2022

EARTH INDEX:
TRACKING THE G20 RESPONSE
TO THE CLIMATE EMERGENCY

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First Revision: April 22, 2022

This revision contains updates to the Canadian scorecard, made to include data published by the Government of Canada on April 15, 2022, in which the emissions inventories for historical years were retroactively revised, with the effect of slightly improving their EARTH INDEX score.

INTRODUCTION

The Corporate Knights EARTH INDEX is a measurement of the speed at which countries (by sector) are reducing greenhouse gas (GHG) emissions relative to the speed required to deliver on their commitments.

Its objective is to create global awareness of whether annual GHG emissions are being reduced fast enough to meet the long-term targets countries have set for themselves. We focus on G20 countries, which account for about 80% of global GHG emissions.

EARTH INDEX has been developed and refined with the input of many collaborators and stakeholders, including Corporate Knights' research division, an advisory network of eminent experts in related fields, and ongoing contributions from CEOs of the Global 100 Most Sustainable Corporations in the World.

With the Glasgow Climate Pact, governments came forward for the first time with sufficiently ambitious targets to hold global warming to below 2°C. But when countries state long-term targets without short-term accountability, trust erodes, which undermines the public consensus required to achieve targets. Increased transparency on short-term results enhances accountability and helps build trust.

Progress must be measured in real time so that countries can be held accountable for delivering on their commitments. For this to happen, we need clear and consistent data, broken down in ways that make sense to specialists and non-specialists alike. The key feature of EARTH INDEX is that it recalibrates annually, based on actual emissions progress. Since this will happen on a sector-by-sector basis, it will be crystal clear where the gaps are, both within and between countries.

Current progress in reducing emissions falls short of even the Paris targets; taking the G20 countries together, emissions actually went up in 2019. Bending the GHG emissions curve is an urgent imperative that will take monumental effort from all of us.

While existing climate initiatives[1] assess countries' policies and pledges in the context of global GHG emission targets required to meet defined climate goals, EARTH INDEX measures the pace of reported GHG emission reductions required to meet targets as laid out by countries themselves.

> *Progress must be measured in real time so that countries can be held accountable for delivering on their commitments.*

(1) Ambition gap analysis by the International Energy Agency, UNEP's Emissions Gap Report (published annually since 2010) and the Climate Action Tracker (tracking progress since 2009).

SCOPE AND CONTEXT: THE G20 EMISSIONS

The Earth Index analysis covers all 43 countries in the G20.[2] They generate 80% of the world's GDP, conduct 75% of world trade, and with a population of 4.6 billion make up 60% of the global population. In 2019, G20 GHG emissions totalled 38.2 billion tonnes of carbon dioxide equivalent (CO2e), about 75% of the world total.[3] Emissions are also concentrated within the G20, with China, the United States, India and the European Union together making up half the total, as illustrated in Figure 1. Bringing global warming under control will require deep cuts in emissions throughout the G20 in this decade – on the order of 50%.

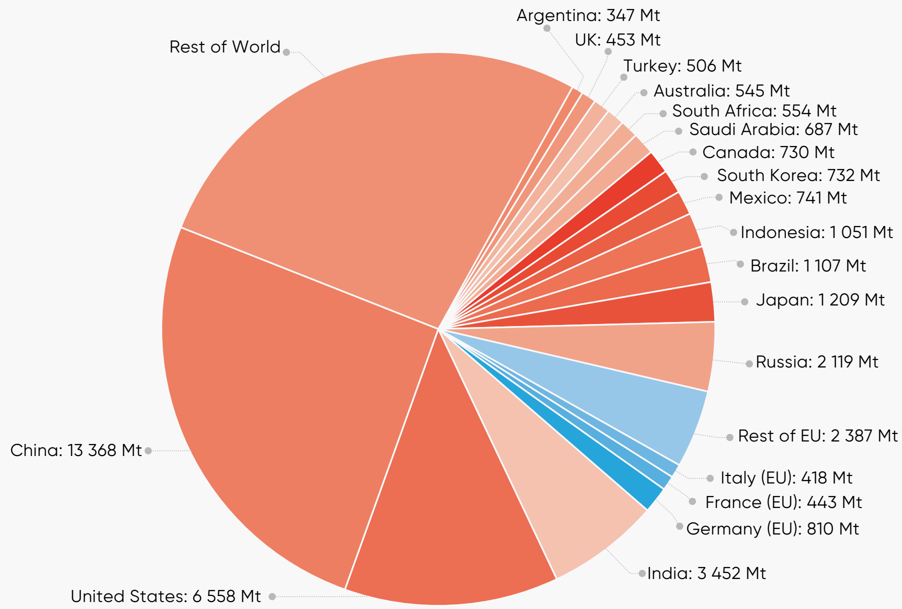


Figure 1: G20 GHG emissions in 2019 – 75% of global total

Figure 2 provides a map of G20 GHG emissions by member and by sector and begins to reveal the nature of the emission reduction challenge. Most emissions are the result of the production and combustion of fossil fuel, but there are significant contributions from industrial and agricultural processes. The underlying causal factors of the fossil fuel emissions vary by sector, from low-

(2) The European Union is counted as one member of the G20, but includes 27 countries, three of which also have independent standing as G20 members: Germany, France and Italy. The other 16 members of the G20 are the United Kingdom, the United States, Canada, Japan, Australia, Saudi Arabia, Korea, Brazil, Russia, India, China, South Africa, Indonesia, Mexico, Argentina, and Turkey.

(3) There is some variation in estimates of global greenhouse gas emissions and how they break down by country, and the most authoritative and comprehensive estimates are published nearly two years after the fact. As explained in more detail in the methodological appendix, we build our estimate of G20 emissions using the inventories filed by the Annex 1 countries under the Framework Convention on Climate Change and the inventories in the European Commissions EDGAR database for the non-Annex 1 countries. All the greenhouse gases reported by the Annex 1 countries are included, and for the non-Annex 1 countries the three primary greenhouse gases are included (carbon dioxide, methane, and nitrous oxide).

temperature heat to provide comfort in buildings, to transport fuels to provide access to all manner of goods and services, to high-temperature heat for transforming minerals into steel and cement, to myriad electricity-specific end uses, including lighting, telecommunications and information processing. The whole system is notoriously inefficient, with nearly 50% of the energy system emissions occurring in the power and fossil fuel industries, before the energy commodities get to the buildings and vehicles and factories where large additional losses occur.

Solutions for eliminating fossil fuels include switching to emission-free energy commodities and renewable resources but also extend deep into the demand chains for fossil fuels.

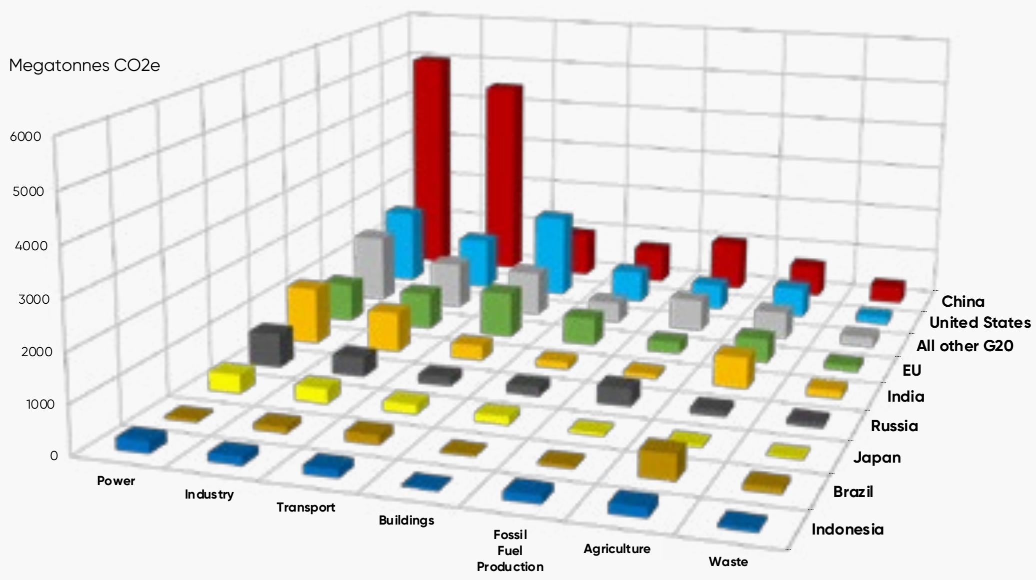


Figure 2: G20 emissions in 2019 by member and by sector

Emissions per Capita and Per Dollar of GDP

The absolute emission levels portrayed in Figure 2 should be viewed in the context of the different historical and present circumstances of the member states. As shown in Figure 3, per capita GDP in the high-income countries is several times higher than in the middle-income countries where 81% of the G20 population resides, and even higher still compared to the per capita income of the 40% of the global population outside of the G20.[4] The wealth of the high-income countries

(4) Throughout this report we refer to the "high-income" and "middle-income" members of the G20. These terms refer to the World Bank Atlas method which classifies low-income countries as those with gross national per capita income of $1,045 or less in 2020; lower middle-income economies are those with a GNI per capita between $1,046 and $4,095; upper middle-income economies are those with a GNI per capita between $4,096 and $12,695; high-income economies are those with a GNI per capita of $12,696 or more. Regarding the G20 member states, the high-income group includes the USA, Canada, the United Kingdom, Japan, Australia, South Korea, and Saudi Arabia, in addition to Germany, France, Italy, and the EU. (Romania and Bulgaria are in the upper middle-income group as individual countries, but are included here as part of the EU, in the high-income category.) The upper middle-income G20 members include Brazil, Russia, China, South Africa, Argentina, Mexico, and Turkey; India and Indonesia are in the lower middle-income group. There are no G20 members in the low-income group.

is in no small measure the result of their intensive use of inexpensive fossil fuels to meet their needs throughout the 20th century while pushing the costs to the environment, and ultimately to the entire global community, into the 21st century.

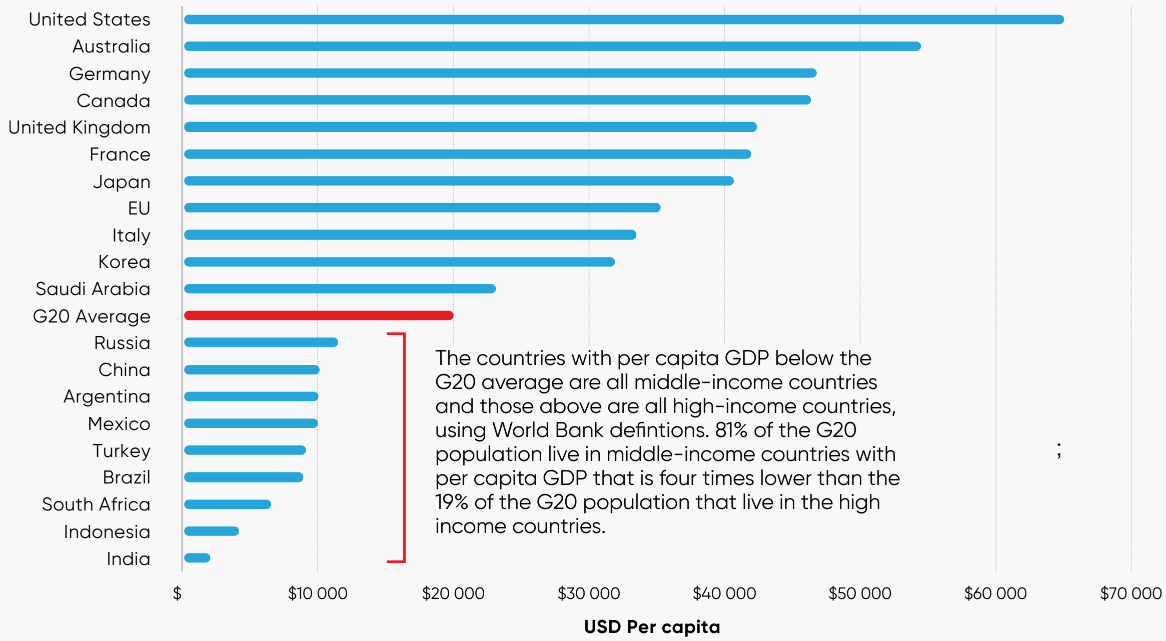


Figure 3: Per capita GDP, G20 (Source: http://data.worldbank.org)

With income levels and energy productivities varying over a wide range within the G20, the map takes on a different pattern when emissions are portrayed on a per capita basis, as in Figure 4, or a per dollar of GDP, as in Figure 5. Low levels of per capita emissions reflect low levels of fossil use, and historically this has signalled low levels of income. This is still true (e.g., India, Indonesia, Brazil), but as the energy transition proceeds, per capita emission levels are declining in some rich countries (e.g., the EU). On the other hand, low emissions per dollar of GDP is characteristic of the advanced industrial and post-industrial economies and indicates both high levels of technological efficiency and post-industrial economic structures in which low-energy-intensive manufacturing and service provision dominate the composition of GDP. High emissions per GDP reflect low productivity and indicate positive synergies between economic development aspirations and the imperative to reduce GHG emissions.

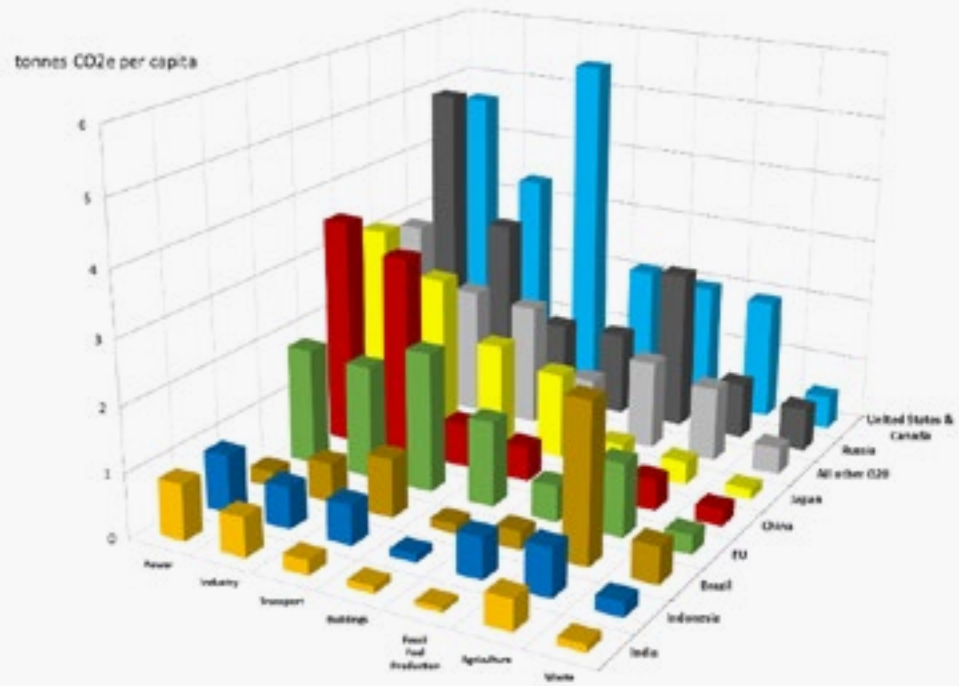


Figure 4: G20 emission per capita in 2019 by member and by sector

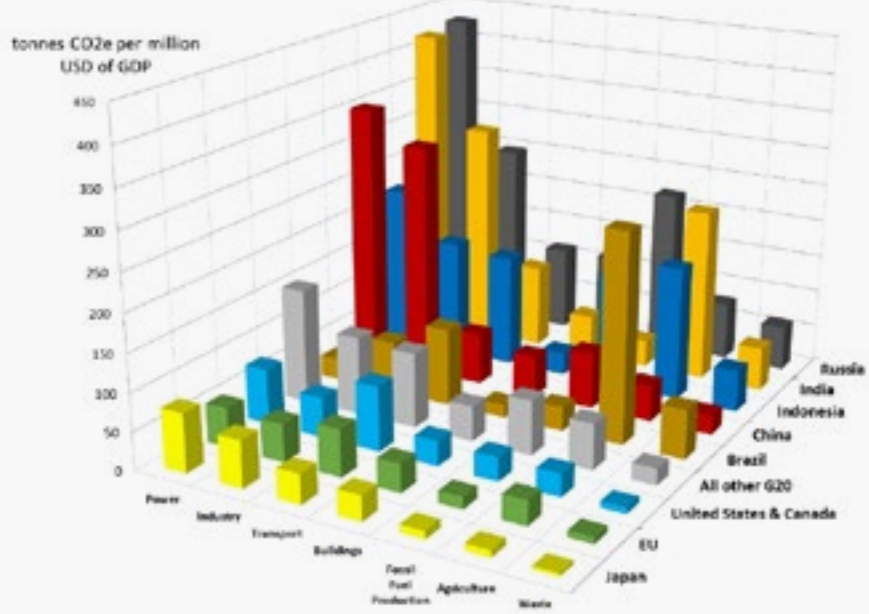


Figure 5: G20 emission per dollar of GDP in 2019 by member and by sector

Emissions and Trade

The emissions profiles presented above, like almost all national GHG inventories, include the emissions that take place within the boundaries of the country. The G20 member states account for 75% of global trade, raising the question of the extent to which country emission totals would be higher or lower if they were consumption-based so that emissions embodied in a country's imports would be included in their inventory, but the emissions embodied in their exports would be assigned to the countries to which the exports were delivered. The energy and therefore the emissions embedded in a dollar's worth of products like steel, primary metals and industrial chemicals can be 10 to 100 times higher than the emissions per dollar embedded in goods like electronics and software, and so the calculation of the net trade in embodied emissions can get complicated.

Using a simplified approach (described in Annex D), we developed a first-order approximation of the trade in GHG emissions between nations, and the results are summarized in Figure 6, grouped by the World Bank's national income categories. The high-income countries import emissions on a net basis, and as a group the middle-income countries (which includes all the countries below the G20 average as shown in Figure 3) are emission exporters. The low-income countries (none of which are G20 members) have very low levels of emissions imports and exports. The same pattern holds for the G20 member states, with China and India being the largest net emission exporters and the EU, UK and the United States being the largest net importers of emissions. The net impact of embodied emissions trade on most country's emissions is only a few percent; Canada, for example, exports about the same quantity of embodied emissions as it imports. China is the largest net exporter of emissions in the world, but even in that case net emission exports peaked 10 years ago and declined during the 2010s.

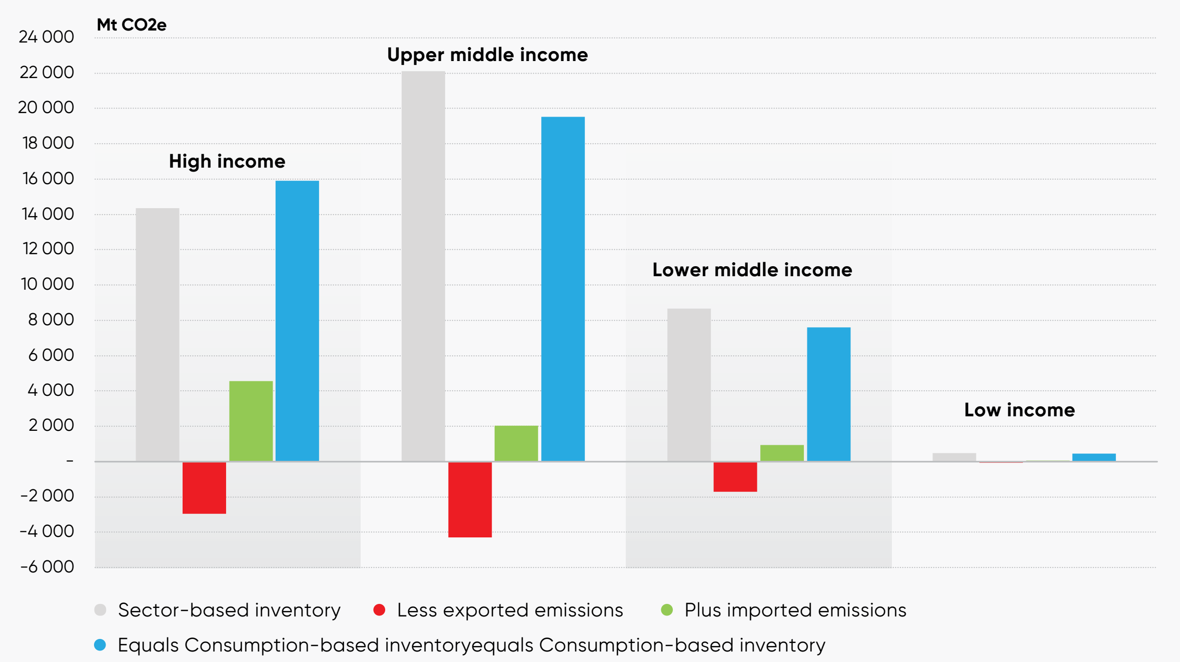


Figure 6: Sector vs. consumption-based inventories

Historical Emissions and 2030 Targets

The historical GHG emissions of the G20 countries are portrayed in Figure 7 for 1990, 2005 and 2019, using the same middle-income and high-income groups portrayed in **groups portrayed in groups portrayed in Figure 3**. The aggregate stated targets of the two groups are also shown in the figure.[5]

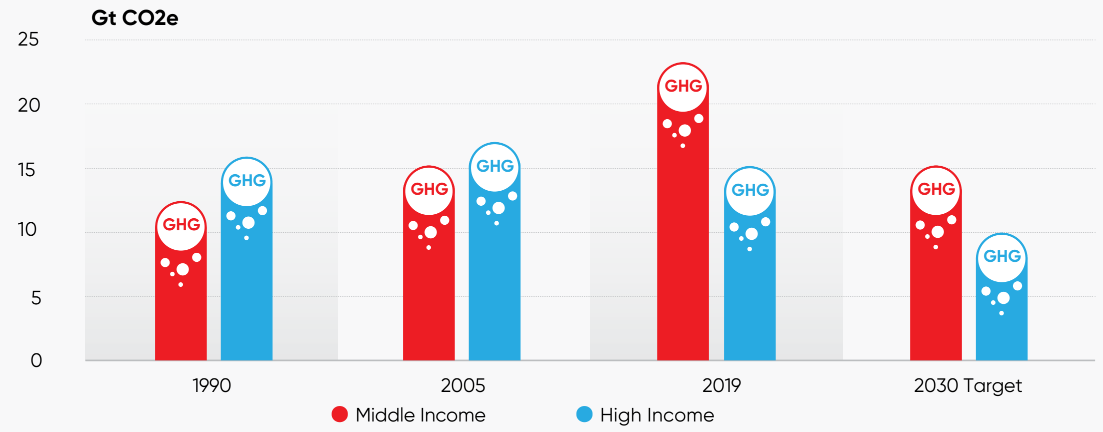


Figure 7: G20 GHG Emissions and 2030 Targets

Led by China, emissions in the middle-income countries have more than doubled since 1990, while aggregate emissions in the high-income group have been relatively stable, even declining slightly since 2005. The middle-income countries' share of G20 emissions has grown from 39% in 1990 to 56% in 2019 and will continue to grow; 81% of the G20 population resides in these countries.

Regarding what the G20 countries say they will do to reduce emissions, we estimate that the aggregate target is 24.7 gigatonnes (Gt) in 2030, 35% lower than actual emissions in 2019, with the middle-income countries targeting a maximum reduction of 29% below 2019 levels, while the high-income countries' aggregate 2030 target is 42% below 2019 emissions levels.

The inadequacy of these targets to contain global warming to 1.5°C is well established (see, for example, Climate Watch). To align with a pathway in which global warming has a good probability of staying below 1.5°C the G20 emissions would need to drop below 20 Gt CO_2 by 2030. The term "emissions gap" is often used to refer to the difference between countries' emission reduction commitments and what it would take to contain global warming to various benchmark average temperatures,[6] but that is not the gap which this report addresses and which EARTH INDEX is intended to illuminate. EARTH INDEX is focused on the "say–do" gap, the difference between the emission reduction outcomes that countries are achieving and the pace of emission reductions that will be necessary for them to meet their stated targets, inadequate as those targets are for effectively responding to the climate emergency.

(5) Most G20 members have a 2030 emission target, expressed as a percent reduction from their emissions in a reference year (usually 1990 or 2005). For those that do not have a 2030 target but have committed to net zero by some future specified year, we have interpolated from 2019 to that year to assign a target emission level in 2030.

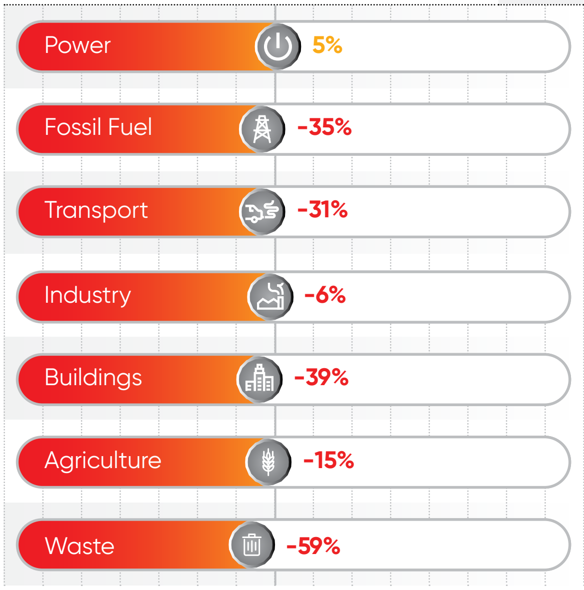
(6) United Nations Environment Programme (2021). Emissions Gap Report 2021: The Heat Is On – A World of Climate Promises Not Yet Delivered. Nairobi. https://www.unep.org/resources/emissions-gap-report-2021.

Figure 8

G20

-15%
Earth Index

Stated emission target	Varies
Emissions in 2019, kt CO2e	38,217,786
Target emissions in 2030, in kt CO2e	25,351,293
Annual kt CO2e reduction needed to meet target:	1,169,681
Emission reduction (or increase) in 2019, kt CO2e	(180,468)
Average annual emission reduction (or increase), 2016-2019	(407,571)
Earth Index based on 2016-2019 trend	**-31%**



Emissions in 2005, kt CO2e	–	–	–	–	–	–	–
Emissions in 2019, kt CO2e	11,551,589	3,299,465	5,768,324	9,236,441	3,066,610	3,948,781	1,346,575
Target emissions in 2030, in kt CO2e	7,884,000	2,155,079	3,597,617	6,321,035	1,980,243	2,527,259	886,059
Annual reductions needed to meet target, kt CO2e	333,417	104,035	197,337	265,037	98,761	129,229	41,865
Actual emission reduction (or increase) in 2019, kt CO2e	17,432	(36,402)	(61,916)	(15,923)	(38,866)	(20,004)	(24,790)

The Earth Index is obtained by dividing the actual emission reductions in 2019 by the annual emission reductions required to meet the stated target. Any result less than 100% indicates insufficient progress to meet the stated target, and when emissions are growing rather than declining, a negative score is obtained.
The data for the calculation are taken from the inventories filed with the UNFCCC for Annex One countries and from the European Commission JRC EDGAR database for non-Annex 1 countries. The Earth Index sectors are defined by groups of IPCC codes. For countries with no 2030 target but a net zero target, a 2030 implied target is assumed by linear interpolation from 2005 to the targeted net zero year. Details available in the Earth Index Methodology document.

EARTH INDEX is calculated for each of the G20 members, as well as for several country groups (EU, G7, BRICS, G20 high-income and G20 middle-income-income). The EARTH INDEX scorecard for the entire G20 is shown in Figure 8; details of the method and the data sources used are provided in Annex A, and Annex B contains a complete set of scorecards.

Commitments are expressed as emission levels in the year 2030, pro-rated over seven sectors: power generation, buildings, industrial production, transportation, the fossil fuel production industry, agriculture and waste. EARTH INDEX is calculated by dividing the emission reduction (or increase) achieved in 2019 by the annual emission reduction that would be required from 2019 to 2030 to meet the country's stated commitment. The result is expressed as a percentage, where 100% indicates that if the 2019 emission reduction were repeated every year until 2030, the target would be exactly met, and a score of more than 100% indicates the target would be exceeded. Any positive score below 100% indicates that emissions declined in 2019 but not by enough to meet the 2030 target. A negative score indicates that emissions increased in 2019, with the negative percentage reflecting how quickly emissions are going in the wrong direction.

The year 2019 was selected as a reference year because at the time the analysis was being done (January through March of 2022) it was the most recent year for which comprehensive and authoritative data was available for all the G20 members. While energy-related carbon dioxide emission data is available within a year, EARTH INDEX requires country and sector disaggregation of all the principal GHGs from both energy and non-energy sources. Nevertheless, the year 2019 is a good reference year for the first set of EARTH INDEX scores (which will be updated annually), as it captures the pace of GHG emission reduction just before the COVID-19 pandemic disrupted the global economy, making emissions data atypical for both 2020 (emissions dropped) and 2021 (emissions rebounded). The 2023 edition of the EARTH INDEX report will include an analysis of the impact of the pandemic and the recovery and will be published after data sets for both 2020 and 2021 are available.

Table A on the following page contains a summary of EARTH INDEX scores by country, country group and sector for all the G20 members.

Summary of EARTH INDEX scores by country and sector

	Power	Fossil Fuel	Industry	Waste	Agriculture	Transport	Buildings	Total
United States	222%	-69%	-21%	-39%	-29%	8%	-27%	42%
Australia	86%	-217%	4%	44%	311%	-14%	-122%	31%
Germany	537%	131%	28%	96%	18%	-22%	-124%	136%
Canada	40%	11%	-10%	-14%	14%	-19%	-27%	6%
United Kingdom	330%	26%	70%	14%	-23%	46%	36%	75%
France	168%	86%	96%	-34%	28%	0%	81%	51%
Japan	158%	152%	73%	48%	-18%	62%	-11%	87%
European Union	461%	74%	77%	31%	21%	-12%	50%	120%
Italy	107%	65%	169%	18%	5%	-26%	43%	54%
Korea, Republic of	-12%	19%	50%	3%	51%	-12%	-22%	4%
Saudi Arabia	36%	-15%	-83%	-23%	81%	282%	-45%	28%
Russian Federation	103%	-86%	38%	-78%	-28%	-1%	57%	27%
China	-242%	-41%	-15%	-177%	-57%	-215%	-176%	-133%
Argentina	241%	98%	173%	79%	90%	129%	193%	136%
Mexico	-70%	814%	-30%	11%	10%	86%	156%	66%
Turkey	286%	-560%	479%	190%	-141%	94%	-374%	118%
Brazil	491%	0%	59%	2%	13%	0%	197%	43%
South Africa	-23%	-18%	-13%	-96%	-19%	-61%	-425%	-62%
Indonesia	-175%	-152%	-89%	-134%	-126%	-189%	39%	-141%
India	-85%	-40%	-191%	-76%	-32%	-277%	-116%	-118%
Country Groups:								
G7	236%	-24%	14%	-21%	-16%	7%	-19%	52%
High Income	225%	-23%	16%	-8%	5%	12%	1%	60%
Middle Income	-153%	-46%	-20%	-90%	-30%	-130%	-114%	-86%
G20	5%	-35%	-6%	-59%	-15%	-31%	-39%	-15%
BRICS	-166%	-28%	-46%	-153%	-127%	-20%	-99%	-95%

Summary of Findings

- For the G20 in total, GHG emissions increased in 2019, resulting in an EARTH INDEX score of -15%. The power sector had a score of 5%, indicating that while there was a slight decline in emissions, the pace of reductions would have to be 20 times higher than in 2019 to be on track for meeting the aggregate G20 target. Emissions increased in all the other sectors, yielding negative EARTH INDEX scores and revealing the extent to which outcomes and aspirations are not yet aligned, at least at the level of the entire G20.

- There is a marked contrast in EARTH INDEX scores for the high-income countries (+60%) as compared to the middle-income G20 members (-86%), and this wide gap exists for every sector except industry. Whereas the middle-income country group has strongly negative EARTH INDEX scores right across the board, for the high-income group scores are positive for the industry, transport, buildings, agriculture and power sectors. As discussed above, the middle-income countries also have lower emission reduction targets than the high-income countries, adding further significance to their relatively low EARTH INDEX scores.

- Within the high-income group, Germany has the highest EARTH INDEX score, at +136%, driven largely by the power sector (+537%), which helped to offset emissions growth in both the buildings and transport sectors. All the high-income G20 members achieved positive total EARTH INDEX scores except Canada, which, with an EARTH INDEX of -6%, lagged far behind the rest of the group.

- Argentina, Brazil, Turkey and Mexico registered solid emission reductions for 2019, but the overall negative result for the middle-income country group was dominated by the negative scores for China, India and Indonesia, all of which scored below -100%.

- Decarbonization of the power sector was the greatest source of G20 emission reductions in 2019, with 14 of the G20 members, including all the high-income countries, achieving positive scores, and 11 of those were over 100%. For the middle-income countries, increased power sector emissions from China, India and Indonesia offset gains in other countries. Going forward, the challenge will be to increase the supply of emission-free electricity fast enough to keep up with the demands created by electrification of buildings, transport and industry.

Overall, the EARTH INDEX results reflect a wide gap between the pace of emission reductions in 2019 and the pace required to meet the countries' own stated commitments, the "say–do" gap. The say-do gap is wider, more certain and more urgently in need of attention than the gap between stated commitments and what would be required to limit global warming to 1.5°C.

There are some encouraging findings, in particular the progress being made in many countries to decarbonize the electricity supply, but meeting the 2030 targets will require increasing annual emission reductions by 65% in the high-income countries and a complete reversal of the momentum that is currently driving up emissions in most of the middle-income countries.

The disparity in both emissions and the direction of emissions growth between the high-income and low-income countries reinforces the imperative of global cooperation in addressing the climate emergency.

The Zero-Emission Energy Index

To achieve a zero-emission energy system, two conditions must be met. First, all end uses of energy must be met with electricity, heat, hydrogen, sustainable biofuels,(7) or some other zero-emission form of energy. Second, all those zero-emission forms of energy (electricity, heat, hydrogen, etc.) must themselves be produced with zero-emission sources and technologies.

This relationship forms the basis of the Corporate Knights Zero-Emission Energy Index (ZEMEX), as illustrated in Figure 9 for a selection of the G20 countries and country groups. The ZEMEX score is the product of the percent of energy end use provided with zero-emission energy and the percent of that energy that is supplied with zero-emission sources. In the figure, the ZEMEX score is represented by the green bars, with a score of 100% representing a zero-emission energy system. Results for all the G20 members and a more detailed description of the method are provided in Annex C.

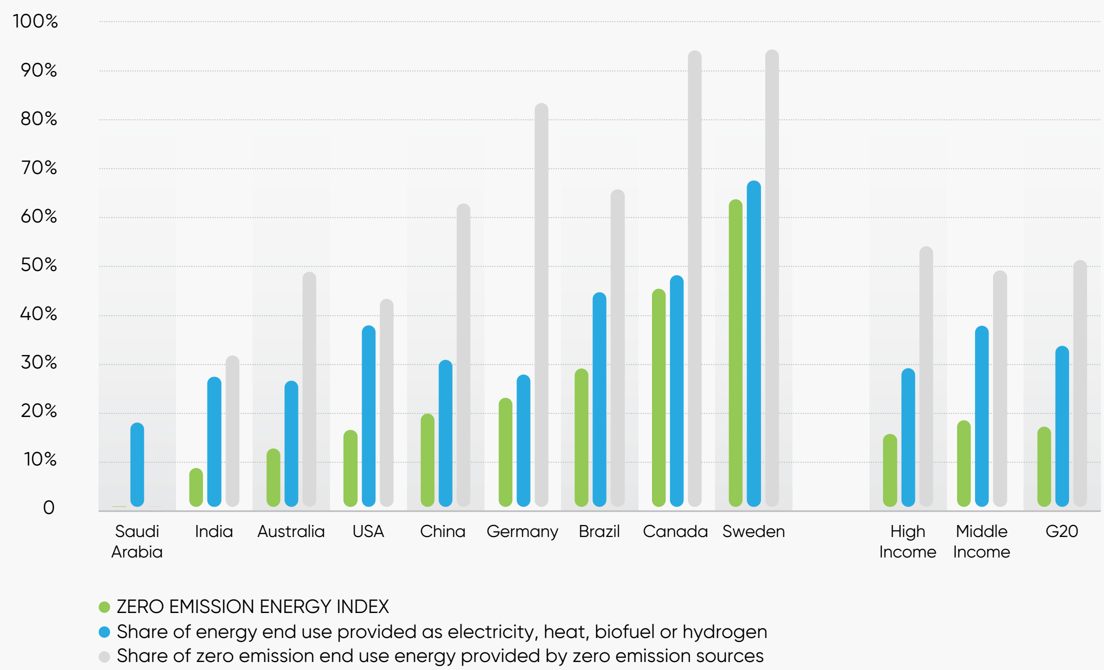


Figure 9: Zero Emission Energy Index (ZEMEZ)

(7) In alignment with IPCC conventions, ZEMEX currently includes bioenergy as zero emission energy both at the end use level and as a fuel for heat and electricity production. This policy is being reviewed considering the questionable sustainability of some industrial-scale bioenergy harvesting operations.

- For the G20 overall, the ZEMEX score in 2019 was 17% (34% of end use supplied with zero-emission free energy, 51% of that energy supplied with zero-emission sources). The middle-income and high-income groups had comparable overall scores (19% and 16%, respectively), although with different contributions from the two components. Zero-emission end-use energy (electricity, bioenergy, heat) is a larger share of total energy end use in the middle-income countries, but in the high-income countries there is a greater share of zero-emission energy in the supply.

- At 64%, Sweden has the highest ZEMEX score in the G20 and probably in the world. At the end-use level, electricity, district heat and direct biomass provide 33%, 13% and 21%, respectively, for a total of 68% of all end-use energy. On the supply side, fully 94% of that 68% is provided by zero-emission renewable, nuclear and biomass sources.

- Brazil also provides 94% of its zero-emission end use with zero-emission sources (hydroelectricity, biomass), but its 45% ZEMEX score is lower than Sweden's because there is no district heating and electricity, and zero-emission energy provides 48% of end-use energy as compared with 68% in Sweden.

- Canada also has a relatively high supply-side contribution to its ZEMEX score (83%, almost all zero-emission electricity), but emission-free energy provides only 28% at the end-use level (mostly electricity, some biomass in the pulp and paper industry), resulting in a ZEMEX score of 23%.

- Australia has a ZEMEX score of only 9%, with electricity and biomass providing 28% of end-use energy, the same as for Canada, but with only 32% of that energy coming from zero-emission sources.

- Saudi Arabia has a ZEMEX score of 0%; while 18% of its energy end use is provided by electricity, none of it is provided with zero-emission sources.

The generally low ZEMEX scores, and their different compositions, reveal both the magnitude of the remaining work needed to complete the transition to a decarbonized energy system (for which the ZEMEX score =100%) and the importance of balancing efficiency, electrification, and other means of decarbonizing end use, while at the same time growing the supply of renewable electricity and other zero-emission energy supplies.

POWER

In 2019, the power sector was by far the largest source of emissions in the G20 countries, with 11.1 Gt CO2e comprising 30% of total emissions, over half of which originated in China and the other middle-income countries, where emissions from the power sector have been growing and continued to do so in 2019, resulting in strongly negative EARTH INDEX scores. In the high-income group, power sector emissions have been declining for 15 years and continued to do so in 2019 at a rate that would be more than sufficient for them to meet their 2030 targets, resulting in a strongly positive EARTH INDEX score for the sector (see Figure 10).

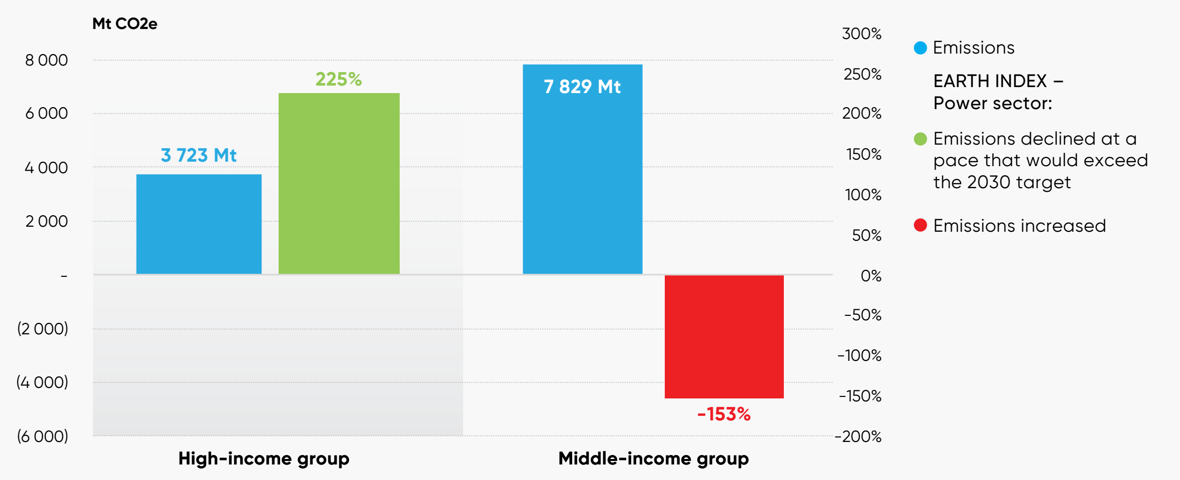


Figure 10: G20 Electric Power

As illustrated by the ZEMEX index in Figure 9, decarbonizing energy systems requires that all end uses are provided with zero-emission energy, and switching buildings, vehicles, industrial processes and other fuel combustion to zero-emission electricity will be the key to achieving this. In a transition to sustainability, electricity's share of total energy end use will rapidly increase to more than twice its current 22%, and this will define the challenge for both achieving and maintaining an emission-free supply.

Renewable electricity and grid modernization are projected to grow at double-digit rates throughout the 2020s, with cumulative investment by 2030 reaching US$10 to 15 trillion. This includes both the generation facilities and the modernization of grids with the digitized instrumentation and controls that are critical to the emerging electricity systems that will be more decentralized than the historic gigawatt hub-and-spoke grids of the 20th century.

The feasibility of growing the electricity supply fast enough to displace current fossil generation and meet the needs of increased electrification of buildings and transportation results from a confluence of technological trends. First, electrification itself reduces energy demand because electric vehicles, heat pumps and other electrical end-use technologies are typically several times more efficient than the combustion-based technologies they replace, so the amount of electricity needed is much less than the amount of fuel being displaced. Second, innovations in smart buildings, the efficiency of lighting and other electrical equipment, and in industrial processes that reduce the need for heat and power are allowing each kilowatt-hour to go further. And third, the costs of the key technologies – wind and solar power and electrical storage – have been declining steeply.[(8)] Meeting the G20 commitments to 2030 emissions will require continued acceleration of installed wind and solar capacity, from current levels of about 740 gigawatts (GW) each to as much as 5,000 GW of solar and 3,000 GW of wind by 2030, bringing their share of global generation capacity to 50% and the total share of renewable electricity (counting hydro) to more than 60%. Even those countries that currently have high proportions of their electricity supply from zero-emission sources will be challenged to maintain and increase those levels as the share of energy use provided by electricity doubles and more. (See Figure 11). For the middle-income countries, it will require a halt to increased coal- and other fossil-fuel-generation expansion in favour of an all-out push for zero-emission electrification.

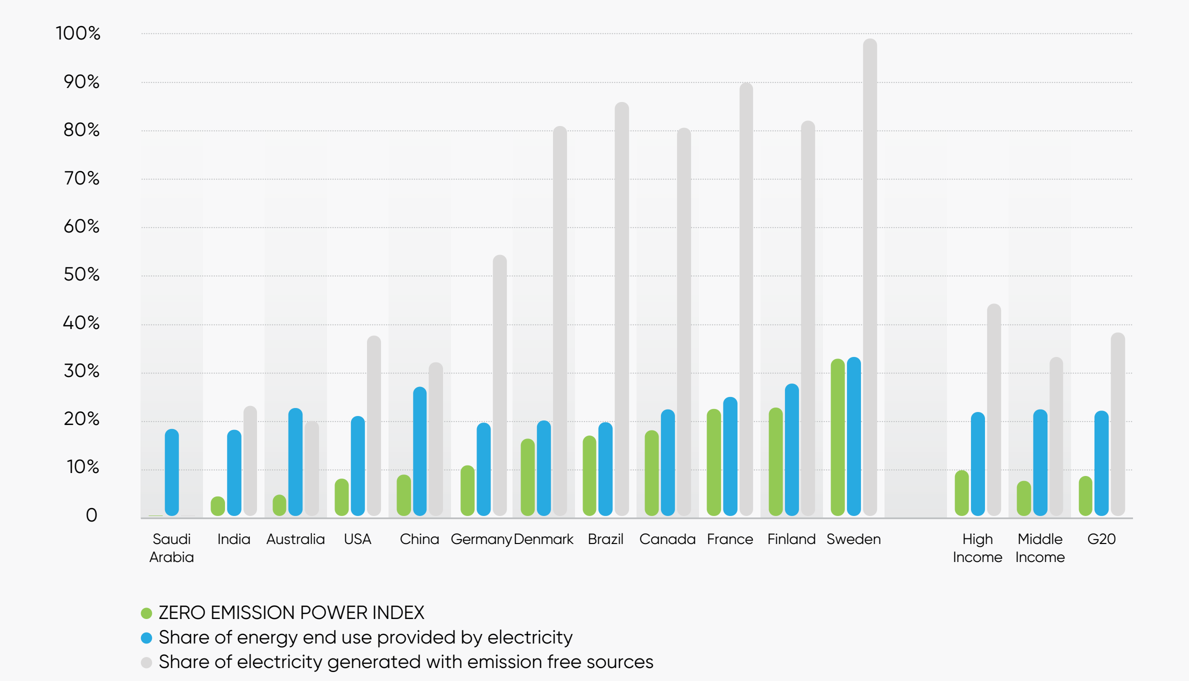


Figure 11: Zero Emission Power Index (ZEPEX)

The electric grids that will be part of sustainable economies will be different from today's electric grids. The increased contribution from converter-connected batteries and variable renewables, the decentralization of generation and corresponding refurbishment of distribution systems, the growth of microgrids and prosumers (grid-connected households and firms that are both producers and consumers of electricity), and the critical role of advanced digitization are all trillion-dollar markets, quite apart from the supply of generating capacity itself.

(8) R. Way, M. C. Ives, P. Mealy, and J. D. Farmer, "Empirically grounded technology forecasts and the energy transition," Institute for New Economic Thinking at the Oxford Martin School, INET Oxford Working Paper No. 2021-01, Sep. 2021 [Online]. Available: https://www.inet.ox.ac.uk/files/energy_transition_paper-INET-working-paper.pdf

These levels of growth in the supply of renewable electricity are technologically feasible; the capital costs of wind and solar generation are now lower than from fossil fuel generation, and the costs of battery storage and the other enabling technologies are declining rapidly. When the cost of GHG emissions is included in the equation, the case for a rapid transition to a largely electrified energy system supplied with renewable generation is compelling. As is often the case with the energy transition, the challenges to be overcome are related to the innovations in regulatory frameworks, financing and business models, and public policies that are needed to overcome the inertia of an archaic business-as-usual approach to power sector planning and investment that does not meet the needs of a modern, decarbonized, 21st-century energy system.

Case Example: Grid Decarbonization in Germany

Energiewende continues to define Germany's push to a low-carbon energy supply that will rely heavily on renewable energy. Included in this transition is a phase-out of nuclear power plants, which will be closed by the end of this year, and a phasing out of coal-fired generation by 2038. The closing of nuclear reactors is a controversial aspect of the program because nuclear electricity production has been replaced primarily by coal-fired production, with one study finding that this cost Germany $12 billion per year in social costs.

Having said that, renewable energy investment has seen much progress in Germany. This is largely due to establishing grid priority for renewable energy sources and introducing feed-in tariffs to encourage the use of renewable energy technologies. Feed-in tariffs provide a tariff above the retail or wholesale rate of electricity to renewable energy technologies. They guarantee a price for anyone selling renewable electricity to the grid and promote security for renewable energy producers. Renewables as a share in electricity generation increased from 5% in 2000 to 16% in 2007 and by 2016 reached almost 35%.

The annual investment in the energy transition still required by Germany ranges from 0.5 to 1.2% of Germany's GDP. Much of the cost of Energiewende has been supported by consumers who have seen rising electricity bills – around €25 billion per year. Arguably, this is due to Germany's role as a pioneer, since the country began this project when renewable energy prices were much higher than they are today. Support payments are fixed for 20 years, so Germany continues to carry this cost.

Sources:
- www.aa.com.tr
- www.nber.org
- www.cleanenergywire.org

In summary, the power sector EARTH INDEX scores clearly reflect the momentum that is building toward a decarbonized electric power system, particularly in the high-income countries. In many countries, China being one notable exception, emission reductions in 2019 were larger than the annual average required to meet targeted 2030 emission levels, and this reflects both the availability of technologically feasible and fundamentally economic alternatives to the status quo, and successful innovations in regulatory and policy strategies for accelerating the transition (see "Grid Decarbonization in Germany" text box). The challenge going forward for countries with positive power sector EARTH INDEX scores will be to maintain and improve them in the face of accelerated end-use electrification strategies in other sectors. For countries in which power sector emissions are increasing, a more fundamental shift is required, away from the historic model that revolved around centralized, fossil-fuelled power stations and toward the new model, with its emphasis on decentralized and renewable generation.

Finally, although mostly in low-income countries and not generally in G20 member states, there are still some 800 million people in the world that do not have access to electricity, and who rely on unsustainable forms of energy, including traditional biomass fuels. They are often remote from the power grid, and the traditional utility model offered little hope that they could be connected any time soon. In contrast, the new model, with its greater decentralization and reliance on distributed, renewable generation, has opened new possibilities for bringing electricity to places that were more difficult to reach with the old approach. While EARTH INDEX is focused on the G20, bringing electricity to those who do not currently have access is a necessary condition of the global sustainability transition.

TRANSPORTATION

The transportation sectors of the G20 countries emitted six Gt CO2e of GHG emissions in 2019, comprising 16% of total emissions. Transportation and buildings are the only two sectors for which the emissions from the high-income countries exceeded those from the middle-income countries. With 20% of the population of the G20, the high-income countries emitted 67% of transport sector emissions.

For the high-income countries, transport emissions declined by 16.5 Megatonnes (Mt) CO2e in 2019, a drop of 0.5%, as compared with 3.8% or 137.1 Mt CO2e annual decline needed to meet 2030 targets. For the middle-income group, transport emissions increased by 78.4 Mt CO2e, compared to the 60.3 Mt CO2e reduction that would have been necessary to be on track to meet 2030 emission targets.

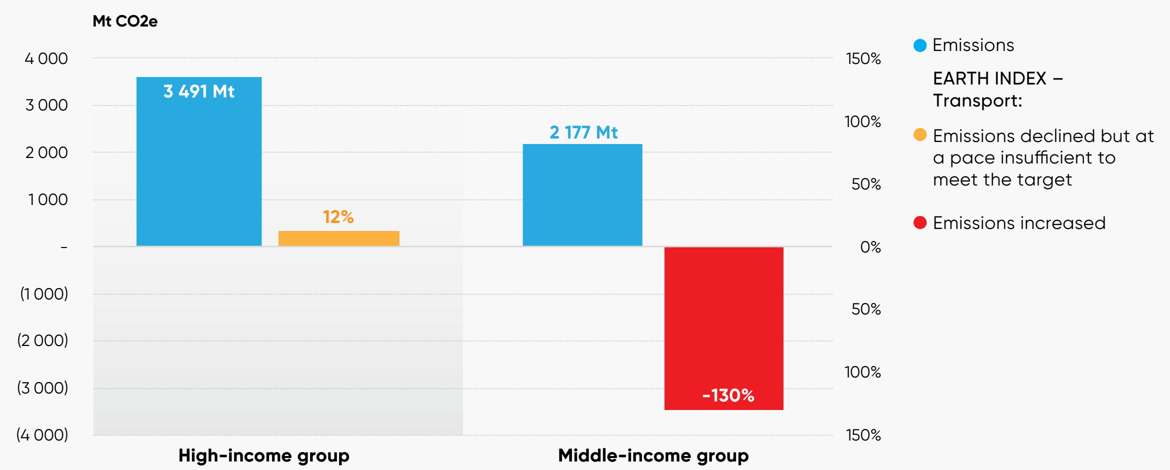


Figure 12: G20 Transport Sector

Emissions from transportation can be reduced through fewer and shorter vehicle trips (including substituting telepresence for mobility via teleshopping, telecommuting, etc.), through higher load factors and occupancies, and through lighter and more efficient vehicles, but vehicle electrification is the most promising pathway to deep and relatively quick reductions in the transportation sector. The feasibility of electrification for some types of vehicles (e.g., long-haul trucking and shipping) is still uncertain, and in the longer term (post-2030) there may be a role for hydrogen in converting these modes to zero-emission operation, but it is electrification that will be the principal driver of decarbonization of the transport sector in the critical decade ahead.

Electric vehicle sales have been on a long-term exponential growth curve and have continued to accelerate since 2019, even in the face of the pandemic slowdown. In fact, global EV sales more than doubled between 2020 and 2021, from three million to more than six million (see Figure 13), with particularly strong growth in China and the EU.

Steep reductions in battery costs will help accelerate EV adoption in the years ahead. The price of battery packs has plunged by more than 80% over the past 10 years and continues to fall. Bloomberg New Energy Finance projects that electric cars will have the same sticker price as combustion cars by the mid-2020s, before accounting for gas savings, though recent commodity price volatility resulting from conflict in Ukraine has added an estimated US$7,000 to the battery costs for an electric car. [9]

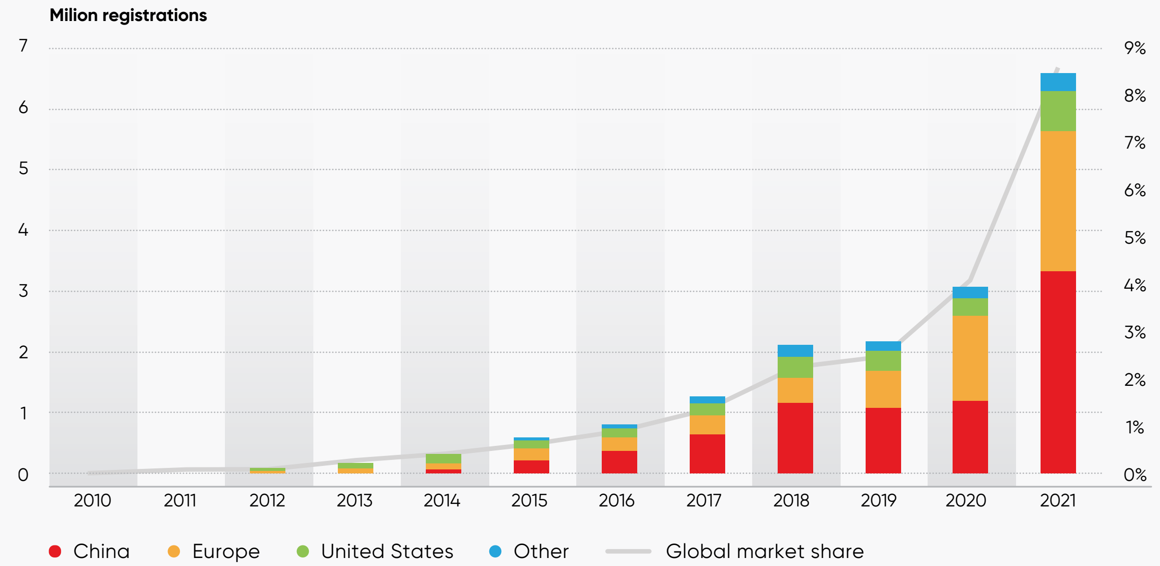


Figure 13: Global sales and market share of electric cars, 2010-2021 (Source: iea.org)

Between 2020 and 2026, the size of the global electric vehicle market (including EV motors, heat management, light-weighting materials, batteries) is expected to increase more than fourfold to reach an estimated global market size of US$1 trillion. As the automotive industry rapidly transitions to electric vehicles, the global market for lithium-ion batteries is expected to exceed US$100 billion by 2030. At the Glasgow climate conference in 2021, over 40 countries, including Canada, committed to ensuring that 100% of cars and vans sold by 2040 are zero emissions, and almost all the major automakers have followed suit.

As with the power sector, the technological feasibility and fundamental economics of the zero-emission alternatives in the transportation sector are necessary but not sufficient to achieve the rate of EV adoption necessary to meet 2030 emission targets. Regulatory and policy innovations are also needed to counter the inertia of the incumbent system and to ensure that the charging infrastructure does not become a limiting factor in EV uptake rates. The countries where the fastest EV adoption rates are occurring are also invariably where such policy and regulatory measures are in place (see "EV Adoption in Norway" text box).

As noted in the discussion of the power sector, the electrification of the transportation sector will represent a significant new source of electricity demand[10] as well as a potentially important source of energy storage for balancing peak electricity supply and demand.

(9) https://www.ft.com/content/61ea7716-02e9-42f0-978b-44ee11b50ba3

(10) A typical, full size electric car driven 25,000 km per year will require about 4,000 kW-hours per year, about half the total annual consumption for lights and appliances in an average single-family dwelling in Canada.

In summary, while the 2019 EARTH INDEX scores for the transportation sector fall short of what is needed to meet 2030 emission targets, these scores will improve quickly if more G20 members can emulate the success of Norway, China, Germany and other countries that are achieving EV penetration rates that were until recently considered to be at least 10 years away.

Case Example: EV Adoption in Norway

Norway's policy measures to accelerate vehicle electrification include tax exemptions, toll exemptions (implemented as early as 1997), partial access to bus lanes and cheaper public parking for those who drive electric vehicles (EVs). The country imposes high vehicle import duties and car registration taxes, and these are currently waived for EVs, effectively subsidizing EV purchases. Norway's value-added tax (VAT) can be up to 25% for a gas burner, but for an EV, it's zero. While Norway has made EVs cheaper by lowering taxes and including extra incentives in the way of tolls and parking, traditional cars have become more expensive, with high VAT taxes, a carbon tax close to 20%, NOX tax and a car-scrapping fee. Norway also has favourable local conditions, including short average trip distances and robust charging infrastructure to support its aggressive incentives.

Norway has set itself the goal of becoming the first country to end the sale of petrol and diesel cars, and to this end pure electric cars made up nearly two-thirds of Norway's new car sales in 2021. As an early adopter of EV incentives, it took 10 years for Norway's EV market share to grow from 1% to 65%, but technology, investment and consumer acceptance have improved since Norway started, and the UK, Germany and other countries that started later are achieving much faster progress.

Sources:
- www.weforum.org
- www.swissinfo.ch
- time.com
- insideevs.com
- www.forbes.com
- www.greencarreports.com

BUILDINGS

In the EARTH INDEX framework, emissions from electricity generation are counted in the power sector, and so the GHG emissions from buildings are associated only with the fossil fuels used to provide space and water heating in those buildings. All types of commercial and residential buildings are included in this sector, so there is a large variation in energy requirements, which will also be higher in cold climates.

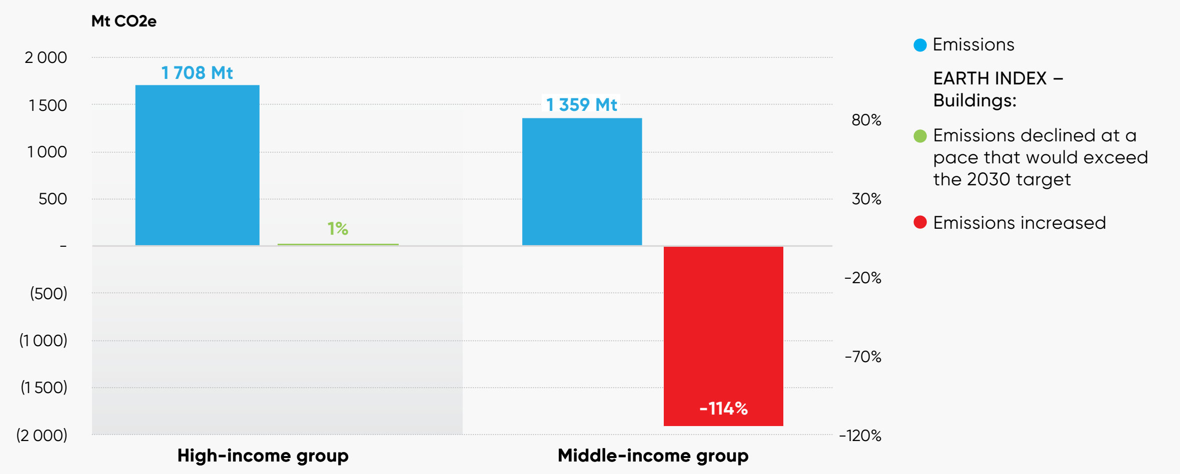


Figure 14: G20 Buildings Sector

In 2019, the building sector emitted 3.1 Gt CO2e, 8% of the G20 total. This is one of two sectors (the other being transportation) where the high-income group's emissions are higher than for the middle-income countries.

For the high-income countries, emissions in 2019 were virtually unchanged from 2018, reflected in the EARTH INDEX score of 1%. Within the group, emissions have been declining in the EU and Japan, offset by increases in the United States, Australia and Canada.

In contrast, GHG emissions from buildings in the middle-income group increased by 3% in 2019, when they would have needed to decline by 3% to be aligned with the 2030 target, resulting in a strongly negative EARTH INDEX score. Building emissions in the middle-income group grew 50% between 2005 and 2019, mostly a reflection of the building boom in China during that period.

Reducing and eliminating GHG emissions from buildings requires improving the thermal efficiency of the building envelope, optimizing energy management with the use of modern control systems, and replacing fossil fuel space- and water-heating technologies with zero-emission sources, usually electricity or district energy. These actions are easier and less expensive to integrate with the design and construction of new buildings than they are to retrofit to existing buildings. Most buildings that will be standing in 2030, and even by 2050 in many countries, have already been built. And so the challenge of decarbonizing the building sector consists largely of the challenge of retrofitting the existing stock of buildings, and there are several hundred million buildings in the world.

Case Example: The Energiesprong Innovation in Market Transformation

The barriers to accelerated adoption to home renovation include the front-end capital cost, the risk that the retrofit may not perform and that the total cost of ownership may increase, the aversity among homeowners to being required to manage the process, and the prolonged disruption to household routines while the work is being done. The Dutch-based Energiesprong addresses all these barriers in its innovative approach to mass, deep retrofits.

Energiesprong retrofits employ technologies such as prefabricated facades, insulated rooftops with solar panels, smart heating controls, and controlled ventilation and air-conditioning equipment. The result is a highly efficient, net-zero-energy building with superior air quality and comfort. It comes with a long-term warranty on both the indoor climate and the energy performance for up to 40 years. The retrofits are completed in less than 10 days, and in some cases are completed in less than a day.

Energiesprong employs independent market development teams to work with regulators, local authorities and banks to create aggregated retrofit projects that result in economies of scale in both labour and materials. This builds momentum so that thousands of retrofits can be carried out in single projects, which in turn gives suppliers the incentive they need to invest in the off-site manufacturing of the components needed for the retrofits. In an approach not unlike that pursued decades ago by the automobile industry, this results in what Energiesprong calls "mass customization" – industrialization of the retrofit industry while simultaneously improving the quality and lowering the cost.

The good news is that buildings are being continuously renovated and upgraded, and it is not atypical for capital investment in the improvement of the existing building stock to be equal to 3 to 5% of GDP, whereas annual investment on the order of 1 to 2% of GDP would be sufficient to permanently eliminate GHG emissions from the building stock.[11]

The bad news is that while the technologies and know-how exist and the economics are fundamentally sound, the current capacity of the building renovation industry, the financing frameworks in place, and the inefficiency and bespoke approach that characterize the status quo are all inadequate to the task. Radical new approaches to financing, risk management and logistics are needed, along with policy and regulatory innovations, to catapult both the rate and the depth of building retrofits to a level that is commensurate with the climate emergency. Beyond the GHG emission reductions, success in tackling the retrofit challenge will come with significant social, economic and public health benefits. The Italian Superbonus program and the Dutch-based Energiesprong initiative (see text boxes) exemplify the type of out-of-the-box creativity needed in this sector.

(11) Canadian households and businesses, for example, invest over CAD $80 billion per year in capital improvements to their homes and buildings, representing 4.4% of GDP and significantly more than the estimated CAD $23 billion (present value) annual investment it would take to convert the country's entire stock of 9 million buildings to zero emissions by 2050 (Efficiency Canada, 2021).

In the case of commercial buildings, the technology is constantly evolving, and advances in building science and materials, electrification and digitization have redefined best practices in the creation of comfortable, healthy, productive and low-emission indoor environments. The average performance of the existing building stock can be improved by at least a factor of three by changing out obsolete and inefficient controls, made feasible by the recent drop in the cost of the sensors, wireless technologies and data-processing components that are the basis for modern building-control systems. Buildings can and will be managed at the level of individual rooms, with anticipation of weather and employee behaviour allowing optimization of building-connected solar, EV charging and discharging, and grid electricity.

Smart buildings are a necessary component of the decarbonization transition, both for the direct emission reductions that result from their efficiency and electrification and for their role in facilitating the decarbonization of electric grids and the electrification of vehicles. Smart buildings growth has been strong for some time, driven by their superior performance and higher profitability, and has accelerated during the pandemic.

The drive to net-zero emissions will only accelerate this trend throughout the 2020s. Commercial buildings are a major source of GHG emissions in cities, and regulations like New York City's Climate Mobilization Act are establishing ambitious emission reduction targets that are driving the market for advanced building technologies and services.

Globally, investment in the buildings sector is projected to grow at a 22% compound annual growth rate between now and 2030, with annual spending of US$1.7 trillion per year. In a successful drive to close the "say–do" gap, the share of "net-zero ready" buildings in the global stock is projected to grow from less than 1% to 25% by 2030 and 85% by 2050.

In summary, technology innovations and cost reductions have outrun the capacity of the building industry to implement the zero-emission solutions that will characterize the next revolution in human habitats and indoor environments. What is required now to close the say–do gap in this sector is a proliferation of the types of disruptive policy and regulatory initiatives represented by New York's Local Law 97 and the types of business model innovations exemplified by Energiesprong.

Case Example: The Italian Superbonus Program

The Italian government's program, officially introduced by Rome in July 2020, represents a boundary-pushing experiment in incentivizing building retrofits. In the two-stream program, the government provides a tax-credit – effectively a rebate – of up to 110% of the cost of qualifying building-improvement projects started after July 1, 2020, and completed by the following dates for various building classes:

- **Single-family homes and sports associations** – *June 30, 2022, or December 31, 2022*, if 30% of works are completed by the first deadline.
- **Multiple unit (2–4) properties, condominiums and non-profit housing** – *December 31, 2023*. The bonus reduces to 70% by December 31, 2024, and 65% by December 31, 2025.
- **Social (public) housing** – *June 30, 2023, or December 31, 2023*, if 60% of the works are completed by the first deadline.

The program serves dual roles: as an economic recovery plan and as an eye-catching attempt to address GHG emissions from Italy's buildings. One stream of the rebate covers a wide variety of energy-efficiency improvement projects, including insulation, HVAC, photovoltaics, energy storage and EV charging stations, and the second stream covers earthquake-proofing measures.

The program has been very popular despite complex qualifying rules, application processes and bureaucratic delays. By the spring of 2022, just over 139,000 individual projects had been approved with a total value of over €24.2 billion, and a total cost to the Italian government of €26.7 billion. Approved retrofits include 21,775 condominiums (64.7 completed), 72,980 single-family homes (74.5% completed) and 44,271 independent real estate units (76.6% completed). Rome has already exceeded 75% of its total cost estimate, and the final cost to the Italian government may well exceed initial expectations, with the ultimate cost over the lifetime of the program estimated to be nearly 2% of GDP.

The program has experienced high levels of fraudulent rebate claims, leading to a pause to dispersals earlier in 2022 to address this, which along with an unintended effect of increasing building costs due to demand, combined with supply shortages related to COVID and supply chain issues, has rendered it more expensive than initially planned for. At the same time, on the positive side, more than 150,000 jobs have been created and GDP grew by 0.7% in 2021, "exactly the sort of growth story some economists say the green transition can deliver for decades."

The Superbonus program is the subject of intense international interest for its radical approach to incentivizing retrofits, and its successes and failures will inform the templating of similar programs in the future.

INDUSTRY

This is the most diverse of the EARTH INDEX sectors, as it includes all manner of industrial activity: mining, construction and manufacturing. GHG emissions are mostly related to fossil fuel combustion for the provision of medium- and high-temperature heat, but in some key industries like steel and cement, there are also significant non-energy process emissions. For a given dollar of output in two different industries, GHG emissions can vary by two orders of magnitude, reflecting the very different amounts and types of energy required for processes as different as blast furnaces, heating an assembly plant or digging ore out of the ground. For general assembly operations, fuel consumption is required mainly for space-heating the factory, and GHG emissions per dollar of output are small. For food and beverage operations that rely on medium-temperature process heat (typically provided with boiler plants), fuel combustion and related GHG emissions are higher but still relatively modest compared to primary processing industries such as smelting and refining, iron- and steel-making, and cement manufacturing, which employ energy-intensive, high-temperature processes.

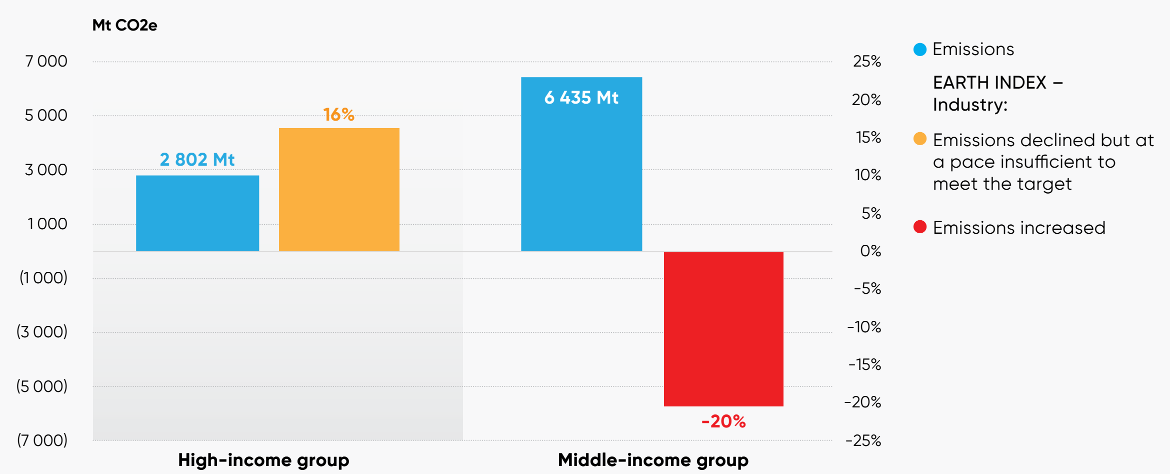


Figure 15: G20 Industry

Second only to the power sector, the G20 industrial sectors contributed 24% of total GHG emissions in 2019, with emissions from middle-income countries twice that of the high-income countries. There is a strong divergence between the middle-income and high-income countries in both the intensity and the direction of industrial emissions. Industrial emissions per dollar of GDP in the middle-income countries are nearly five times higher than in the high-income countries, reflecting large differences in both economic structure and energy productivity, exacerbated by the greater fuel intensity of industrial energy use and the greater carbon intensity of industrial fuels in the middle-income countries (i.e., less electricity, more coal). As for growth trends, in 2019 industrial emissions in the high-income countries were 14% below 2005 levels and 22% below 1990 levels; in contrast, industrial sector emissions were 53% higher than in 2005 and 158% above 1990 levels. Between 1990 and 2019, the industrial sector emissions of the middle-income countries grew from 2.5 Gt CO2e to 6.4 Gt CO2e, with 81% of the growth occurring in China.

The negative EARTH INDEX industrial sector score for the middle-income group (see Figure 15) reflects an increase of 32.9 Mt CO2e in 2019, when to be on track with 2030 targets they would have had to decline by 160 Mt CO2e. India led the industrial sector emissions growth in the middle-income countries in 2019 with an increase of 32 Mt CO2e compared to China's 16 Mt CO2e growth that year. For the high-income countries, industrial sector emissions declined by 17 Mt CO2e in 2019, as compared to the 105 Mt CO2e pace that would be needed to align with meeting their 2030 targets.

Given these dynamics, the prospects for closing the say–do gap for G20 industrial sector emissions hinge on achieving accelerated progress in the high-income countries while at the same time achieving much higher levels of energy productivity and energy efficiency and faster substitution of zero-emission fuels in China, India and the other middle-income countries. Even after allowing for trade effects and the structurally lower energy intensity of the high-income economies, there remains a wide gap in the emission intensity of the industrial systems of the high- and low-income countries. All else being equal, on an absolute and on a dollar per tonne of CO2e basis, the opportunities for reducing emissions from industrial production are higher in the middle-income countries, underscoring the strategic importance of increasing international investment in the industrial sectors of those economies.

The fossil fuel combustion that gives rise to industrial sector emissions is almost entirely for the generation of space and process heat, but over a wide range of temperatures and applications that make it difficult to generalize about decarbonization solutions. Energy efficiency and process innovations that reduce the amount or the temperature of the heat required are often the most effective and the most cost-effective decarbonization strategies in the industrial sector.

For general assembly and manufacturing operations, fuel consumption is used mainly for space-heating, and the options for achieving zero emissions are like those for commercial buildings: improve the thermal efficiency of the building shell, adopt modern energy-management controls, and switch out the fossil fuel heating system.

For food and beverage production and other industries that employ medium-temperature heat (temperatures below 400°C), there can be electrification options (for example, microwave and induction heating) and process innovations for using heat more efficiently, reducing the temperature required, or eliminating heating process stages altogether.

For the primary industries, energy-intensive and high-temperature technologies are integral to the material transformations taking place (e.g., blast furnaces, cement kilns, smelters), and there can be very significant non-energy-related emissions that are also integral to the production process. For many materials, including paper and steel and metals, manufacturing from recycled inputs is much less energy intensive and more amenable to electrification than starting with virgin raw materials, and recycling is therefore a very effective decarbonization strategy in these industries. A combination of biomass and electrification have reduced fossil fuel combustion to very low levels in the pulp and paper industry in Canada and other countries, and biofuels can play a role in other industries as well. Electric primary steel-making technology promises to displace traditional blast-furnace production processes, and even in the cement industry, perhaps the most difficult to decarbonize of the primary industries, there are emerging processes that could radically reduce GHG intensity (see "Geopolymer Cement" text box).

Beyond innovations for decarbonizing the production of steel, cement and the other primary materials that have been the foundation of the built environment for more than a century, breakthroughs in the development of carbon fibre and other new engineered materials, including biomass-based materials, may displace the older, denser and more emission-intensive building materials of the 19th and 20th centuries.

In summary, closing the say-do gap for industrial sector emissions presents difficult challenges in a world that has grown accustomed to using the brute force of high temperature heat from fossil fuel combustion to achieve the rapid and large-scale material transformations on which the high-income economies have quite literally been built. But the resulting industrial production system is ripe for disruption by the wave of materials and process innovations that is gaining in momentum in the drive to respond to the climate emergency. Industry-by-industry collaboration on a global scale will facilitate the rapid dissemination of these innovations and help to forestall the unsustainable consequences of continued reliance on fossil fueled industrialization.

Case Example: Geopolymer Cement

Cement is mankind's most utilized commodity, surpassed only by water. At first, this fact may seem startling. But look down, look up, look over and you'll likely find yourself in some way surrounded by this ubiquitous material. The manufacturing of cement, however, bears a striking environmental cost. The prolonged heating of calcium carbonate to high temperatures to chemically strip CO2 from the rock to produce cement "clinker" generates an enormous carbon footprint from the direct release of carbon and from the burning of fuels to heat the reaction. With a total CO2-emissions-intensity ratio of nearly 1:1, the continued production of traditional Portland cement poses a very real threat to climate targets and climate health alike (Davidovits, 2013). The solution: create a new concrete.

Enter geopolymer cement, a promising contender vying for the throne that Portland cement currently occupies. Boasting a manufacturing process with CO2 emissions 70 to 90% lower than traditional cement production, geopolymer cements may represent a panacea to an industry burdened with a crippling emissions footprint (Davidovits, 2013; J.S.J van Deventer et. Al, 2012). Unlike its emissions-intensive counterpart, the most efficient production techniques of geopolymer cement forgo high temperatures and chemical stripping of calcium carbonate in favour of waste valorization and room temperature chemistry. Slag (from steel production) and fly ash (from coal-fired powerplants) are reacted with an alkali-silicate solution to form an alumina-silicate polymer that is used to create a strong, clinker-free acid-resistant concrete. Utilizing the waste materials from other industries is an obvious double-edged sword, simultaneously promoting the circular economy while depending on by-products of the coal industry (i.e., fly ash). As coal-fired power plants close and the supply of fly ash becomes more volatile, geopolymer cement formulators will need to adapt to use other raw materials, such as slags or clays.

As a concept, geopolymer cements are not new, with the first cement of its kind patented in the US in 1985. Since then, however, the science behind these cements has struggled with issues of scaling, safety, standardization and supply chains (J.S.J van Deventer et. Al, 2012). It is only recently that companies have been able to surmount these obstacles, with several commercially viable geopolymer cements being successfully introduced into US, French and Australian markets, among others. If the geopolymer cement industry can solve the inherent issues of an emerging industry, such as supply chain problems, it will be well positioned to shift the cement paradigm in a cleaner and more sustainable direction.

Sources:
- J.S.J van Deventer, J.P. Provis and P. Duxson (2012). "Technical and commercial progress in the adoption of geopolymer cement." *Minerals Engineering.* Vol. 29.
- J. Davidovits (2013). "Geopolymer Cement: A Review." Institute Geopolymere.

AGRICULTURE

The greenhouse gas emissions in this sector consist mostly of methane emissions associated with ruminants and their manure management, and with nitrous oxide emissions associated with nitrogen fertilizer. For some countries, the agriculture sector emissions also include the energy-related emissions from agricultural vehicles and equipment,[12] but these emissions are typically only about 10% of total sector emissions. In 2019, agriculture sector emissions comprised 10% of G20 GHG emissions; they have been constant at 8 to 9% of emissions in the high-income countries but in the middle-income countries have been on a long-term decline as a share of emissions, from 22% in 1990 to 11% in 2019. Agriculture is responsible for 50% of global methane emissions and 75% of global nitrous oxide emissions.

In 2019, agriculture sector emissions declined slightly in the high-income group, but 20 times slower than would be required to be on track for meeting their 2030 commitments. In the middle-income countries, 2019 emissions were up by 23 Mt CO2e, mostly in Brazil and Indonesia, whereas a reduction of 76 Mt CO2e would have been required to be on track for meeting 2030 commitments.

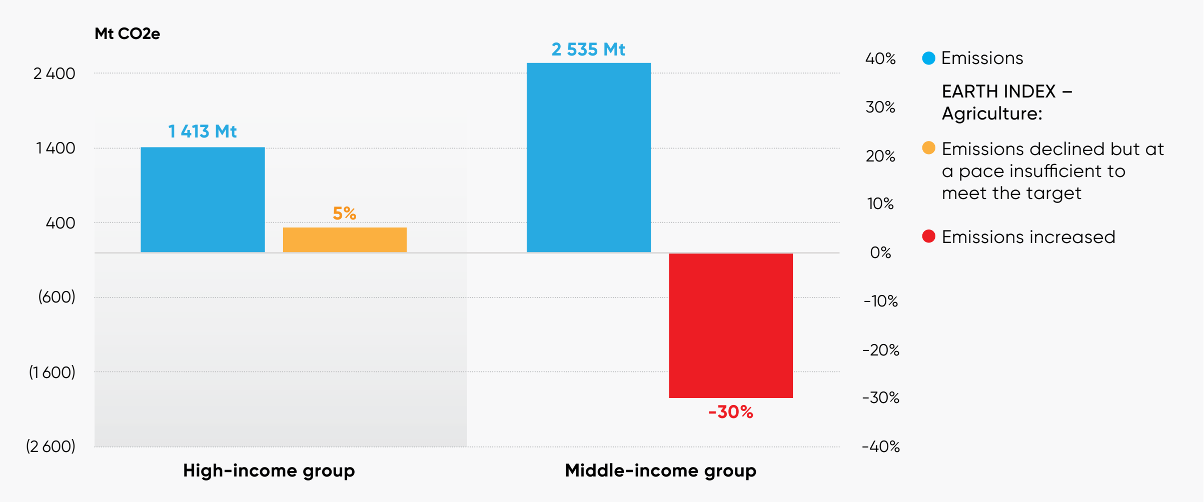


Figure 16: G20 Agriculture

The agricultural sector emissions included here are not directly related to fossil fuel combustion but are the result of farming practices that have developed over decades, and which vary according to the mix of livestock and crops being produced. There are technologically feasible and economically cost-effective strategies for reducing agricultural GHG emissions, including cover cropping and low till or conservation tillage, feed amendments and manure management (including anaerobic digestion and energy recovery), and reduced and controlled use of nitrogen fertilizer to minimize subsequent nitrous oxide emissions.

(12) For the Annex 1 countries under the Framework Convention on Climate Change, greenhouse gas inventories allow an estimate of the combined energy and non-energy components of greenhouse gas emissions from the agricultural sector. For the non-Annex 1 countries, the energy-related emissions from agricultural machinery are not shown as a separate line in the EDGAR inventory reports (see Annex A) and so the agriculture sector emissions are for non-energy sources only for all the middle-income countries except Russia. The energy-related emissions are included for all the high-income countries except Korea and Saudi Arabia.

WASTE

The GHG emissions that are included in the waste sector consist almost entirely of the methane emissions that result from the anaerobic decay of organic wastes in landfills and wastewater treatment facilities. These emissions totalled 1.3 Gt CO2e in the G20 in 2019, 4% of total G20 emissions. EARTH INDEX scores are negative (Figure 17), reflecting a very slight overall increase in emissions in the high-income countries in 2019, and with over half the larger increase in the middle-income countries occurring in China.

In the high-income countries, waste sector emissions have declined 40% since 1990 in the EU and Australia, and by 70 to 75% in Germany and the UK. Progress has been slower in North America, with waste sector emissions higher in Canada in 2019 than they were in 1990.

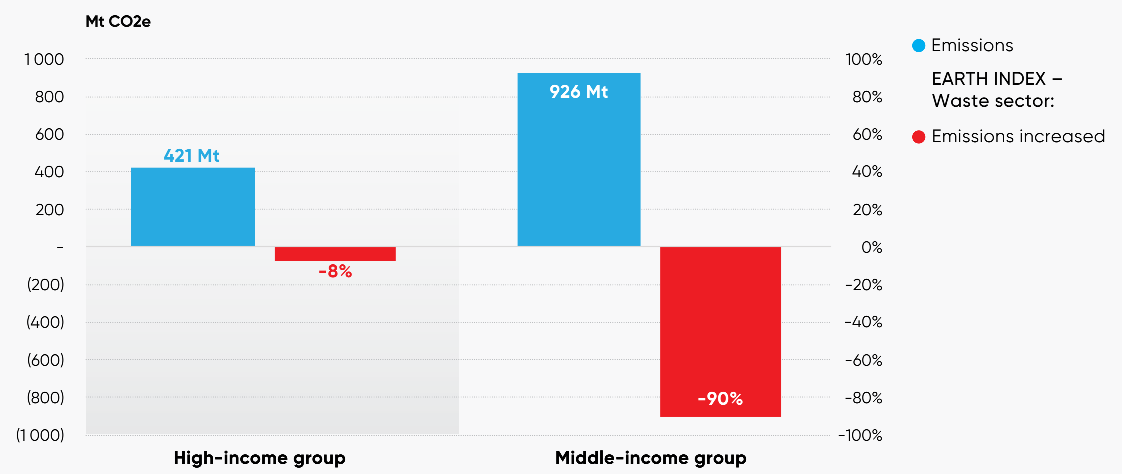


Figure 17: G20 Waste Sector

In the middle-income countries, waste sector emissions were up by 2.5% in 2019 over 2018; emissions in these countries have doubled since 1990, with most of the increase in China, India and Indonesia.

Methane emissions from the waste sector can be reduced by reducing the generation of organic waste, by diverting it from landfills to composting or to engineered digestor facilities with the methane recovery, or by capturing and burning methane emissions at landfills and wastewater treatment plants. These are all tried-and-true techniques, and their application in Europe is responsible for the declining rate of waste sector emissions there and the positive EARTH INDEX scores for the waste sectors in the EU, Germany, Italy, Japan, Australia and the United Kingdom.

Because methane is disproportionately effective at causing global warming in the short-term (20 years), reductions in methane emissions can play a strategic role in addressing the climate emergency in the next critical decade. For the waste sector, this underscores the importance of international collaboration and investment for deploying methane-reduction technologies at landfills and wastewater treatment plants everywhere.

FOSSIL FUEL PRODUCTION

Most emissions associated with fossil fuel occur in the sectors that use them, but the fossil fuel production industry itself generates GHG emissions from use of its own product to extract, refine and transport oil, gas and coal, and from the direct venting of carbon dioxide and methane that occurs throughout the system, from the wells to the end uses.

In 2019, fossil fuel production accounted for 9% of total G20 GHG emissions but twice that much in several of the producing countries, with Canada having the highest proportion of its emissions from this sector at 25%. G20 countries trade heavily in fossil fuels, and there are significant interdependencies, most notably the European dependence on Russian oil and gas.

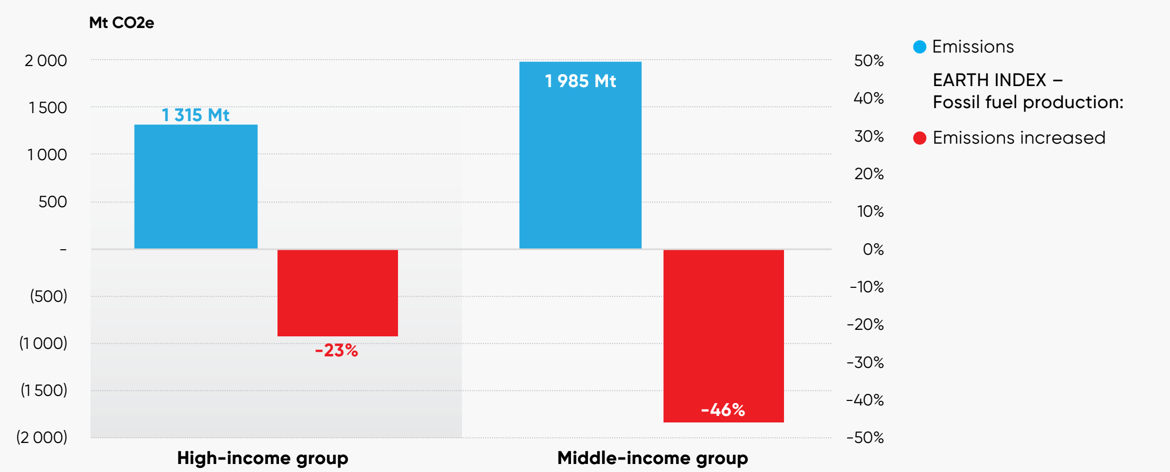


Figure 18: G20 Fossil Fuel Production

Production and emissions increased in 2019, yielding negative EARTH INDEX scores for this sector in both the high-income and middle-income countries (Figure 18). In the high-income group, emissions are mostly from oil and gas production in the United States, Saudi Arabia, Canada and Australia. In the middle-income group, the largest oil and gas producers are China, Russia and Indonesia. Over half the G20 coal production takes place in China, with the United States, India and Australia being the largest producers outside China. While emissions per unit of energy are higher from coal combustion than other fossil fuels, emissions associated with its production are smaller than for oil and gas.

In the transition to a low-carbon future, declining use will be the primary reason that emissions from fossil fuel production decline. Emissions will decline with consumption, and consumption will decline as fossil fuel technology is displaced by electric vehicles, heat pumps, zero-emission generation and other innovations that will reduce the role of fossil fuels in providing energy services and amenities. Reducing dependence on fossil fuels is a national security priority in many countries that are dependent on imports and therefore vulnerable to supply disruptions, and support will be particularly strong in these countries for accelerated adoption of efficiency, renewable energy and other zero-emission alternatives.

Within the industry, the emissions intensity of fossil fuel production will also decline as the transition proceeds. As the demand for fossil fuel softens and carbon pricing proliferates, the more energy- and emission-intensive sources of oil and gas will become less competitive, and their share of the market will decline unless they can deploy technological innovations such as carbon capture and storage while remaining competitive.

In summary, while the emission intensity of fossil fuel production will improve as the transition proceeds, EARTH INDEX scores for the fossil fuel production industry will be primarily determined by the speed with which the consuming sectors transition away from oil and gas dependence. In fact, positive EARTH INDEX scores for the fossil fuel sector would represent a strong signal that the world has turned a corner in its response to the climate change emergency.

ANNEX A. EARTH INDEX METHOD

OBJECTIVE

1. EARTH INDEX tracks the progress of countries toward meeting their GHG emissions targets.

SCOPE

2. The initial release of EARTH INDEX covers the 19 countries plus the European Union (EU) that together constitute the G20. The countries are assessed in two groups: United Nations Framework Convention on Climate Change (UNFCCC) Annex I and non-Annex I countries.

3. For Annex I countries, the full range of GHG emissions in UNFCCC inventories are included. For the non-Annex I countries, the three principal GHGs are included: carbon dioxide, methane and nitrous oxide. Changes in GHG emissions and absorption due to land use, land use change and forestry (LULUCF) are not included in EARTH INDEX at this time.

4. EARTH INDEX is based on annual emissions data up to and including the most recent year for which comprehensive emissions inventory is available for all G20 countries.

DATA SOURCES

5. The method used to calculate EARTH INDEX is identical for all countries in the G20, but there are differences in data sources and sector definitions between countries included in Annex I of the UNFCCC and the non-Annex I countries.

- For Annex I countries, EARTH INDEX uses data from the UNFCCC inventories filed by countries.

- For non-Annex I countries, EARTH INDEX uses data from the European Commission Emissions Database for Global Atmospheric Research (EDGAR).

6. Stated commitments are based on the most recent targets identified in filings with the UNFCCC and other national commitments. In the case of EU members, the more ambitious of the a) national target or b) EU target (55% reduction by 2030 relative to 1990) is taken. National targets are converted using a linear scale to actual levels of GHG emissions in the target year (usually 2030) to facilitate the EARTH INDEX method described below.

7. GHG emissions are also disaggregated by seven economic sectors: agriculture, buildings, fossil fuels, industry, power, transport and waste. While the sector names are the same or nearly identical for all countries in EARTH INDEX, there are differences between Annex I and non-Annex I countries in the detailed definition of the sectors. These differences result from the higher level of aggregation published in the EDGAR database as compared to the more disaggregated presentation by the Intergovernmental Panel on Climate Change (IPCC) sector codes in the UNFCCC inventories.

8. In the case of the non-Annex 1 countries, data for energy-related emissions were available in the EDGAR database only to 2018. For each country and each sector, we projected 2019 emissions,

using a simple trend projection of the 2015 to 2018 data (after first assessing the growth as being essentially linear). Next, we calculated the ratio of CH4:CO2 and N2O:CO2 for each country and tested (successfully) the hypothesis that this ratio does not vary significantly from year to year. We took the average CH4:CO2 ratio for 2016 to 2018 and the average N2O ratio for the 2016 to 2018 period for each country and multiplied it by the 2019 CO2 (available from the EDGAR's October 2019 data for CO2) to generate an estimate of 2019 CH4 and N20 for each country. Very small adjustments were sufficient to normalize the sector-by-sector estimates to align with the estimates of total CH4 and N20.

CALCULATION METHOD

9. The main EARTH INDEX for countries is the emissions reduction achieved in the most recent year according to reported data, divided by the annual emissions reductions required to meet the country's stated target.

$$\textbf{EARTH INDEX (\%)} = \left(\frac{\text{Emissions 2018 - Emissions 2019}}{\frac{\text{(Emissions 2019 - Emissions target)}}{\text{(2030-2019)}}} \right)$$

For example, a country with a target of reducing GHG emissions by 45% below 1990 levels by 2030 and that emitted 1,000 megatonnes (Mt) in 1990 therefore has a 2030 emissions target of 550 Mt. If that country emitted 900 Mt in 2018 and 875 Mt in 2019, its EARTH INDEX result for 2019 would be 85%, indicating that the progress made in 2019 was 85% of the annual progress required to meet its 2030 target:

$$\textbf{EARTH INDEX} = \left(\frac{900\text{-}875}{\frac{875\text{-}550}{2030\text{-}2019}} \right) = \frac{25}{29.5} = \mathbf{85\%}$$

10. To calculate target GHG emissions levels and annual required emissions reductions at the sector level, the target 2030 emissions level (for countries with 2030 targets) for each sector is the sector's most recent reported annual emissions multiplied by the percent reduction in total national emissions needed to meet the 2030 target. For example, if a country with an emissions target of 1,000 Mt in 2030 has emissions in 2019 of 1,600 Mt, then it must reduce its emissions by 37.5% to meet its 2030 target. Sector emission reduction targets in this example would therefore be set equal to 37.5% of 2019 emissions for each sector.

11. For countries that have committed to net-zero emissions but not to an interim 2030 target, the annual emissions reduction required to reach the target is calculated for both at the country and sector level by dividing the latest year for which emissions data is available by (n - latest year), where "n" is the year by which the country has committed to achieving net-zero emissions.

OUTPUT

12. Each year, eight EARTH INDEX scores are calculated for each country; one for total emissions and one for each of the seven economic sectors. These are published in scorecard format (see ANNEX B) that will facilitate at-a-glance comparisons between countries and economic sectors within countries.

EARTH INDEX Sector Definitions for Annex 1 Countries

EARTH INDEX Sector	IPCC Code	
Power	1.A.1.a	Public Electricity and Heat Production
Fossil Fuel	1.A.1.b	Petroleum Refining
Fossil Fuel	1.A.1.c	Manufacture of Solid Fuels and Other Energy Industrsies
Fossil Fuel	1.A.3.e.i	Pipeline Transport
Fossil Fuel	1.B	Fugitive Emissions from Fuels
Industry	1.A.2	Manufacturing Industries and Construction
Industry	1.A.5	Other (not specified elsewhere)
Industry	2.A	Mineral Industry
Industry	2.B	Chemical Industry
Industry	2.C	Metal Industry
Industry	2.D	Non-Energy Products from Fuels and Solvent Use
Industry	2.E	Electronics Industry
Industry	2.F.1.c	Industrial Refrigeration
Industry	2.F.2	Foam Blowing Agents
Industry	2.F.4	Aerosols
Industry	2.F.5	Solvents
Industry	2.F.6	Other Applications
Industry	2.G	Other Product Manufacture and Use
Industry	2.H	Other
Transport	1.A.3	Transport
Transport	EXCEPT 1.A.3.e.i Pipeline Transport	
Transport	2.F.1.d	Transport Refrigeration
Transport	2.F.1.e	Mobile Air-conditioning
Buildings	1.A.4.a	Commercial/Institutional
Buildings	1.A.4.b	Residential
Buildings	2.F.1.a	Commercial Refrigeration
Buildings	2.F.1.b	Domestic Refrigeration
Buildings	2.F.1.f	Stationary Air-conditioning
Buildings	2.F.3	Fire Protection
Agriculture	3.	Agriculture
Agriculture	1.A.4.c	Agriculture/Forestry/Fishing
Waste	5.	Waste

Sector definitions for non-Annex I countries available on request. Please email research@corporateknights.com

ANNEX B. EARTH INDEX SCORECARDS

G20

-15%
Earth Index

Stated emission target	Varies
Emissions in 2019, kt CO2e	38,217,786
Target emissions in 2030, in kt CO2e	25,351,293
Annual kt CO2e reduction needed to meet target:	1,169,681
Emission reduction (or increase) in 2019, kt CO2e	(180,468)
Average annual emission reduction (or increase), 2016-2019	(407,571)
Earth Index based on 2016-2019 trend	**-31%**

Power	5%
Fossil Fuel	-35%
Transport	-31%
Industry	-6%
Buildings	-39%
Agriculture	-15%
Waste	-59%

Emissions in 2005, kt CO2e	–	–	–	–	–	–	–
Emissions in 2019, kt CO2e	11,551,589	3,299,465	5,768,324	9,236,441	3,066,610	3,948,781	1,346,575
Target emissions in 2030, in kt CO2e	7,884,000	2,155,079	3,597,617	6,321,035	1,980,243	2,527,259	886,059
Annual reductions needed to meet target, kt CO2e	333,417	104,035	197,337	265,037	98,761	129,229	41,865
Actual emission reduction (or increase) in 2019, kt CO2e	17,432	(36,402)	(61,916)	(15,923)	(38,866)	(20,004)	(24,790)

G7

52%
Earth Index

Stated emission target, percent below 2012 by 2030	21%
Emissions in 2019, kt CO2e	10,622,249
Target emissions in 2030, in kt CO2e	5,873,586
Annual kt CO2e reduction needed to meet target:	431,697
Emission reduction (or increase) in 2019, kt CO2e	225,839
Average annual emission reduction (or increase), 2016-2019	67,916
Earth Index based on 2016-2019 trend	**14%**

Power	236%
Fossil Fuel	-24%
Transport	7%
Industry	14%
Buildings	-19%
Agriculture	-16%
Waste	-21%

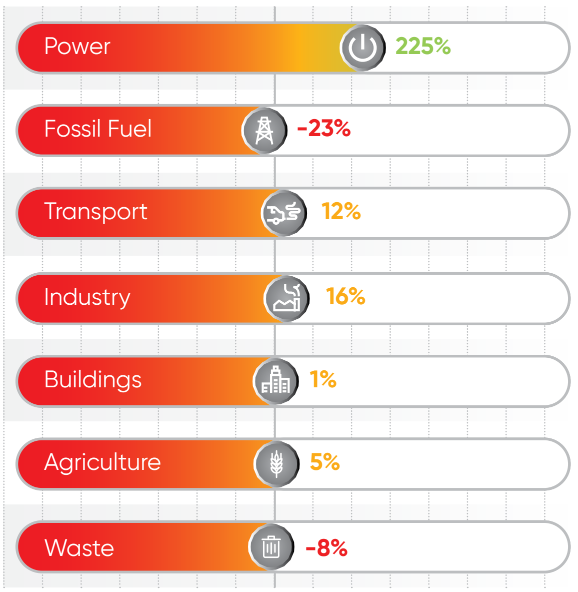
Emissions in 2005, kt CO2e	–	–	–	–	–	–	–
Emissions in 2019, kt CO2e	2,470,277	901,340	2,722,172	1,952,482	1,312,368	986,745	276,864
Target emissions in 2030, in kt CO2e	1,374,064	495,695	1,496,771	1,087,598	726,448	540,825	152,184
Annual reductions needed to meet target, kt CO2e	99,656	36,877	111,400	78,626	53,265	40,538	11,335
Actual emission reduction (or increase) in 2019, kt CO2e	234,778	(8,853)	8,061	10,910	(10,338)	(6,358)	(2,361)

The EARTH INDEX is obtained by dividing the emission reductions in 2019 by the annual emission reductions required to meet the stated target. Any result less than 100% indicates insufficient progress to meet the stated target, and when emissions are growing rather than declining, a negative score is obtained.
For Non Annex 1 countries under the UNFCCC, emissions data and sector definitions are taken from the EDGAR database; details available in the Earth Index Methodology document.

G20 High Income

60% Earth Index

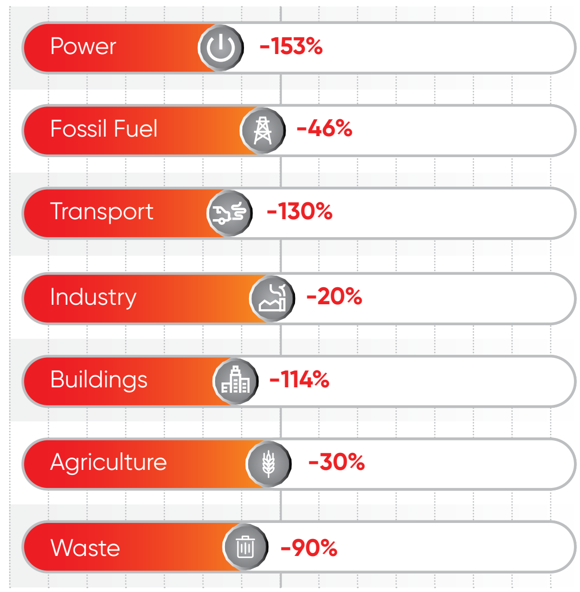
Stated emission target	Varies
Emissions in 2019, kt CO2e	14,972,527
Target emissions in 2030, in kt CO2e	8,770,256
Annual kt CO2e reduction needed to meet target:	563,843
Emission reduction (or increase) in 2019, kt CO2e	338,347
Average annual emission reduction (or increase), 2016-2019	99,619
Earth Index based on 2016-2019 trend	**16%**



G20 Middle Income

-86% Earth Index

Emission target by 2030	Varies
Emissions in 2019, kt CO2e	23,245,259
Target emissions in 2030, in kt CO2e	16,581,037
Annual kt CO2e needed to meet target:	605,838
Emission reduction (or increase) in 2019, kt CO2e	(518,816)
Average annual emission reduction (or increase), 2016-2019	(507,191)
Earth Index based on 2016-2019 trend	**-74%**



G20 High Income

	Power	Fossil Fuel	Transport	Industry	Buildings	Agriculture	Waste
Emissions in 2005, kt CO2e	-	-	-	-	-	-	-
Emissions in 2019, kt CO2e	3,722,908	1,314,643	3,591,335	2,801,561	1,707,886	1,413,496	420,696
Target emissions in 2030, in kt CO2e	2,190,529	766,800	2,083,636	1,649,426	1,002,356	830,546	246,963
Annual reductions needed to meet target, kt CO2e	139,307	49,804	137,064	104,740	64,139	52,995	15,794
Actual emission reduction (or increase) in 2019, kt CO2e	314,125	(11,474)	16,464	16,938	731	2,782	(1,218)

G20 Middle Income

	Power	Fossil Fuel	Transport	Industry	Buildings	Agriculture	Waste
Emissions in 2005, kt CO2e	-	-	-	-	-	-	-
Emissions in 2019, kt CO2e	7,828,681	1,984,822	2,176,989	6,434,880	1,358,724	2,535,285	925,879
Target emissions in 2030, in kt CO2e	5,693,471	1,388,279	1,513,982	4,671,608	977,886	1,696,713	639,096
Annual reductions needed to meet target, kt CO2e	194,110	54,231	60,273	160,297	34,622	76,234	26,071
Actual emission reduction (or increase) in 2019, kt CO2e	(296,693)	(24,928)	(78,379)	(32,860)	(39,597)	(22,786)	(23,572)

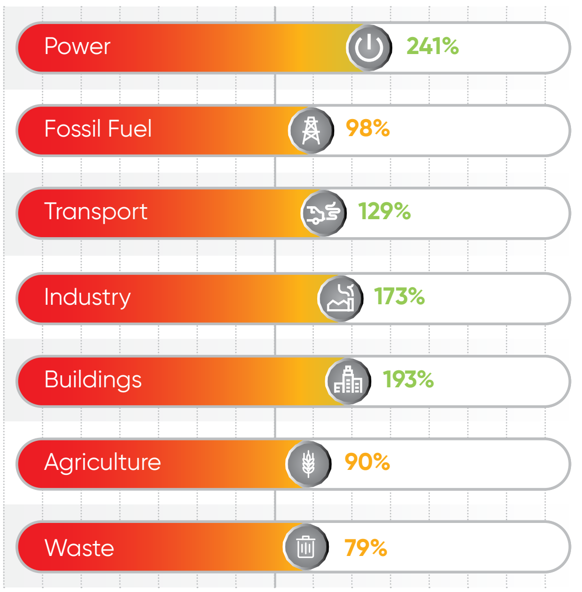
The EARTH INDEX is obtained by dividing the emission reductions in 2019 by the annual emission reductions required to meet the stated target. Any result less than 100% indicates insufficient progress to meet the stated target, and when emissions are growing rather than declining, a negative score is obtained.
For Non Annex 1 countries under the UNFCCC, emissions data and sector definitions are taken from the EDGAR database; details available in the Earth Index Methodology document.

Annex B. EARTH INDEX Scorecards

ARGENTINA

136% Earth Index

Emission target, net zero by 2050	100%
Emissions in 2005, kt CO2e	327,656
Emissions in 2019, kt CO2e	346,653
Target emissions in 2030, in kt CO2e	223,647
Annual kt CO2e needed to meet target:	11,182
Emission reduction (or increase) in 2019, kt CO2e	15,216
Average annual emission reduction (or increase), 2016-2019	8,654
Earth Index based on 2016-2019 trend	**68%**

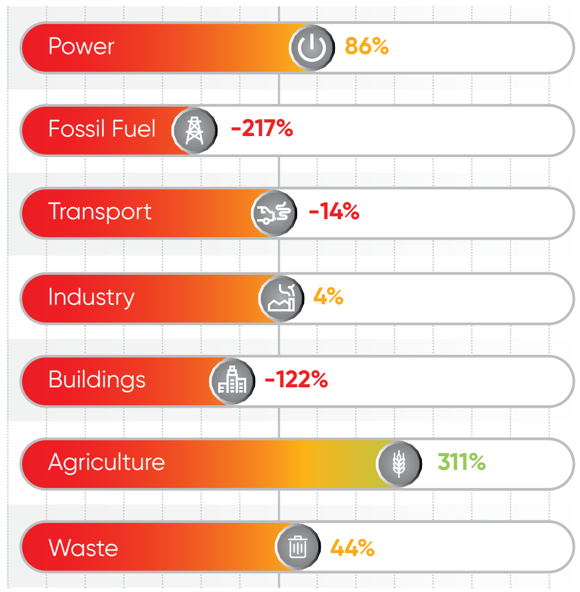


Emissions in 2005, kt CO2e	32,744	34,473	40,197	39,889	32,538	133,590	14,226
Emissions in 2019, kt CO2e	47,277	38,277	43,625	38,627	35,997	130,291	12,559
Target emissions in 2030, in kt CO2e	30,501	24,695	28,145	24,921	23,224	84,059	8,103
Annual reductions needed to meet target, kt CO2e	1,525	1,235	1,407	1,246	1,161	4,203	405
Actual emission reduction (or increase) in 2019, kt CO2e	3,679	1,215	1,809	2,161	2,245	3,787	319

AUSTRALIA

31% Earth Index

Stated emission target, percent below 2005 by 2030:	28%
Emissions in 2005, kt CO2e	524,211
Emissions in 2019, kt CO2e	545,153
Target emissions in 2030, in kt CO2e	382,674
Annual kt CO2e reduction needed to meet target:	14,771
Emission reduction (or increase) in 2019, kt CO2e	4,579
Average annual emission reduction (or increase), 2016-2019	(955)
Earth Index based on 2016-2019 trend	**-6%**



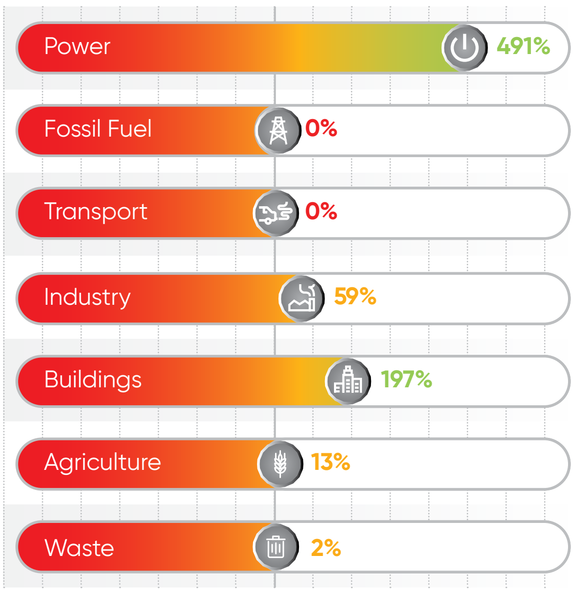
Emissions in 2005, kt CO2e	196,762	57,790	82,612	69,288	17,042	86,329	14,389
Emissions in 2019, kt CO2e	179,451	86,295	101,228	64,260	25,008	76,471	12,439
Target emissions in 2030, in kt CO2e	125,967	60,576	71,058	45,108	17,555	53,680	8,731
Annual reductions needed to meet target, kt CO2e	4,862	2,338	2,743	1,741	678	2,072	337
Actual emission reduction (or increase) in 2019, kt CO2e	4,187	(5,072)	(376)	74	(825)	6,442	149

The EARTH INDEX is obtained by dividing the emission reductions in 2019 by the annual emission reductions required to meet the stated target. Any result less than 100% indicates insufficient progress to meet the stated target, and when emissions are growing rather than declining, a negative score is obtained.
For Non Annex 1 countries under the UNFCCC, emissions data and sector definitions are taken from the EDGAR database; details available in the Earth Index Methodology document.

BRAZIL

43% Earth Index

Emission target, net zero by 2050	100%
Emissions in 2005, kt CO2e	939,158
Emissions in 2019, kt CO2e	1,107,311
Target emissions in 2030, in kt CO2e	535,320
Annual kt CO2e needed to meet target:	51,999
Emission reduction (or increase) in 2019, kt CO2e	22,289
Average annual emission reduction (or increase), 2016-2019	10,121
Earth Index based on 2016-2019 trend	**17%**

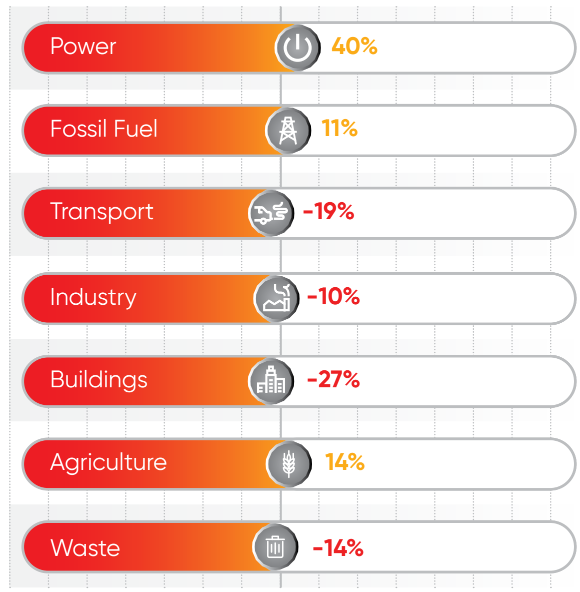


Emissions in 2005, kt CO2e	34,542	45,147	138,746	125,566	36,039	462,590	96,528
Emissions in 2019, kt CO2e	54,360	59,551	192,841	129,076	31,991	518,020	121,473
Target emissions in 2030, in kt CO2e	26,280	28,789	93,227	62,401	15,466	250,432	58,725
Annual reductions needed to meet target, kt CO2e	2,553	2,796	9,056	6,061	1,502	24,326	5,704
Actual emission reduction (or increase) in 2019, kt CO2e	12,544	(6)	(2)	3,579	2,954	3,106	114

CANADA

6% Earth Index

Stated emission target, percent below 2005 by 2030:	45%
Emissions in 2005, kt CO2e	741,182
Emissions in 2019, kt CO2e	738,283
Target emissions in 2030, in kt CO2e	407,650
Annual kt CO2e reduction needed to meet target:	30,058
Emission reduction (or increase) in 2019, kt CO2e	1,717
Average annual emission reduction (or increase), 2016-2019	(7,730)
Earth Index based on 2016-2019 trend	**-23%**



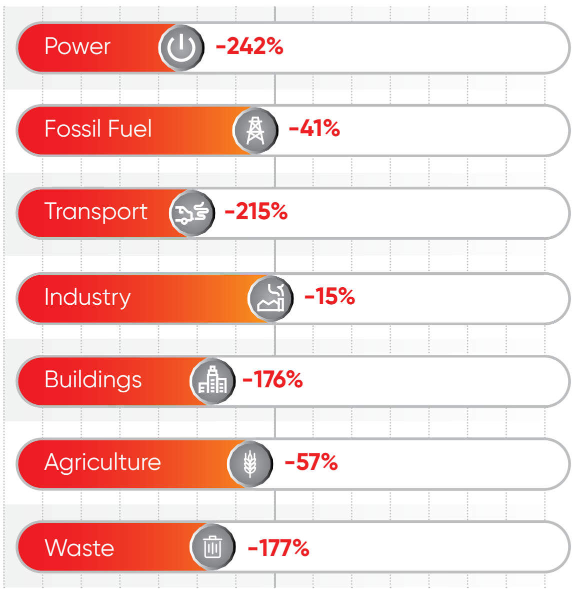
Emissions in 2005, kt CO2e	124,855	154,813	155,042	116,776	81,932	74,328	30,972
Emissions in 2019, kt CO2e	68,632	182,268	180,910	110,216	86,458	74,179	27,581
Target emissions in 2030, in kt CO2e	38,186	101,411	100,655	61,322	48,104	41,272	15,346
Annual reductions needed to meet target, kt CO2e	2,768	7,351	7,296	4,445	3,487	2,992	1,112
Actual emission reduction (or increase) in 2019, kt CO2e	1,121	(96)	(1,425)	(452)	(951)	427	(393)

The EARTH INDEX is obtained by dividing the emission reductions in 2019 by the annual emission reductions required to meet the stated target. Any result less than 100% indicates insufficient progress to meet the stated target, and when emissions are growing rather than declining, a negative score is obtained.
For Non Annex 1 countries under the UNFCCC, emissions data and sector definitions are taken from the EDGAR database; details available in the Earth Index Methodology document.

CHINA

-133% Earth Index

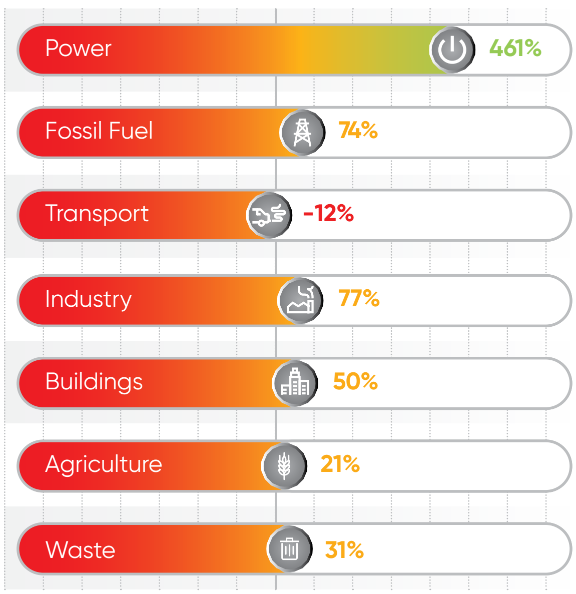
Emission target, net zero by 2050	100%
Emissions in 2005, kt CO2e	7,738,390
Emissions in 2019, kt CO2e	13,367,806
Target emissions in 2030, in kt CO2e	9,781,322
Annual kt CO2e needed to meet target:	326,044
Emission reduction (or increase) in 2019, kt CO2e	(433,799)
Average annual emission reduction (or increase), 2016-2019	(323,660)
Earth Index based on 2016-2019 trend	**-87%**



EUROPEAN UNION

120% Earth Index

Stated emission target, percent below 2005 by 2030:	55%
Emissions in 2005, kt CO2e	5,657,987
Emissions in 2019, kt CO2e	4,057,595
Target emissions in 2030, in kt CO2e	2,546,094
Annual kt CO2e reduction needed to meet target:	137,409
Emission reduction (or increase) in 2019, kt CO2e	165,506
Average annual emission reduction (or increase), 2016-2019	81,719
Earth Index based on 2016-2019 trend	**52%**



China

Emissions in 2005, kt CO2e	2,388,219	641,493	403,612	2,885,153	500,726	678,319	240,868
Emissions in 2019, kt CO2e	5,037,571	1,070,408	976,948	4,464,305	767,355	681,293	369,925
Target emissions in 2030, in kt CO2e	3,686,028	783,226	714,840	3,266,565	561,480	498,507	270,677
Annual reductions needed to meet target, kt CO2e	122,868	26,108	23,828	108,885	18,716	16,617	9,023
Actual emission reduction (or increase) in 2019, kt CO2e	(297,330)	(10,639)	(51,157)	(16,299)	(32,950)	(9,448)	(15,977)

European Union

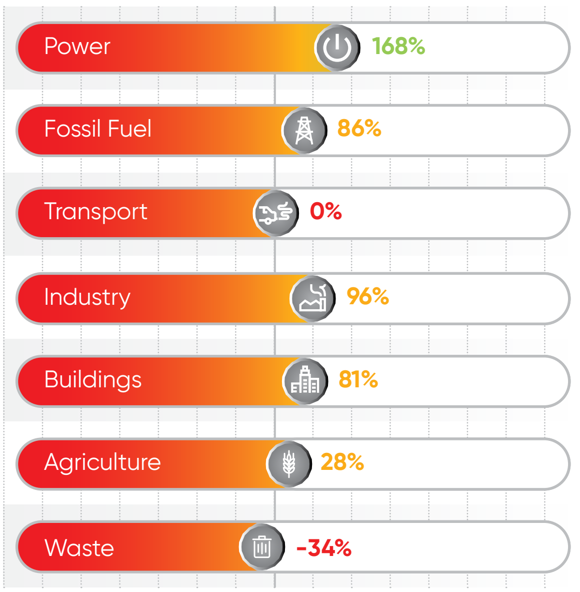
Emissions in 2005, kt CO2e	1,437,527	436,103	789,075	1,397,729	724,673	633,215	239,665
Emissions in 2019, kt CO2e	818,683	249,198	970,888	785,382	589,409	509,424	134,610
Target emissions in 2030, in kt CO2e	513,714	156,369	609,221	492,818	369,848	319,658	84,466
Annual reductions needed to meet target, kt CO2e	27,724	8,439	32,879	26,597	19,960	17,251	4,559
Actual emission reduction (or increase) in 2019, kt CO2e	127,837	6,218	(4,082)	20,605	9,903	3,596	1,428

The EARTH INDEX is obtained by dividing the emission reductions in 2019 by the annual emission reductions required to meet the stated target. Any result less than 100% indicates insufficient progress to meet the stated target, and when emissions are growing rather than declining, a negative score is obtained.
For Non Annex 1 countries under the UNFCCC, emissions data and sector definitions are taken from the EDGAR database; details available in the Earth Index Methodology document.

FRANCE

51% Earth Index

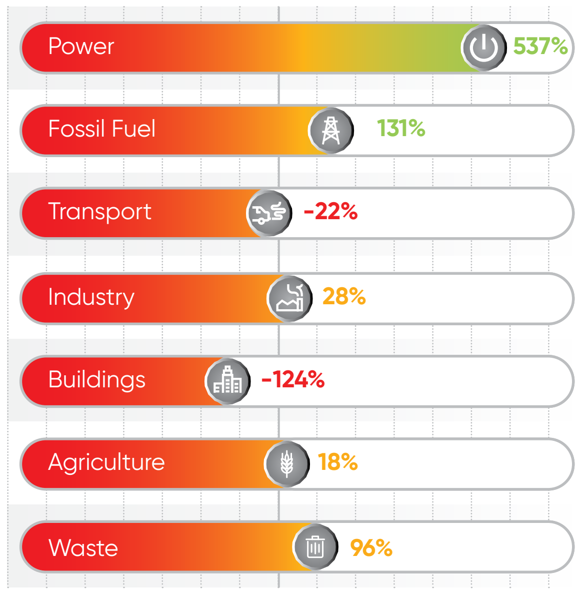
Stated emission target, percent below 2005 by 2030:	55%
Emissions in 2005, kt CO2e	547,128
Emissions in 2019, kt CO2e	442,985
Target emissions in 2030, in kt CO2e	246,208
Annual kt CO2e reduction needed to meet target:	17,889
Emission reduction (or increase) in 2019, kt CO2e	9,050
Average annual emission reduction (or increase), 2016-2019	8,025
Earth Index based on 2016-2019 trend	**39%**



GERMANY

136% Earth Index

Stated emission target, percent below 2005 by 2030:	65%
Emissions in 2005, kt CO2e	1,248,577
Emissions in 2019, kt CO2e	809,799
Target emissions in 2030, in kt CO2e	437,002
Annual kt CO2e reduction needed to meet target:	33,891
Emission reduction (or increase) in 2019, kt CO2e	46,092
Average annual emission reduction (or increase), 2016-2019	32,723
Earth Index based on 2016-2019 trend	**85%**



France:

Emissions in 2005, kt CO2e	49,829	27,970	122,984	150,065	84,697	93,974	17,609
Emissions in 2019, kt CO2e	29,827	13,173	135,870	91,833	69,458	84,378	18,445
Target emissions in 2030, in kt CO2e	16,578	7,321	75,515	51,040	38,604	46,897	10,252
Annual reductions needed to meet target, kt CO2e	1,204	532	5,487	3,708	2,805	3,407	745
Actual emission reduction (or increase) in 2019, kt CO2e	2,025	459	13	3,553	2,282	969	(252)

Germany:

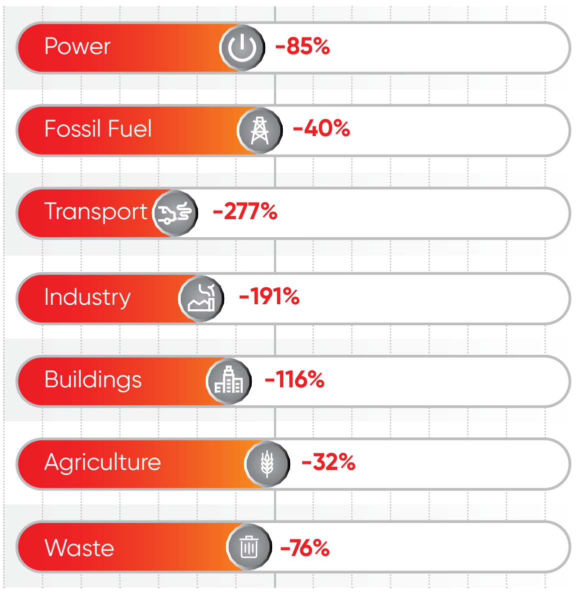
Emissions in 2005, kt CO2e	341,031	125,122	163,821	295,739	197,609	87,019	38,235
Emissions in 2019, kt CO2e	217,942	40,101	168,437	180,221	125,919	67,936	9,243
Target emissions in 2030, in kt CO2e	117,611	21,640	90,896	97,255	67,951	36,661	4,988
Annual reductions needed to meet target, kt CO2e	9,121	1,678	7,049	7,542	5,270	2,843	387
Actual emission reduction (or increase) in 2019, kt CO2e	49,006	2,192	(1,557)	2,123	(6,550)	508	370

The EARTH INDEX is obtained by dividing the emission reductions in 2019 by the annual emission reductions required to meet the stated target. Any result less than 100% indicates insufficient progress to meet the stated target, and when emissions are growing rather than declining, a negative score is obtained.
For Non Annex 1 countries under the UNFCCC, emissions data and sector definitions are taken from the EDGAR database; details available in the Earth Index Methodology document.

INDIA

-118% Earth Index

Emission target, net zero by 2050	100%
Emissions in 2005, kt CO2e	1,956,913
Emissions in 2019, kt CO2e	3,451,589
Target emissions in 2030, in kt CO2e	2,707,129
Annual kt CO2e needed to meet target:	67,678
Emission reduction (or increase) in 2019, kt CO2e	(80,020)
Average annual emission reduction (or increase), 2016-2019	(107,228)
Earth Index based on 2016-2019 trend	**-139%**

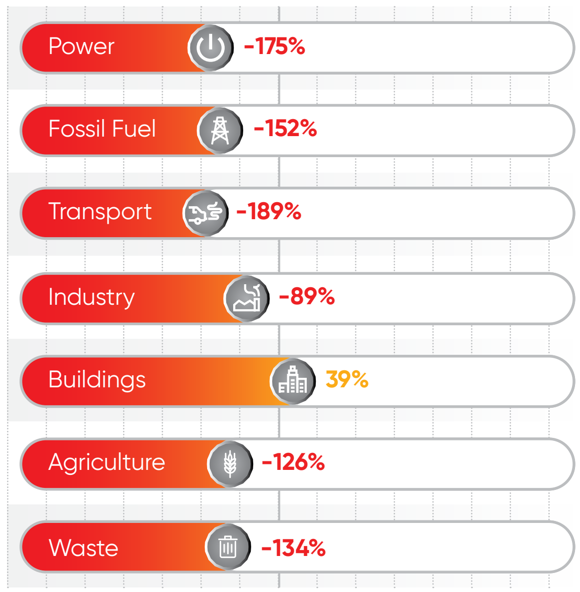


	Power	Fossil Fuel	Transport	Industry	Buildings	Agriculture	Waste
Emissions in 2005, kt CO2e	564,801	99,301	117,427	366,402	107,170	574,130	127,683
Emissions in 2019, kt CO2e	1,201,951	101,874	317,948	848,637	156,846	659,516	164,817
Target emissions in 2030, in kt CO2e	942,706	79,901	249,371	665,597	123,017	517,268	129,268
Annual reductions needed to meet target, kt CO2e	23,568	1,998	6,234	16,640	3,075	12,932	3,232
Actual emission reduction (or increase) in 2019, kt CO2e	(20,031)	(797)	(17,242)	(31,786)	(3,579)	(4,114)	(2,471)

INDONESIA

-141% Earth Index

Emission target, net zero by 2050	29%
Emissions in 2005, kt CO2e	692,562
Emissions in 2019, kt CO2e	1,051,403
Target emissions in 2030, in kt CO2e	491,719
Annual kt CO2e needed to meet target:	50,880
Emission reduction (or increase) in 2019, kt CO2e	(71,567)
Average annual emission reduction (or increase), 2016-2019	(63,309)
Earth Index based on 2016-2019 trend	**-109%**



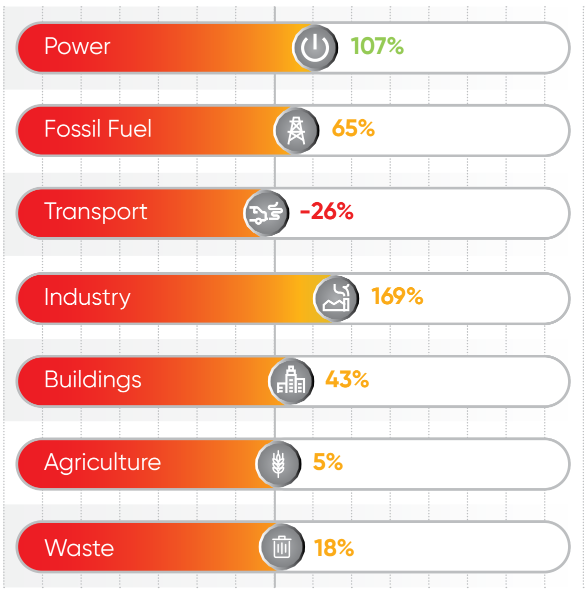
	Power	Fossil Fuel	Transport	Industry	Buildings	Agriculture	Waste
Emissions in 2005, kt CO2e	123,295	116,663	90,183	125,797	26,436	162,938	47,250
Emissions in 2019, kt CO2e	243,689	170,113	167,411	174,254	34,160	199,649	62,128
Target emissions in 2030, in kt CO2e	113,968	79,558	78,295	81,495	15,976	93,372	29,056
Annual reductions needed to meet target, kt CO2e	11,793	8,232	8,101	8,433	1,653	9,662	3,007
Actual emission reduction (or increase) in 2019, kt CO2e	(20,631)	(12,486)	(15,342)	(7,545)	650	(12,181)	(4,034)

The EARTH INDEX is obtained by dividing the emission reductions in 2019 by the annual emission reductions required to meet the stated target. Any result less than 100% indicates insufficient progress to meet the stated target, and when emissions are growing rather than declining, a negative score is obtained.
For Non Annex 1 countries under the UNFCCC, emissions data and sector definitions are taken from the EDGAR database; details available in the Earth Index Methodology document.

ITALY

54% Earth Index

Stated emission target, percent below 2005 by 2030:	60%
Emissions in 2005, kt CO2e	518,720
Emissions in 2019, kt CO2e	418,281
Target emissions in 2030, in kt CO2e	207,488
Annual kt CO2e reduction needed to meet target:	19,163
Emission reduction (or increase) in 2019, kt CO2e	10,269
Average annual emission reduction (or increase), 2016-2019	6,472
Earth Index based on 2016-2019 trend	**30%**

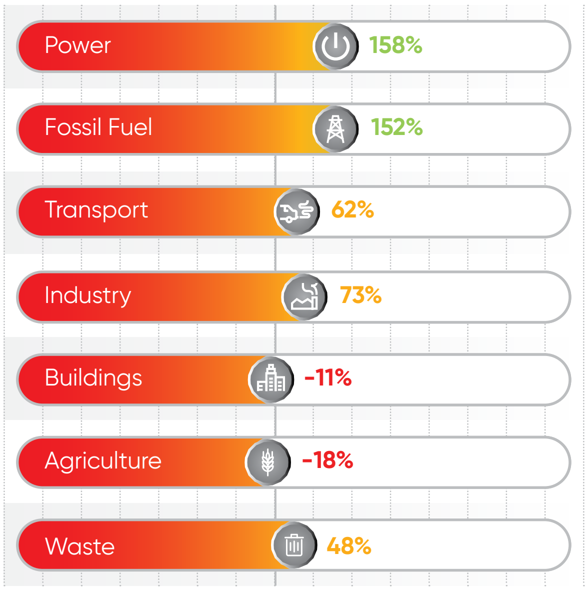


	Power	Fossil Fuel	Transport	Industry	Buildings	Agriculture	Waste
Emissions in 2005, kt CO2e	109,072	42,109	101,797	133,842	69,790	44,805	17,304
Emissions in 2019, kt CO2e	67,257	32,736	106,354	68,538	87,365	37,847	18,184
Target emissions in 2030, in kt CO2e	33,363	16,239	52,757	33,998	43,337	18,774	9,020
Annual reductions needed to meet target, kt CO2e	3,081	1,500	4,872	3,140	4,002	1,734	833
Actual emission reduction (or increase) in 2019, kt CO2e	3,303	976	(1,273)	5,307	1,720	88	148

JAPAN

87% Earth Index

Stated emission target, percent below 2005 by 2030:	46%
Emissions in 2005, kt CO2e	1,405,889
Emissions in 2019, kt CO2e	1,209,493
Target emissions in 2030, in kt CO2e	759,180
Annual kt CO2e reduction needed to meet target:	40,938
Emission reduction (or increase) in 2019, kt CO2e	35,528
Average annual emission reduction (or increase), 2016-2019	30,788
Earth Index based on 2016-2019 trend	**66%**



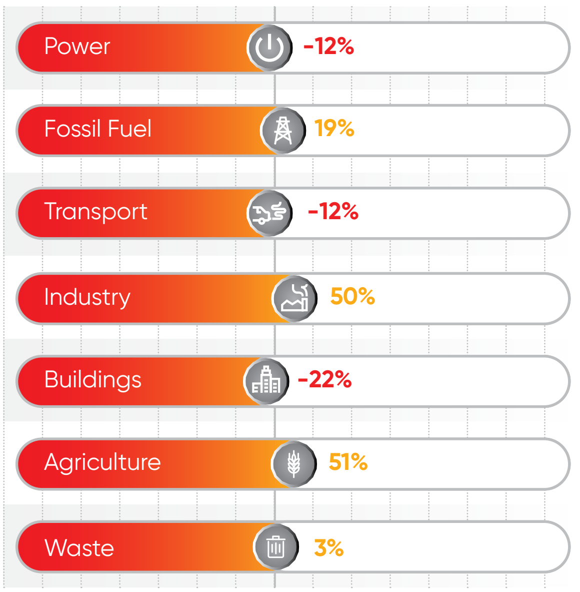
	Power	Fossil Fuel	Transport	Industry	Buildings	Agriculture	Waste
Emissions in 2005, kt CO2e	523,924	63,416	220,236	367,057	161,696	47,006	22,554
Emissions in 2019, kt CO2e	398,248	53,024	203,599	318,240	169,908	46,107	20,367
Target emissions in 2030, in kt CO2e	249,974	33,282	127,796	199,754	106,649	28,941	12,784
Annual reductions needed to meet target, kt CO2e	13,479	1,795	6,891	10,771	5,751	1,561	689
Actual emission reduction (or increase) in 2019, kt CO2e	21,247	2,723	4,290	7,854	(641)	(276)	331

The EARTH INDEX is obtained by dividing the emission reductions in 2019 by the annual emission reductions required to meet the stated target. Any result less than 100% indicates insufficient progress to meet the stated target, and when emissions are growing rather than declining, a negative score is obtained.
For Non Annex 1 countries under the UNFCCC, emissions data and sector definitions are taken from the EDGAR database; details available in the Earth Index Methodology document.

KOREA, REPUBLIC OF

4% Earth Index

Emission target, net zero by 2050	40%
Emissions in 2005, kt CO2e	732,531
Emissions in 2019, kt CO2e	731,578
Target emissions in 2030, in kt CO2e	439,519
Annual kt CO2e needed to meet target:	26,551
Emission reduction (or increase) in 2019, kt CO2e	953
Average annual emission reduction (or increase), 2016-2019	(8,043)
Earth Index based on 2016-2019 trend	**-27%**

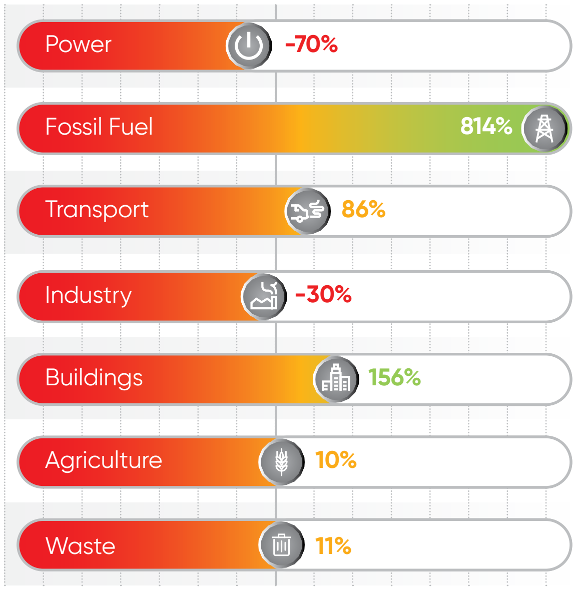


Emissions in 2005, kt CO2e	332,154	62,193	102,381	135,028	58,753	22,661	19,361
Emissions in 2019, kt CO2e	333,549	61,777	102,825	132,602	59,235	22,248	19,341
Target emissions in 2030, in kt CO2e	200,390	37,114	61,775	79,665	35,588	13,366	11,620
Annual reductions needed to meet target, kt CO2e	12,105	2,242	3,732	4,812	2,150	807	702
Actual emission reduction (or increase) in 2019, kt CO2e	(1,395)	416	(444)	2,426	(483)	414	20

MEXICO

66% Earth Index

Emission target, net zero by 2050	22%
Emissions in 2005, kt CO2e	743,420
Emissions in 2019, kt CO2e	740,644
Target emissions in 2030, in kt CO2e	579,868
Annual kt CO2e needed to meet target:	14,616
Emission reduction (or increase) in 2019, kt CO2e	9,645
Average annual emission reduction (or increase), 2016-2019	2,157
Earth Index based on 2016-2019 trend	**13%**



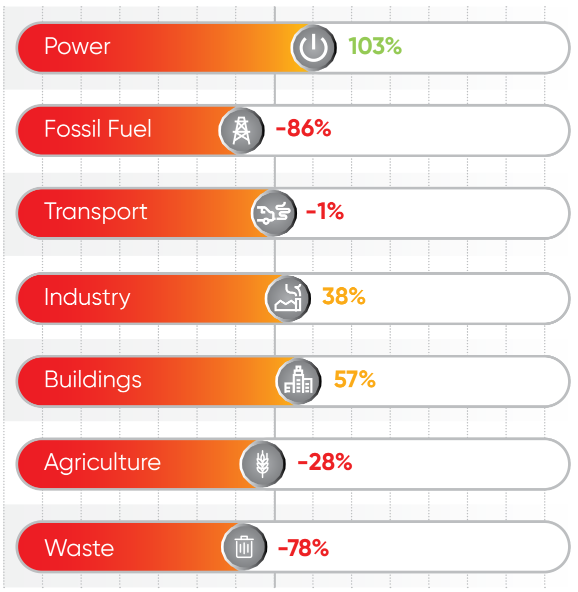
144,975	95,048	153,005	168,183	32,730	97,070	52,409
157,704	56,462	150,662	184,911	31,733	101,934	57,236
123,471	44,206	117,957	144,772	24,845	79,807	44,812
3,112	1,114	2,973	3,649	626	2,012	1,130
(2,190)	9,069	2,565	(1,103)	975	209	122

The EARTH INDEX is obtained by dividing the emission reductions in 2019 by the annual emission reductions required to meet the stated target. Any result less than 100% indicates insufficient progress to meet the stated target, and when emissions are growing rather than declining, a negative score is obtained.
For Non Annex 1 countries under the UNFCCC, emissions data and sector definitions are taken from the EDGAR database; details available in the Earth Index Methodology document.

RUSSIAN FEDERATION

27% Earth Index

Stated emission target, percent below 2005 by 2030:	100%
Emissions in 2005, kt CO_2e	1,965,385
Emissions in 2019, kt CO_2e	2,119,432
Target emissions in 2030, in kt CO_2e	0
Annual kt CO_2e reduction needed to meet target:	51,693
Emission reduction (or increase) in 2019, kt CO_2e	14,149
Average annual emission reduction (or increase), 2016-2019	(27,408)
Earth Index based on 2016-2019 trend	**-47%**

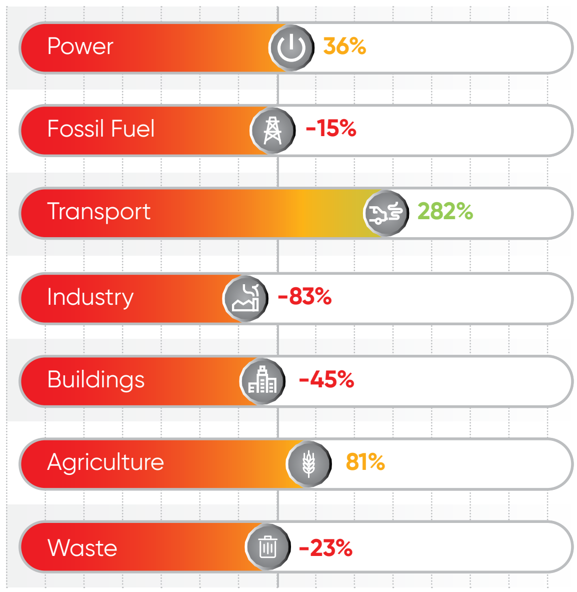


	Power	Fossil Fuel	Transport	Industry	Buildings	Agriculture	Waste
Emissions in 2005, kt CO_2e	800,878	369,933	131,097	351,406	110,439	132,181	69,451
Emissions in 2019, kt CO_2e	720,353	368,870	189,970	416,147	193,918	130,021	100,153
Target emissions in 2030, in kt CO_2e	527,088	269,905	139,002	304,498	141,891	95,137	73,283
Annual reductions needed to meet target, kt CO_2e	17,570	8,997	4,633	10,150	4,730	3,171	2,443
Actual emission reduction (or increase) in 2019, kt CO_2e	18,062	(7,700)	(28)	3,902	2,706	(882)	(1,913)

SAUDI ARABIA

28% Earth Index

Emission target, net zero by 2050	39%
Emissions in 2005, kt CO_2e	687,017
Emissions in 2019, kt CO_2e	687,017
Target emissions in 2030, in kt CO_2e	419,080
Annual kt CO_2e needed to meet target:	24,358
Emission reduction (or increase) in 2019, kt CO_2e	6,881
Average annual emission reduction (or increase), 2016-2019	6,201
Earth Index based on 2016-2019 trend	**22%**



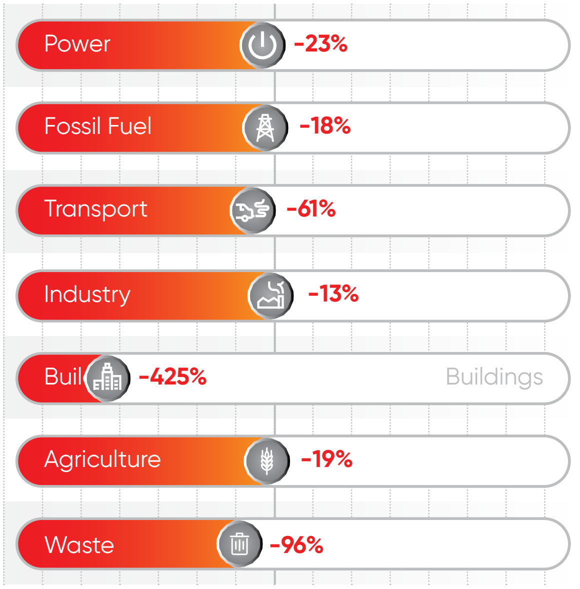
	Power	Fossil Fuel	Transport	Industry	Buildings	Agriculture	Waste
Emissions in 2005, kt CO_2e	235,974	102,042	104,883	207,426	4,608	8,769	23,314
Emissions in 2019, kt CO_2e	235,974	102,042	104,883	207,426	4,608	8,769	23,314
Target emissions in 2030, in kt CO_2e	143,944	62,246	63,979	126,530	2,811	5,349	14,222
Annual reductions needed to meet target, kt CO_2e	8,366	3,618	3,719	7,354	163	311	827
Actual emission reduction (or increase) in 2019, kt CO_2e	3,052	(556)	10,488	(6,094)	(74)	253	(188)

The EARTH INDEX is obtained by dividing the emission reductions in 2019 by the annual emission reductions required to meet the stated target. Any result less than 100% indicates insufficient progress to meet the stated target, and when emissions are growing rather than declining, a negative score is obtained.
For Non Annex 1 countries under the UNFCCC, emissions data and sector definitions are taken from the EDGAR database; details available in the Earth Index Methodology document.

SOUTH AFRICA

-62% Earth Index

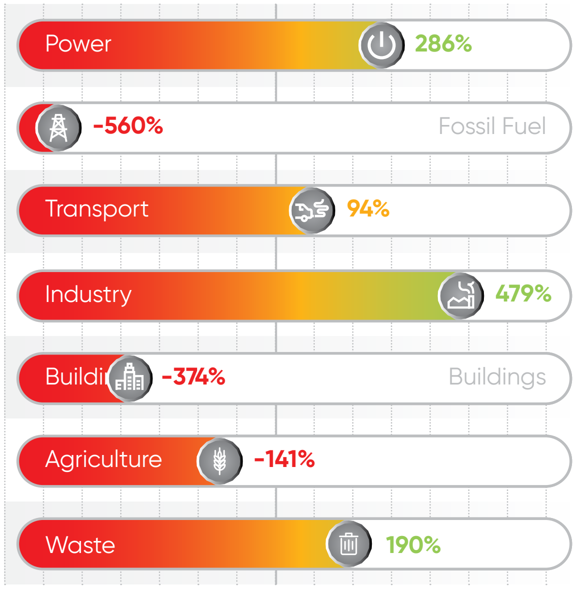
Emission target, net zero by 2050	100%
Emissions in 2005, kt CO2e	516,645
Emissions in 2019, kt CO2e	554,339
Target emissions in 2030, in kt CO2e	357,638
Annual kt CO2e needed to meet target:	17,882
Emission reduction (or increase) in 2019, kt CO2e	(11,125)
Average annual emission reduction (or increase), 2016-2019	(4,121)
Earth Index based on 2016-2019 trend	**-20%**



TURKEY

118% Earth Index

Stated emission target, percent below 2005 by 2030:	21%
Emissions in 2005, kt CO2e	447,582
Emissions in 2019, kt CO2e	506,080
Target emissions in 2030, in kt CO2e	353,590
Annual kt CO2e reduction needed to meet target:	13,863
Emission reduction (or increase) in 2019, kt CO2e	16,396
Average annual emission reduction (or increase), 2016-2019	(2,398)
Earth Index based on 2016-2019 trend	**-15%**



Emissions in 2005, kt CO2e	211,255	111,540	43,868	72,207	26,306	35,530	15,939	120,889	14,818	62,144	116,040	58,289	56,026	19,377
Emissions in 2019, kt CO2e	226,660	99,584	55,738	68,191	48,154	35,674	20,340	139,116	19,683	81,846	110,732	58,570	78,886	17,248
Target emissions in 2030, in kt CO2e	146,232	64,248	35,960	43,994	31,067	23,015	13,123	97,198	13,752	57,185	77,367	40,922	55,116	12,051
Annual reductions needed to meet target, kt CO2e	7,312	3,212	1,798	2,200	1,553	1,151	656	3,811	539	2,242	3,033	1,604	2,161	472
Actual emission reduction (or increase) in 2019, kt CO2e	(1,712)	(564)	(1,097)	(293)	(6,607)	(220)	(632)	10,916	(3,020)	2,114	14,524	(5,992)	(3,044)	899

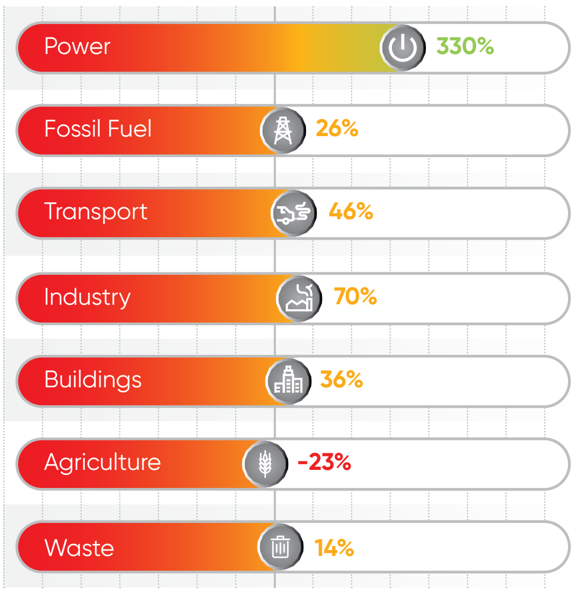
The EARTH INDEX is obtained by dividing the emission reductions in 2019 by the annual emission reductions required to meet the stated target. Any result less than 100% indicates insufficient progress to meet the stated target, and when emissions are growing rather than declining, a negative score is obtained.
For Non Annex 1 countries under the UNFCCC, emissions data and sector definitions are taken from the EDGAR database; details available in the Earth Index Methodology document.

Annex B. EARTH INDEX Scorecards

UNITED KINGDOM

75% Earth Index

Stated emission target, percent below 2005 by 2030:	68%
Emissions in 2005, kt CO2e	794,869
Emissions in 2019, kt CO2e	453,101
Target emissions in 2030, in kt CO2e	254,358
Annual kt CO2e reduction needed to meet target:	18,068
Emission reduction (or increase) in 2019, kt CO2e	13,566
Average annual emission reduction (or increase), 2016-2019	10,348
Earth Index based on 2016-2019 trend	**50%**

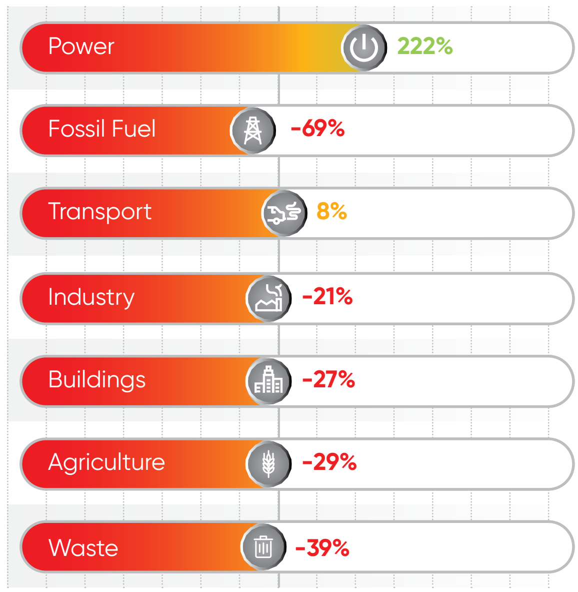


Emissions in 2005, kt CO2e	205,402	73,749	122,475	167,807	105,868	54,561	65,007
Emissions in 2019, kt CO2e	60,004	37,357	123,809	71,092	94,128	47,415	19,296
Target emissions in 2030, in kt CO2e	33,685	20,971	69,503	39,909	52,841	26,617	10,832
Annual reductions needed to meet target, kt CO2e	2,393	1,490	4,937	2,835	3,753	1,891	769
Actual emission reduction (or increase) in 2019, kt CO2e	7,894	383	2,281	1,997	1,335	(430)	106

UNITED STATES

42% Earth Index

Stated emission target, percent below 2005 by 2030:	52%
Emissions in 2005, kt CO2e	7,423,031
Emissions in 2019, kt CO2e	6,558,345
Target emissions in 2030, in kt CO2e	3,563,055
Annual kt CO2e reduction needed to meet target:	272,299
Emission reduction (or increase) in 2019, kt CO2e	113,104
Average annual emission reduction (or increase), 2016-2019	(12,669)
Earth Index based on 2016-2019 trend	**-4%**



Emissions in 2005, kt CO2e	2,430,986	488,151	1,913,154	1,223,320	612,019	577,386	178,015
Emissions in 2019, kt CO2e	1,628,366	542,681	1,803,193	1,112,343	679,130	628,883	163,748
Target emissions in 2030, in kt CO2e	884,668	294,831	979,649	604,320	368,962	341,663	88,962
Annual reductions needed to meet target, kt CO2e	67,609	22,532	74,868	46,184	28,197	26,111	6,799
Actual emission reduction (or increase) in 2019, kt CO2e	150,182	(15,490)	5,732	(9,473)	(7,534)	(7,644)	(2,670)

The EARTH INDEX is obtained by dividing the emission reductions in 2019 by the annual emission reductions required to meet the stated target. Any result less than 100% indicates insufficient progress to meet the stated target, and when emissions are growing rather than declining, a negative score is obtained.
For Non Annex 1 countries under the UNFCCC, emissions data and sector definitions are taken from the EDGAR database; details available in the Earth Index Methodology document.

ANNEX C. ZERO EMISSION ENERGY (ZEMEX) AND ZERO EMISSION POWER (ZEPEX) INDICES

The Zero-Emission Energy Index (ZEMEX) is calculated by multiplying the percentage of carbon-free final energy consumption by the percentage of carbon-free energy in the domestic energy supply. Carbon-free energy includes electricity, heat, direct biomass and direct renewables.

The Zero-Emission Power Index (ZEPEX) is calculated as the product of the percentage of final energy end-use demand provided by electricity and the percentage of that electricity supplied with zero-emission generation.

Energy data is collected from the IEA World Energy Balances data tables.

Table C1. Zero-emission energy and zero-emission power indices

Country	Zero Emission Energy Index (ZEMEX)			Zero Emission Power Index (ZEPEX)		
	Demand	Supply	Earth Index	Demand	Supply	Earth Index
Argentina	24%	48%	12%	19%	36%	7%
Australia	28%	32%	9%	22%	20%	4%
Brazil	48%	94%	45%	19%	86%	17%
Canada	28%	83%	23%	22%	80%	18%
China	38%	43%	16%	27%	32%	9%
European Union	35%	70%	25%	21%	63%	13%
France	36%	90%	32%	25%	90%	22%
Germany	31%	63%	20%	19%	54%	11%
India	45%	65%	29%	18%	23%	4%
Indonesia	30%	58%	17%	14%	17%	2%
Italy	32%	50%	16%	21%	41%	9%
Japan	31%	31%	10%	29%	26%	8%
Korea	30%	36%	11%	25%	31%	8%
Mexico	27%	36%	10%	21%	19%	4%
Russia	34%	22%	7%	12%	37%	5%
Saudi Arabia	18%	0%	0%	18%	0%	0%
South Africa	32%	31%	10%	23%	12%	3%
Spain	31%	68%	21%	24%	59%	14%
Turkey	27%	53%	14%	21%	44%	9%
United Kingdom	25%	61%	15%	20%	57%	11%
United States	27%	49%	13%	21%	37%	8%
G20	34%	51%	17%	22%	38%	8%
High Income	29%	54%	16%	22%	44%	10%
Middle Income	38%	49%	19%	22%	33%	7%

ANNEX D. CONSUMPTION-BASED EMISSIONS

A country's consumption-based emissions are the greenhouse gas emissions that result from production and delivery of all the goods and services consumed in the country, regardless of where those goods and services are produced. It differs from the more commonly employed sector-based emissions inventory, which counts the emissions that take place within the country, whether they are the result of production for domestic consumption or not, and does not count emissions embedded in goods and services imported from outside the country.

The calculation of very detailed and precise consumption-based inventories is complex, but they can be estimated with simple methods, which is the approach we have taken.

1. We begin with the country's sector-based inventory, using the Emissions Database for Global Atmospheric Research (EDGAR) Database and partition it into two parts: the emissions associated with the final consumption of the household sector, which we call the final consumption emissions, and the emissions that are used to generate the country's GDP, which we call the productive economy emissions.

2. Emissions associated with final consumption in the household sector are estimated as the sum of three components:

    - the EDGAR residential sector emissions from fuel combustion, plus 50% of the waste sector emissions in the EDGAR inventory,
    - the EDGAR power sector emissions multiplied by the portion of national electricity consumption in the residential sector, according to the IEA World Energy Balances, and
    - the EDGAR transportation sector emissions multiplied by the portion of transportation energy used for personal transportation, according to the IEA Energy Efficiency data product.

3. After subtracting the emissions from final consumption in the household sector from the EDGAR inventory to get the emissions of the productive economy, we divide the productive economy emissions into the portion associated with domestic consumption and the portion that is exported. We do this by multiplying the productive economy emissions by the percent of the country's GDP that is exported, according to the World Bank trade statistics. This involves the simplifying assumption that the portion of a country's productive economy emissions that is exported can be equated with the portion of a country's GDP that is exported.

4. Two of these three components of the country's emissions inventory – the final consumption emissions and the portion of the productive economy emissions associated with domestic consumption – form two components of the country's consumption-based emissions. What remains is to estimate the emissions that are embodied in the country's imports.

5. To estimate emissions that are embodied in imports, we start with the portion of each country's emissions inventory that is exported, as calculated in Step 2 above. Using World Bank data, we distribute each country's exported emissions to each other country on the assumption

that the share of exports received by each country is equal to its share of exports received. We can then sum the imported emissions for each country to get an estimate of the total emissions of embedded imports for each country.

6. We add the result of Step 5 to the final consumption emissions and the share of the productive economy emissions associated with domestic consumption to obtain the consumption-based emissions for the country.

Table D1. Consumption-based and sector-based emissions of G20 members

Country	Consumption-Based Emissions				Total sector-based emissions
	Final consumption	Productive economy for domestic consumption	Embodied in imports	Total consumption-based emissions	
	Mt CO2e	Mt CO2e	Mt CO2e	Mt CO2e	Mt CO2e
Argentina	75	244	26	345	362
Australia	133	326	99	558	552
Brazil	218	773	93	1,085	1,130
Canada	202	353	158	713	724
China	2,072	8,735	657	11,463	12,934
European Union	1,145	1,235	1,904	4,285	3,696
France	149	184	216	550	421
Germany	264	309	426	999	845
India	672	2,134	207	3,013	3,372
Indonesia	241	580	94	914	980
Italy	136	173	211	521	391
Japan	333	745	329	1,407	1,238
Korea	143	342	248	733	730
Mexico	183	343	150	675	750
Russia	520	1,202	136	1,858	2,207
Saudi Arabia	188	321	79	589	694
South Africa	118	306	49	474	543
Spain	109	147	142	398	335
Turkey	139	285	111	535	555
United Kingdom	165	190	262	617	442
United States	2,265	3,266	1,192	6,723	5,966
G20	8,814	21,381	5,794	35,989	36,740
High-income	4,658	6,763	4,553	15,974	14,363
Middle-income	6,166	18,488	2,968	27,622	30,778