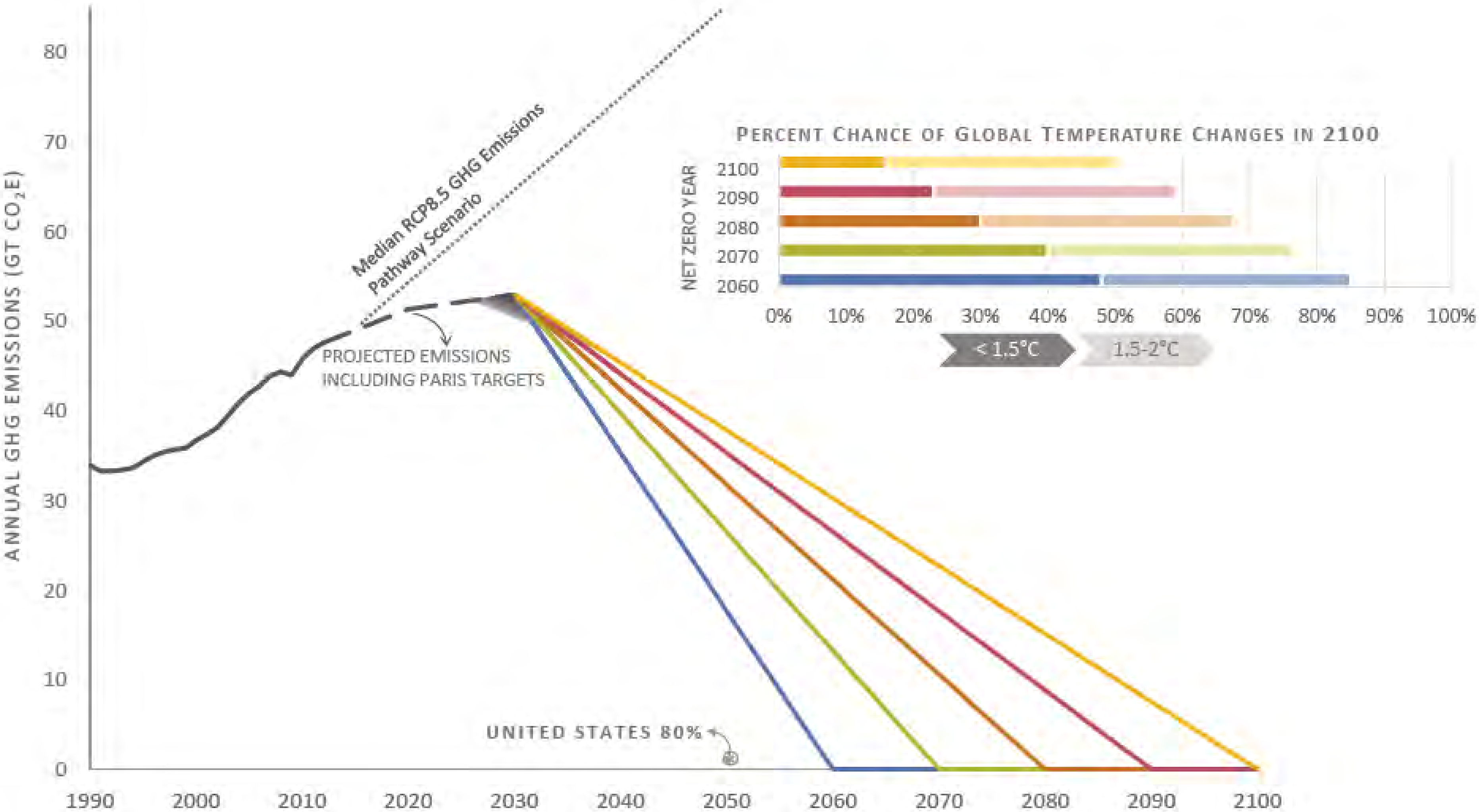
United States Mid-Century Strategy
FOR DEEP DECARBONIZATION

NOVEMBER 2016

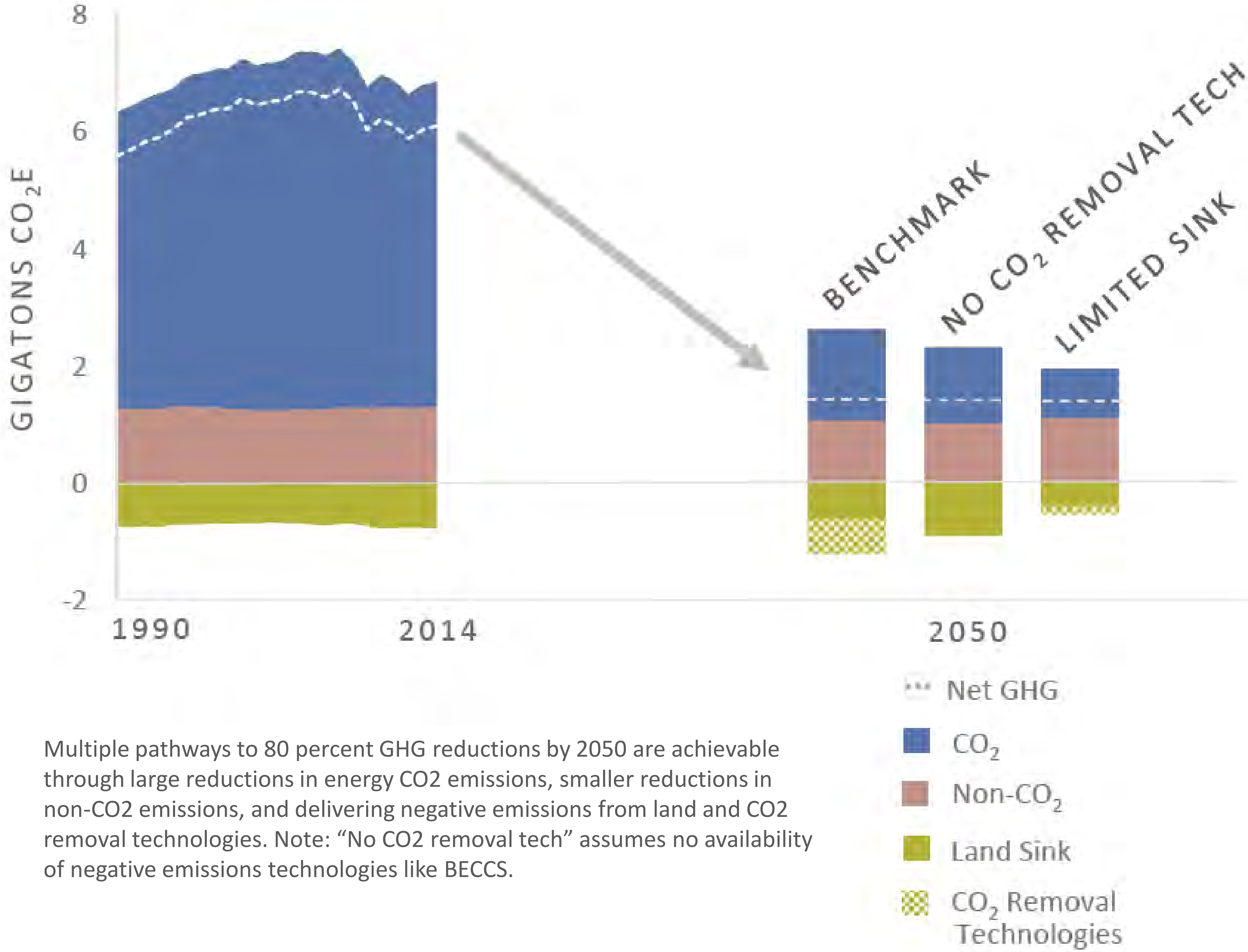
Global emissions trajectories to net-zero GHG emissions and probability of global temperature changes



The United States MCS puts the nation on a path consistent with a successful global outcome. Achieving the Paris Agreement temperature goals will require increasing global ambition leading to 2030 and steep reductions to net-zero global GHG emissions following 2030. We show the probability of staying below 2°C and 1.5°C across global scenarios by 2100. While there could be an overshoot of the Paris Agreement temperature objectives before 2100, achieving net-zero GHG emissions globally could bring temperatures below peak levels in 2100 and beyond.

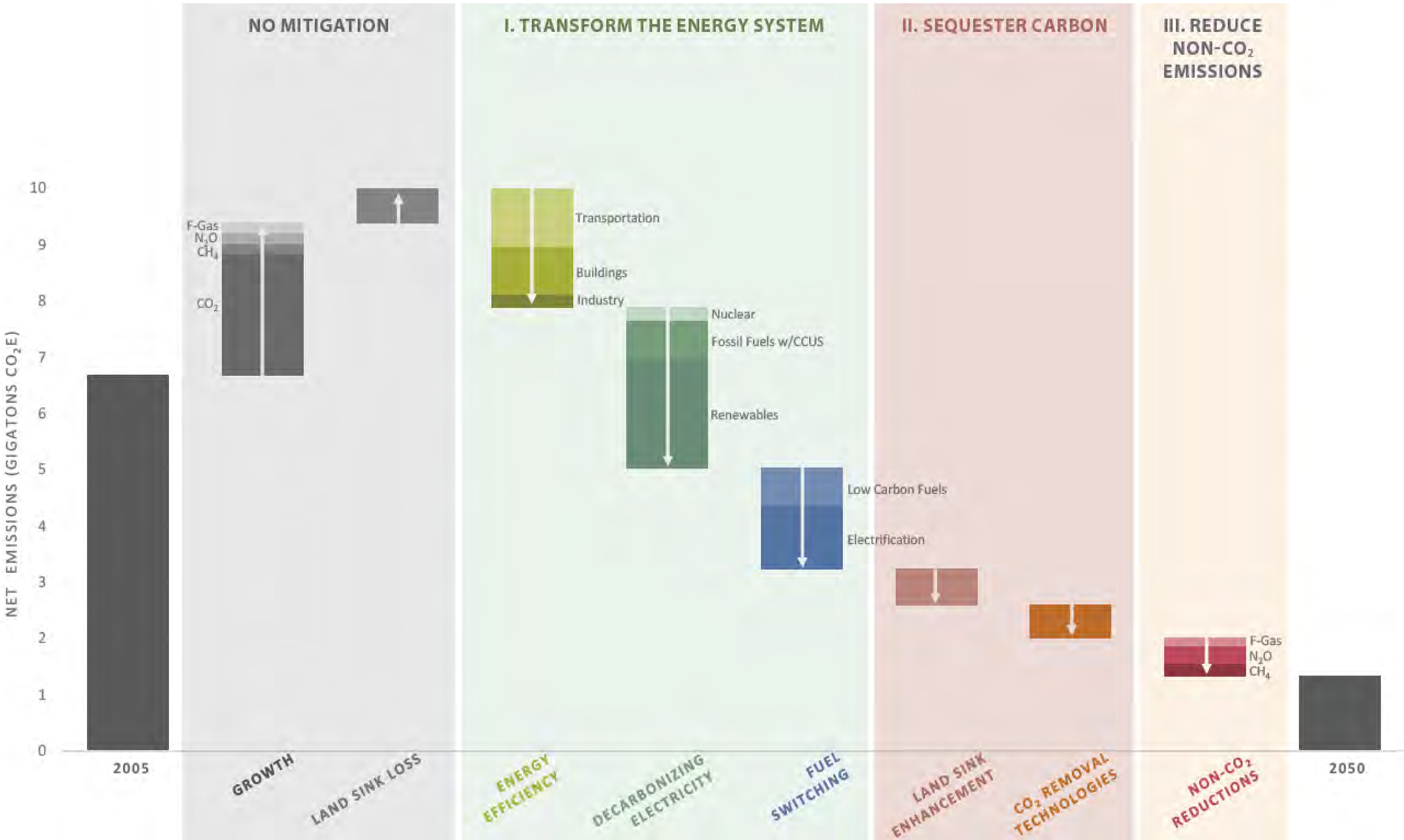

A VISION
FOR 2050

U.S. Net GHG Emissions under three MCS scenarios



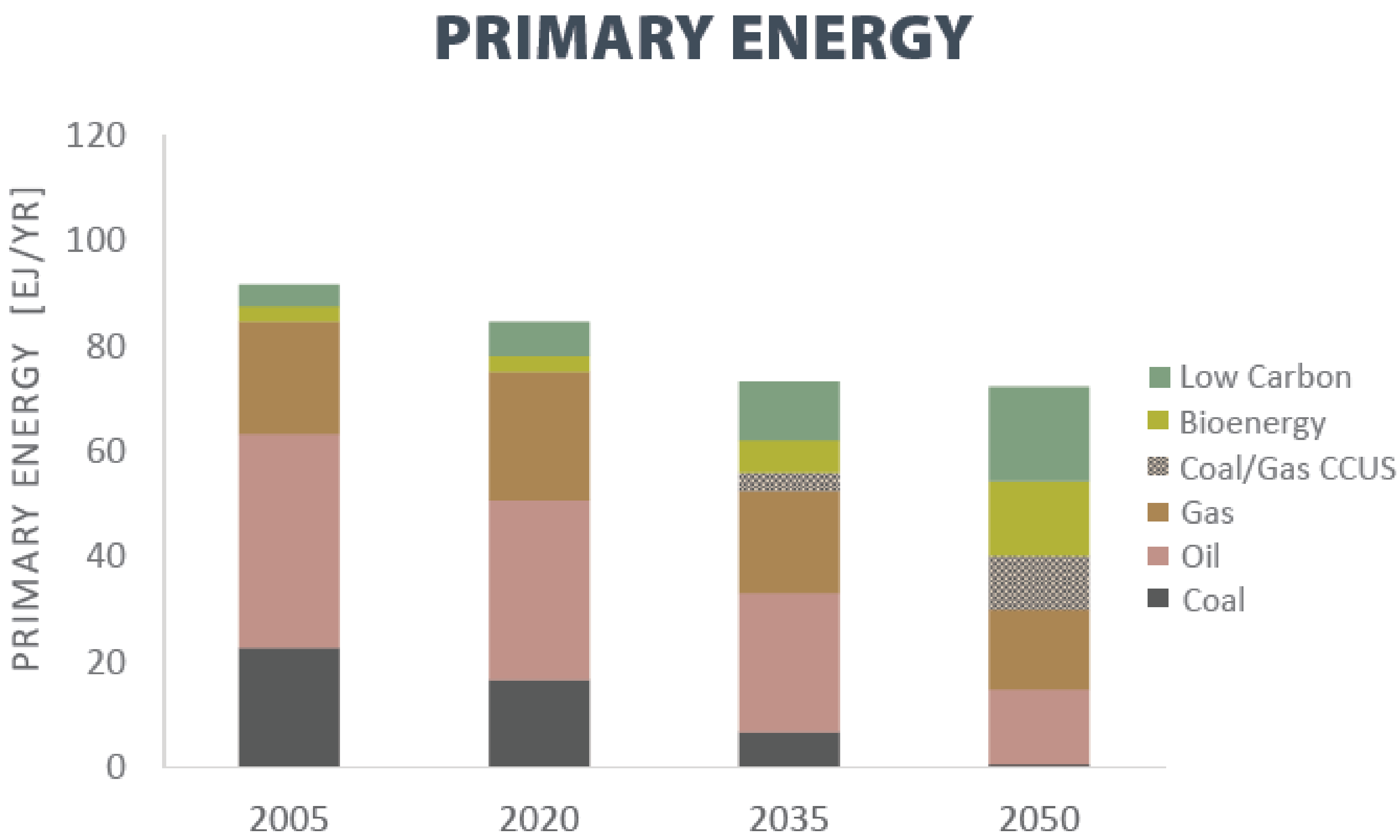
Multiple pathways to 80 percent GHG reductions by 2050 are achievable through large reductions in energy CO2 emissions, smaller reductions in non-CO2 emissions, and delivering negative emissions from land and CO2 removal technologies. Note: “No CO2 removal tech” assumes no availability of negative emissions technologies like BECCS.

Components of MCS 80 Percent GHG Reductions in MCS Benchmark Scenario



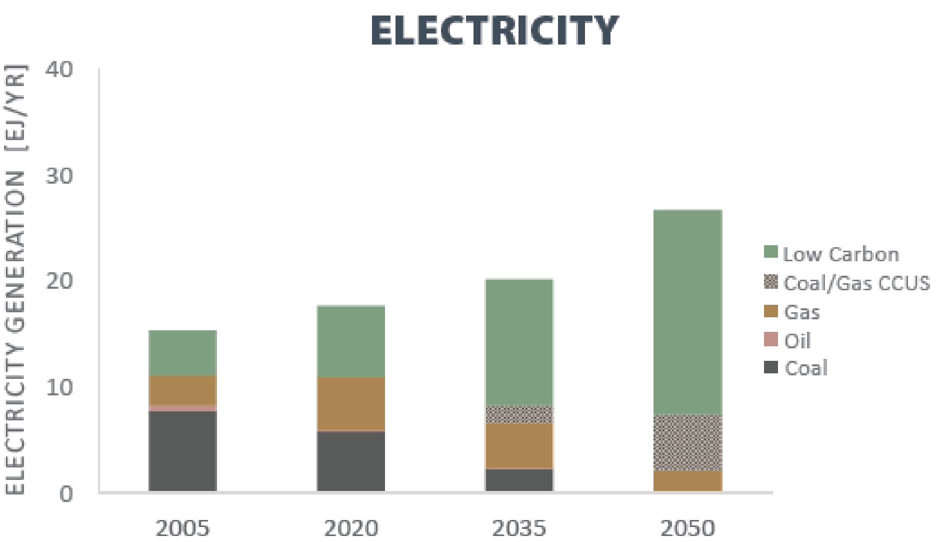
DECARBONIZING THE U.S. ENERGY SYSTEM

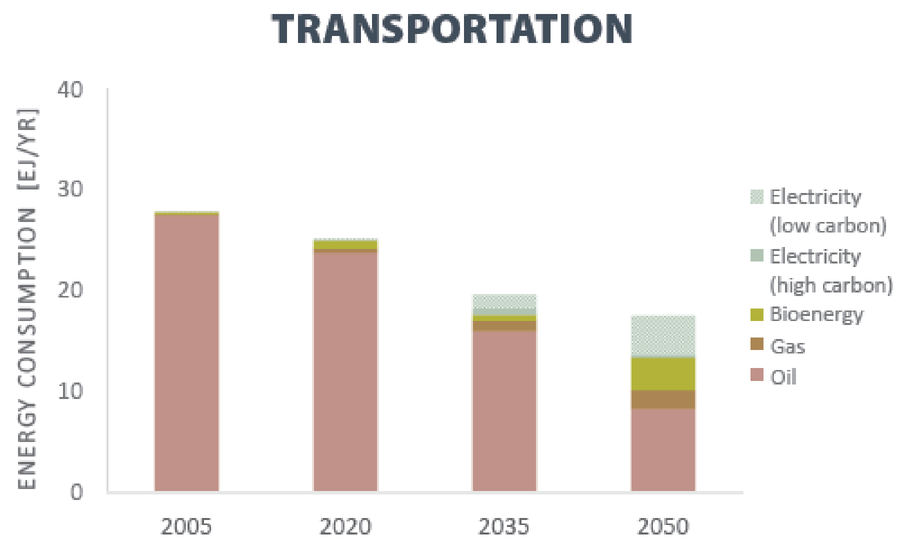
U.S. ENERGY SYSTEM TRANSITION BY SECTOR IN MCS BENCHMARK SCENARIO

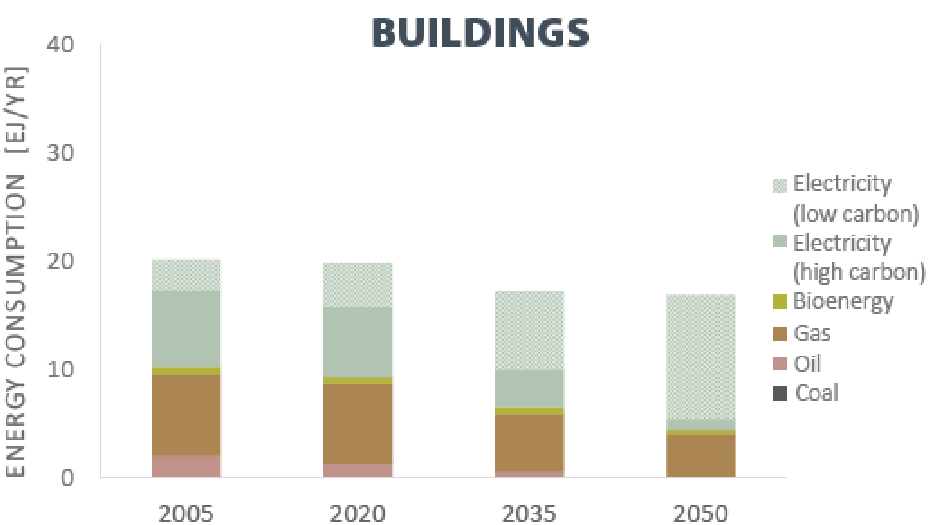


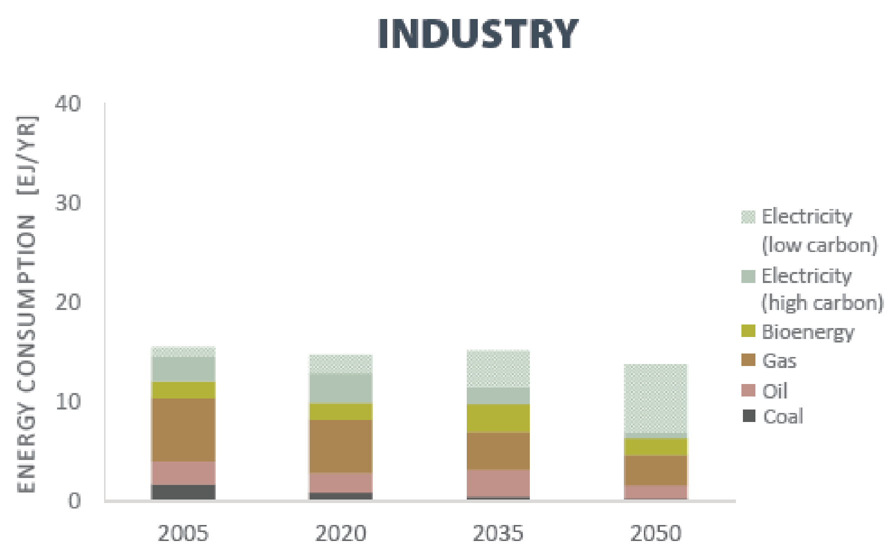
Primary Energy declines over time with a growing economy as a result of improved energy efficiency across sectors. The electricity system is nearly decarbonized by 2050, and electricity production increases to support electrification across transportation, buildings, and industry. Efficiency increases markedly in the transportation sector, largely through the deployment of electric vehicles, which consume 1.6 to 3.7 times less energy per mile than conventional vehicles.

U.S. ENERGY SYSTEM TRANSITION BY SECTOR IN MCS BENCHMARK SCENARIO



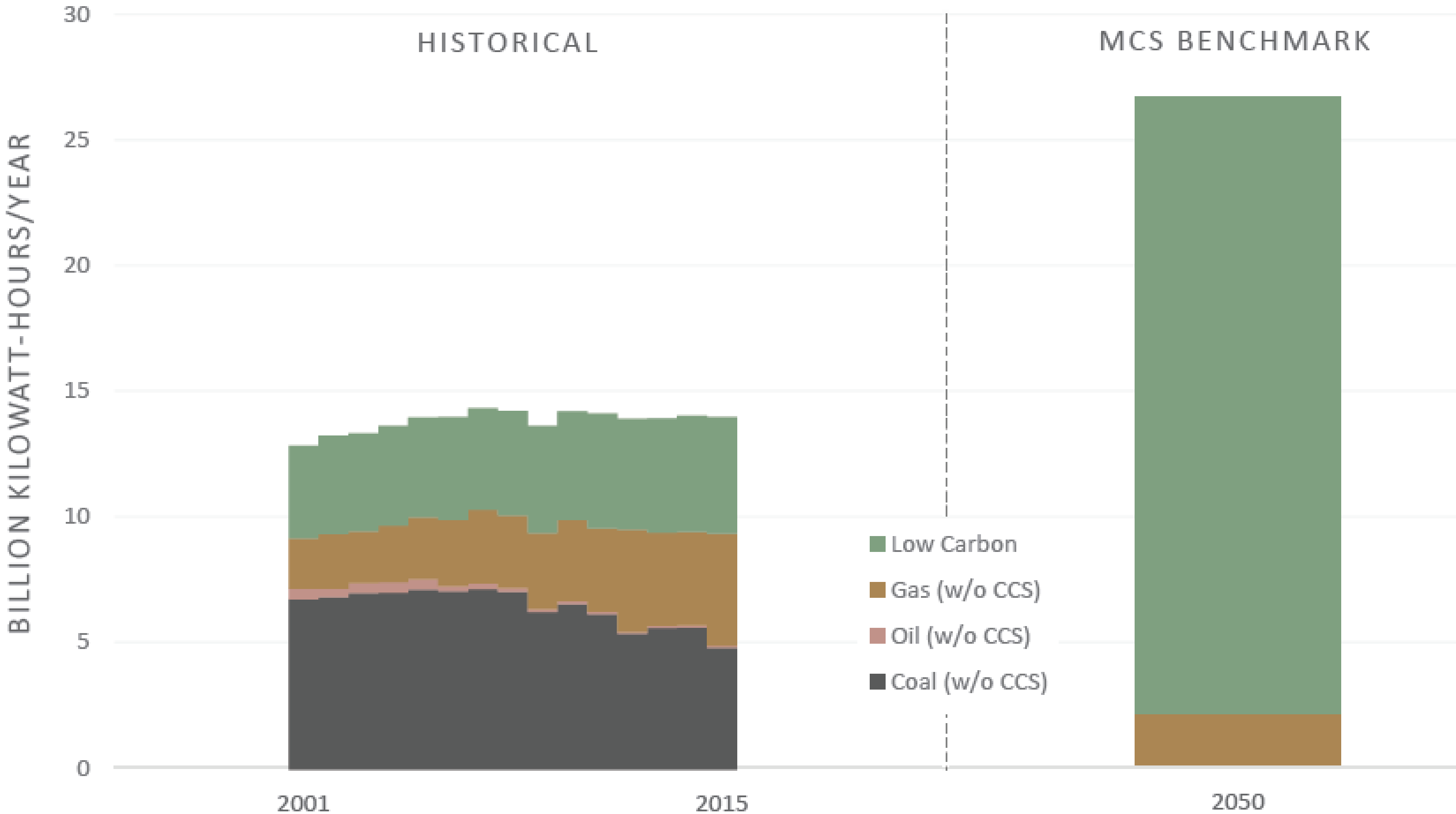




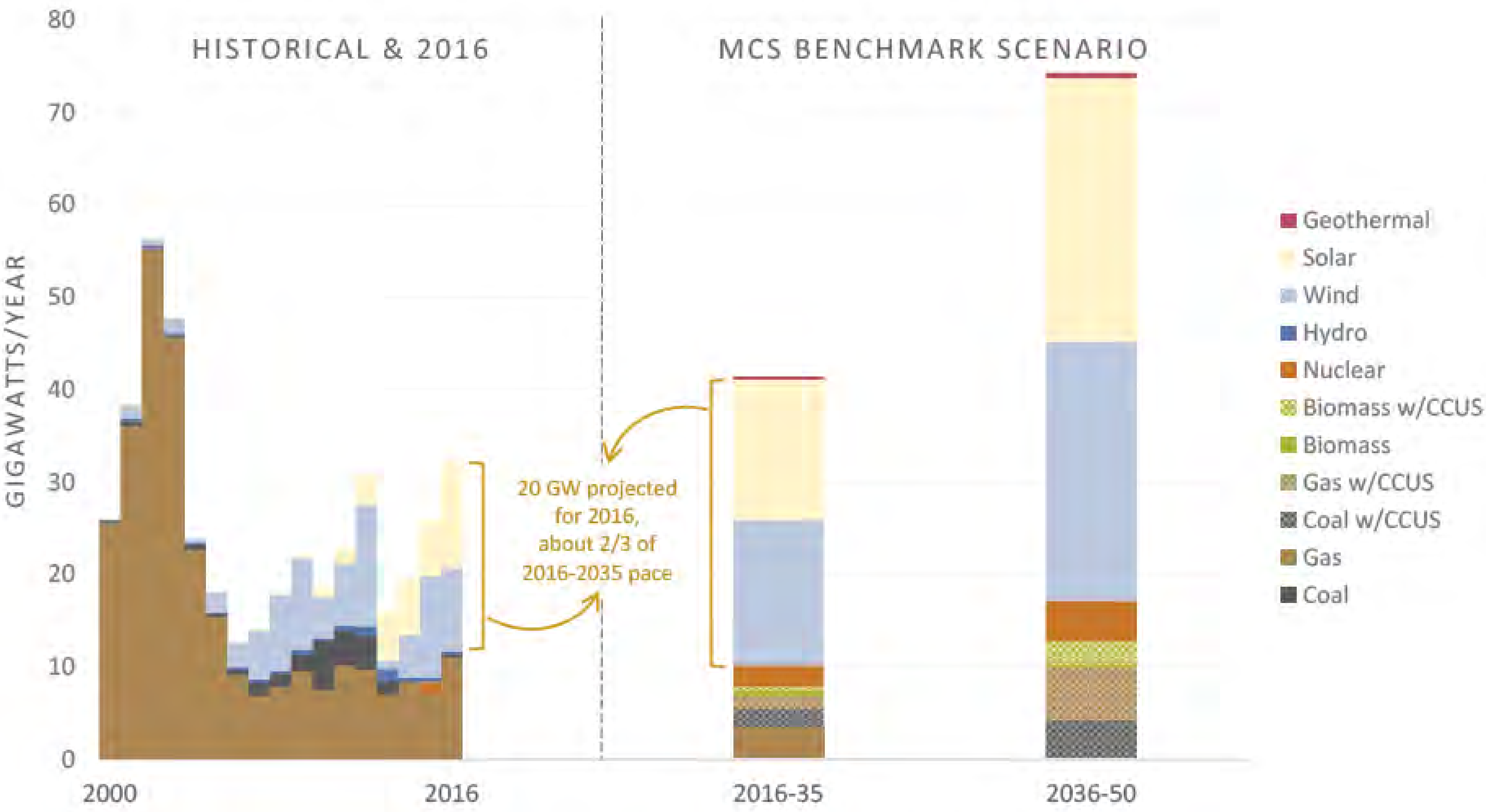


Primary Energy declines over time with a growing economy as a result of improved energy efficiency across sectors. The electricity system is nearly decarbonized by 2050, and electricity production increases to support electrification across transportation, buildings, and industry. Efficiency increases markedly in the transportation sector, largely through the deployment of electric vehicles, which consume 1.6 to 3.7 times less energy per mile than conventional vehicles.

Net Generation in the Electric Power Sector, Historical and MCS Benchmark Scenario

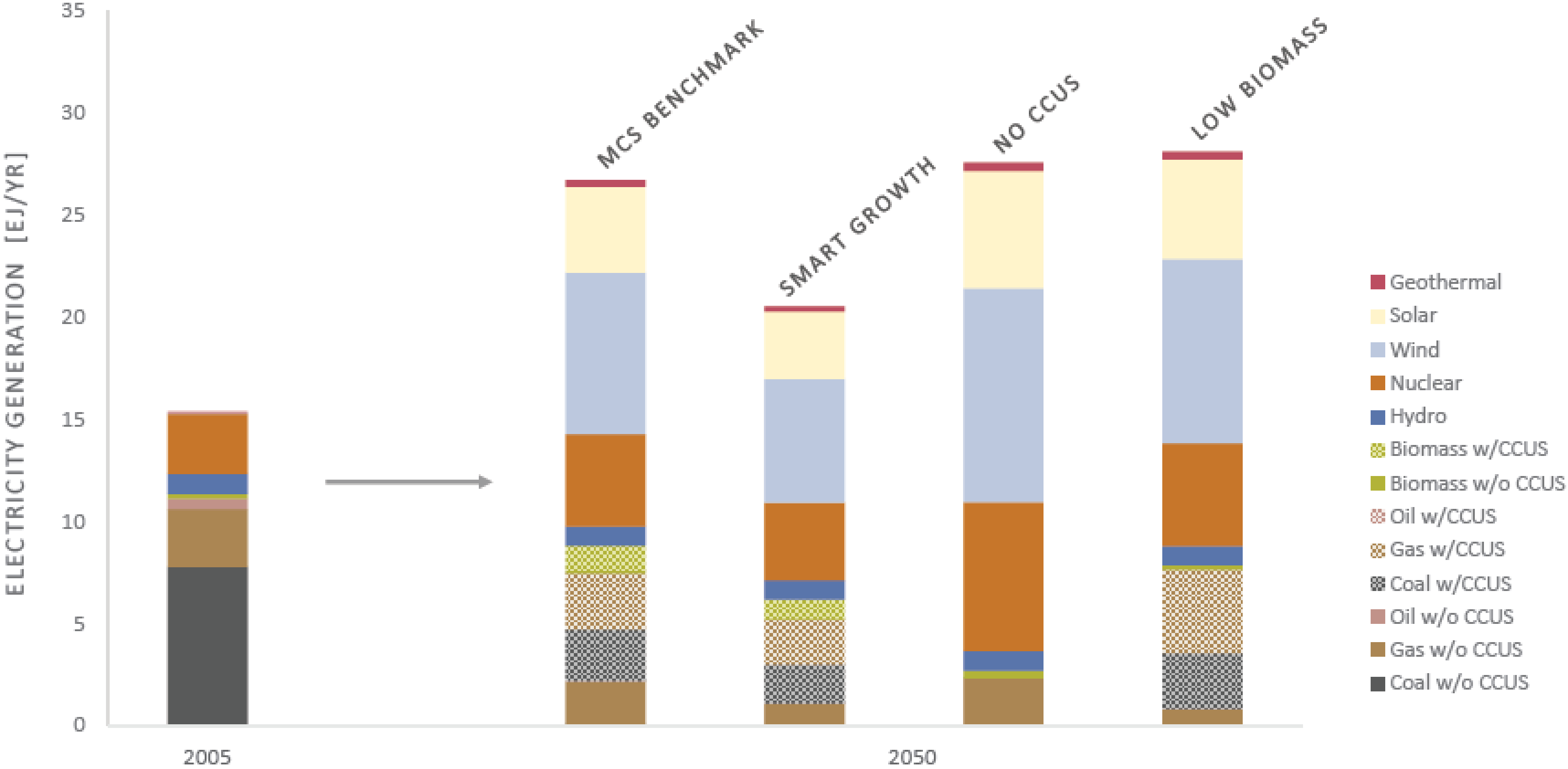


Average Annual Capacity Additions by Fuel, Historical and MCS Benchmark Scenario

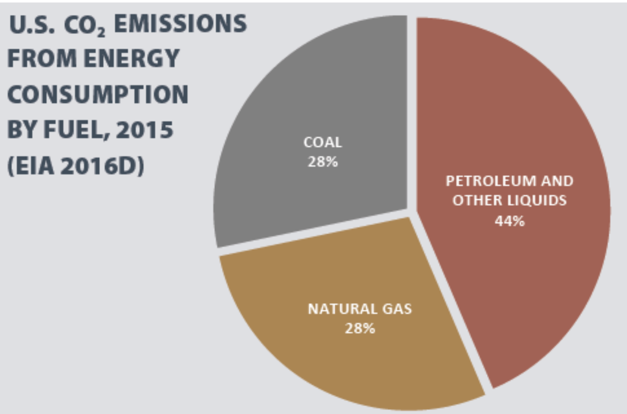


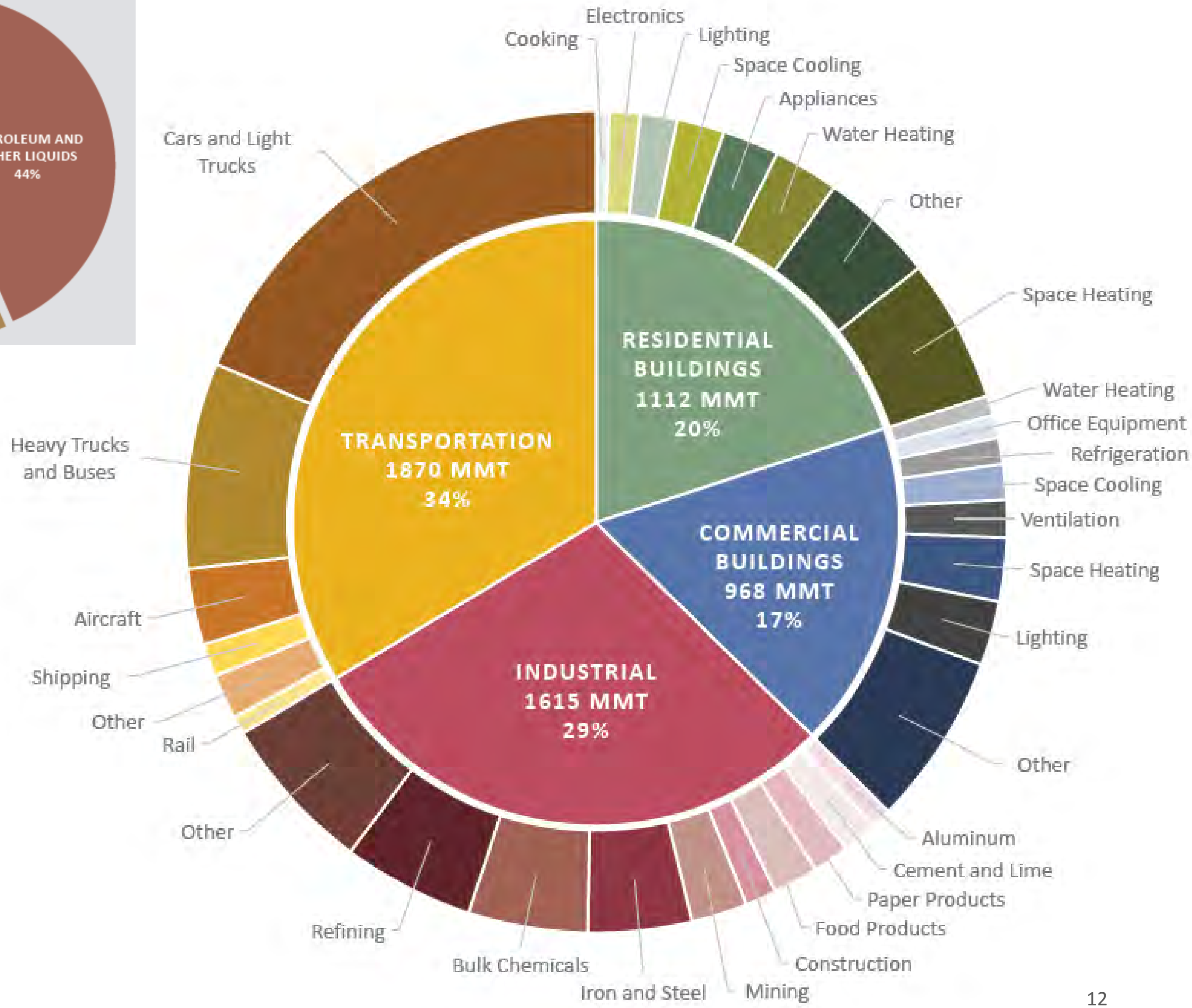
Note: The United States is projected to deploy 100 GW of additional wind and solar generation in 2016-2021 in part due to tax incentives finalized in 2015 (Mai et al. 2016). Source: 2016 data are AEO 2016 reference case projections (EIA 2016a; MCS analysis).

ELECTRICITY GENERATION ACROSS MCS SCENARIOS

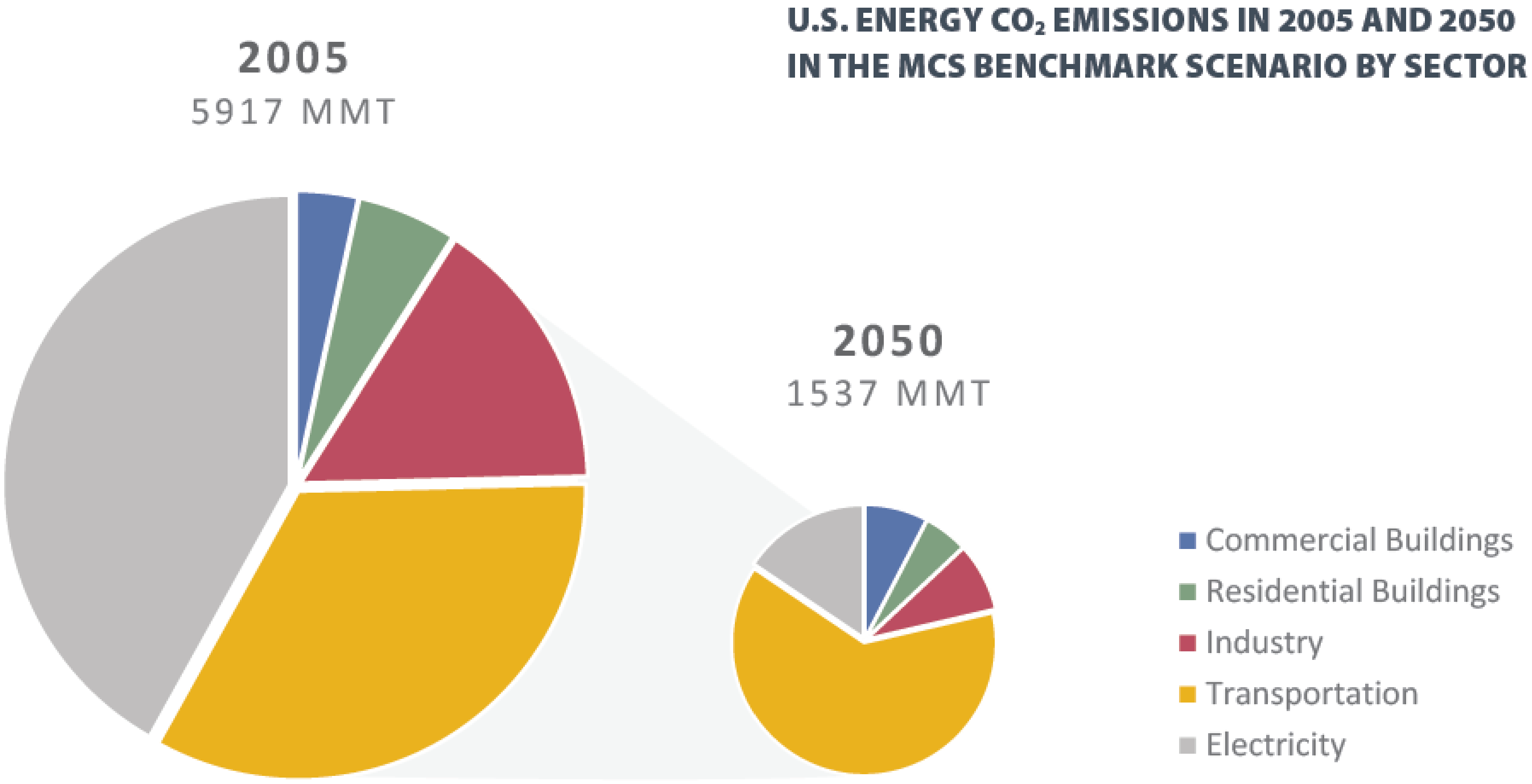


CO_2 Emissions by Sector and End Use with Electricity Distributed Across End-Use Sectors, 2014



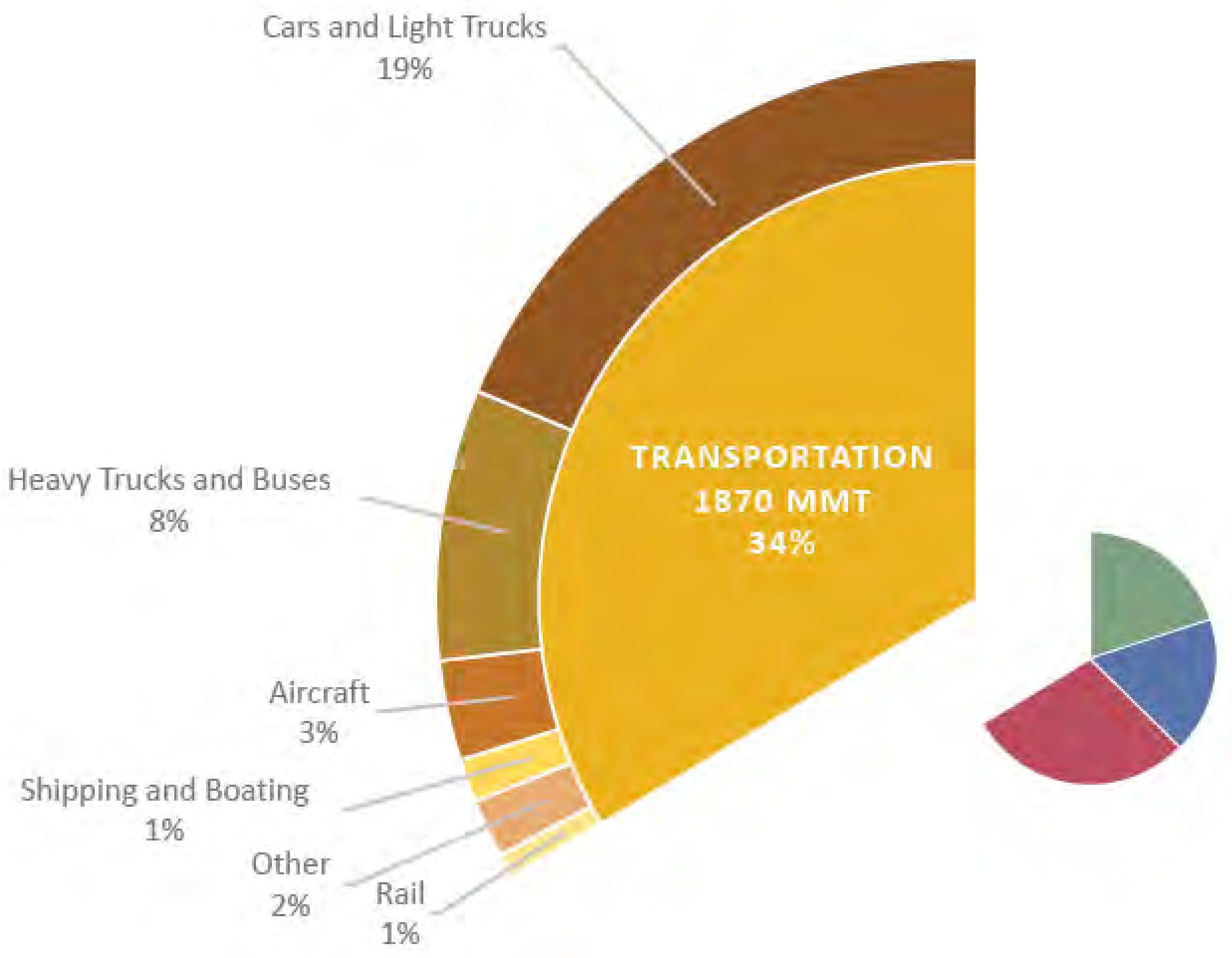


THE MCS VISION FOR A LOW-CARBON U.S. ENERGY SYSTEM IN 2050

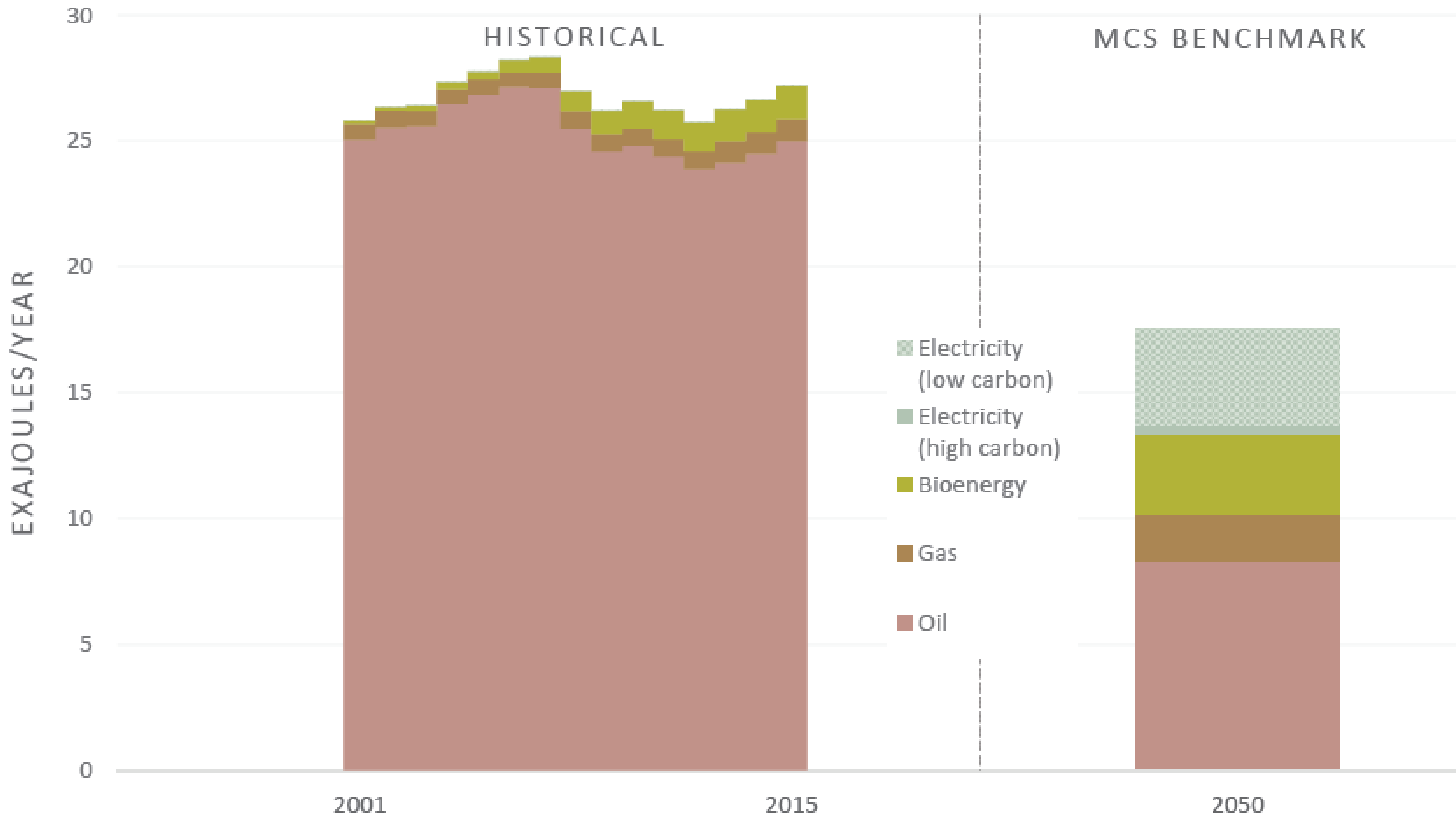


Note: The 2050 chart does not account for the negative emissions generated by CO2 removal technologies, resulting in 963 MMT CO2 of net emissions in the energy sector.

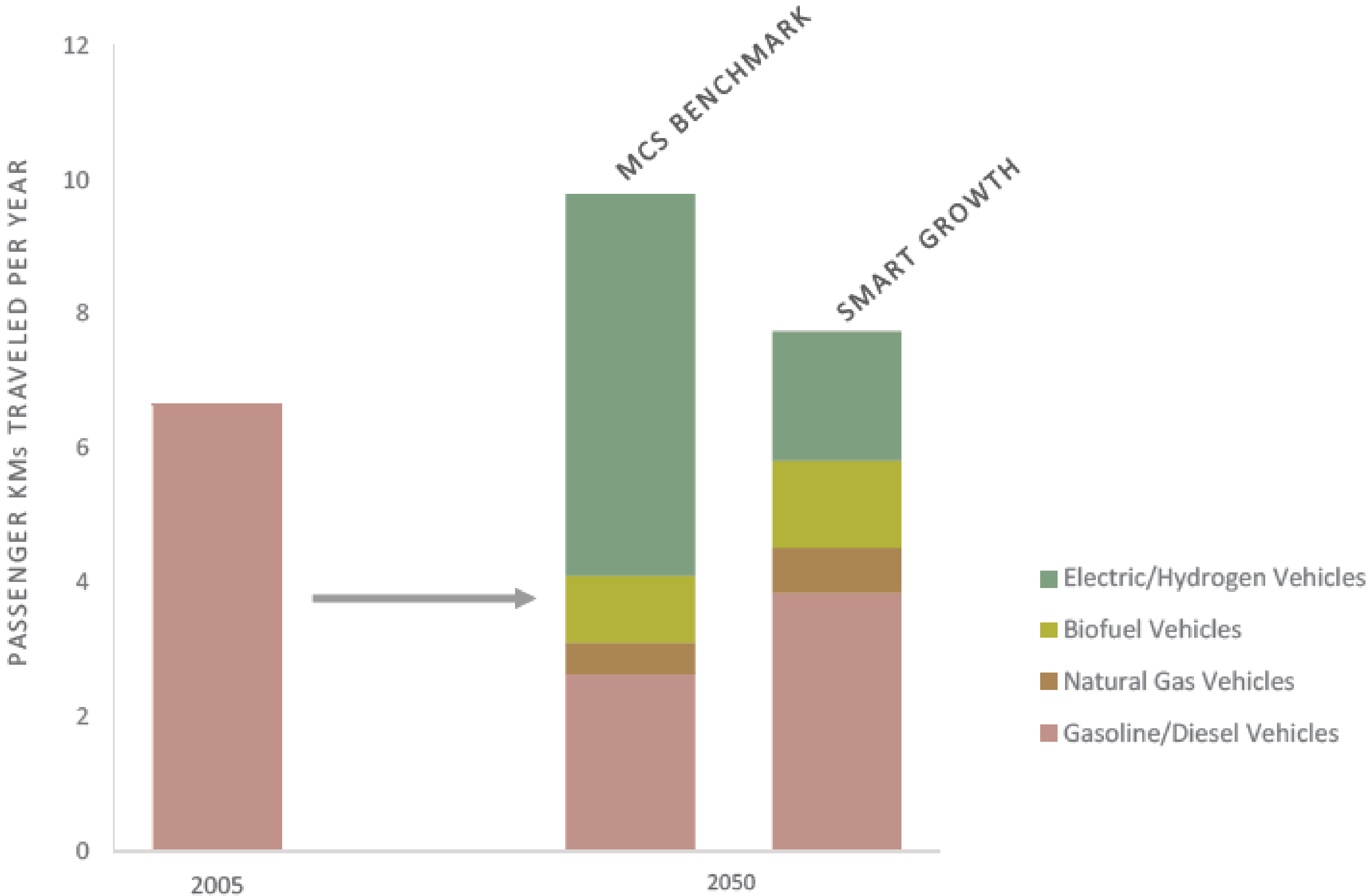
CO_2 Emissions by Sector and End Use with Electricity Distributed Across End-Use Sectors, 2014



Transportation Sector Energy Use, Historical and MCS Benchmark Scenario

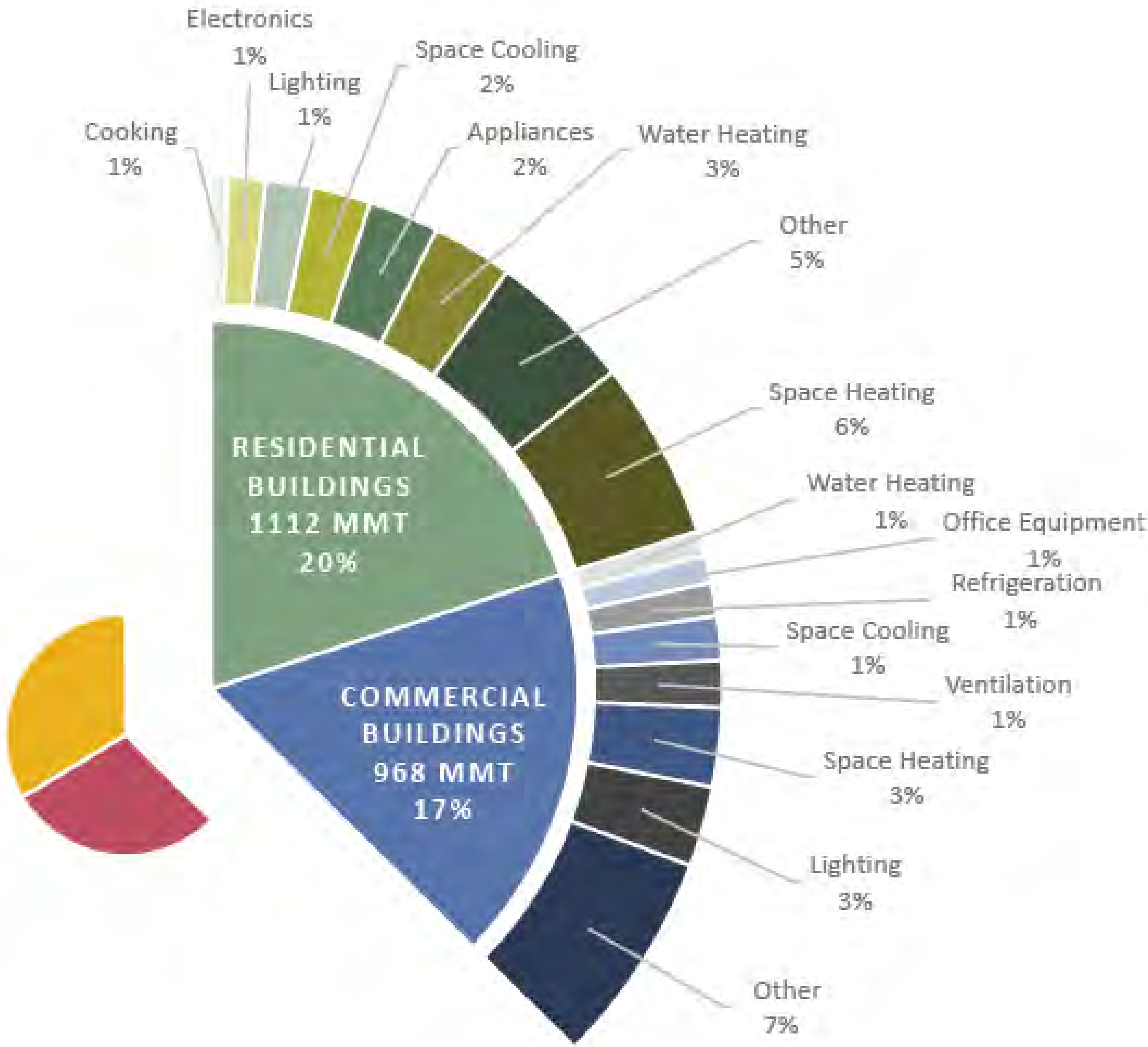


U.S. Light-Duty Vehicles Miles Travelled in the MCS

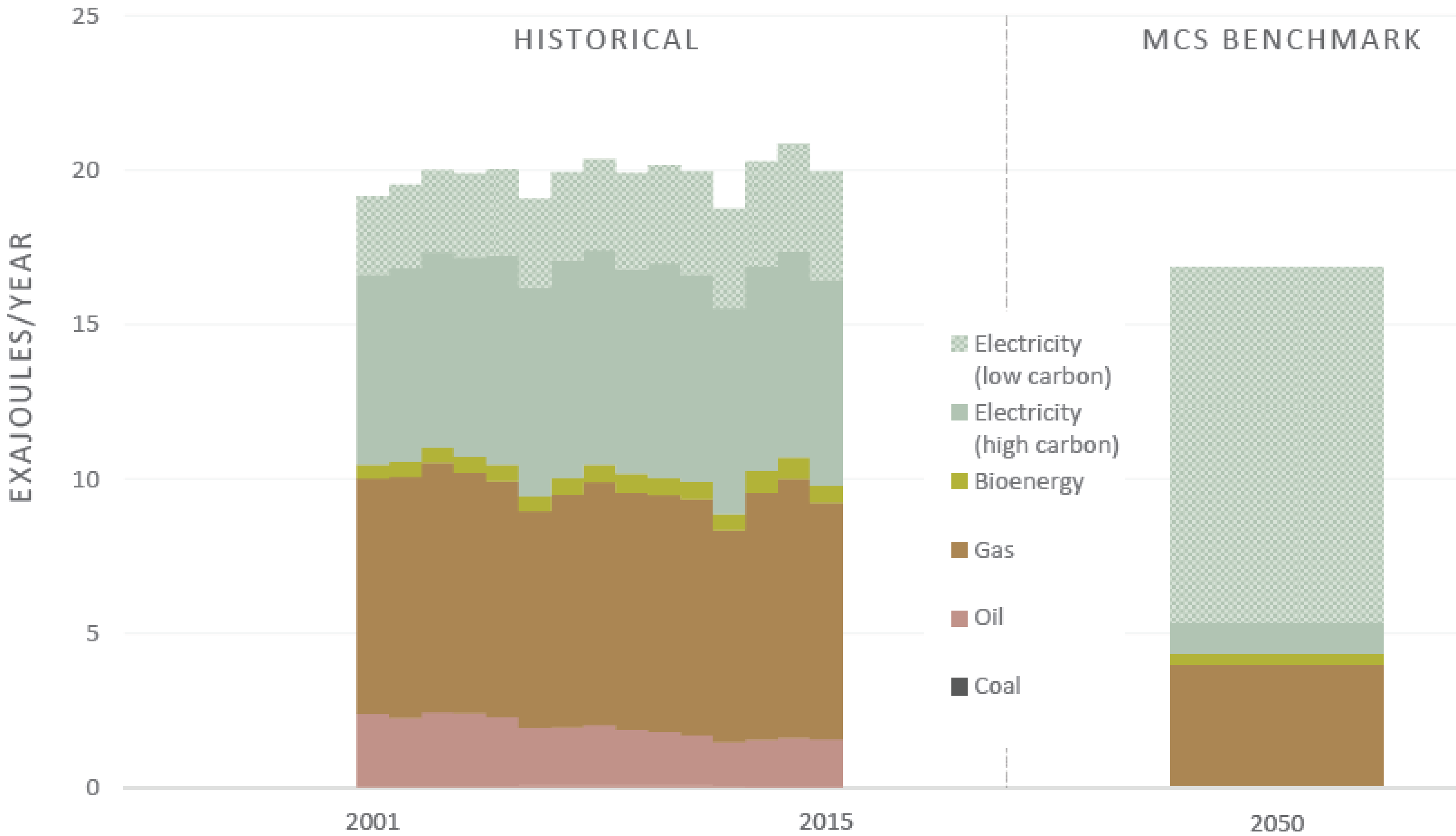


MCS analysis highlights two pathways to a low GHG transportation sector, with an aggressive deployment pathway for clean vehicles in the MCS Benchmark Scenario and the “Smart Growth” scenario focusing on improved mass transit and urban planning.

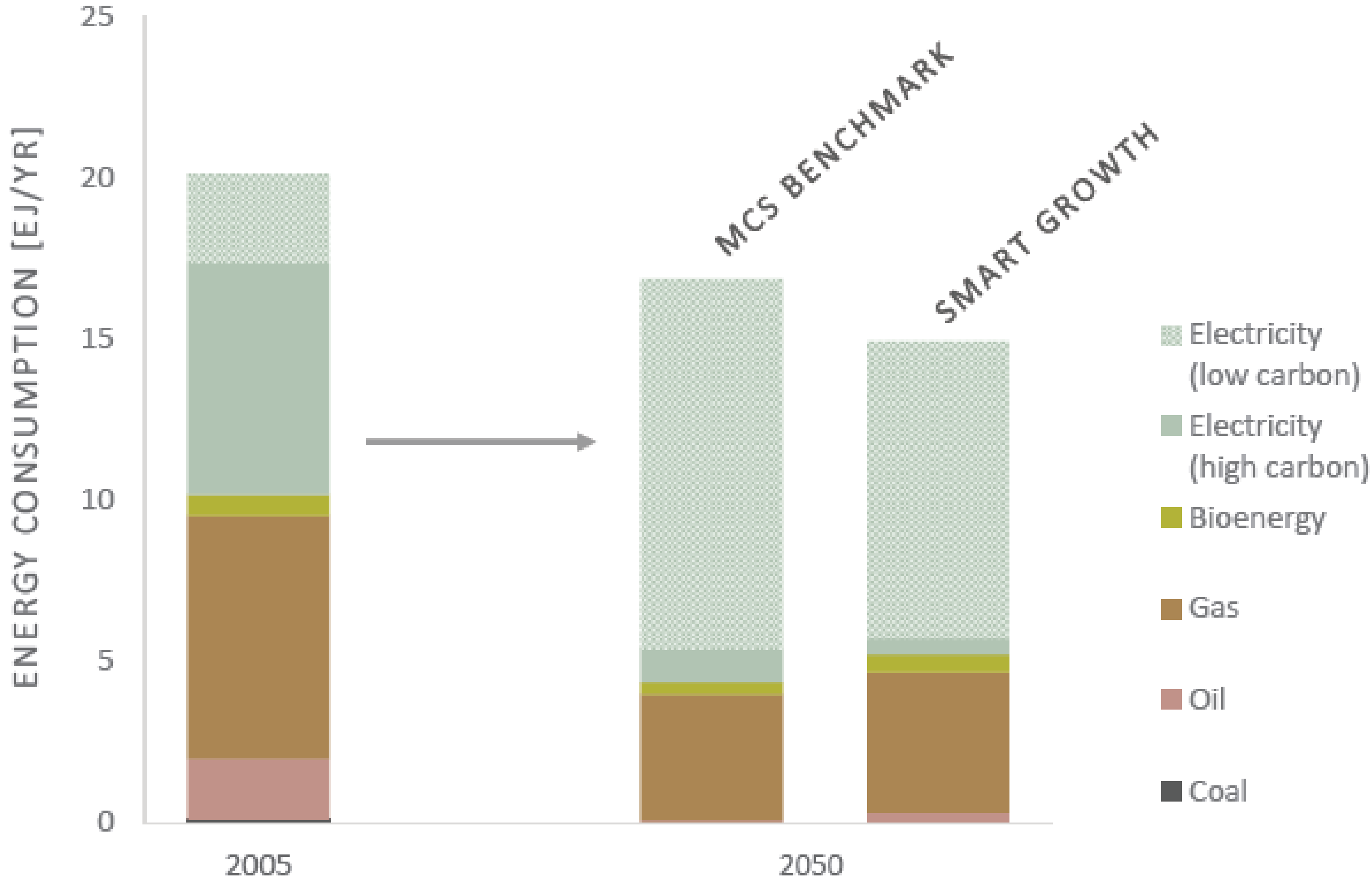
CO_2 Emissions by Sector and End Use with Electricity Distributed Across End-Use Sectors, 2014



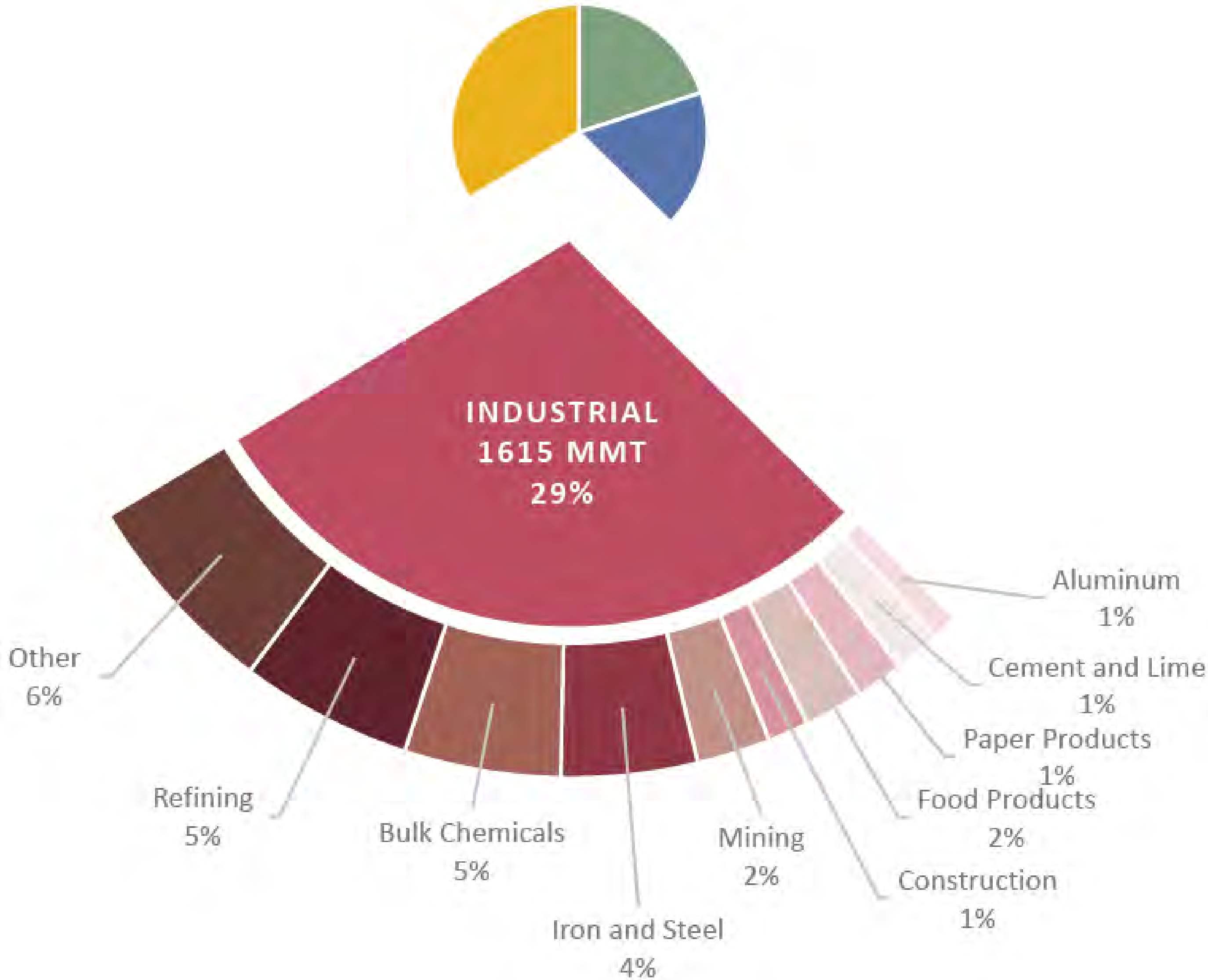
BUILDING SECTOR ENERGY USE, HISTORICAL AND MCS BENCHMARK SCENARIO



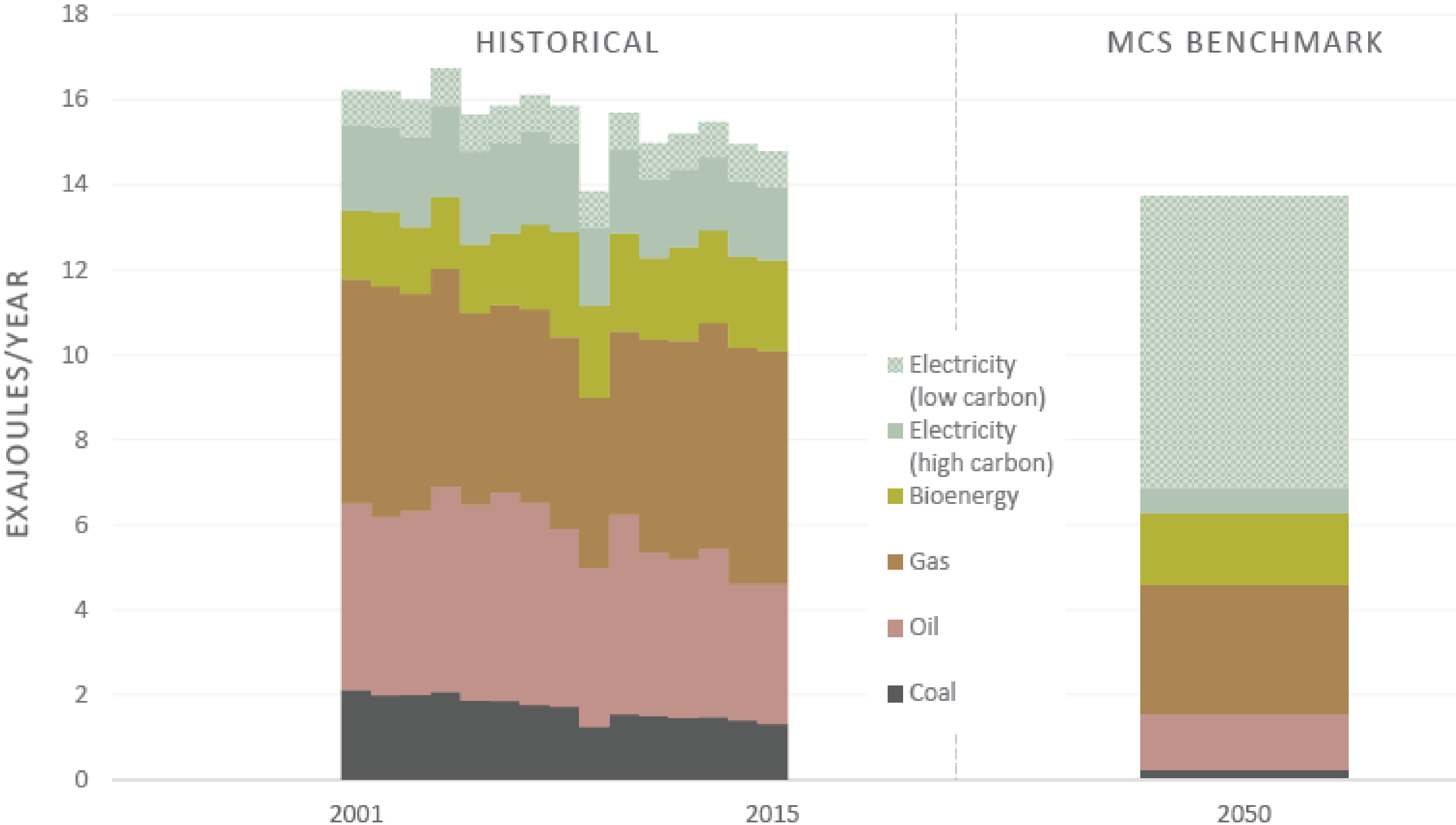
Building Sector Energy Use, Historical and MCS



CO_2 Emissions by Sector and End Use with Electricity Distributed Across End-Use Sectors, 2014

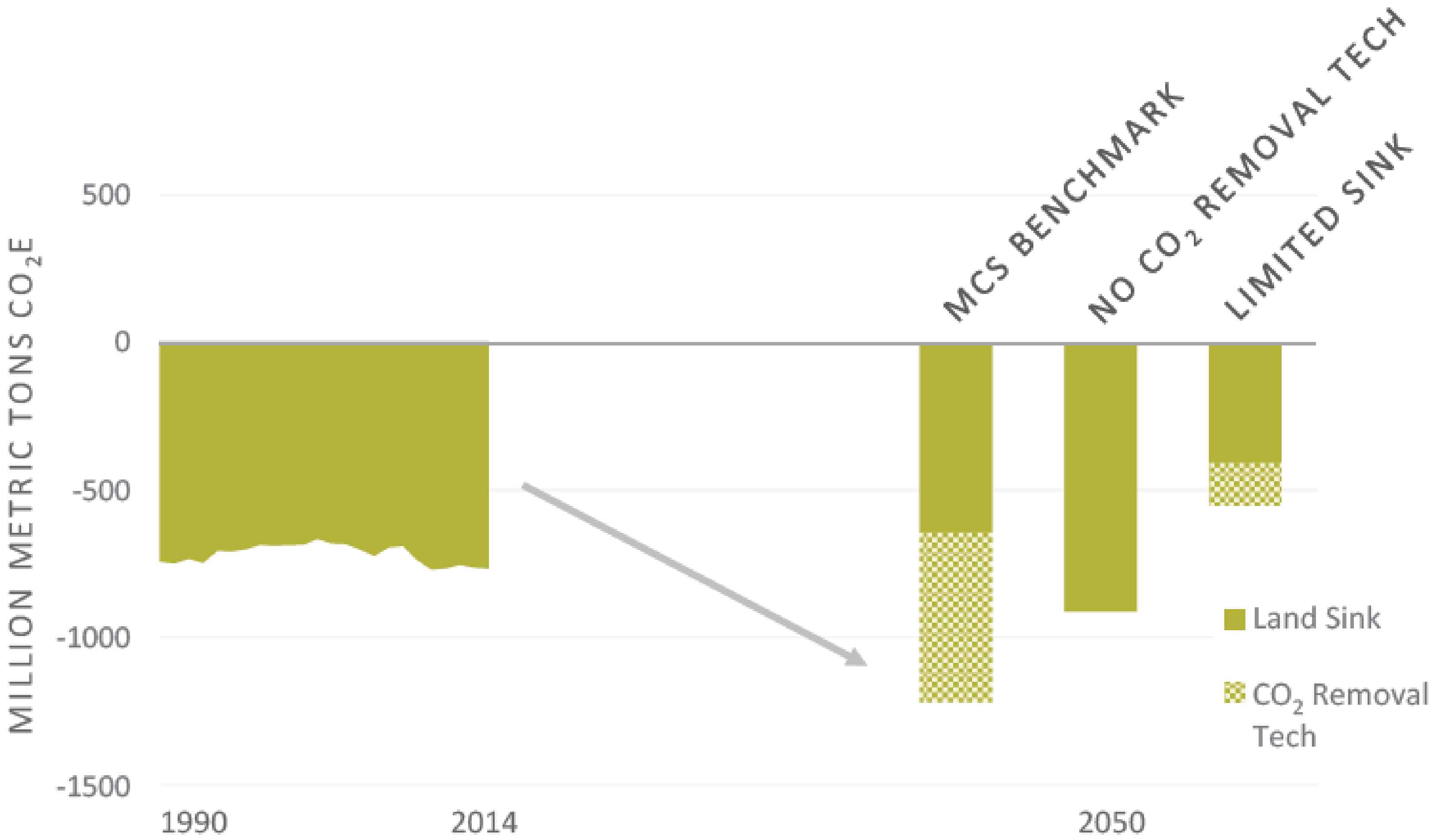


Industrial Sector Energy Use, Historical and MCS Benchmark Scenario

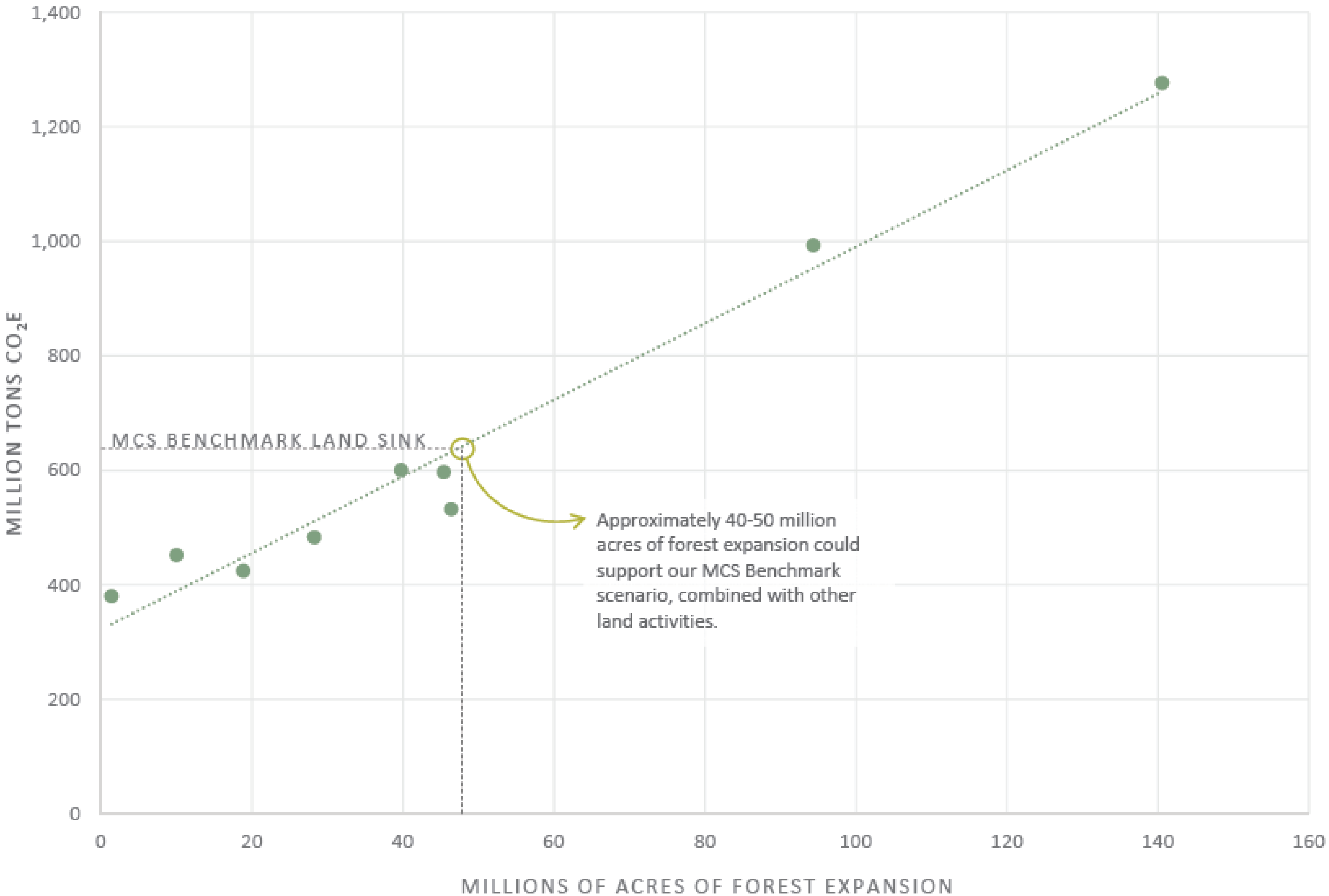


STORING CARBON AND REDUCING EMISSIONS WITH U.S. LANDS

MCS Negative Emissions Scenarios

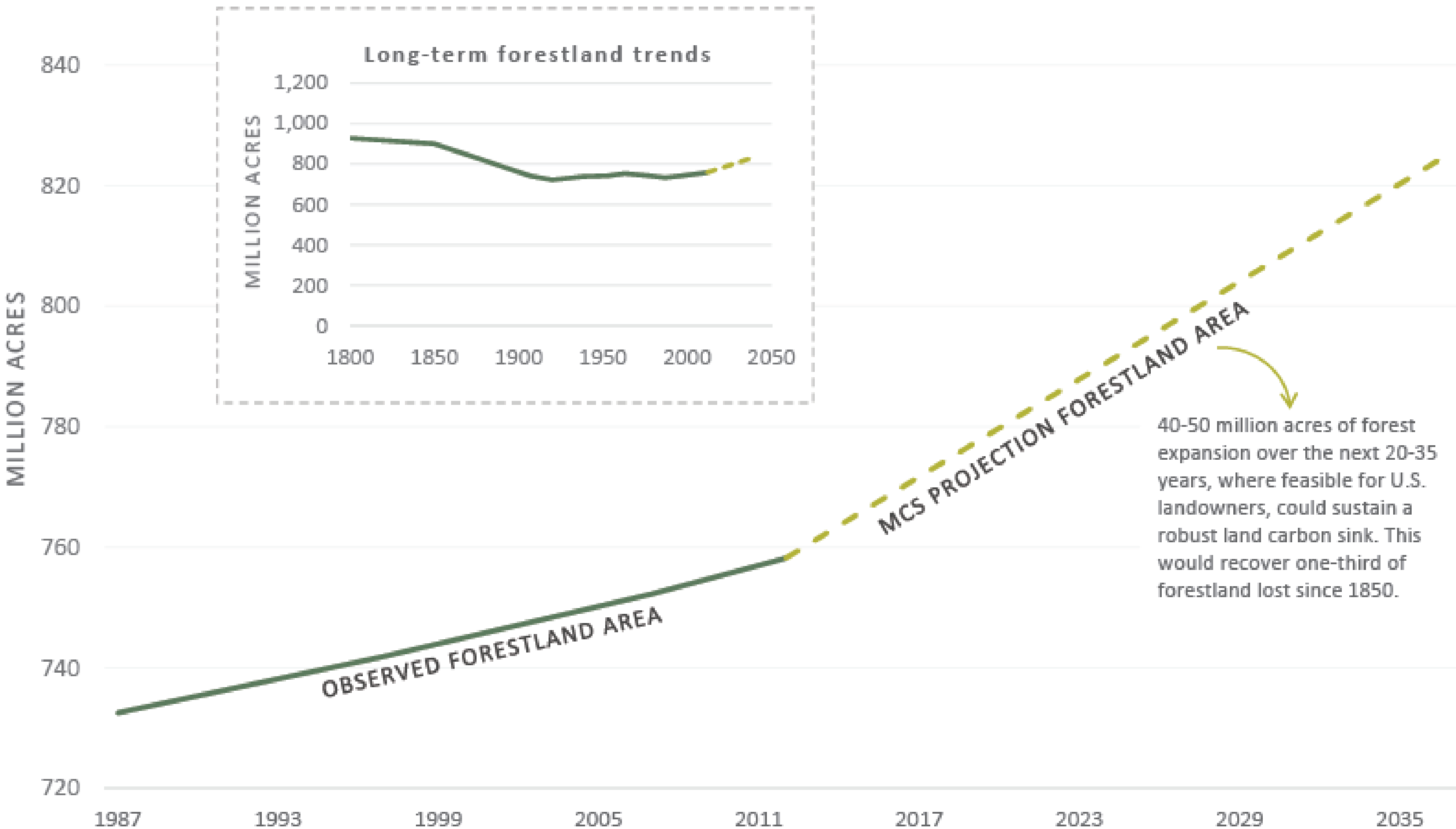


Cumulative Afforestation and Average Annual CO_2 Stock Change



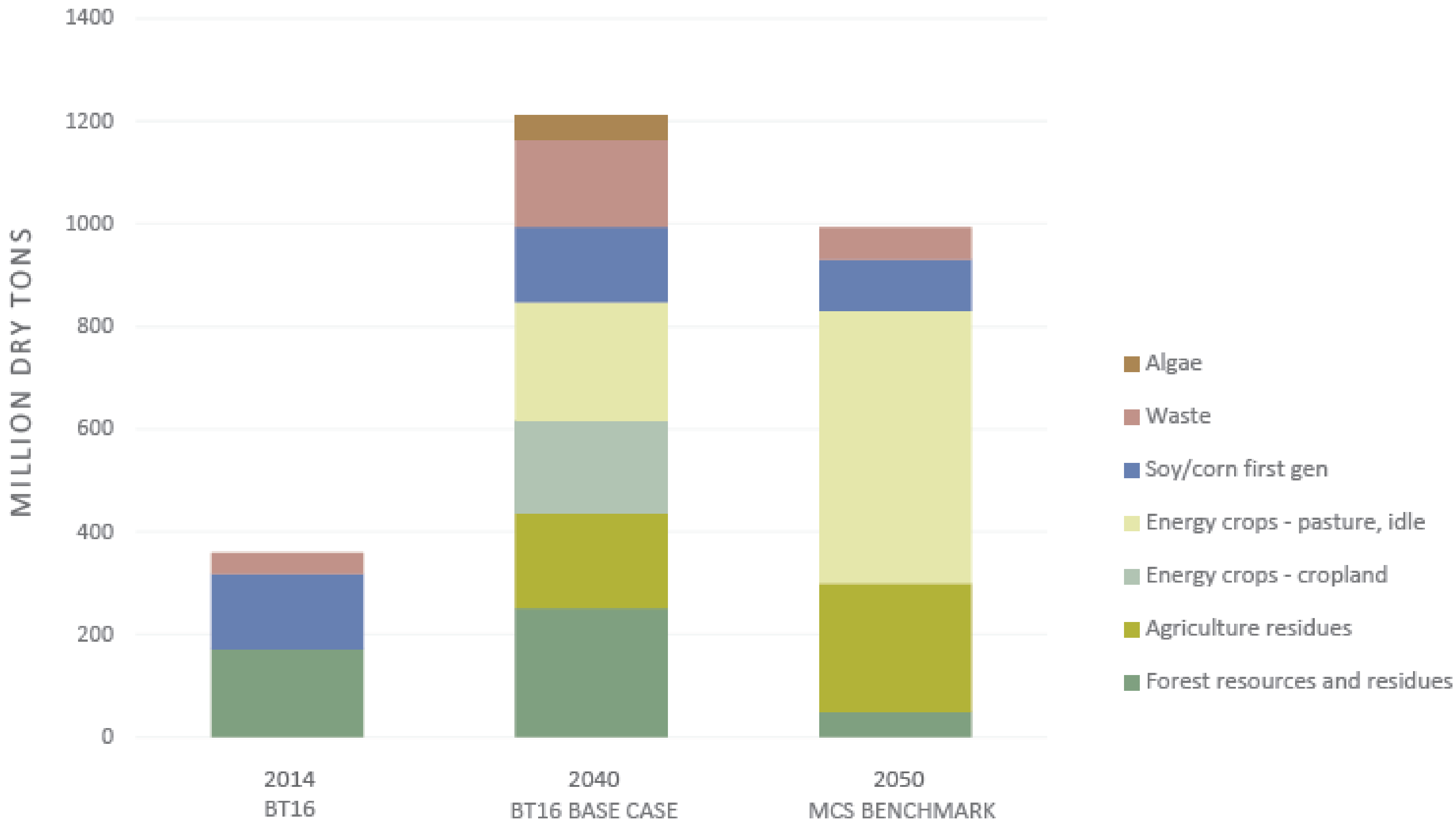
This figure shows cumulative net forest expansion by 2050 (x-axis) and the average annual CO2 stock change between 2015 and 2050 (y-axis) across three models used to assess MCS land sector dynamics (GCAM, GTM, and USFAS). Each dot represents a distinct land carbon sink scenario developed by one of the three models, with nine scenarios developed in total. These estimates do not reflect all possible forest sink projections.

Historical forest expansion compared to Potential MCS forest expansion



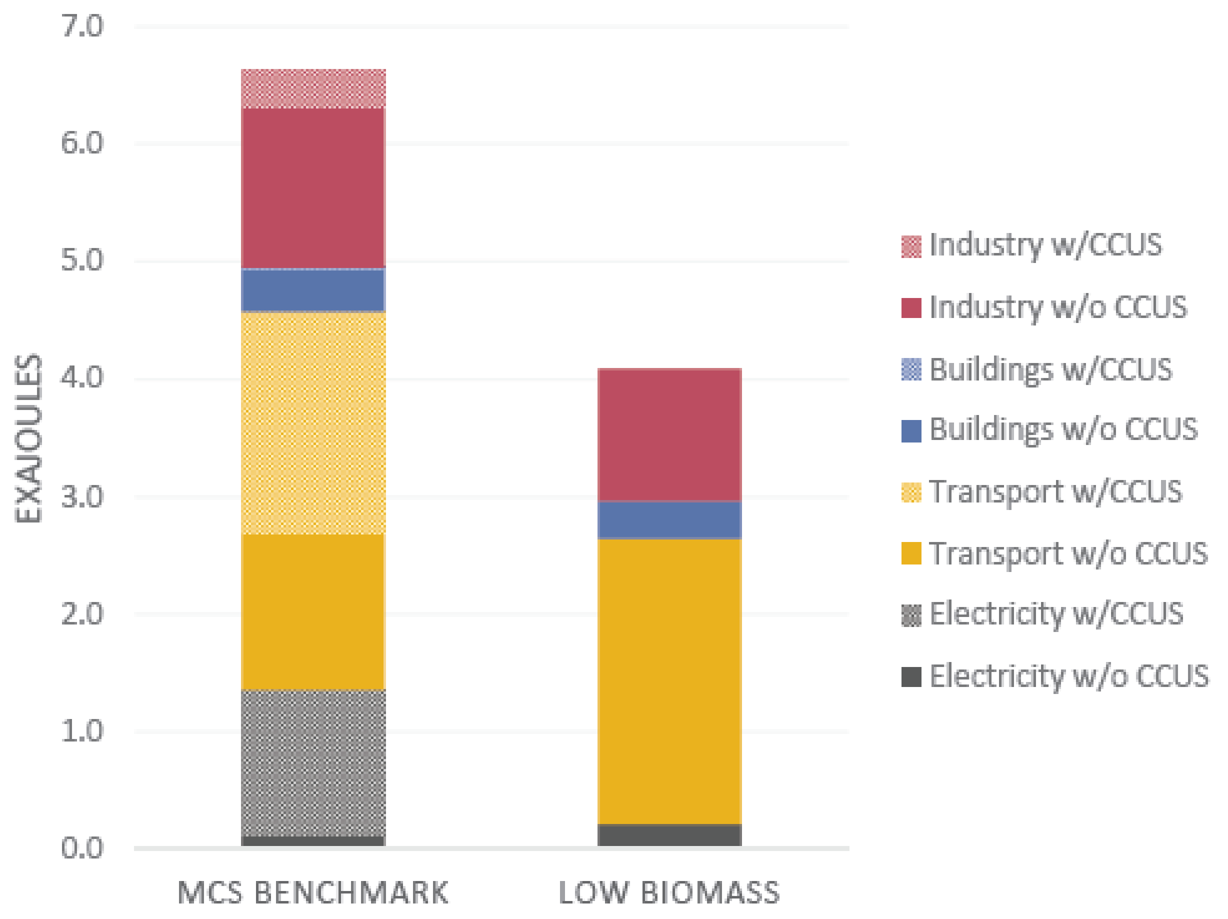
Note: Historic data from 1630 to 2007 based on Kellogg 1909 and Oswalt et al. 2014. To account for uncertainty in observed forest expansion after 2007, this figure shows an average annual increase in forest area from 2007-2012 that reflects a longer-term average trend based on three separate data sources, including the FIA (1987-2007) as found in Oswalt 2014, the 2007 USDA Major Land Use Database (1992-2007), and the 2015 FAO Global Forest Resources Assessment (1990-2015). The resulting average annual increase for the 2007-2012 period is 1.2 million acres/year. 2017-2035 projection based on analysis of forest expansion that could support the MCS Benchmark scenario. Forest expansion is estimated to occur before 2035 in order to achieve desired 2050 carbon sink levels.

FUTURE BIOMASS SUPPLY ESTIMATES

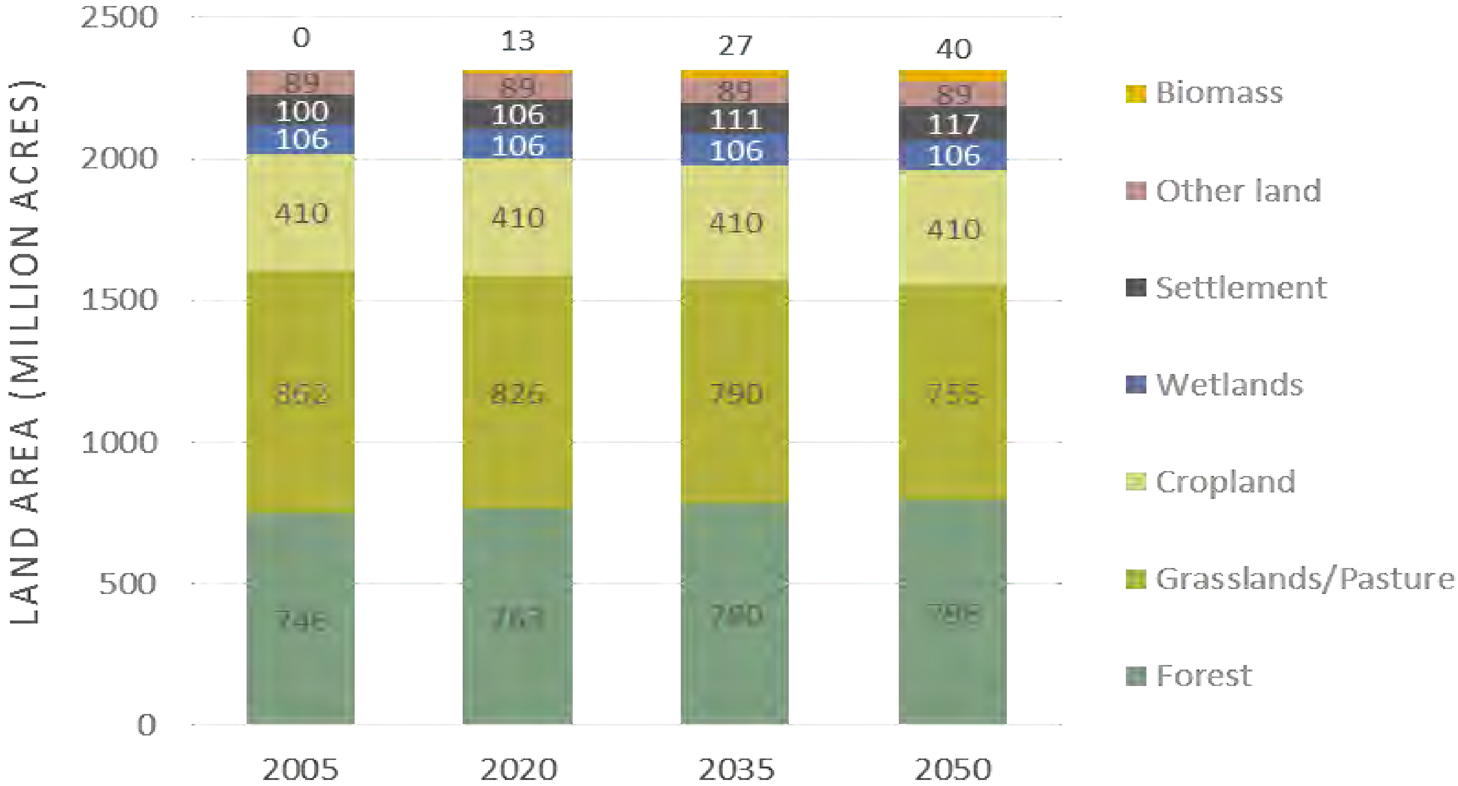


BIOENERGY USE ACROSS THE ENERGY SECTOR

Bioenergy (EJ) in the MCS analysis across electricity, transport, industry, and buildings, 2050. Note that the Low Biomass scenario includes no BECCS by assumption.



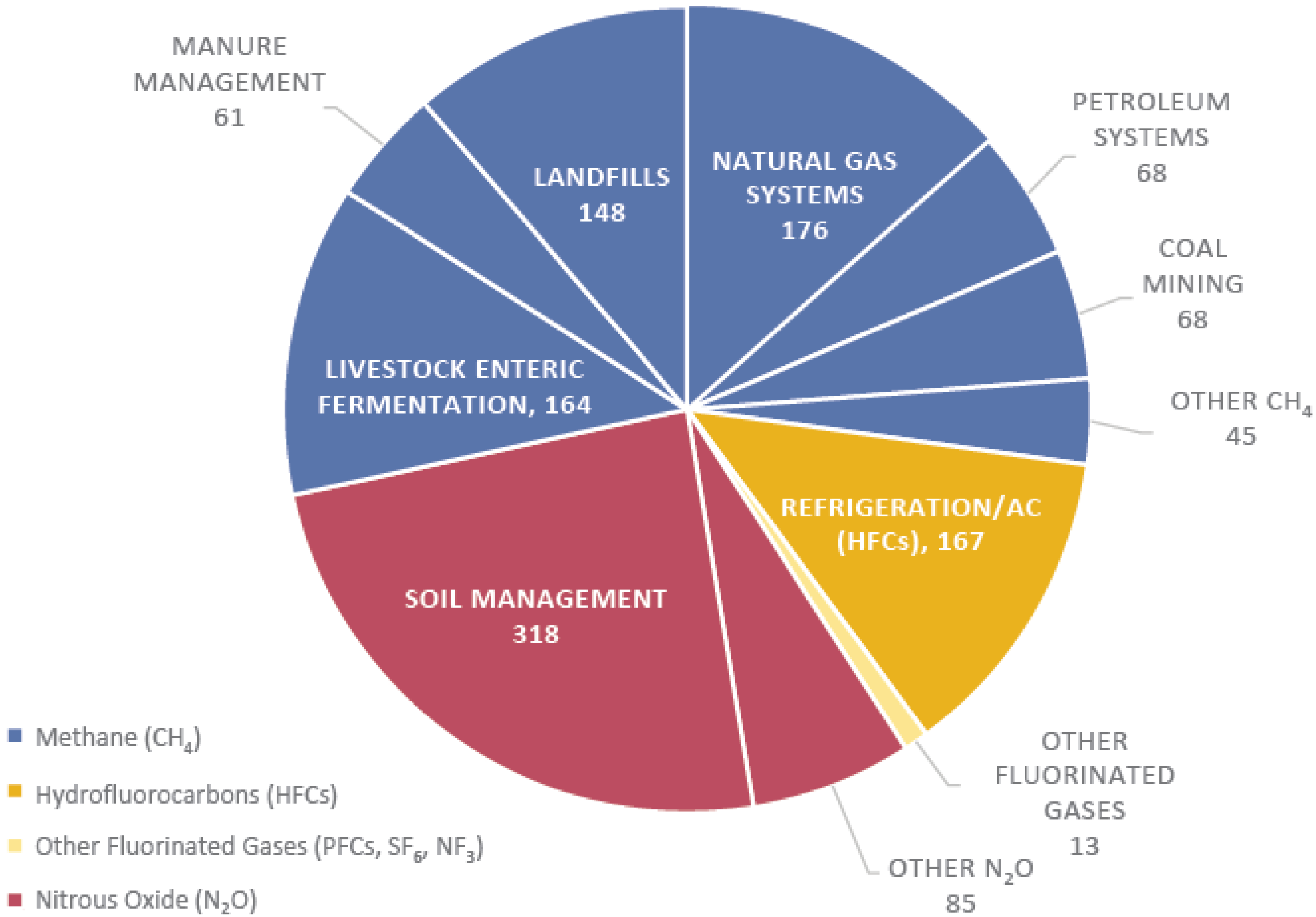
POTENTIAL 2050 LAND USE CHANGES CONSISTENT WITH MCS



The results presented here exemplify a potential future U.S. land use scenario that could be consistent with the U.S. MCS vision, reflecting 50 million acres of forest expansion, 40 million acres of biomass production, 17 million acres of developed land expansion, and constant cropland levels. Such a future would need to go hand in hand with strategies to minimize impacts to natural grasslands, natural forests, wetlands, and other high value conservation areas.

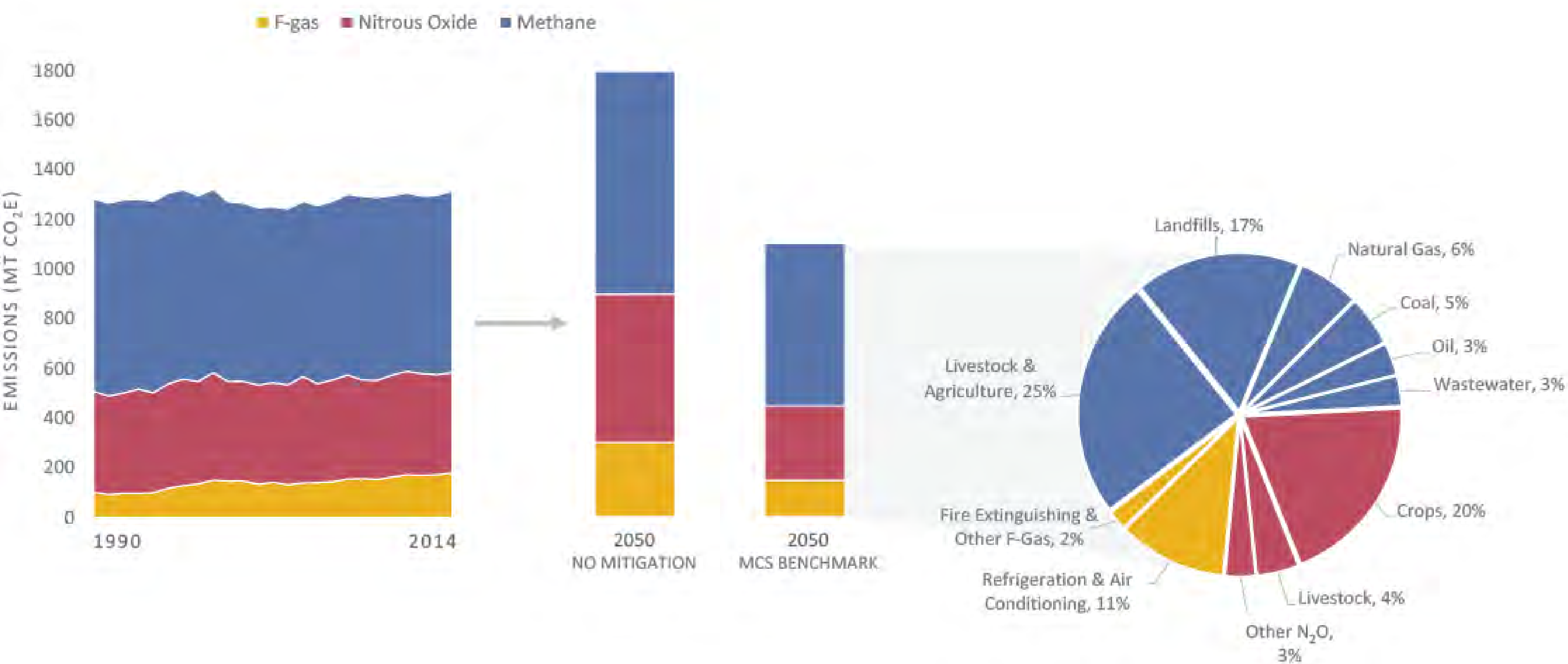
REDUCING NON-CO_2 EMISSIONS

Sources of U.S. Non-CO_2 GHG Emissions by Gas, 2014 (MMT CO_2E)



Note: These calculations use the U.S. GHG Inventory for 1990-2014 that assumes a 100-year GWP based on IPCC AR4 estimates. Source: EPA 2016a.

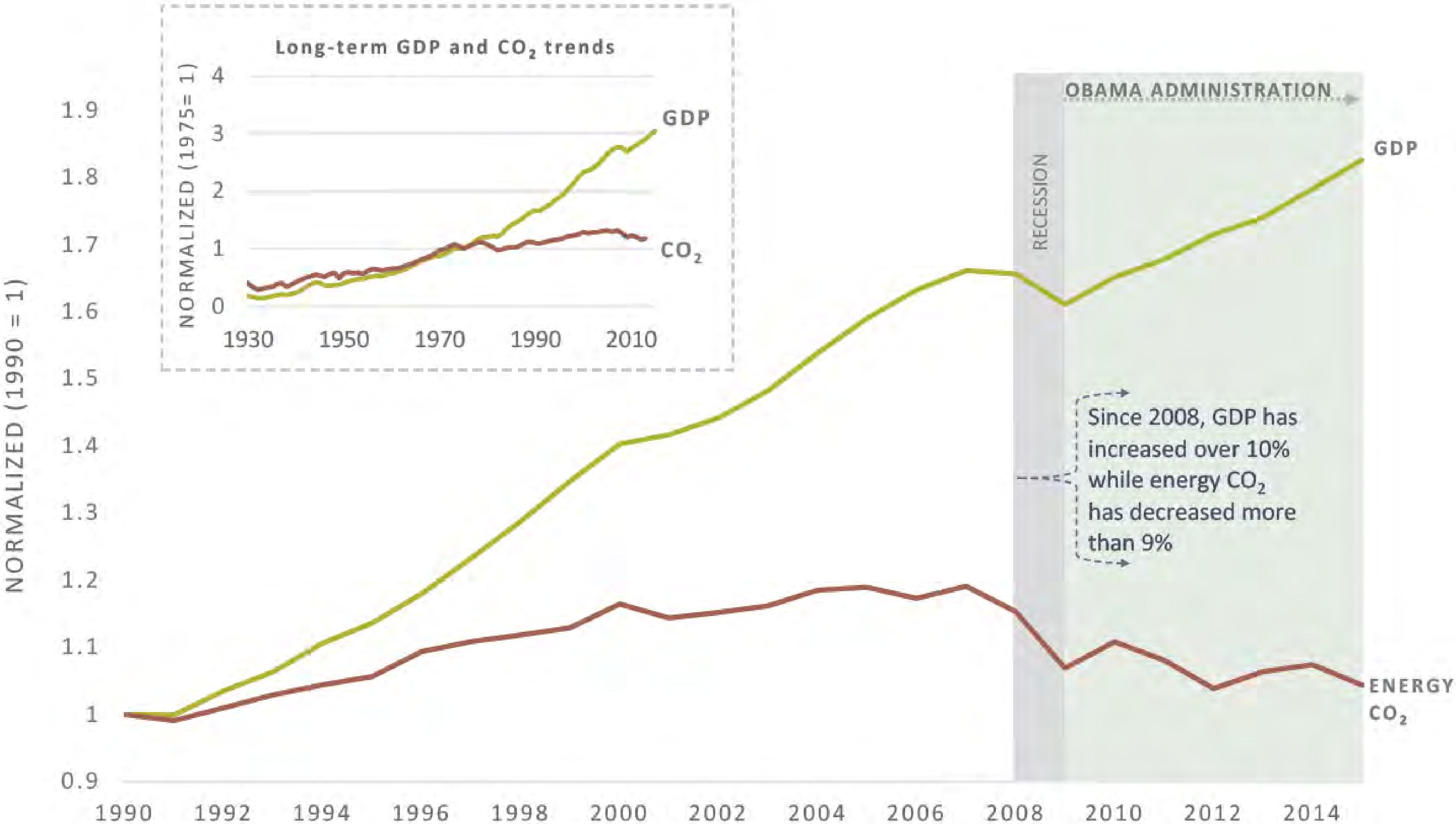
U.S. Non-CO_2 Mitigation by 2050, Compared to "No Mitigation" Scenarios



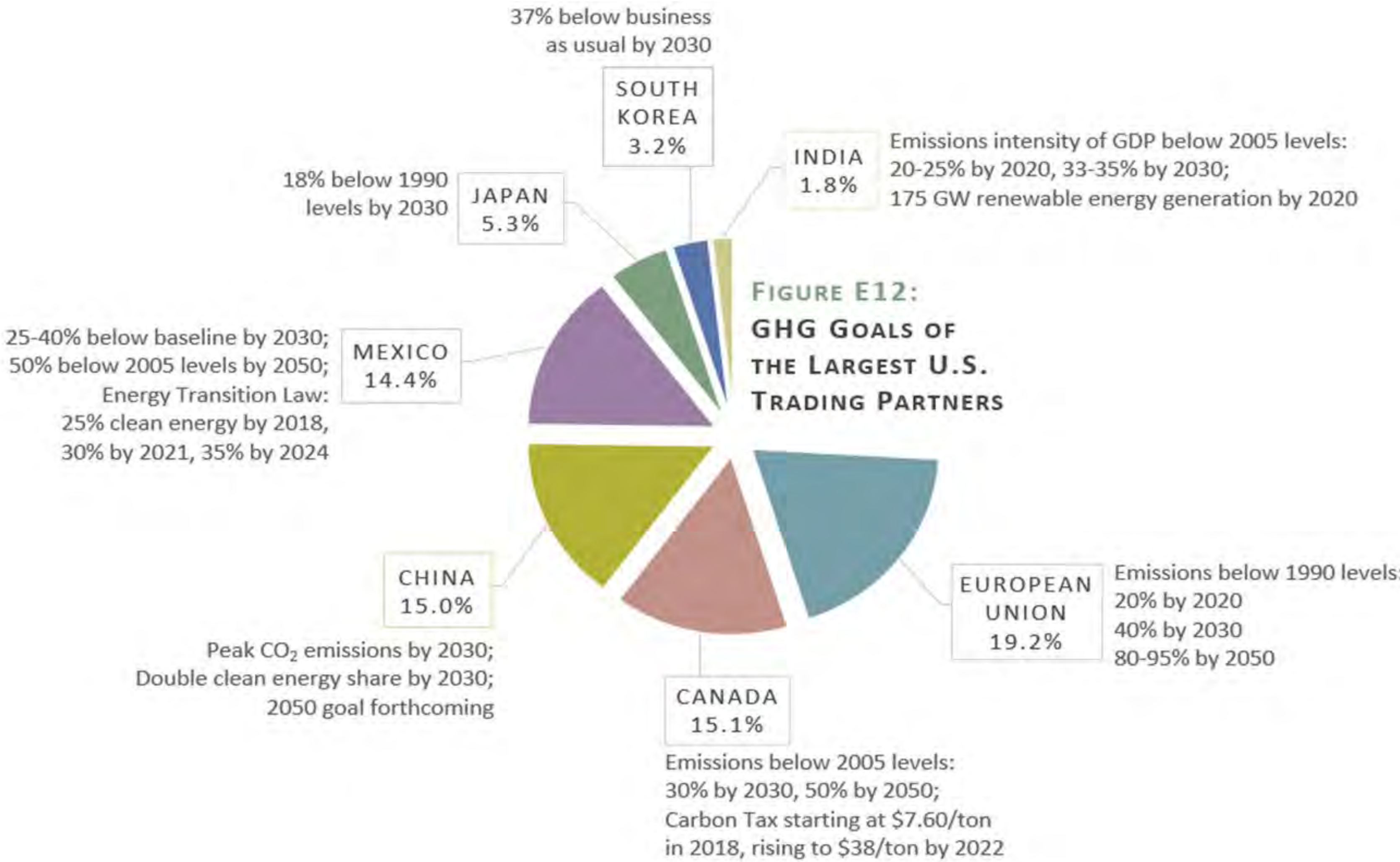
Emissions are down only modestly compared to 2005 emissions levels but are considerably lower than a projection of emissions in 2050 without mitigation efforts. Note: "MCS Benchmark" emissions are scaled to be consistent with EPA projections data used in the Global Mitigation of Non-CO2 Greenhouse Gases report (EPA Report 430R13011) in order to reflect residual non-CO2 emissions consistent with U.S. GHG Inventory data. These projections include distinct activity assumptions from those used in GCAM non-CO2 results displayed in previous chapters. Source: "No Mitigation" estimates for each non-CO2 gas are sourced from the Deep Decarbonization Pathways Project, with historical data from the U.S. GHG Inventory (Williams et al. 2014, EPA 2016a). "No Mitigation" scenarios estimates are per Deep Decarbonization Pathways Project (Williams et al 2014).

THE MIDCENTURY STRATEGY AND THE U.S. ECONOMY

U.S. Energy CO_2 Emissions and GDP



CLIMATE COMMITMENTS OF MAJOR U.S. TRADE PARTNERS



Note: Segment size represents country's contribution to U.S. total trade volume (U.S. Census Bureau 2016). Total trade equals imports from country plus U.S. exports to country. Remainder of circle is comprised of other trading partners, the large majority of which have also developed NDCs.

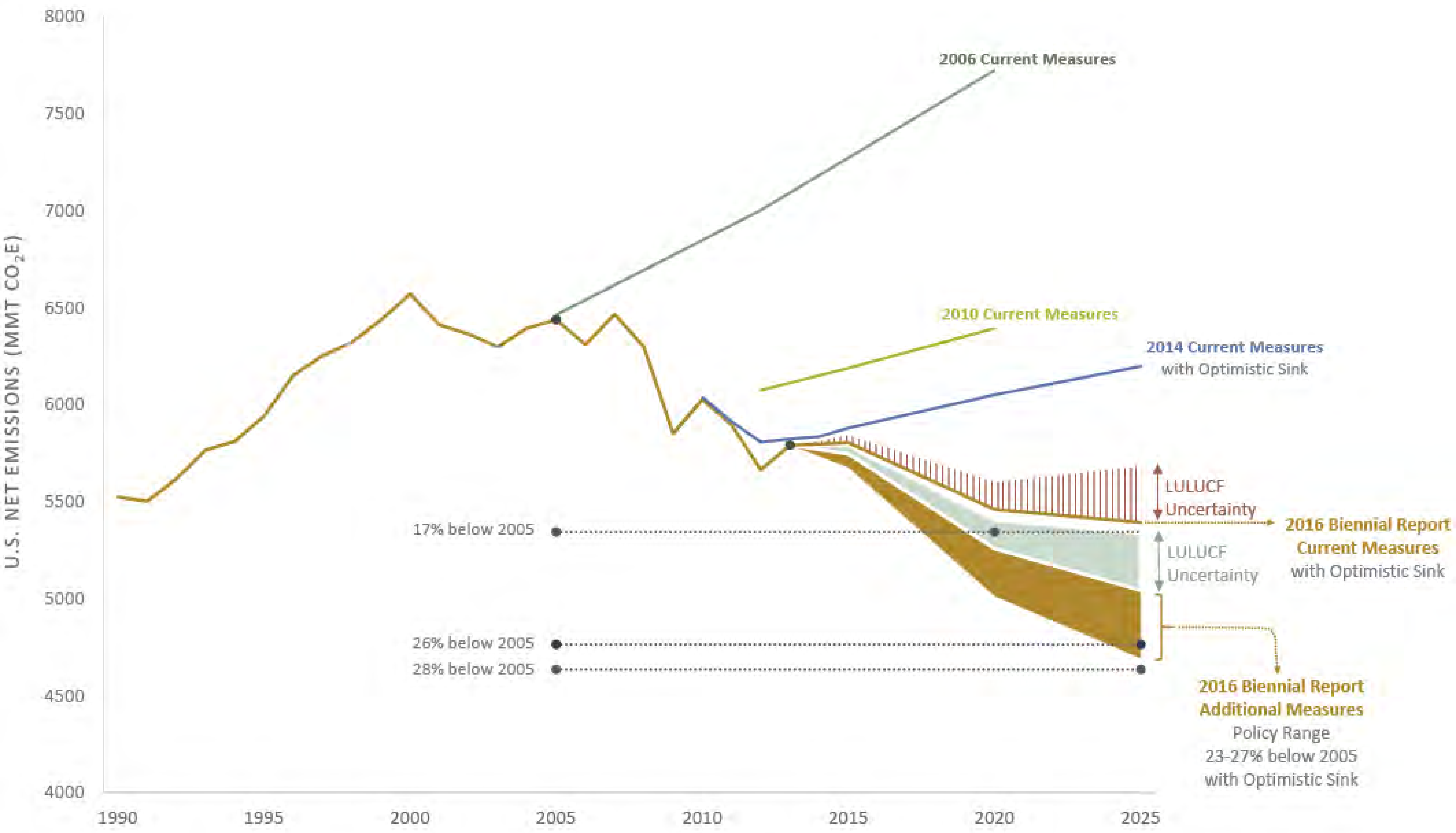
Thank You

unfccc.int/focus/long-term_strategies/items/9971.php

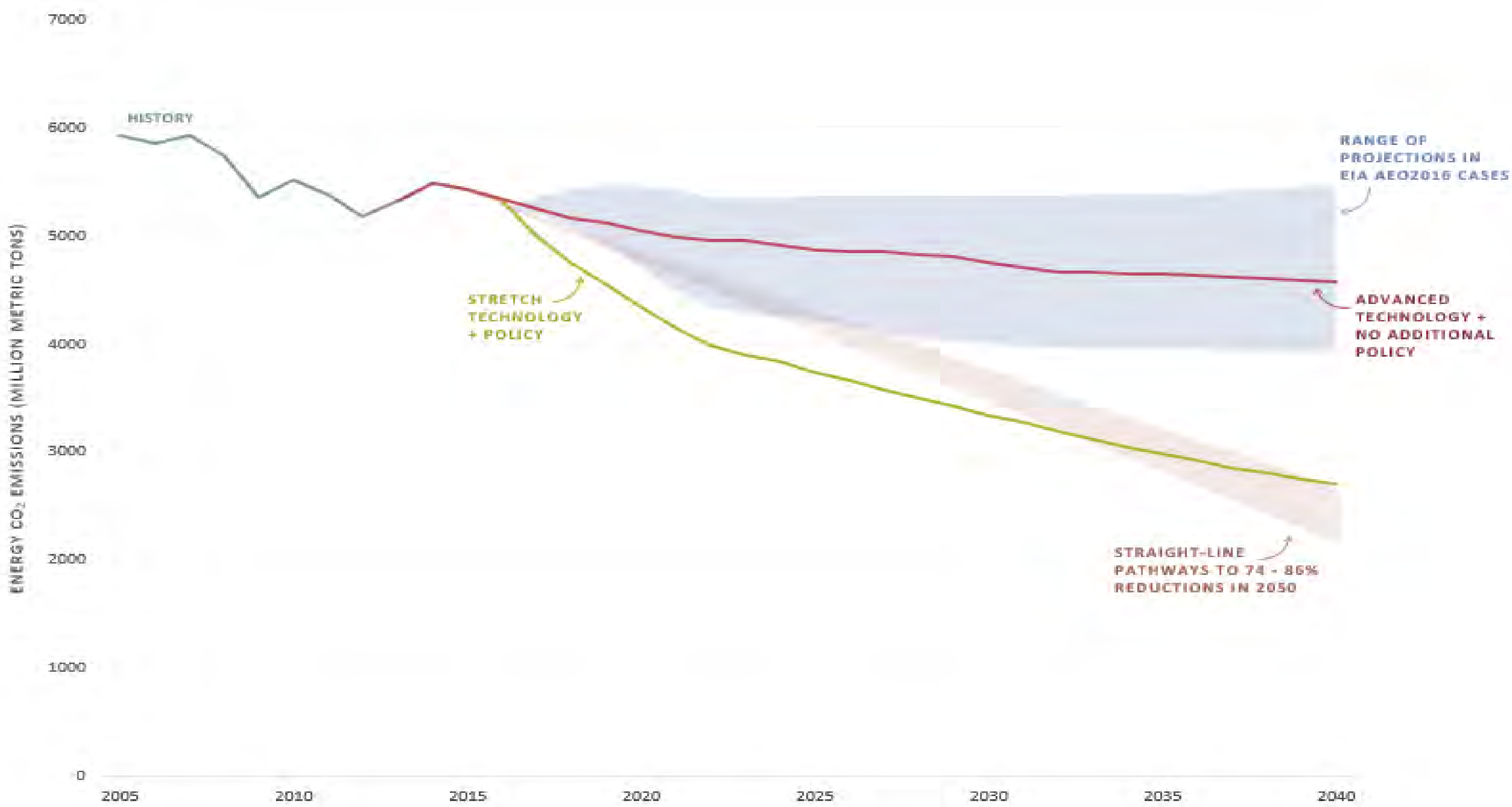
www.whitehouse.gov/sites/default/files/docs/mid_century_strategy_report-final.pdf

APPENDIX

U.S. Emissions Projections with Current Measures and Additional Measures Consistent with Obama Administration's Climate Action Plan (U.S. Department of State 2016).

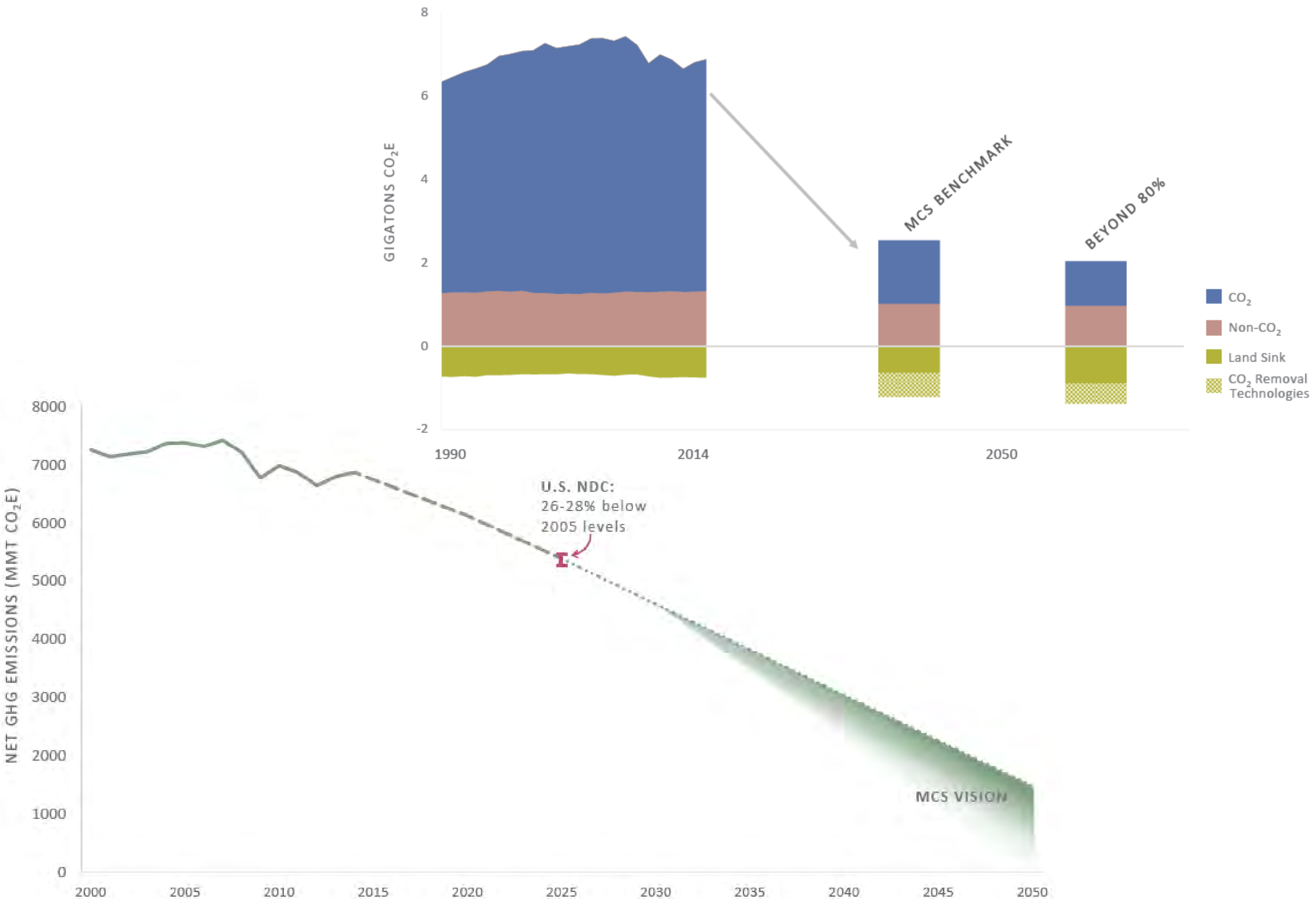


ENERGY CO_2 EMISSIONS UNDER CURRENT AND EXPANDED AMBITION

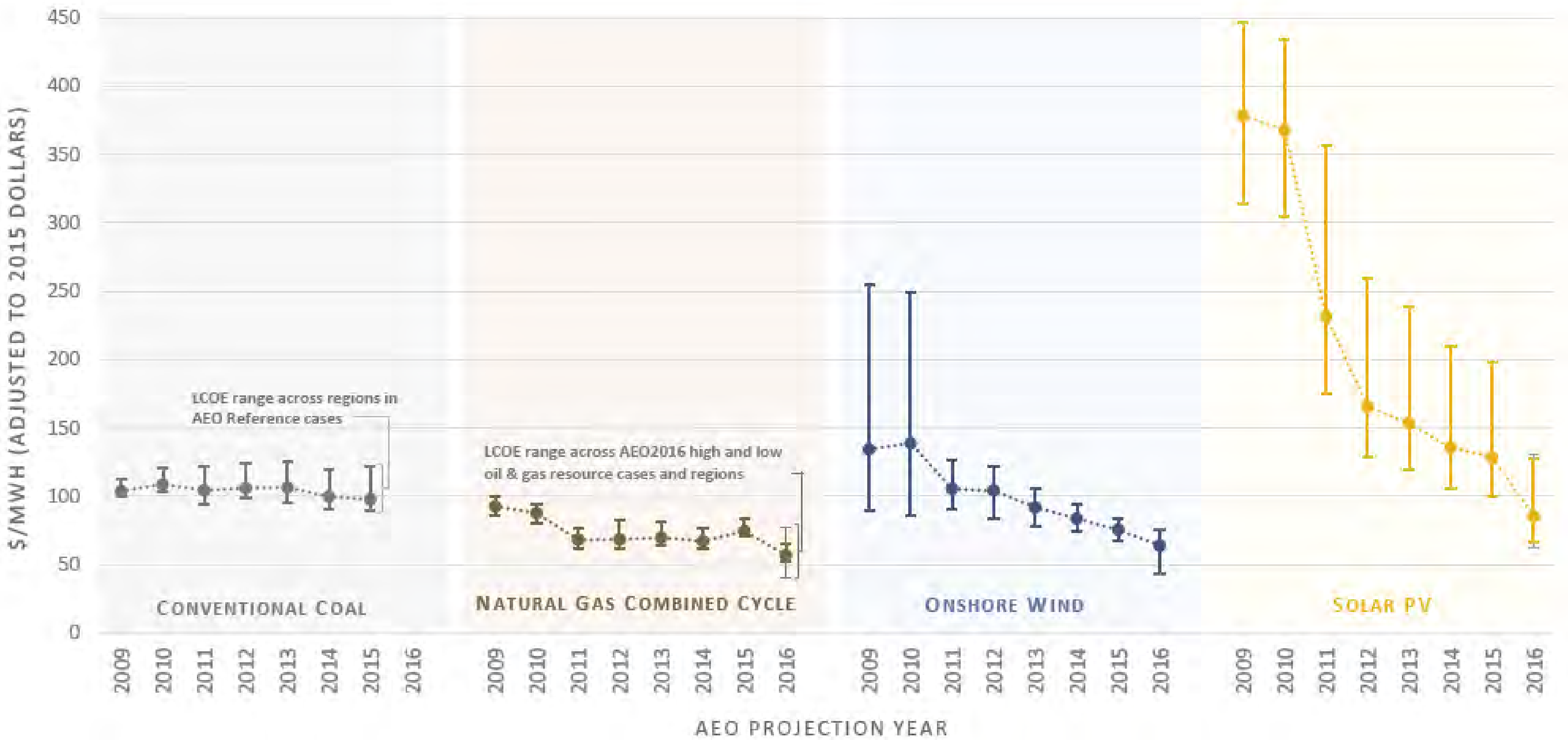


Modeling by the U.S. Department of Energy in National Energy Modeling System
"Advanced Technology + No Additional Policy" assumes technologies achieve current DOE program goals.
"Stretch Technology + Policy" assumes (1) carbon price of $20 per metric ton, starting in 2017 and increasing at 5 percent per year; (2) additional support for technological progress (such as through Mission Innovation).
MCS scenarios in GCAM that achieve 80 percent reductions in economy-wide net GHG emissions show energy CO2 reductions of 74 to 86 percent.

BEYOND 80 MCS PATHWAY



U.S. EIA LEVELIZED COST OF ELECTRICITY (LCOE) PROJECTIONS FOR SELECTED TECHNOLOGIES, AVERAGE, AND RANGE

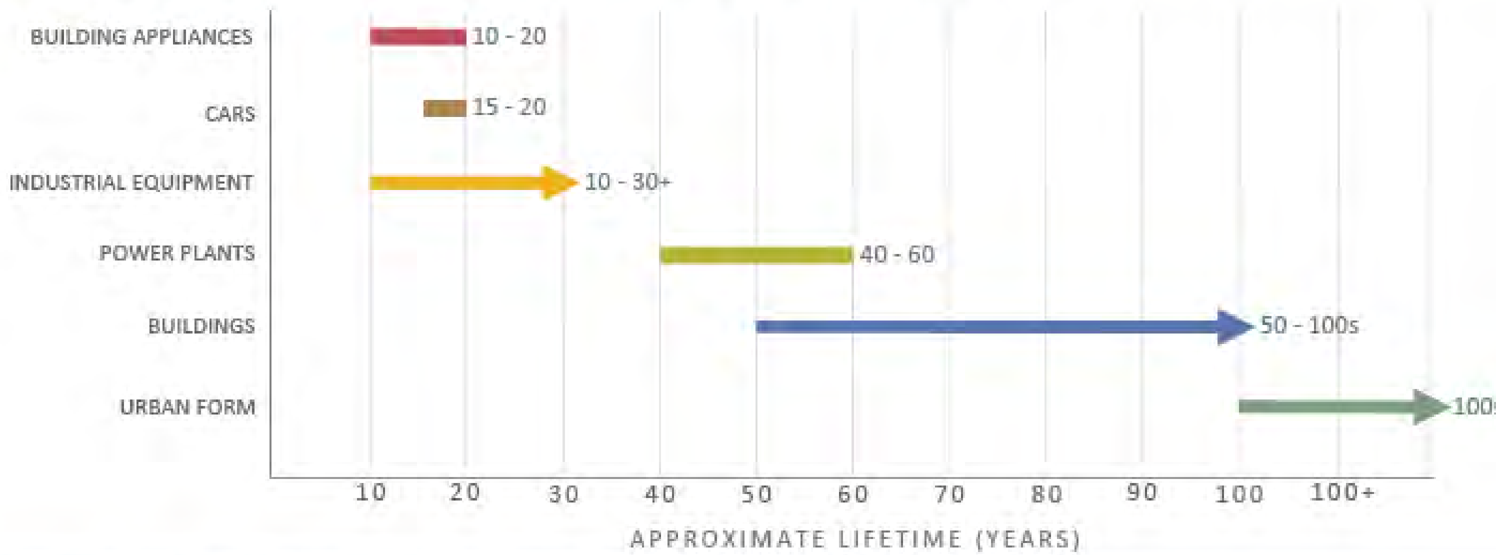


Note: Each LCOE projection is for plants having start dates five years after the projection year (e.g., 2013 for AEO2008, 2021 for AEO2016). Ranges represent the minimum and maximum LCOE across regions in EIA's AEO Reference cases; the extended ranges shown for AEO2016 represent the range of LCOE's across regions from the AEO2016 High Oil and Gas Resource and Technology and Low Oil and Gas Resource and Technology cases. "Conventional coal" values are for EIA's pulverized coal (without CCS) model technology type; AEO2016 does not contain LCOE estimates for coal plants without CCS. "Natural gas combined cycle" values are for EIA's "advanced combined cycle" model technology type. In addition, the LCOE values shown reflect EIA's assumptions for new plant costs at the time of each projection; do not reflect the impact of production tax credits or investment tax credits; and are adjusted to 2015 dollars using a GDP price deflator index reflecting AEO2016 macroeconomic indicators and historical inflation. Sources: U.S. Energy Information Administration, National Energy Modeling System.

FIGURE 4.3: APPROXIMATE GESTATION TIME RANGES FOR RDD&D

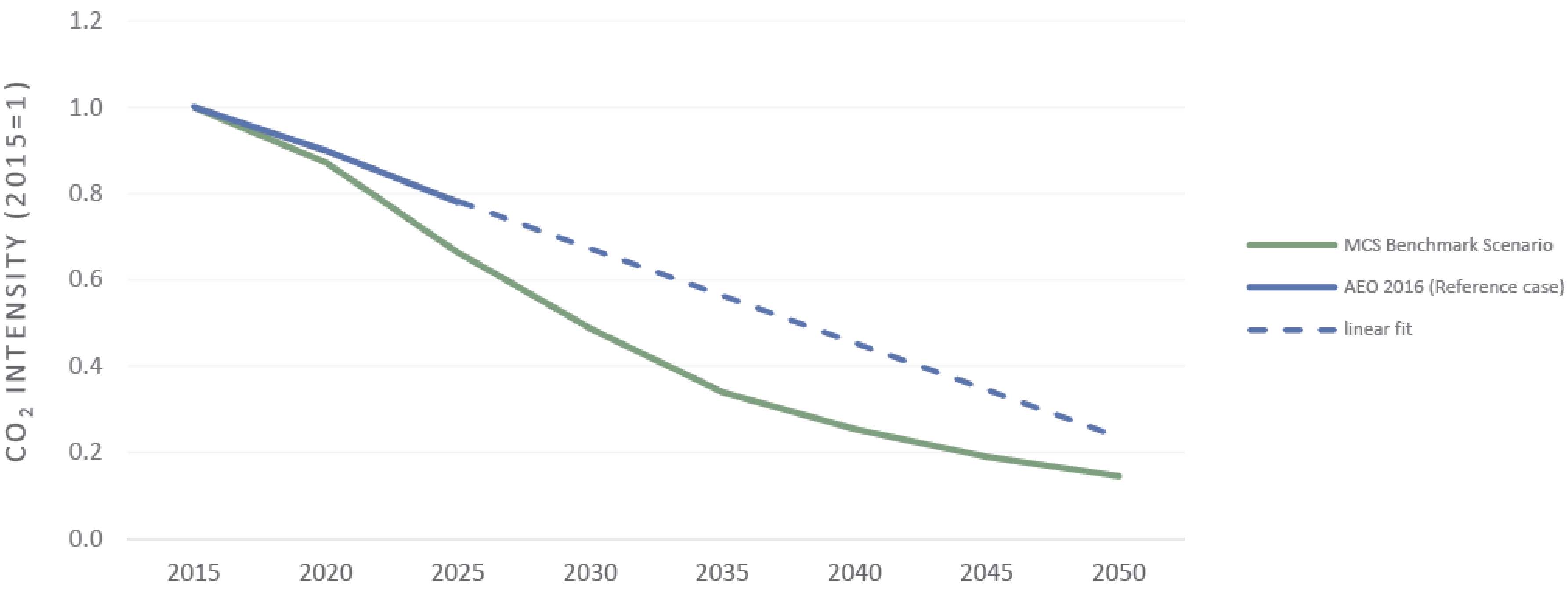
Note that RDD&D is not a linear process; there can be substantial interaction and iteration across these various activities.

FIGURE 4.4: APPROXIMATE LIFETIME RANGES FOR VARIOUS CAPITAL STOCKS



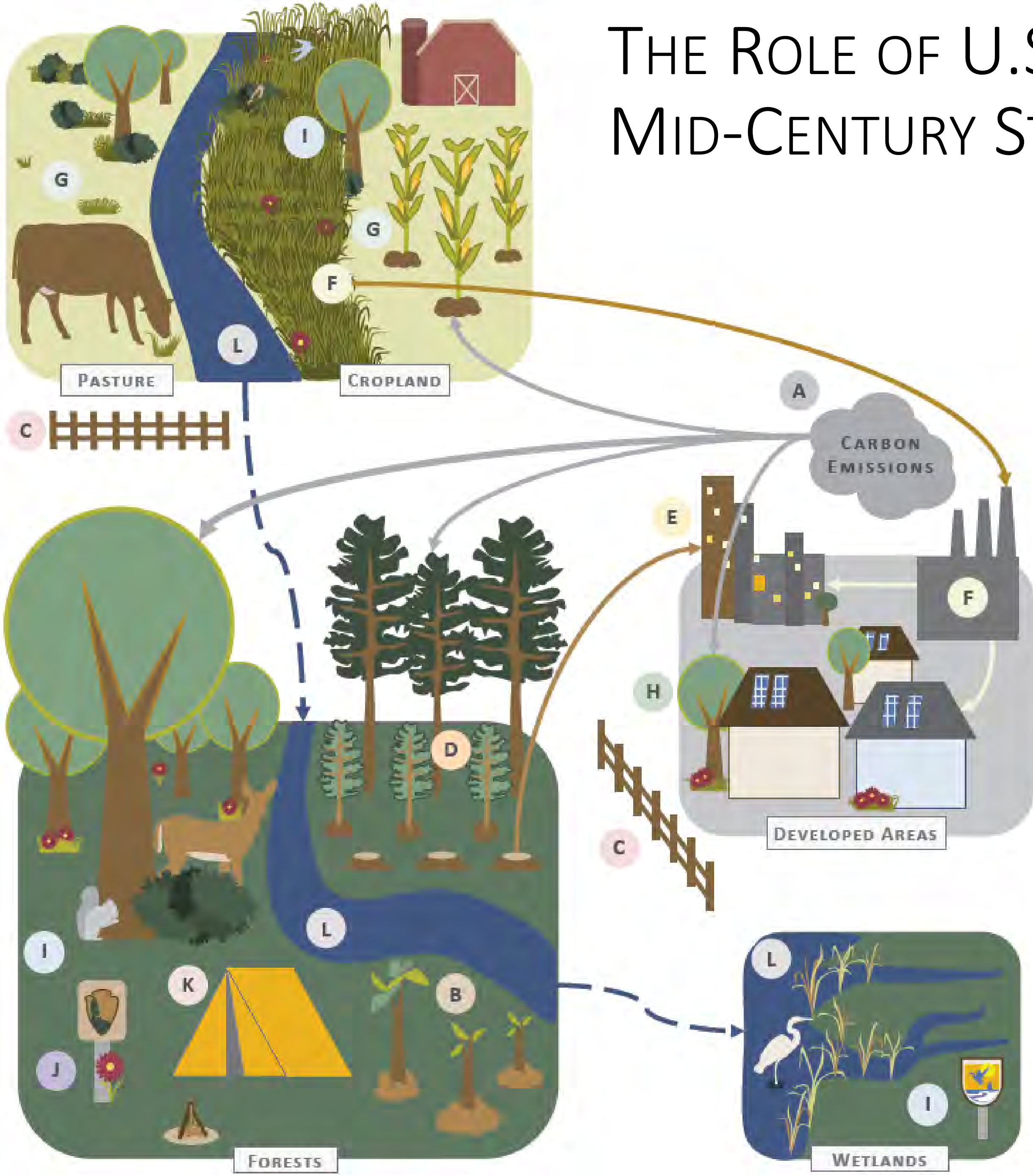
Source: Lutz et al. 2011; Davis, Diegel, & Boundy 2015; EIA 2011; O'Connor 2004.

FIGURE 4.11: FLEET-WIDE EMISSIONS INTENSITY FOR LIGHT-DUTY VEHICLES UNDER THE MCS BENCHMARK SCENARIO RELATIVE TO A STRAIGHT-LINE EXTENSION OF NEAR-TERM PROJECTIONS TO 2025



Note: Emissions intensities were calculated for each year by dividing fleet-wide LDV emissions by total vehicle miles traveled. Since existing light-duty vehicle fuel economy and GHG emissions standards only extend to 2025, this figure linearly extrapolates Annual Energy Outlook 2016 reference case projections through 2025 out to 2050. The fleet-wide emissions intensity of light-duty vehicles declines 76 percent between 2015 and 2050, relative to 86 percent in the MCS Benchmark scenario.

The Role of U.S. Lands in the Mid-Century Strategy



A — Carbon dioxide from all sectors of the economy is captured and stored by forests, agricultural lands, and urban trees.

B — Reforestation and afforestation will play a large role in enhancing the carbon sink.

C — Avoided forest conversion will preserve forest carbon.

D — Improved forest management can increase carbon sequestration in existing forests.

E — Tall wood buildings will store carbon and reduce the need for fossil fuel-intensive construction materials.

F — Perennial grasses grown on marginal or underutilized land and other carbon-beneficial forms of biomass will help us meet renewable energy demand.

G — Carbon storage in cropland and pasture can be increased through practices like no-till, cover crops, management intensive grazing, agroforestry, and other innovations.

H — Planting urban trees can increase carbon sequestration, even in developed areas.

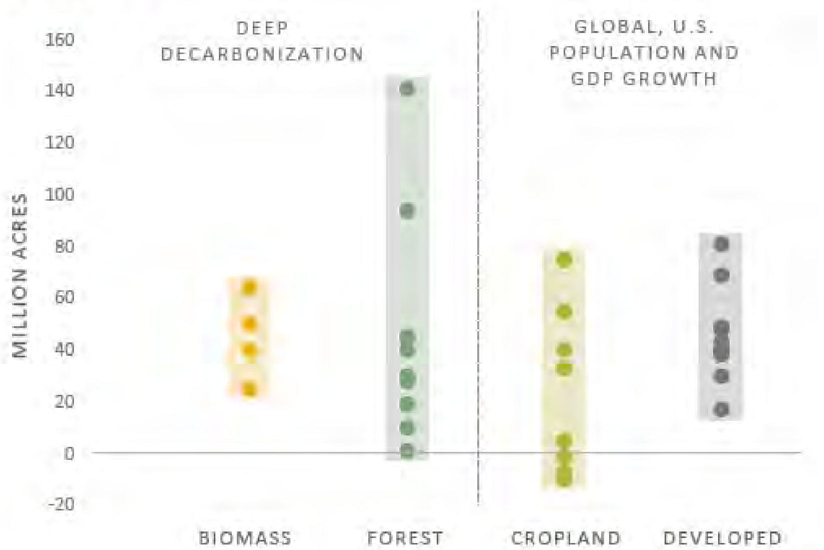
I — Protecting natural landscapes and avoiding disturbances will be key to maintaining carbon sinks and providing habitats for wildlife.

J — Federal lands will play an important role in preserving carbon stocks and providing early action.

K — U.S. lands will continue to provide recreation opportunities for the American public.

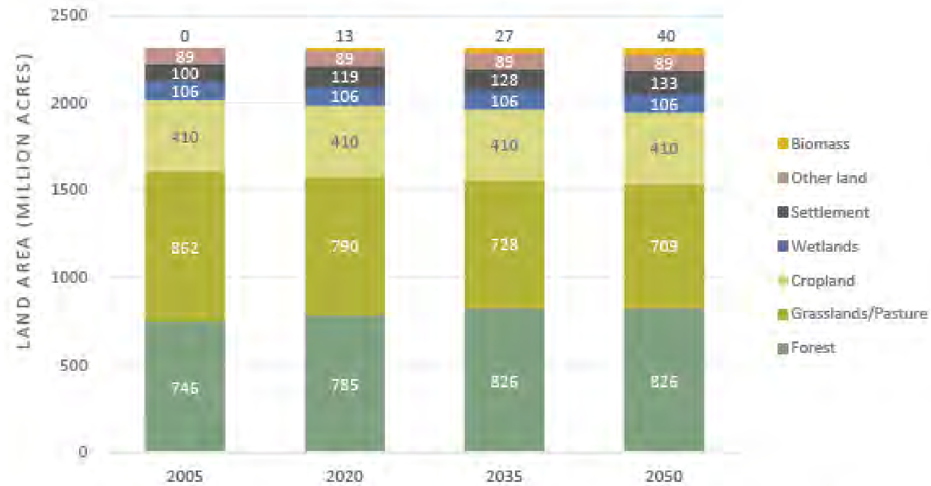
L — Water considerations will grow increasingly important as we weigh carbon sequestration options, with some parts of the country predicted to get drier and others wetter under a changing climate.

FIGURE A:



Range of 2050 land use change estimates produced by different research and modeling exercises for four key land use change drivers: carbon beneficial biomass production to decarbonize the energy sector, forestland expansion to increase carbon sequestration, cropland expansion in response to growing global food demand assumptions, and developed land expansion due to U.S. population growth. Note that not all four elements are represented in each model/study included here. Each dot represents a single literature or model-based estimate of additional cumulative acreage of the respective land use type by 2050. It is important to note that these scenarios and models contain different parameters, input data, and assumptions so the results are not directly comparable. They are compiled here to illustrate the range of possible outcomes in 2050 using different analytic approaches and assumptions. The estimates represented here were generated across 10 studies and modeling exercises with 24 distinct scenarios (USDA 2016, Radeloff et al. 2012, Oswalt et al. 2014, Sands et al. 2014, DOE 2016, EPA 2009, MCS, including GCAM, USFAS, and GTM).

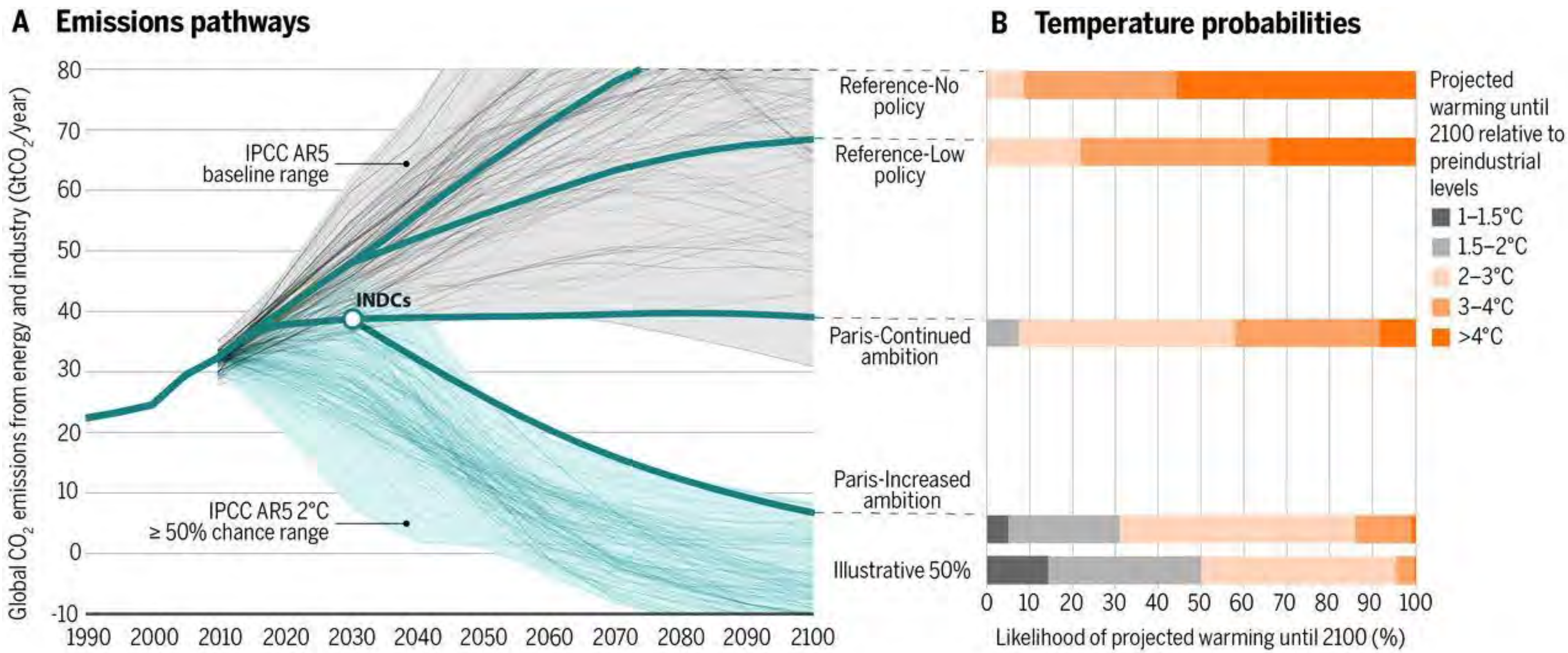
FIGURE B:



Potential land use outcome in 2050 as drawn from the evaluation of the broader selection of different studies and analyses discussed in Figure A. The results presented here exemplify a potential future U.S. land use scenario that could be consistent with the U.S. MCS vision. The illustrative results above—reflecting 50 million acres of net afforestation to maintain and enhance the land sink and 40 million acres of biomass production to support carbon beneficial forms of bioenergy, all compared to 2015 areas—are consistent with estimates from Figures 5.3 and 5.5 above. This figure further reflects 17 million acres of developed land expansion from 2015, consistent with USDA estimates for low developed land expansion (2016), and constant cropland levels.

Can Paris pledges avert severe climate change?

Reducing risks of severe outcomes and improving chances of limiting warming to 2°C



Global CO_2 emissions and probabilistic temperature outcomes of Paris. (**A**) Global CO_2 emissions from energy and industry (includes CO_2 emissions from all fossil fuel production and use and industrial processes such as cement manufacture that also produce CO_2 as a byproduct) for the four emissions scenarios explored in this study. The IPCC AR5 emissions ranges are from (*12*). The IPCC AR5 baseline range comprises scenarios that do not include new explicit GHG mitigation policies throughout the century. The IPCC AR5 2°C ≥ 50% range comprises scenarios that limit global warming until 2100 to less than 2°C with at least a 50% chance. The faint lines within the IPCC ranges represent the actual emissions trajectories that determine the range (*12*). (**B**) Likelihoods of different levels of increase in global mean surface temperature change during the 21st century relative to preindustrial levels for the four scenarios. Although (A) shows only CO_2 emissions from energy and industry, temperature outcomes are based on the full suite of GHG, aerosol, and short-lived species emissions generated by the GCAM (*9*) simulations (see SM). The Illustrative 50% scenario in (B) corresponds to an emissions pathway that achieves a 50% chance of maintaining temperature change below 2°C until 2100 (see SM). Other 50% pathways could lead to a range of temperature distributions depending on cumulative CO_2 emissions and representations of other GHGs.

Science AAAS

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