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## **PARIS REINFORCE (PR) input to the first global stocktake**

### SYR (a)

The state of greenhouse gas emissions by sources and removals by sinks and mitigation efforts undertaken by Parties, including the information referred to in Article 13, para 7(a), and Article 4, paras 7c, 15 and 19, of the Paris Agreement

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### Key Points:

- Global energy-related CO<sub>2</sub> emissions are projected to grow from ~33 GtCO<sub>2</sub> in 2019 to 30-35 GtCO<sub>2</sub> by 2030, 20-40 GtCO<sub>2</sub> by 2050, and 17-43 GtCO<sub>2</sub> by 2100 (Gambhir et al., 2020).
- Current climate policies lead to a global energy emission range of 32-36 GtCO<sub>2</sub> in 2030, and 26-40 GtCO<sub>2</sub> in 2050 (Sognaes et al., 2021).
- Current NDCs lead to a global energy emission range of 30-34 GtCO<sub>2</sub> in 2030 and between 23-38 GtCO<sub>2</sub> in 2050 (Sognaes et al., 2021).
- 1.5°C requires -7.6% annual emission reductions between 2020-2030 (UNEP, 2019). However, energy related CO<sub>2</sub> emissions alone decrease by 0% to -5.88% (median) by 2030 (Gambhir et al., 2020; Sognaes et al., 2021).
- Current EU policies (excluding the Fit-for-55 package, due to be formalised) lead to a reduction of -33% to -45% in EU energy related CO<sub>2</sub> emissions between 2020-2030, and -47% from 2020-2050 (compared to 1990) (Nikas et al., 2021).
- EU Member State's National Energy Climate Plans (NECPS) focus on CO<sub>2</sub>, CH<sub>4</sub> and NH<sub>3</sub>, whereas PMs, SO<sub>x</sub> and land-use CO<sub>2</sub> emissions are less mentioned (Sognaes et al., 2020).

### About the project

PARIS REINFORCE (PR) is an EU Horizon 2020 funded project, with a consortium of thirteen European and five international partners. PR's fundamental aim is to enhance and improve climate policymaking. To do so, the consortium has access to a range of sophisticated climate-economic scientific models and brings together a wide range of knowledge and expertise to produce interdisciplinary analyses and reports. PR has been working on a number of additional Deliverables which will prove relevant to the GST. However, analyses are unfinished and thus remain to be published. PR will update our inputs with our latest results once they are complete.

### Summary of the relevant work

Gambhir et al. (2020) investigated the state of global energy-related CO<sub>2</sub> emissions based on current levels of ambition. Given 2019 emission levels of ~33 GtCO<sub>2</sub>, projections indicate that we are heading towards a range of 30-35 GtCO<sub>2</sub> by 2030. Thus, emissions are unlikely to experience significant fluctuations in the next decade (excluding COVID-related changes). Emissions increase to ~20-40 GtCO<sub>2</sub> in 2050, and to ~17-43 GtCO<sub>2</sub> in 2100. These projections highlight the ambiguous relationship between current levels of ambition and future emission levels; they also indicate that there are a range of potential emission futures. Emissions are unlikely to rise to levels that see the highest emission-growth pathways, which reach emission levels of 50-80 GtCO<sub>2</sub>.

Gambhir et al. compares these results to IEA scenarios. The authors note that energy-related CO<sub>2</sub> emission estimates in 2030 are lower than in the IEA's 2019 Current Policies (CPs) scenario (IEA, 2019) and, in most instances, the IEA's 2019 Stated Policies (SPs) scenario (IEA, 2019). The IEA analyses are not sufficiently transparent to investigate why this difference occurs. However, the IEA has historically shown conservative estimates for renewable costs and renewably deployment levels (Mohn, 2020; Gambhir, 2017; Hoekstra, 2017) which is likely to be a substantial differentiator between IEA CPs 2019 projections and our projections. Considering the IEA's updated 2021 scenarios, Gambhir et al.'s energy-related CO<sub>2</sub> emission estimates in 2030 are comparable with both the IEA's 2021 Announced Pledges Scenario (APS) and the IEA's 2021 Stated Policies scenario (STEPS) which reported 2030 CO<sub>2</sub> emissions of ~33.4-36 GtCO<sub>2</sub> respectively.

Sognaes et al. (2021) conducted a comprehensive scenario analysis, separating the effects of NDCs and current



policies (CPs) on GHG emissions, to explore how global energy CO<sub>2</sub> emissions would evolve. CP-constrained scenarios reached emission levels of 32-36 GtCO<sub>2</sub> in 2030, and 26-40 GtCO<sub>2</sub> in 2050. NDC-constrained scenarios reached emission levels of 30-34 GtCO<sub>2</sub> in 2030, and 23-38 GtCO<sub>2</sub> in 2050. Combining CP and NDC scenarios produces a range of 30-36 GtCO<sub>2</sub> in 2030, and 23-40 GtCO<sub>2</sub> in 2050. Global energy demand was found to increase over time across the majority of models.

These findings are lower than previous analyses for emission levels in 2030: the UNEP (2021), for example, estimate a range of 46-58 GtCO<sub>2</sub>e based on CPs and NDCs; Benveniste et al. (2018) estimate 56.8-66.5 GtCO<sub>2</sub>eq yr<sup>-1</sup> based on NDCs; Rogelj et al. (2017) estimate 47.1-62.9 GtCO<sub>2</sub>eq yr<sup>-1</sup> based on NDCs; and the UNFCCC (2021) estimate 51.7-58.4 GtCO<sub>2</sub>eq. Regarding studies that utilise similar models and methods, our emissions intensities per GDP are below IEA World Energy Outlook 2019 scenarios (IEA, 2019), and our global energy CO<sub>2</sub> emission estimates are lower than those in CD-LINKS scenarios (McCullum et al., 2018). Emissions in our NDC-constrained scenarios also account for those regions that are on track to outperform their NDCs, thus were anticipated to be lower. Emission estimates in CP-constrained scenarios are lower as inter alia our baseline emissions are lower, partly due to the use of updated technology costs harmonised across models.

Nikas et al. (2021) focused on the energy future of the EU alone based on current policy projections. Current policies do not include any policy instruments of the Fit-for-55 package, since these have not been formalised and deployed. Between 1990-2015, CO<sub>2</sub> emissions in the EU decreased by ~ 0.86 Gt, from 4.12-3.26 Gt (annual average decline of -0.9%). Between 2020 and 2030, models show an absolute reduction of -33% to -45% compared to 1990 levels. Between 2020 and 2050, the median CO<sub>2</sub> emissions from EU energy supply decrease by -47% from 1990 levels. Median decarbonisation rates are -42% for industry, -30% for buildings, and -32% for transport. Median EU CO<sub>2</sub> emissions in 2050 are ~ 2.1 Gt (1.0-2.35 Gt), representing an emission reduction of -43% to -76% compared to 1990 levels.

Assuming a non-CO<sub>2</sub> emission range of 0.5 - 0.67 MtCO<sub>2</sub>eq in 2030 (European Commission, 2019; European Commission, 2020), GHG emission reduction in 2030 would range between -39% and -51% compared to 1990 levels, assuming stagnated policy ambition (i.e., excluding any new policy packages). This is insufficient to meet the EU Green Deal goal of a -55% reduction (European Commission, 2020).

Primary energy is projected to decline from 67.7 EJ/y in 2020 to 59.9 EJ/y in 2030 and stabilise at ~61.3 EJ/y in 2050. Across the EU energy system, models projected median CO<sub>2</sub> emission intensity declining from 48.3 kgCO<sub>2</sub>/GJ in 2020 to 30.5 kgCO<sub>2</sub>/GJ in 2050. The use of fossil fuels in the EU primary energy mix decreases from 59-86% in 2020 to 36-71% in 2050.

It should be noted that global models provide a more optimistic view than regional EU models, largely due to a higher flexibility of mitigation options - with a projected range of 2.1-2.35 Gt in regional models, compared to 1.0-1.65 Gt in global models. These results conform to existing scenarios in the literature (e.g., Mantzos et al., 2019).

To meet the 1.5°C goal of the PA, emissions must fall by -7.6% annually from 2020-2030 (UNEP, 2019) or approximately 45% from 2010 levels by 2030 (IPCC, 2018; UNFCCC, 2021). Based on analyses by Gambhir et al. (2020) we can estimate an approximate -1.51% reduction in energy-related CO<sub>2</sub> emissions alone between 2019 and 2030 based on current levels of ambition.

When assuming 2020 emission levels of 34 GtCO<sub>2</sub> as reported by Le Quéré et al. (2021), Sognaes et al.'s analyses suggest that under the NDC-constrained scenario energy CO<sub>2</sub> emissions decrease by -11.76% to 0% by 2030. The CP-constrained scenario produces a much broader range of energy-related emission futures of between -5.88% to +5.88% by 2030. These findings are reflected in the wider literature. For example, emission projections for the



30 highest-emitting economies are expected to increase by approximately 0.4% annually between 2021-2030 (Nascimento et al., 2021), and the UNFCCC (2021) predicts GHG emissions to rise by 16.3% by 2030 relative to 2010 levels.

Among PR research, global emission projections are consistent. The global energy CO<sub>2</sub> emission ranges reported by Gambhir et al. (2020) and Sognaes et al. (2021) overlap for both 2030 and 2050 – 30-35 GtCO<sub>2</sub> vs. 30-36 GtCO<sub>2</sub> in 2030, and 20-40 vs. 23-40 GtCO<sub>2</sub> in 2050, respectively. Nikas et al.'s (2021) emission projections for EU energy CO<sub>2</sub> are compatible with these findings, with EU CO<sub>2</sub> emissions being between 1.0-2.35 GtCO<sub>2</sub> in 2050, indicating Parties' are not on track to achieve net-zero by 2050. There are, however, slight differences between projections of primary and final energy demands reported at the global level by Sognaes et al. (2021) and at the EU level by Nikas et al. (2021). Sognaes et al. projects that global primary and final energy demands increases over time, whereas Nikas et al. (2021) finds that EU primary and final energy demands experience a net decrease. This suggests that the EU's climate policies may be more effective than many other Parties'.

Cain et al. (2021) has investigated the role of CO<sub>2</sub> and non-CO<sub>2</sub> emissions – specifically methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) – on global temperatures. The scenarios presented here are 1.5°C compatible, taken from the IPCC Special Report on the Global Warming of 1.5°C (SR15) scenario database (Rogelj et al., 2018). The results reflect the median of 1.5°C-compatible scenarios.

Analysis indicates that peak warming will occur in 2046. Separating the impact of individual GHG emissions on peak temperature, CH<sub>4</sub> contributes +0.033°C, N<sub>2</sub>O contributes +0.11°C, and CO<sub>2</sub> contributes +1.18°C.

CH<sub>4</sub> emission production and warming contribution peaks in the present decade (with an approximate 0.4°C contribution to warming above pre-industrial levels). Between 2020 and 2100, CH<sub>4</sub> emissions decline by 57-65% and reduce warming by approximately 0.14°C across this same period (Figure 1; Figure 2). CH<sub>4</sub> was found to be the only major GHG with declining induced warming between 2020-2050 in 1.5°C compatible mitigation scenarios.

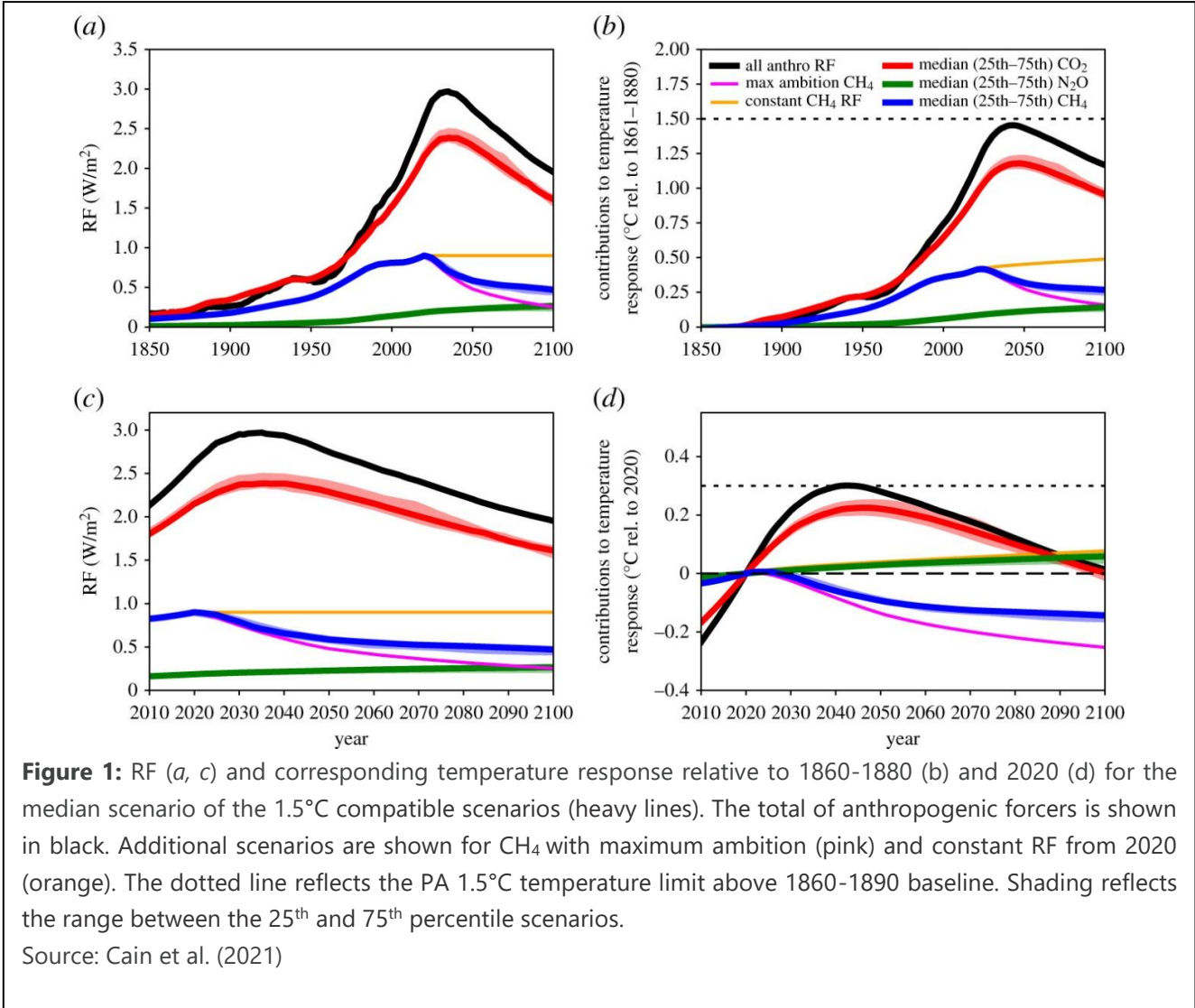
CO<sub>2</sub> continues to increase global mean temperature by approximately +1.18°C at peak warming until net-zero emissions are reached (0 GtCO<sub>2</sub>yr<sup>-1</sup> occurs in approximately 2046). CO<sub>2</sub> emissions then become net-negative, and by 2100 CO<sub>2</sub>-induced warming returns to 2017 ("present-day" at the time of publication) (Figure 1; Figure 2).

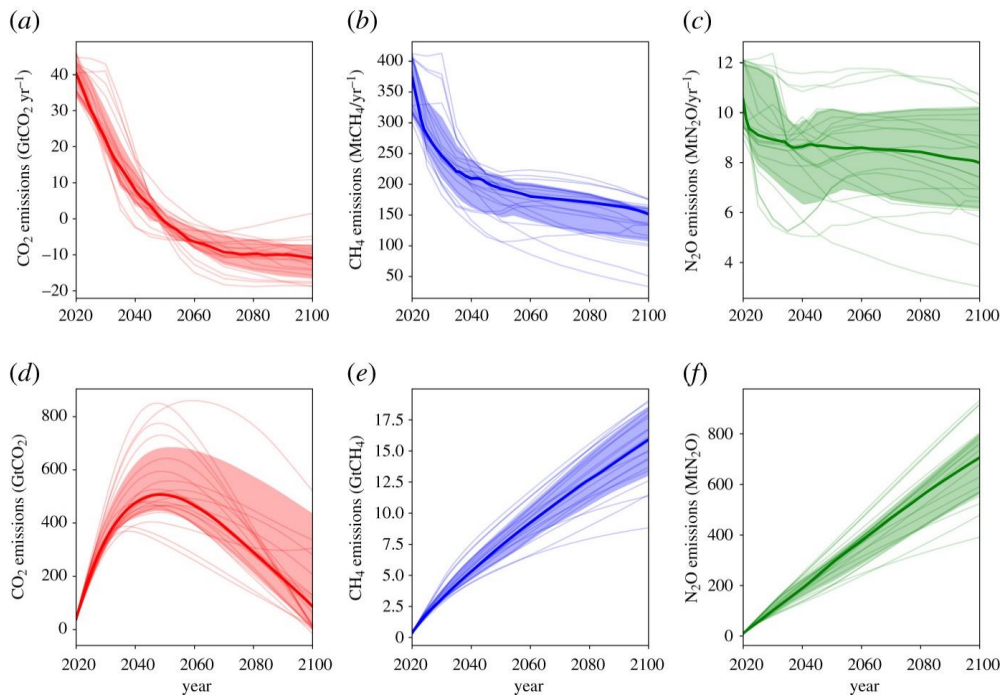
N<sub>2</sub>O's contribution to global temperature increase continues beyond 2100. Neither CH<sub>4</sub> nor N<sub>2</sub>O reach net-zero emissions before 2100 in 1.5°C compatible scenarios (Figure 1; Figure 2). Figure 3 illustrates net-zero GHG emission year for different classifications of the IPCC SR15 scenarios.

These results align with similar investigations, such as the IPCC (2018) and the UNEP (2021) stating that global CO<sub>2</sub> emissions must reach net-zero by 2050 not to exceed a 1.5°C temperature increase. However, to achieve the 1.5°C temperature goal, the UNEP (2021) state that global GHG emissions must reach net-zero 15-20 years after achieving net-zero CO<sub>2</sub> emissions (i.e., ~2065-2070), whereas Cain et al.'s projections do not require achieving net-zero CH<sub>4</sub> or N<sub>2</sub>O before the end of century in 1.5°C-compatible scenarios (Figure 2).

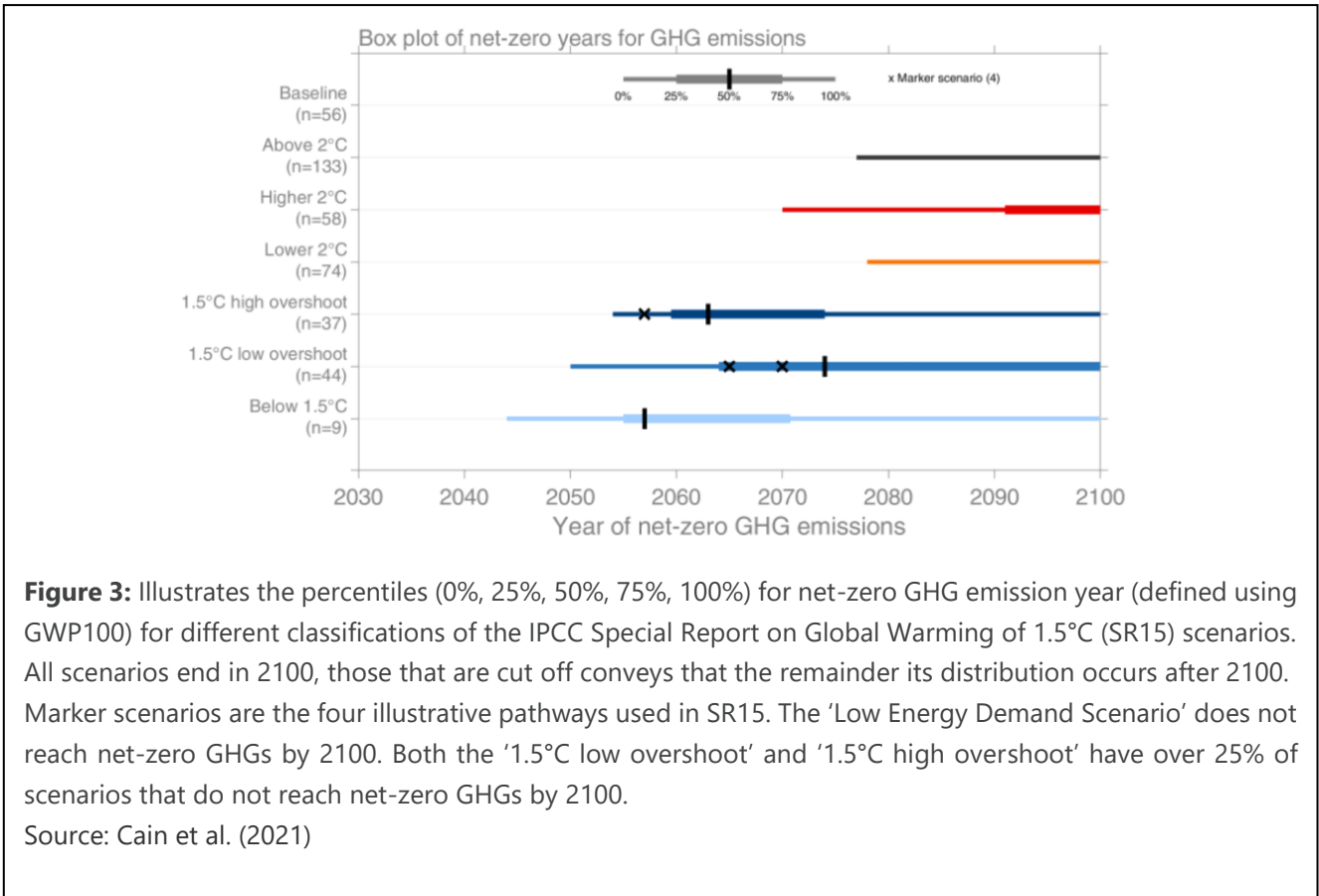
Sognaes et al. (2020) has investigated the national energy climate plans (NECPs) submitted by EU member states (MSs) to explore where GHG mitigation efforts will be focused. All countries appear to mention CO<sub>2</sub> emissions and are considering the required policy mix to reduce them. The majority of countries also reference CH<sub>4</sub> and NH<sub>3</sub>; however, PMs, SO<sub>x</sub> and land-use CO<sub>2</sub> emissions are less frequently mentioned. Further, whilst all NECPs touch upon the SDGs, very few mentioned them clearly – except for SDG 13 "climate action" which was covered in all NECPs.







**Figure 2:** Annual emissions of CO<sub>2</sub> (a), CH<sub>4</sub> (b) and N<sub>2</sub>O (c), and cumulative emissions of CO<sub>2</sub> (d), CH<sub>4</sub> (e) and N<sub>2</sub>O (f) since 2005 that are compatible with a 1.5°C limit to warming. Heavy lines reflect median emissions. Shading reflects the interquartile range.  
Source: Cain et al. (2021)



**Figure 3:** Illustrates the percentiles (0%, 25%, 50%, 75%, 100%) for net-zero GHG emission year (defined using GWP100) for different classifications of the IPCC Special Report on Global Warming of 1.5°C (SR15) scenarios. All scenarios end in 2100, those that are cut off conveys that the remainder its distribution occurs after 2100. Marker scenarios are the four illustrative pathways used in SR15. The 'Low Energy Demand Scenario' does not reach net-zero GHGs by 2100. Both the '1.5°C low overshoot' and '1.5°C high overshoot' have over 25% of scenarios that do not reach net-zero GHGs by 2100.

Source: Cain et al. (2021)

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