

**Table 2.2 | The assessed remaining carbon budget and its uncertainties.** Shaded blue horizontal bands illustrate the uncertainty in historical temperature increase from the 1850–1900 base period until the 2006–2015 period as estimated from global near-surface air temperatures, which impacts the additional warming until a specific temperature limit like 1.5°C or 2°C relative to the 1850–1900 period. Shaded grey cells indicate values for when historical temperature increase is estimated from a blend of near-surface air temperatures over land and sea ice regions and sea-surface temperatures over oceans.

Additional Warming since 2006–2015 [°C] <sup>(1)</sup>	Approximate Warming since 1850–1900 [°C] <sup>(1)</sup>	Remaining Carbon Budget (Excluding Additional Earth System Feedbacks <sup>(5)</sup> ) [GtCO <sub>2</sub> from 1.1.2018] <sup>(2)</sup>			Key Uncertainties and Variations <sup>(4)</sup>					
		Percentiles of TCRE <sup>(3)</sup>			Earth System Feedbacks <sup>(5)</sup>	Non-CO <sub>2</sub> scenario variation <sup>(6)</sup>	Non-CO <sub>2</sub> forcing and response uncertainty	TCRE distribution uncertainty <sup>(7)</sup>	Historical temperature uncertainty <sup>(1)</sup>	Recent emissions uncertainty <sup>(8)</sup>
33rd	50th	67th	[GtCO <sub>2</sub> ]	[GtCO <sub>2</sub> ]						
0.3		290	160	80	Budgets on the left are reduced by about –100 on centennial time scales	±250	–400 to +200	+100 to +200	±250	±20
0.4		530	350	230						
0.5		770	530	380						
<b>0.53</b>	<b>~1.5°C</b>	<b>840</b>	<b>580</b>	<b>420</b>						
0.6		1010	710	530						
0.63		1080	770	570						
0.7		1240	900	680						
0.78		1440	1040	800						
0.8		1480	1080	830						
0.9		1720	1260	980						
1		1960	1450	1130						
<b>1.03</b>	<b>~2°C</b>	<b>2030</b>	<b>1500</b>	<b>1170</b>						
1.1		2200	1630	1280						
1.13		2270	1690	1320						
1.2		2440	1820	1430						

## Notes:

- <sup>(1)</sup> Chapter 1 has assessed historical warming between the 1850–1900 and 2006–2015 periods to be 0.87°C with a ±0.12°C *likely* (1-standard deviation) range, and global near-surface air temperature to be 0.97°C. The temperature changes from the 2006–2015 period are expressed in changes of global near-surface air temperature.
- <sup>(2)</sup> Historical CO<sub>2</sub> emissions since the middle of the 1850–1900 historical base period (mid-1875) are estimated at 1940 GtCO<sub>2</sub> (1640–2240 GtCO<sub>2</sub>, one standard deviation range) until end 2010. Since 1 January 2011, an additional 290 GtCO<sub>2</sub> (270–310 GtCO<sub>2</sub>, one sigma range) has been emitted until the end of 2017 (Le Quéré et al., 2018).
- <sup>(3)</sup> TCRE: transient climate response to cumulative emissions of carbon, assessed by AR5 to fall *likely* between 0.8–2.5°C/1000 PgC (Collins et al., 2013), considering a normal distribution consistent with AR5 (Stocker et al., 2013). Values are rounded to the nearest 10 GtCO<sub>2</sub>.
- <sup>(4)</sup> Focussing on the impact of various key uncertainties on median budgets for 0.53°C of additional warming.
- <sup>(5)</sup> Earth system feedbacks include CO<sub>2</sub> released by permafrost thawing or methane released by wetlands, see main text.
- <sup>(6)</sup> Variations due to different scenario assumptions related to the future evolution of non-CO<sub>2</sub> emissions.
- <sup>(7)</sup> The distribution of TCRE is not precisely defined. Here the influence of assuming a lognormal instead of a normal distribution shown.
- <sup>(8)</sup> Historical emissions uncertainty reflects the uncertainty in historical emissions since 1 January 2011.

## 2.3 Overview of 1.5°C Mitigation Pathways

Limiting global mean temperature increase at any level requires global CO<sub>2</sub> emissions to become net zero at some point in the future (Zickfeld et al., 2009; Collins et al., 2013). At the same time, limiting the residual warming of short-lived non-CO<sub>2</sub> emissions can be achieved by reducing their annual emissions as much as possible (Section 2.2, Cross-Chapter Box 2 in Chapter 1). This would require large-scale transformations of the global energy–agriculture–land–economy system, affecting the way in which energy is produced, agricultural systems are organized, and food, energy and materials are consumed (Clarke et al., 2014). This section assesses key properties of pathways consistent with limiting global mean temperature to 1.5°C relative to pre-industrial levels, including their underlying assumptions and variations.

Since the AR5, an extensive body of literature has appeared on integrated pathways consistent with 1.5°C (Section 2.1) (Rogelj et al., 2015b, 2018; Akimoto et al., 2017; Löffler et al., 2017; Marcucci et al., 2017; Su et al., 2017; Bauer et al., 2018; Bertram et al., 2018; Grubler et al., 2018; Holz et al., 2018b; Kriegler et al., 2018a; Liu et al., 2018; Luderer et al., 2018; Strefler et al., 2018a; van Vuuren et al., 2018; Vrontisi et al., 2018; Zhang et al., 2018). These pathways have global coverage and represent all GHG-emitting sectors and their interactions. Such integrated pathways allow the exploration of the whole-system transformation, and hence provide the context in which the detailed sectoral transformations assessed in Section 2.4 of this chapter are taking place.

The overwhelming majority of published integrated pathways have been developed by global IAMs that represent key societal systems