climate change to infrastructure and people.
- Technology risk: reliance on a particular technology to achieve an outcome creates the potential for adverse consequences if the technology fails to be developed or deployed.
- Policy risk: Changes in policy or regulations in response to climate change could result in the loss of value of some assets.
- Market risk: Changes in relative prices from increased prices of CO2 for instance, could reduce financial returns and hence increase risks to investors.
- Residual risk: refers to adverse consequences that cannot be quantified in probabilistic terms. This is different from how the term 'residual risk' is generally used in IPCC, where it means the risk remaining after adaptation and risk reduction efforts. Authors should take care to check the meaning of the term 'residual risk' where it is used in primary literature and avoid copying the term if it refers to quantifiable vs non-quantifiable risk to avoid confusion.

A.B.10. GHG emissions metrics

The choice of emissions metrics has important implications in determining the level of abatement of any given emission, the level and cost of global, national and sectoral mitigation efforts as well as the possible emission reduction pathways to support long-term climate policy goals. These metrics compare the effect of an individual emission pulse of a unit mass of a non-CO_2 gas over a chosen time horizon with the effect the emission of the same unit mass of CO_2.

There is an ongoing debate in the literature around the various GHG emissions metrics, those adopted in AR5 and others that have been developed since AR5. This debate has been discussed extensively in a Cross-Chapter box on GHG Metrics.[3]

In this below section of Annex B the aim is to summarise the Cross-Chapter box. We invite reviewers to comment briefly on this section below and more extensively on the Cross-Chapter box.

Three main metrics are considered. Firstly, Global Warming Potential (GWP) which compares gases based on the integrated radiative forcing over the chosen time horizon. The most commonly used time horizons for GWP is 100 years (GWP_{100}), which is also used to report aggregate CO_2-equivalent emission under the UNFCCC.

Secondly, Global Temperature change Potential (GTP) which compares gases based on the temperature change at the end of the time horizon. GTP, both fixed and dynamic time horizon are used. In the latter case, the time horizon is adjusted so that it matches the year in which emissions are expected to peak in a given mitigation scenario. For instance, for a goal of limiting warming to 1.5°C, temperatures would peak around 2055 and therefore for emissions occurring in the year 2020, GTP_{35} would be used.

Finally, Global Warming Potential* (GWP*) which compares the impact on global temperature from a sustained change in methane CH_4 emissions with a one-off pulse emission of CO2. This metric enables a better estimation of temperature outcomes from cumulative emissions of Short-Lived Climate Forces (SLCFs) in mitigation scenarios, but the literature has yet to demonstrate its use for other policy context.

These metrics can be applied for both annual emissions and in the case of extended time series of emission to inform long-term emission targets and pathways. WGIII of AR6 reports emissions and mitigation options for individual gases wherever possible. Where the literature on mitigation does not provide information on individual gases, it reports CO_2-equivalent emissions using GWP_{100} without feedbacks. Finally, it should be noted that this decision is also inline with the Paris Agreement rulebook.

[3] Box 2.2 Cross chapter box- GHG emission metrics, Chapter 2, AR6.

Part III: Data sets

A.B.11. Historical data

In order to aid coherency and consistency, core historic data presented throughout the report uses the same sources and applied the same methodologies and standards, which are detailed here:

- The standard country aggregations to regions are detailed in section A.B.1 above
- The central historic GHG emission data set was based on Emissions Database for Global Atmospheric Research (EDGAR) (JRC, 2019) data. This data set provides annual emissions on a country level for the time span 1970 to 2018.
- As default dataset for GDP in Purchasing Power Parity (PPP) World Bank data was supplemented. Ata later stage, this will be extended (to a longer time span, more countries) using IMF data.

A.B.11.1. Mapping of emission sources to sectors

The list below shows how emission sources are mapped to sectors throughout the WGIII AR6. This defines unambiguous system boundaries for the sectors as represented in Chapters 6, 7 and 9-11 in the report and enables a discussion and representation of emission sources without double-counting.

Emission sources refer to the definitions by the IPCC Task Force on National Greenhouse Gas Inventories (TFI) (IPCC, 2006). Where further disaggregated data was required, additional source categories were introduced consistent with the underlying datasets (JRC, 2019). This information appears in the following systematic sequence throughout this section:

Emission source category (chapter emission source category numbering)

Emission Source (Sub-)Category (IPCC Task force definition) [gases emitted by emission source (CO2 data set used)]

A common dataset ('EDGAR') is used across WGIII AR6 chapters to ensure consistent representation of emission trends across the report.

Uncertainties of this data are comprehensively treated in Ch2 Box 2.1.

Source of FOLU emission data is the Blue model (Bookkeeping of Land Use Emissions model) by Le Quéré et al, 2018.

A.B.11.2. Energy Systems (Chapter 6)

Description	Code	Emission source category
Public Electricity Generation	1A1a1	(this column is a placeholder)
Public Combined Heat and Power gen.	1A1a2	
Public Heat Plants	1A1a3	
Public Electricity Generation (own use)	1A1a4	
Electricity Generation (autoproducers)	1A1a5	
Combined Heat and Power gen. (autoprod.)	1A1a6	
Heat Plants (autoproducers)	1A1a7	
Electrical Equipment Use (incl. site inst.)	2F8b	

Indirect N2O from NOx emitted in cat. 1A	7B1	
Indirect N2O from NH3 emitted in cat. 1A	7C1	
Public Electricity Generation (biomass)	1A1ax1	
Public Combined Heat and Power gen. (biom.)	1A1ax2	
Public Heat Plants (biomass)	1A1ax3	
Public Electricity Gen. (own use) (biom.)	1A1ax4	
Electricity Generation (autoproducers) (biom.)	1A1ax5	
Combined Heat and Power gen. (autopr.) (biom.)	1A1ax6	
Heat Plants (autoproducers) (biomass)	1A1ax7	
Refineries	1A1b	
Refineries (biomass)	1A1bx	
Gas works	1A1c3	
Other transformation sector (BKB, etc.)	1A1c5	
Gas works (biom.)	1A1cx3	
Fuel comb. charcoal production (biom.)	1A1cx4	
Other transf. sector (BKB, etc.) (biom.)	1A1cx5	
Hard coal mining (gross)	1B1a1	
Methane recovery from coal mining	1B1a1r	
Abandoned mines	1B1a2	
Brown coal mining	1B1a3	
Fuel transformation in gas works	1B1b2	
Fuel transformation charcoal production	1B1b3x	
Fuel transformation of solid fuels (BKB Plants, coal liquefaction, patent fuel plants)	1B1b4	
Oil production	1B2a1	
Oil production	1B2a1x	
Oil transmission	1B2a2	
Tanker loading	1B2a3-l	
Tanker oil transport (crude and NGL)	1B2a4-l	
Transport by oil trucks	1B2a4-t	
Oil refineries (evaporation)	1B2a5(e)	
Fuel transformation from liquid fuels (petrochemical plants)	1B2a6	
Gas production	1B2b1	
Gas transmission	1B2b3	
Gas distribution	1B2b4	
Fuel transformation of gaseous fuels (GTL, Blend, (re-)gasif./Liquef., NSF)	1B2b5	
Venting and flaring during oil and gas production	1B2c	
Coal fires (underground)	7A1	
Oil fires (Kuwait)	7A2	

A.B.11.3. AFOLU (Chapter 7)

Description	Code	Emission source category
Agriculture and forestry (fos.)	1A4c1	
Off-road machinery: agric./for. (diesel)	1A4c2	

Fishing (fos.)	1A4c3	
Non-specified other (fos.)	1A4d	
Agriculture and forestry (biom.)	1A4c1x	
Fishing (biom.)	1A4c3x	
Non-specified other (biom.)	1A4dx	
Off-road machinery: mining (diesel)	1A5b1	
Rice cultivation	4C	
CO2 from agricultural lime application	4D4b	
Savannah fires	4E	
Dairy cattle	4A1-d	
Non-dairy cattle	4A1-n	
Buffalo	4A2	
Sheep	4A3	
Goats	4A4	
Camels and Lamas	4A5	
Horses	4A6	
Mules and asses	4A7	
Swine	4A8	
Manure Man.: Dairy Cattle (confined)	4B1-d	
Manure Man.: Non-Dairy Cattle (confined)	4B1-n	
Manure Man.: Buffalo (confined)	4B2	
Manure Man.: Sheep (confined)	4B3	
Manure Man.: Goats (confined)	4B4	
Manure Man.: Camels and llamas (confined)	4B5	
Manure Man.: Horses (confined)	4B6	
Manure Man.: Mules and asses (confined)	4B7	
Manure Man.: Swine (confined)	4B8	
Manure Man.: Poultry (confined)	4B9	
Synthetic Fertilizers	4D11	
Animal Manure Applied to Soils	4D12	
Direct soil emissions	4D13	
Crop Residue	4D14	
Cultivation of Histosols	4D15	
Pasture, Range and Paddock Manure	4D2	
Indirect N2O: Atm. Depos. - agricult. (4D)	4D3a	
Indirect N2O: Leaching and Run-Off - agri.	4D3b	
CO2 from urea application	4D4a	
Field burning of agric. res.: cereals	4F1	
Field burning of agric. res.: pulses	4F2	
Field burning of agric. res.: tuber and roots	4F3	
Field burning of agric. res.: sugar cane	4F4	
Field burning of agric. res.: other	4F5	

A.B.11.4. Buildings (Chapter 9)

Description	Code	Emission source category

Commercial and public services (fos.)	1A4a	
Residential (fos.)	1A4b	
Commercial and public services (biom.)	1A4ax	
Residential (biom.)	1A4bx	
Fire Extinguishers	2F3	
Aerosols	2F4	
Adiabatic prop.: shoes and others	2F9a	
Soundproof windows	2F9c	

A.B.11.5. Transport (Chapter 10)

Description	Code	Emission source category
Domestic air transport	1A3a	
Road transport (incl. evap.) (foss.)	1A3b	
Non-road transport (rail, etc.) (fos.)	1A3c	
Inland shipping (fos.)	1A3d	
Non-road transport (fos.)	1A3e	
Road transport (incl. evap.) (biom.)	1A3bx	
Non-road transport (rail, etc.)(biom.)	1A3cx	
Inland shipping (biom.)	1A3dx	
Non-road transport (biom.)	1A3ex	
International air transport	1C1	
International marine transport (bunkers)	1C2	
Adiabatic prop.: tyres	2F9b	
International marine transport (biom.)	1C2x	

A.B.11.6. Industry (Chapter 11)

Description	Code	Emission source category
Fuel combustion coke ovens	1A1c1	
Blast furnaces (pig iron prod.)	1A1c2	
Iron and steel	1A2a	
Non-ferrous metals	1A2b	
Chemicals	1A2c	
Pulp and paper	1A2d	
Food and tobacco	1A2e	
Other industries (stationary) (fos.)	1A2f	
Off-road machinery: construction (diesel)	1A2f1	
Off-road machinery: mining (diesel)	1A2f2	
Iron and steel (biomass)	1A2ax	
Non-ferrous metals (biomass)	1A2bx	
Chemicals (biomass)	1A2cx	
Pulp and paper (biomass)	1A2dx	
Food and tobacco (biomass)	1A2ex	
Fuel transformation coke ovens	1B1b1	
Cement production	2A1	
Lime production	2A2	

Limestone and Dolomite Use	2A3	
Crude steel production total	2C1a	
Blast furnaces	2C1b	
Ferroy Alloy production	2C2	
Magnesium foundries: SF6 use	2C4a	
Aluminium foundries: SF6 use	2C4b	
Foam Blowing	2F2	
F-gas as Solvent	2F5	
Semiconductor Manufacture	2F7a	
Flat Panel Display (FPD) Manufacture	2F7b	
Photo Voltaic (PV) Cell Manufacture	2F7c	
Electrical Equipment Manufacture	2F8a	
F-gas/ODP consumption	2F9	
Accelerators/HEP	2F9d	
Misc. (AWACS, other military and misc.)	2F9e	
Unknown SF6 use	2F9f	
Solvents in paint	3A	
Degreasing and dry cleaning	3B	
Chemical products	3C	
Other product use	3D	
Waste incineration - hazardous	6C	
Other waste	6D	
Indirect N2O from NOx emitted in cat. 2-3	7B2	
Indirect N2O from NH3 emitted in cat. 2-3	7C2	
Other industries (stationary) (biom.)	1A2fx	
Soda ash production	2A4a	
Soda ash use	2A4b	
Glass production	2A7a	
Ammonia production (gross CO2)	2B1g	
CO2-ammonia stored in urea	2B1s	
Nitric acid production	2B2	
Adipic acid production	2B3	
Silicon carbide production	2B4a	
Calcium carbide production	2B4b	
Carbon black production	2B5a	
Ethylene production	2B5b	
Styrene production	2B5d	
Methanol production	2B5e	
Caprolactam production	2B5f	
Other bulk chemicals production	2B5g	
Urea production	2B5g1	
Vinyl chloride production	2B5g2	
Glyoxal production	2B5h1	
Sinter production	2C1d	
Aluminium production (primary)	2C3a	
Aluminium production (secondary)	2C3b	

Lead production (primary)	2C5lp	
Magnesium production (primary)	2C5mp	
Zinc production (primary)	2C5zp	
Production of halocarbons	2E1	
Refrigeration and Air Conditioning	2F1a	
Non-energy use of lubricants/waxes (CO2)	2G1	
Other Non-energy use of fuels (CO2 only)	2G2	
Use of N2O as anaesthesia	3D1	
Use of N2O in aerosol spray cans	3D3	
Managed waste disposal on land	6A1	
Industrial wastewater	6B1	
Domestic and commercial wastewater	6B2	
Waste incineration - biogenic	6Cax	
Waste incineration - uncontrolled MSW burning	6Cb1	
Waste incineration - other non-biogenic	6Cb2	

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