Xcel Energy carbon emissions targets and limiting warming to less than 2 degrees C

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Summary of main results

Climate researchers have carried out a large number of studies of how much and how fast greenhouse gas emissions would have to be reduced in order to achieve the Paris Agreement target of limiting warming to less than 2 degrees Celsius, or even to below 1.5 C. We drew on the results of those studies to compare Xcel Energy's emissions reduction goals to emissions pathways consistent with the Paris targets. In those pathways, global carbon emissions generally decline to zero (in net terms) by around 2070 or later to stay below 2 C, and by around 2050 to stay below 1.5 C.

However, emissions associated with one company in one country are just a fraction of global emissions, so we compared Xcel Energy's goals to a more detailed and more relevant set of results from these studies: net carbon emissions from the electricity sector in industrialized countries. We found that the Xcel Energy goals represent reductions that are consistent with, and in most cases larger than, those that occur in this sector in scenarios that achieve the Paris Agreement climate targets.

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[2] The report was finalized on December 31, 2018. Figures 1 and 2 were updated with the most recent Xcel Energy emissions data and minor typos fixed on March 4, 2019.

Approach

A recent report of the Intergovernmental Panel on Climate Change[3] assessed the scientific literature on emissions scenarios consistent with the Paris Agreement climate change targets. To support that assessment, researchers created a database of 416 published emissions scenarios.[4] The scenarios were developed using computer models that calculate the greenhouse gas emissions and warming that would result from the production and consumption of energy, food, transportation and other goods in regions around the world over the coming decades. The future is uncertain, so these scenarios investigate a wide range of possibilities about how fast population, incomes, and energy demand may grow and what kinds of climate policies may be pursued to achieve the Paris targets.

We compared the Xcel Energy goals to a subset of these scenario results. First, we selected two sets of scenarios: those that would be likely (defined as having a greater than 66% chance) to stay below 2 C, and those that would be more likely than not (defined as having a greater than a 50% chance) to stay below 1.5 C or to only slightly (and temporarily) exceed that level.[5] Next, we extracted results from these scenarios for carbon dioxide emissions from the electricity sector in industrialized countries.[6] These outcomes are the best comparison to Xcel Energy goals that are available from the scenario database. Models that produce emissions scenarios do not represent individual companies, nor even all individual countries. Results are reported in the database as totals for groups of countries for different sectors of the economy. By using results for the industrialized country electricity sector, we can compare Xcel Energy goals to emissions pathways that occur on average across the electricity sectors of countries at similar levels of economic development to the US.

Finally, we excluded scenarios in which net carbon emissions from the industrialized country electricity sector are negative at any time in the future, through 2100. Net negative emissions result from technologies like biomass energy with carbon capture and storage (BECCS) that generate electricity while removing carbon from the atmosphere. Scenarios with these technologies often allow for higher global emissions in the first few decades that are compensated for by negative emissions later in the

[3] IPCC, 2018: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. In Press. Hereafter, "IPCC SR 1.5 C."

[4] Huppmann, D. et al. IAMC 1.5°C Scenario Explorer and Data hosted by IIASA. Integrated Assessment Modeling Consortium & International Institute for Applied Systems Analysis, 2018. doi: 10.22022/SR15/08-2018.15429, url: data.ene.iiasa.ac.at/iamc-1.5c-explorer.

[5] These categories follow the grouping used in the IPCC report in ref. 3. The lower likelihood of achieving the target in the 1.5 C case (50%) is used because of the difficulty of achieving it with higher likelihood. "Slightly exceeding" the target is defined as staying below 1.6 C.

[6] We use the phrase "industrialized countries" to refer to the region defined in the IPCC database as "OECD90+EU," which contains countries that were members of the OECD as of 1990, as well as current EU member countries and candidates. Note this does not include Russia and other members of the Former Soviet Union (the "REF" region in the database). Specific countries included are: Albania, Australia, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Canada, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Macedonia, Montenegro, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States of America.

century. However, these technologies are unproven at large scales and involve possible risks to biodiversity and food prices due to the large amount of land that may be required for growing biofuels.

Our selection process left us with 17 scenarios consistent with the 2 C goal, and 5 scenarios consistent with the 1.5 C target, a reflection that achieving the lower target without net negative emissions in the electricity sector is relatively uncommon in the scientific literature.

Results

The comparison in Figure 1 shows that Xcel Energy's 2030 and 2050 goals represent emissions reductions that are larger than those that occur in the industrialized country electricity sector in most of the global emissions scenarios likely to limit warming to below 2 C. Xcel Energy's goals are also within the range of reductions that occur in the limited number of scenarios achieving the 1.5 C target. These figures show scenario results to 2050; beyond 2050, these scenarios generally indicate low or zero net carbon emissions continuing through the end of the century.

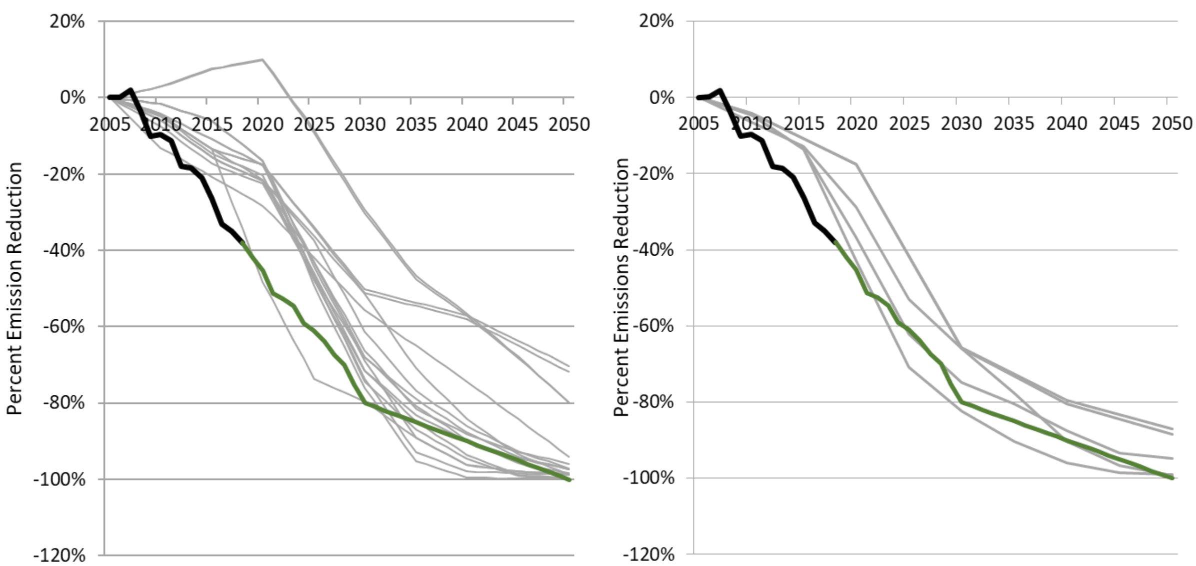

Figure 1: Xcel Energy carbon emissions reduction goals (in green, with historical emissions in black) compared to scenarios of emissions from the industrialized country electricity sector (in gray). Emissions scenarios are from global scenarios likely to remain below 2 C warming (left) or more likely than not to avoid 1.5 C warming (right) without significantly exceeding that level. Emissions expressed as a percent reduction relative to levels in 2005.

Additional analysis: overview

The remainder of this report explores additional dimensions of the subset of emissions scenarios from the IPCC database to which the Xcel Energy targets are compared in our main results. The analysis provides context to this comparison by investigating whether this subset of emissions scenarios has unusual features that users should be aware of. We structure the analysis around a set of questions about several features of the scenarios: industrialized country electricity sector emissions beyond 2050, electricity sector and total emissions in the five major world regions for which scenario results are available, the role of negative emissions and carbon capture and storage (CCS) technology, and assumptions about the nature of climate policy, energy demand, land use, and non-CO_2 emissions.

In general we do not find the subset of scenarios we use to be unusual or to have unexpected features. Emissions beyond 2050 remain relatively constant, and emissions in other regions and across the economy as a whole follow the broad features of emissions pathways for the industrialized country electricity sector. Electricity sector emissions do not differ substantially before 2050 from those that allow for net negative emissions, and while both types of scenarios make substantial use of CCS, little of that use occurs before 2050. Further, a range of different climate policy approaches is reflected in the subset of scenarios, and as a group they do not exhibit extreme outcomes for energy demand, land use, or emissions from non-CO_2 greenhouse gases.

Electricity sector emissions through 2100

Do trends in carbon emissions from the electricity sector in industrialized countries change beyond 2050?

The main results compared Xcel Energy goals to reductions that occur in emissions scenarios through 2050. Figure 2 extends this comparison through 2100, showing that trends change little beyond 2050. Industrialized country emissions in the electricity sector remain relatively constant, with emissions at or near zero, over the second half of the century. By design, this set of scenarios does not include scenarios with substantial net negative emissions in the electricity sector for this region at any point in time over the century.

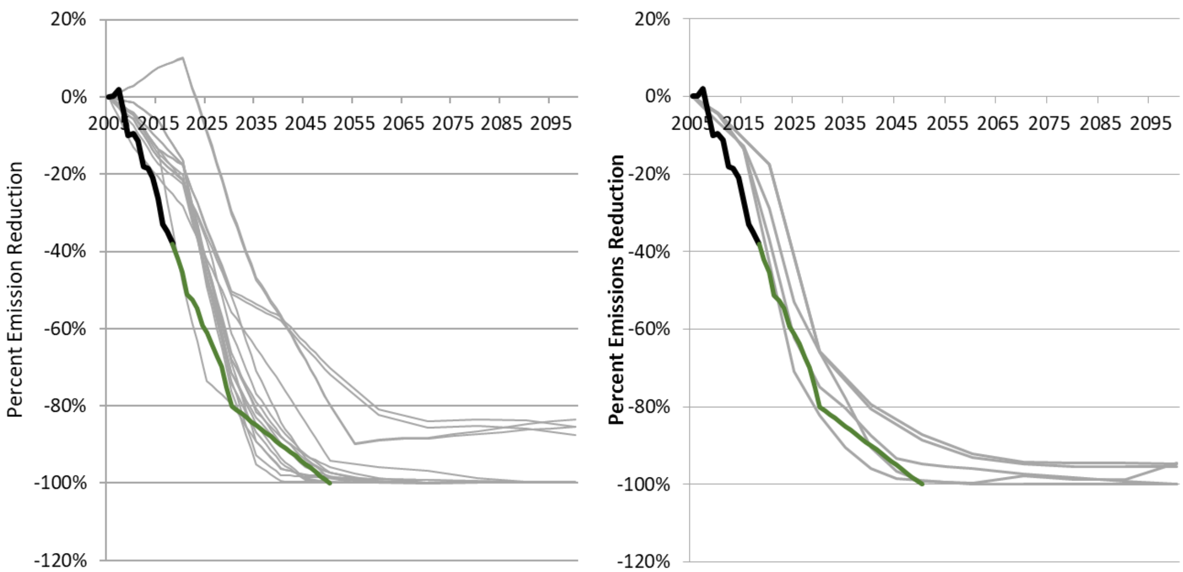

Figure 2: Xcel Energy carbon emissions reduction goals (in green, with historical emissions in black) compared to scenarios of emissions from the industrialized country electricity sector (in gray). Emissions scenarios are from global scenarios likely to remain below 2 C warming (left) or more likely than not to avoid 1.5 C warming (right) without significantly exceeding that level. Emissions expressed as a percent reduction relative to levels in 2005, over the period 2005-2100.

Electricity sector emissions across regions

Do trends in electricity sector emissions differ substantially in other regions relative to those in industrialized countries?

Electricity sector emissions in other world regions have broadly similar features to those in the industrialized countries. Regional emissions in the subset of scenarios from the IPCC database used in our comparison[7] vary across regions in terms of their current level and trends in the first decade, but then in all cases fall to zero or very low levels by around mid-century or later, and somewhat earlier in some 1.5 C scenarios (Figure 3). A small number of scenarios include modest net-negative emissions in the electricity sector in other (non-industrialized country) regions.

Comparing regional electricity sector emissions in cumulative terms over the period 2000-2100 (Figure 4) shows that they vary in absolute amounts across regions, with emission highest in Asia, and lowest in Latin America, with emissions from industrialized countries the second largest regional source. Global emissions and emissions in Asia tend to be lower in the 1.5 C than the 2 C scenarios.

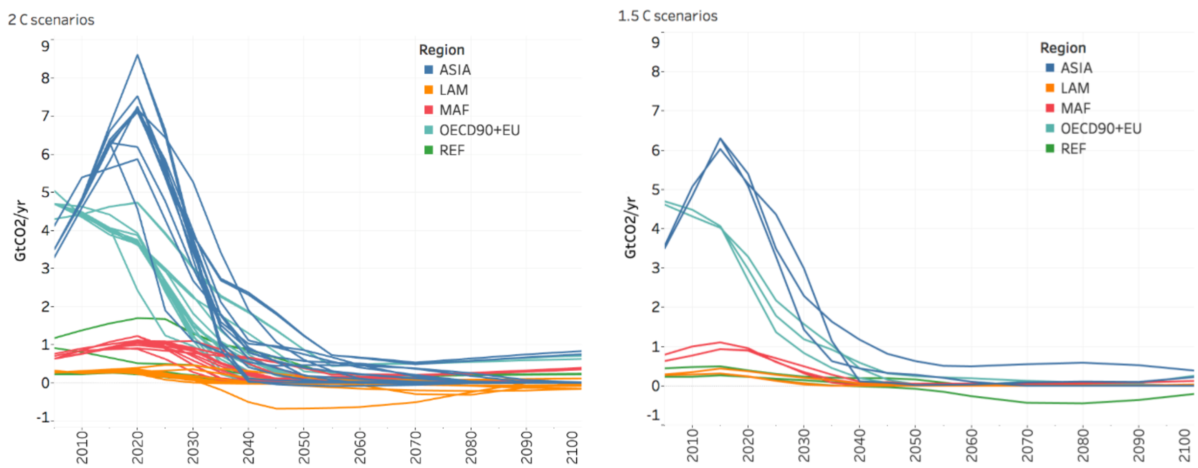

Figure 3: Carbon emissions from the electricity sectors for all 5 global regions for which data are available in the IPCC scenarios database, for 2 C (left) and 1.5 C (right) scenarios, in billion tons of CO_2 per year. The regions include Asia (ASIA), Latin America (LAM), Middle East and Africa (MAF) and the Reforming Economies (REF), in addition to the industrialized country region (OECD90+EU) shown in Figures 1 and 2.

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[7] In the remainder of this report, we use 15 scenarios that achieve the 2 C target and 3 scenarios that achieve the 1.5 C target, without requiring net negative emissions, rather than the 17 and 5 scenarios, respectively, used in Figures 1 and 2. For four scenarios from the POLES modeling team, results in the IPCC database were recorded incorrectly and we therefore excluded them from our analysis. For electricity sector emissions in the industrialized country region, we obtained correct results directly from the POLES modeling team at the EU Joint Research Centre in Seville, Spain, and included those in Figures 1 and 2.

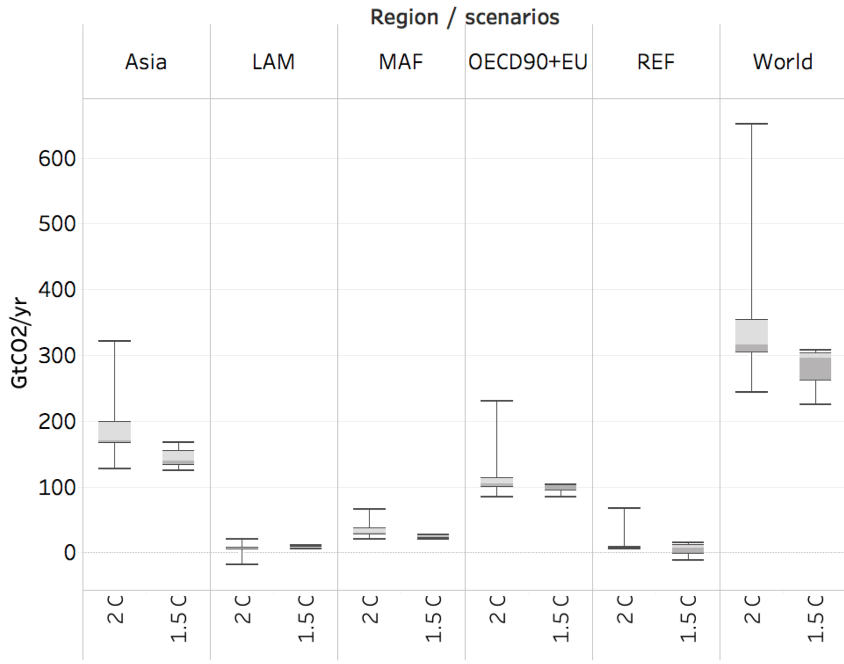
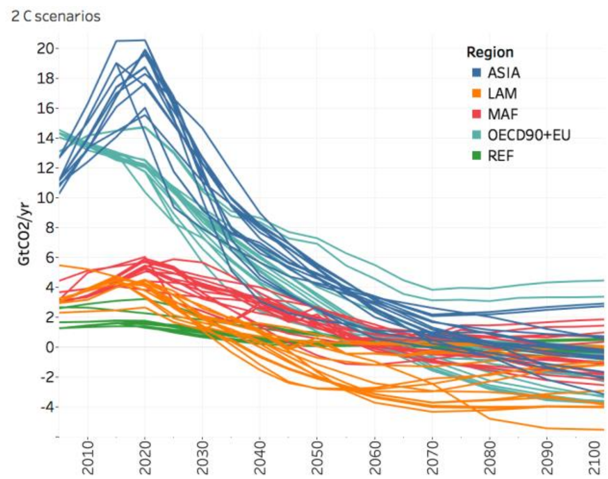


Figure 4: Cumulative emissions (2000-2100) from the electricity sectors across 5 global regions and the world in both 1.5 C and 2 C scenarios, in billion tons of CO_2. Gray boxes indicate the range in which 50% of the scenarios fall (from the 25th to the 75th percentile). Black lines indicate the full range of scenario outcomes. See Figure 3 for region definitions.

Total emissions across regions

Do trends in total (economy-wide) carbon emissions differ substantially from those from the electricity sector in industrialized countries or in other regions?

Total carbon emissions from all sectors (including land use) follow a broadly similar trend over time compared to emissions from the electricity sector, falling to zero or low levels in the second half of the century (or around mid-century in the 1.5 C scenarios). However, the range of outcomes is somewhat wider for economy-wide emissions, with some regions (particularly Asia) in some scenarios exhibiting substantial positive emissions late in the century, while others (particularly Latin America) have substantially negative net emissions. These negative emissions occur predominantly in the second half of the century and as shown in Figure 3 above are not primarily from the electricity sector, but rather mainly from the production of biofuels (liquid fuels, biogas, or hydrogen) and from afforestation.



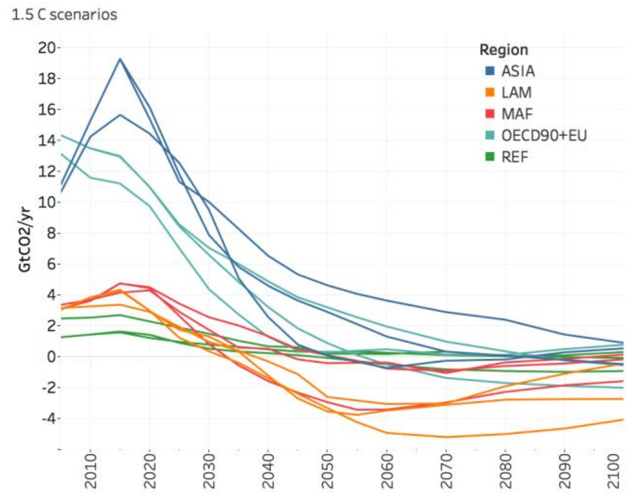


Figure 5: Total (economy-wide) carbon emissions across five global regions, for 2 C (left) and 1.5 C (right) scenarios, in billion tons of CO_2 per year.

The role of negative emissions

How does our subset of scenarios from the IPCC database, which excludes net negative emissions from the electricity sector, differ from scenarios that allow net negative emissions? Is the use of CCS technology substantial even without net negative emissions?

Negative emissions occur when carbon dioxide is removed from the atmosphere. There are several processes or technologies that can lead to negative emissions. In the energy sector, negative emissions occur when energy is derived from biomass (i.e., bioenergy) and is combined with carbon capture and storage (CCS). The combination is typically abbreviated as BECCS. Non-energy approaches include direct air capture, enhanced weathering, or afforestation. CCS can also be combined with fossil fuel-based energy production, resulting in low or zero (but not negative) emissions.

Emissions scenarios that employ negative emissions technologies can result in emissions that are negative in gross or net terms. Gross negative emissions are the sum of emissions from all negative emissions technologies. However, in scenarios employing negative emissions technologies, positive emissions typically occur at the same time. For example, power production may be based on a mix of fossil fuel and BECCS technologies. Net negative emissions occur when gross negative emissions are large enough to more than offset positive emissions.

For the analysis supporting our main results, we excluded any scenarios in which industrialized country electricity sector emissions were substantially net negative in any year. Figure 6 shows that most 1.5 and 2 C scenarios contain net negative emissions in this sector, but there were still a substantial number of 2 C scenarios without net negative emissions, and several 1.5 C scenarios. They also show that scenarios with or without net negative emissions in this sector do not differ substantially in emissions pathways before 2050. That is, one set is not systematically higher or lower than the other over the first half of the century. In contrast, as a general rule, scenarios of global economy-wide carbon emissions with net negative emissions late in the century typically have higher emissions in the first few decades, compared to other scenarios. This occurs because meeting a given global temperature target requires limiting cumulative carbon emissions over the century to a particular total budget. Negative emissions late in the century allows for higher positive emissions early in the century, while staying within the same cumulative emissions budget. However, this relationship does not extend to emissions from a single sector in a single region, as is evident in Figure 6.

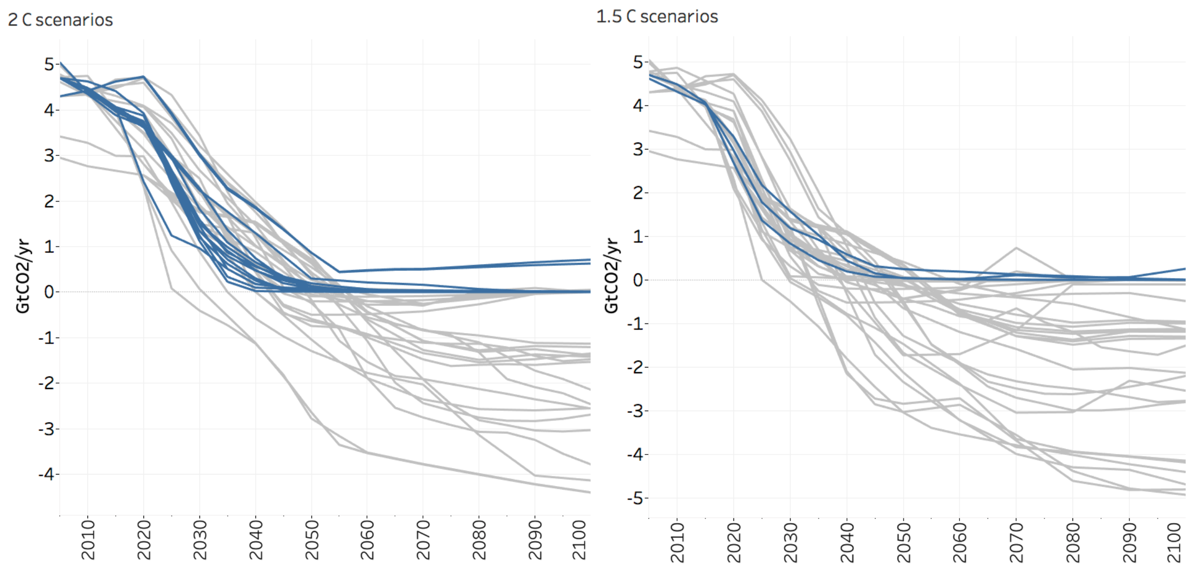


Figure 6: Electricity sector carbon emissions for industrialized countries in 2 C (left) and 1.5 C (right) scenarios, in billion tons of CO_2 per year. Gray lines represent scenarios with net negative emissions while blue lines do not decline substantially below zero throughout the time horizon.

While industrialized country electricity sector emissions remain net positive throughout 2100 in our subset of scenarios, some of these scenarios do include substantial use of CCS. Considering all scenarios achieving the 2 C target, about a third of cumulative economy-wide carbon emissions from industrialized countries are captured through CCS by 2100. However, most of this carbon capture occurs in the second half of the century (Figure 7). Specifically, the mean percentage of cumulative emissions from industrialized countries captured with CCS in 2 C scenarios is 31% (23% for 1.5 C scenarios). The mean percentage captured before 2050 is just 6%.

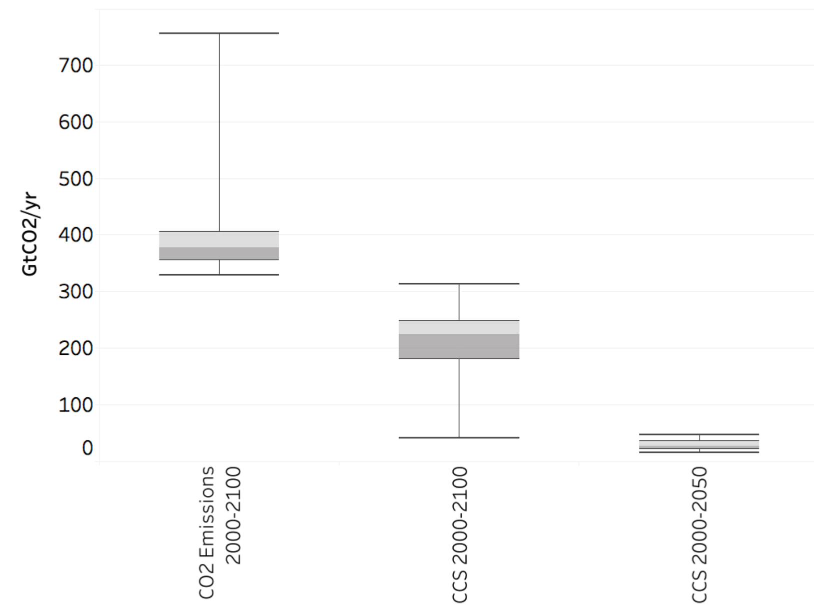


Figure 7: Cumulative total carbon emissions and CCS in industrialized countries for 2 C scenarios, in billion tons of CO_2.

Climate policy

Does the subset of scenarios used in this analysis assume a specific approach to climate policy that strongly affects the results?

One important factor affecting the nature of emissions pathways for achieving the 2 C or 1.5 C targets is the type of climate policy that is assumed in the models producing the scenarios. For example, if policies are assumed to begin immediately and be widespread globally, then global emissions reductions in the near term will be larger, and declines in emissions over later decades less steep, than they otherwise would be. In contrast, if policies are assumed to be phased in over time and apply more to some regions than others, global emissions will be higher in the near term and declines in emissions over later decades will be steeper. Results for emissions from particular sectors will also depend on whether policies are economy-wide or sector-specific.

The emissions scenarios we use in this report include a range of different assumptions and therefore do not reflect the influence of a particular approach to climate policy. While all scenarios assume eventual global participation in economy-wide mitigation, policies in the next two decades vary across scenarios. In some, mitigation begins in 2020 across all sectors and countries. In others, mitigation is global but is phased in over the next 20 years, and in others regionally differentiated mitigation occurs through 2030 before converging to global approaches.[8]

Energy demand

Do 1.5 C and 2 C scenarios tend to achieve these temperature goals by substantially reducing demand for energy, especially electricity in industrialized countries?

[8] IPCC SR 1.5 C, sections 2.3.1.3 and 2.3.5.

The IPCC Special Report found that scenarios achieving the 1.5 C temperature target tend to have a somewhat lower range of global energy demand than the group of all scenarios as a whole.[9] It is likely that this outcome results partly from assumptions in the scenarios about shifts in consumer behavior toward less energy intensive lifestyles, as well as from higher energy prices in these scenarios as a result of mitigation policies put in place to reduce emissions, which induce a reduction in demand.

However, examining demand for electricity (as opposed to energy as a whole) in industrialized countries, we find that scenarios achieving the 1.5 C or 2 C targets do not have particularly low energy demand relative to the range over all scenarios (Figure 8). If anything, they tend to cluster in the upper half of the range, consistent with the general finding that in low mitigation scenarios, a common outcome is for a shift toward electrification of the energy system (combined with decarbonization of electricity supply), which leads to somewhat higher demand for electricity than would otherwise be the case.[10]

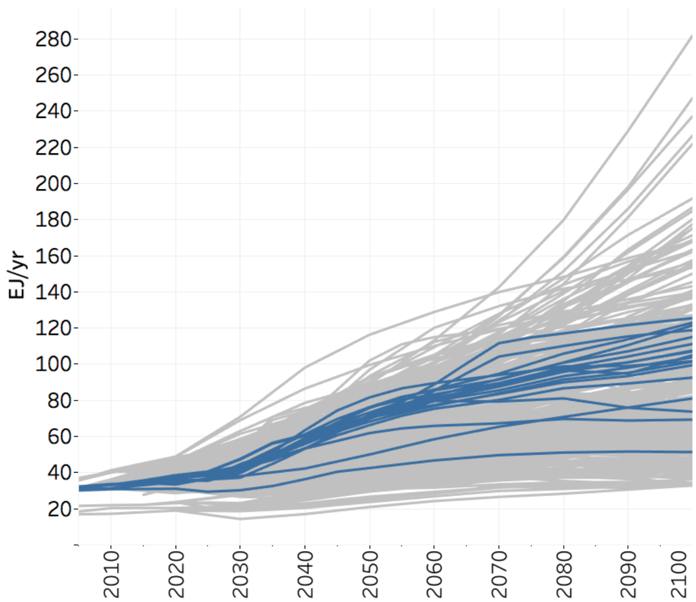


Figure 8: Final energy demand for electricity in industrialized countries in scenarios achieving 1.5 C or 2 C temperature targets (blue) version all other scenarios (gray) in the scenarios database, in exajoules (10^{18} joules) of energy use per year.

Land use

Do these scenarios imply exceptionally large amounts of land use in order to achieve the 1.5 C or 2 C temperature targets?

Many scenarios achieving low mitigation targets tend to use increasing amounts of bioenergy over the century, sometimes combined with carbon capture and storage. One of the risks of an energy system heavily reliant on bioenergy is substantial land use for producing biomass-based fuels, which can compete for land used for food production or set aside for the preservation of ecosystems. As shown in

[9] IPCC SR 1.5 C, section 2.3.1.1.
[10] IPCC SR 1.5 C, section 2.4.2.2.

Figure 9, the subset of scenarios used in this report do not have high amounts of land use for bioenergy in industrialized countries compared to other scenarios achieving 1.5 C or 2 C targets; in fact in the case of the 1.5 C target, the subset used here exhibits substantially less.

In the scenarios used for comparison to the Xcel Energy goals, land for energy crops reaches a maximum of about 120 million hectares in the industrialized countries (Figure 9) and not more than about 20% of total cropland used for energy crops.

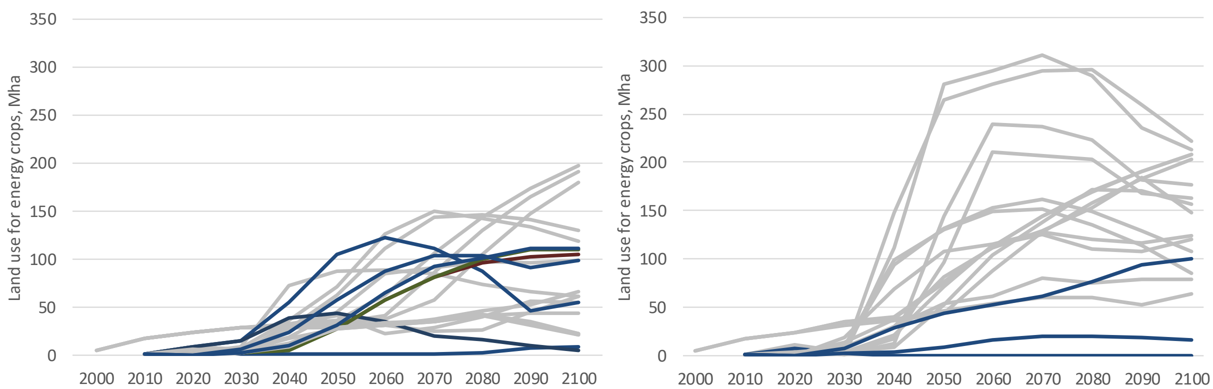


Figure 9: Land use for bioenergy crops in industrialized countries in in 2 C (left) and 1.5 C (right) scenarios, in millions of hectares. Gray lines represent scenarios with net negative emissions in the electricity sector while blue lines are scenarios in which emissions do not decline substantially below zero throughout the time horizon. Fewer scenarios are plotted in this figure compared to figures 3, 5 and 6 because not all modeling groups reported results for land used for bioenergy production.

Non-CO_2 emissions

Do these scenarios imply exceptionally large reductions in emissions of non-CO_2 greenhouse gases?

Although carbon dioxide is the main human-caused greenhouse gas, emissions of several other gases make substantial contributions to projected future warming, most importantly methane (CH_4) and nitrous oxide (N_2O), as well as a range of halocarbons. Reductions in emissions of these non-CO_2 greenhouse gases can contribute to achieving temperature targets.

However, achieving the 1.5 C and 2 C temperature targets is dominated by reductions in carbon emissions.[11] Reductions in methane and nitrous oxide are made to a lesser extent because known options for mitigation of emissions of these gases are more limited. Both gases have substantial sources in the agriculture sector (for example from livestock production and from nitrogen fertilizers) and therefore significant emissions remain even in low warming scenarios.

[11] IPCC SR 1.5 C, section 2.3.3.1.