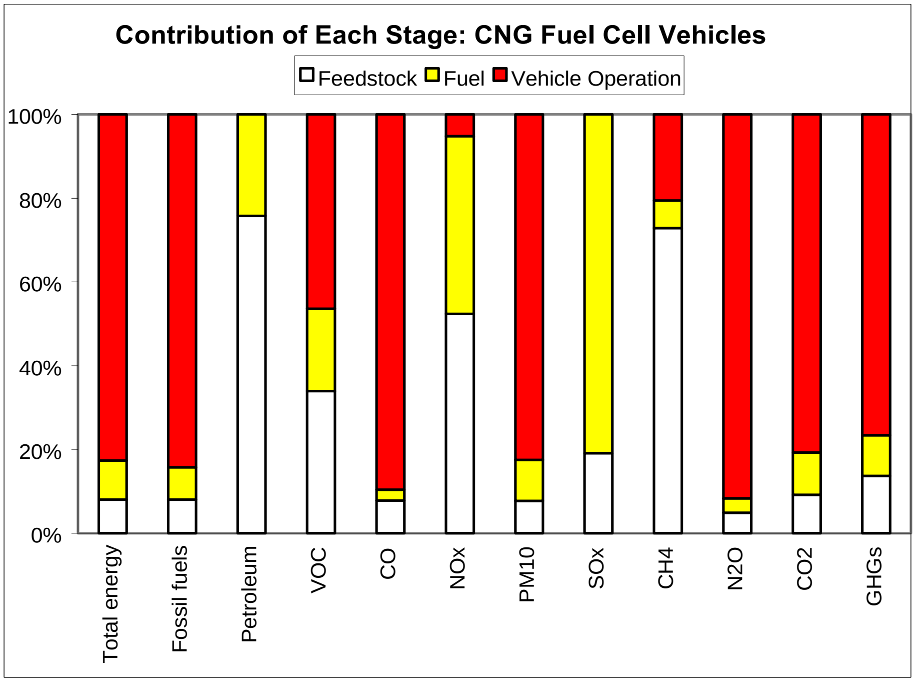

Figure 6.21 Shares of Fuel-Cycle Energy Use and Emissions by Stage: FCVs Fueled with CNG

Stage contribution results for cellulosic-ethanol-fueled vehicles (dedicated ethanol vehicles and FCVs) are not presented, because those results are distorted by energy and emission credits for the electricity generated at cellulosic ethanol plants. If energy and emission credits for the generated electricity were not considered, upstream biomass farming and cellulosic ethanol production would contribute significantly to total fuel-cycle energy use and emissions.

6.4 Per-Mile Energy Use and Emissions Results

In this section, we present per-mile, fuel-cycle energy use and emission results for the near- and long-term technologies included in GREET 1.5. Calculated per-mile energy use and emissions for three light-duty vehicle types — passenger cars, LDT1, and LDT2 — are presented in Appendix B. Changes in per-mile energy use and emissions associated with alternative fuels and advanced transportation technologies relative to baseline GVs are presented in this section.

Among the three light-duty vehicle types, the absolute amounts of fuel-cycle energy use (in Btu/mi) and emissions (in g/mi) increase in the following order: passenger cars, LDT1, and LDT2. For alternative transportation technologies, even if the relative changes in energy use and emissions are similar among the three types, the changes in absolute amounts will be different. In particular, application of a given technology to LDT2 will result in greater changes in per-mile energy use and emissions than its application to LDT1, and application to LDT1 will result in greater changes than its application to passenger cars. Users can employ the per-mile energy and emission results presented in Appendix B to determine the absolute energy and emission benefits per mile driven.

The relative changes by a given alternative fuel or an advanced transportation technology certainly differ among the three light-duty vehicle types, although the differences between passenger cars and LDT1 are generally smaller (because the same relative fuel economy and emission changes for vehicle operations are assumed for these two types; see Table 4.35). Our discussion of the relative changes in fuel-cycle energy use and emissions is based on the results for passenger cars, and the figures presented in the sections below are for passenger cars. Similar figures giving relative changes for LDT1 and LDT2 are presented in Appendix C. Numerical values of relative changes for passenger cars, LDT1, and LDT2 are presented in Appendix D.

6.4.1 Near-Term Technologies

The next nine figures show changes in fuel-cycle energy use and emissions of various near-term alternative fuels and transportation technologies relative to conventional GVs fueled with CG. Figure 6.22 shows changes in fuel-cycle total energy use. Use of ethanol, methanol, CNG, FRFG2, or CARFG2 in conventional SI engines causes increases in total energy use. The increases associated with M85 and E85 are above 15% and 20%, respectively. The increases are caused primarily by the significant amount of energy consumed during ethanol and methanol production. The increases associated with CNG are caused by CNGV fuel economy penalties. Use of EVs, HEVs, or CIDI engines fueled with diesel results in decreased fuel-cycle total energy use. The decreases are caused mainly by the high energy efficiencies of these vehicle technologies.

Figure 6.23 presents changes in fuel-cycle total fossil energy use for each fuel or vehicle type. Fossil fuels here include petroleum, NG, and coal. Use of M85 in methanol FFVs results in an increase of about 15% in per-mile fossil energy use, which is caused primarily by the large amount of NG used in methanol production at methanol plants. Use of CNG results in small increases in per-mile fossil energy use. Large fossil energy reductions occur with E85 and with diesel in CIDI engines, EVs, or HEVs. The large reduction with E85 occurs because ethanol is a nonfossil fuel; large reductions for CIDI vehicles, EVs, and HEVs are attributable to their high energy efficiencies. Use of LPG also results in reductions.

Figure 6.24 shows petroleum displacement by fuel and vehicle technology. As expected, use of non-petroleum-based fuels reduces petroleum use substantially. Among the vehicle technologies that use petroleum-based fuels, grid-connected and grid-independent HEVs and CIDI vehicles reduce petroleum use by more than 50% because of their efficiency gains. Use of RFG results in a small decrease in petroleum use because the MTBE and ETBE used in RFG are not petroleum based. The limited reduction by E10 occurs because 90% of the fuel blend is gasoline. The limited reduction by petroleum-based LPG occurs apparently because the fuel is petroleum based. The reduction by diesel CIDIs is attributable to vehicle efficiency gains.

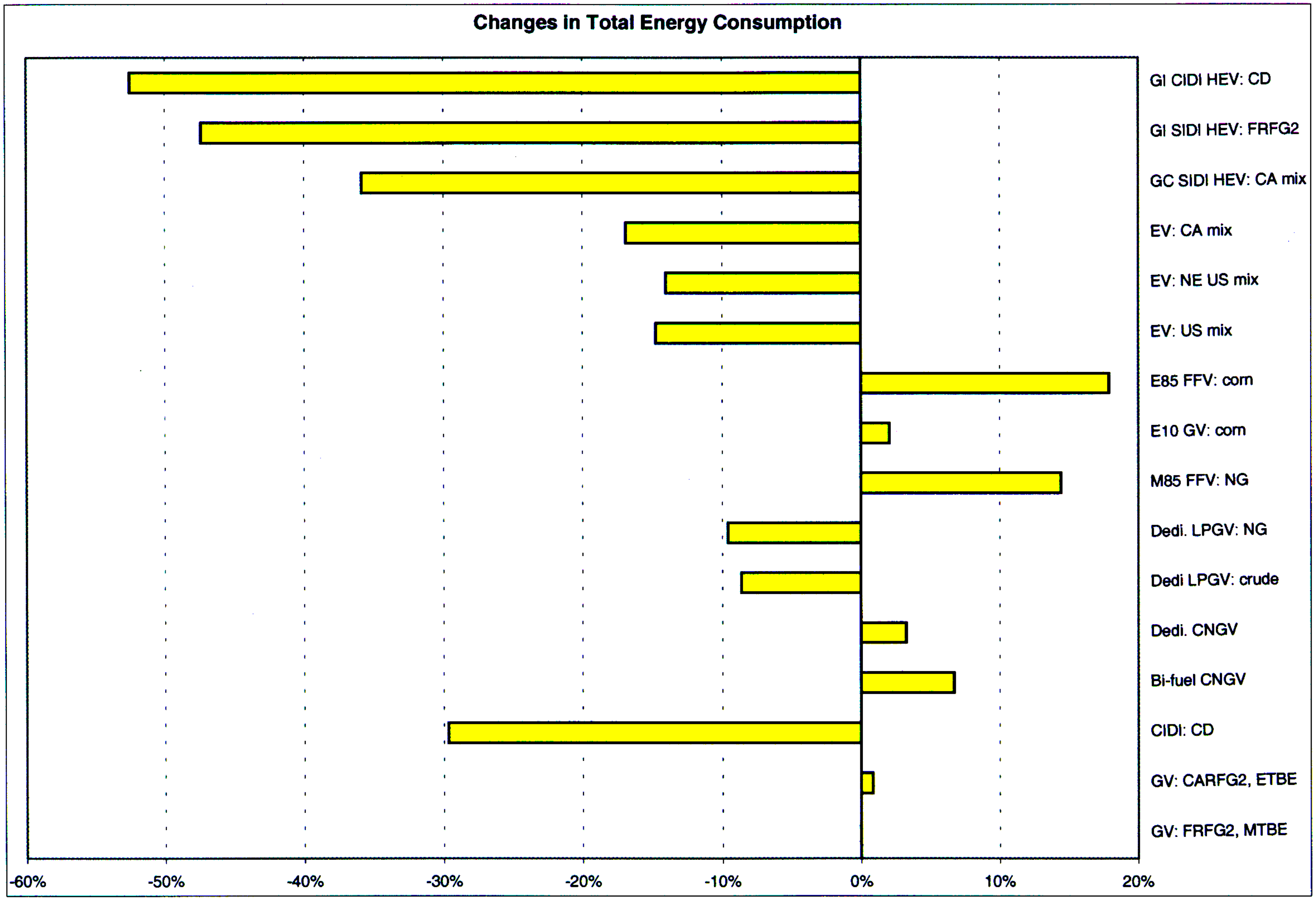

Figure 6.22 Changes in Fuel-Cycle Total Energy Use Relative to GVs Fueled with CG: Near-Term Technologies

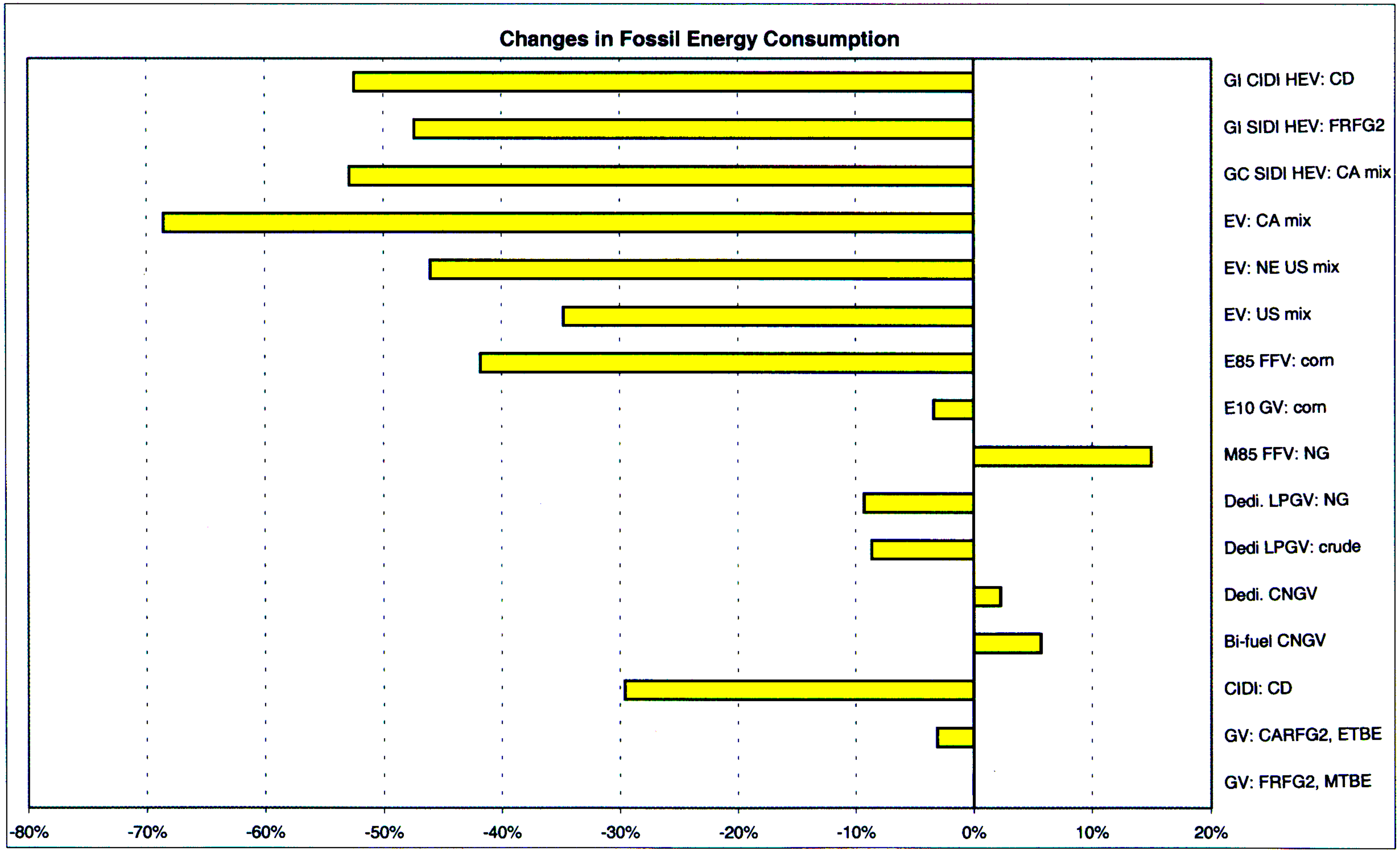

Figure 6.23 Changes in Fuel-Cycle Fossil Energy Use Relative to GVs Fueled with CG: Near-Term Technologies

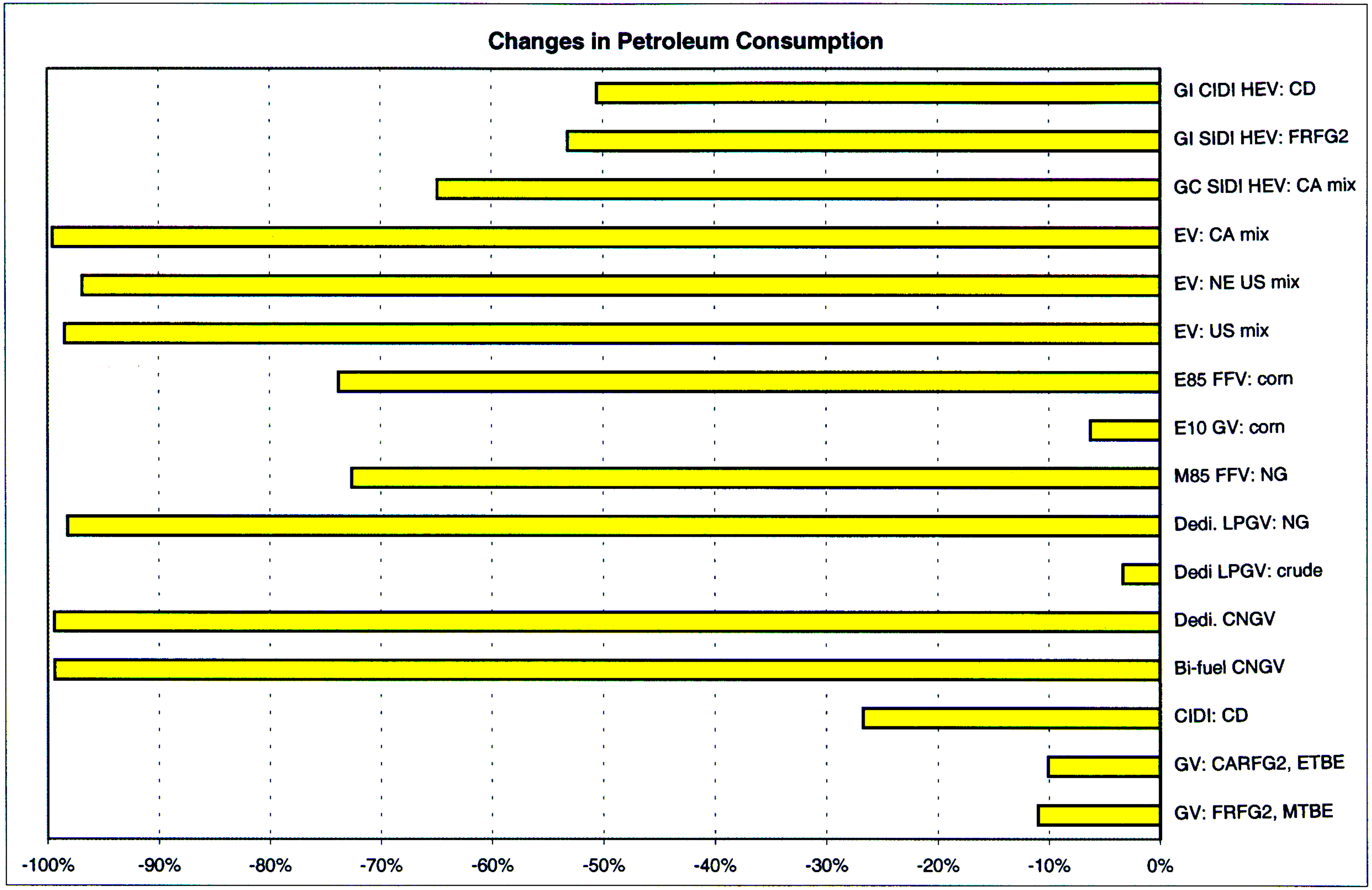

Figure 6.24 Changes in Fuel-Cycle Petroleum Use Relative to GVs Fueled with CG: Near-Term Technologies

Figure 6.25 shows changes in emissions of CO_2 and CO_2-equivalent GHGs. GHG emissions are the sum of emissions of CO_2, CH_4, and N_2O, weighted by their GWPs. Except for use of RFG, where a tiny increase in GHG emissions occurs, use of any fuel or vehicle technology helps reduce GHG emissions. The largest reductions occur for EVs with the California electric generation mix, under which 48% of electricity is produced from hydropower plants. In general, EVs and HEVs reduce GHG emissions by more than 40%, mainly because of their efficiency gains. Significant reductions are also achieved by use of CIDI vehicles and E85 FFVs. The CIDI reduction results from vehicle efficiency gains. The E85 reduction occurs because ethanol is produced from a renewable resource (corn). Even emissions from corn farming and ethanol production are taken into account. Use of LPG and CNG achieves moderate reductions. Use of E10 results in only a small reduction (a few percentage points) because gasoline still accounts for most of E10. The small reduction by M85 FFVs is attributable to methanol production emissions. Use of ETBE in RFG results in a smaller benefit than use of MTBE because ETBE is produced from ethanol.

The reductions in CO_2 and GHG emissions are similar for the combinations of fuels and vehicle technologies considered, except for CNG and E85, which resulted in smaller reductions in GHG emissions than in CO_2 emissions. The smaller GHG emissions reduction by CNGVs is attributable to a large amount of CH_4 emissions during upstream stages of the NG cycle. The smaller reduction by E85 is attributable to a large amount of N_2O emissions during corn farming.

Figure 6.26 presents changes in both total and urban VOC emissions. Use of any fuel or vehicle technology helps reduce fuel-cycle total and urban VOC emissions, except for E10 and E85, both of which produce small increases in VOC emissions (urban VOC emissions are reduced by use of E85). The increase in total VOC emissions with E85 is caused by significant VOC emissions released during ethanol production. High VOC emissions during ethanol production and high VOC evaporative emissions during vehicle operation cause the increases in both total and urban VOC emissions when E10 is used. Use of EVs achieves better than 90% reductions in both total and urban VOC emissions. In fact, use of EVs almost eliminates urban VOC emissions. Use of LPGVs, CNGVs, diesel CIDI, CNGVs, grid-connected HEVs, or diesel HEVs achieves greater-than-40% reductions. Use of RFG or M85 FFVs achieves reductions of about 20%.

Figure 6.27 shows that use of the subject fuels or vehicle technologies helps reduce both total and urban fuel-cycle CO emissions. Because the greater portion of fuel-cycle emissions occurs during vehicle operation for these fuels or technologies (except for EVs), urban CO emissions, where vehicular CO emissions occur, are very close to total CO emissions. Use of EVs and diesel fuels in HEVs or CIDI engines helps reduce CO emissions by more than 80%. Use of CNGVs, LPGVs, methanol FFVs, ethanol FFVs, E10 FFVs, and HEVs results in reductions in CO emissions of around 40%. Use of RFG reduces CO emissions by about 20%.

Figure 6.28 indicates that NO_x emissions can decrease or increase, depending on the fuels or vehicle technologies used. For urban NO_x emissions, diesel engines face the challenge of

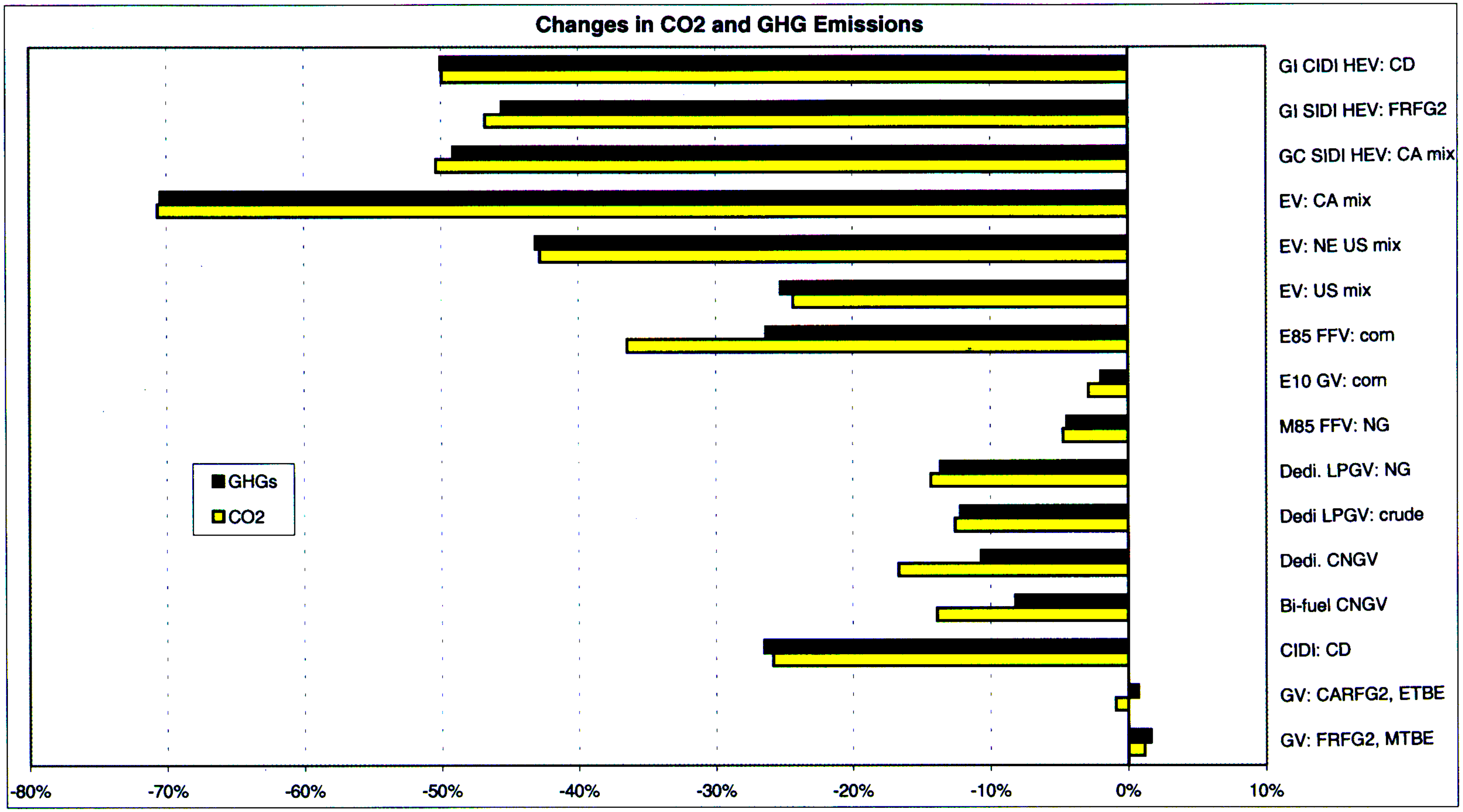

Figure 6.25 Changes in Fuel-Cycle GHG Emissions Relative to GVs Fueled with CG: Near-Term Technologies

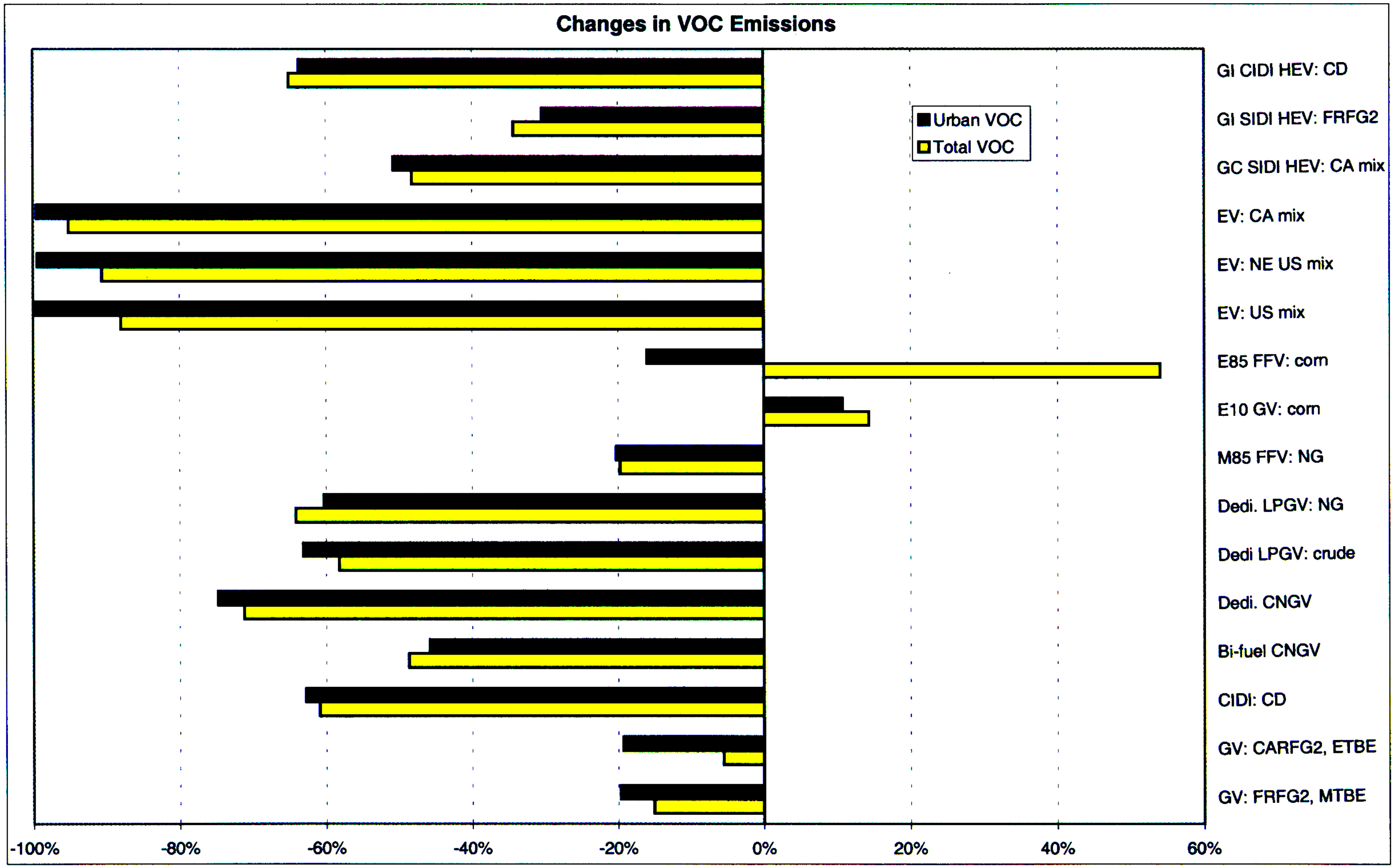

Figure 6.26 Changes in Fuel-Cycle VOC Emissions Relative to GVs Fueled with CG: Near-Term Technologies

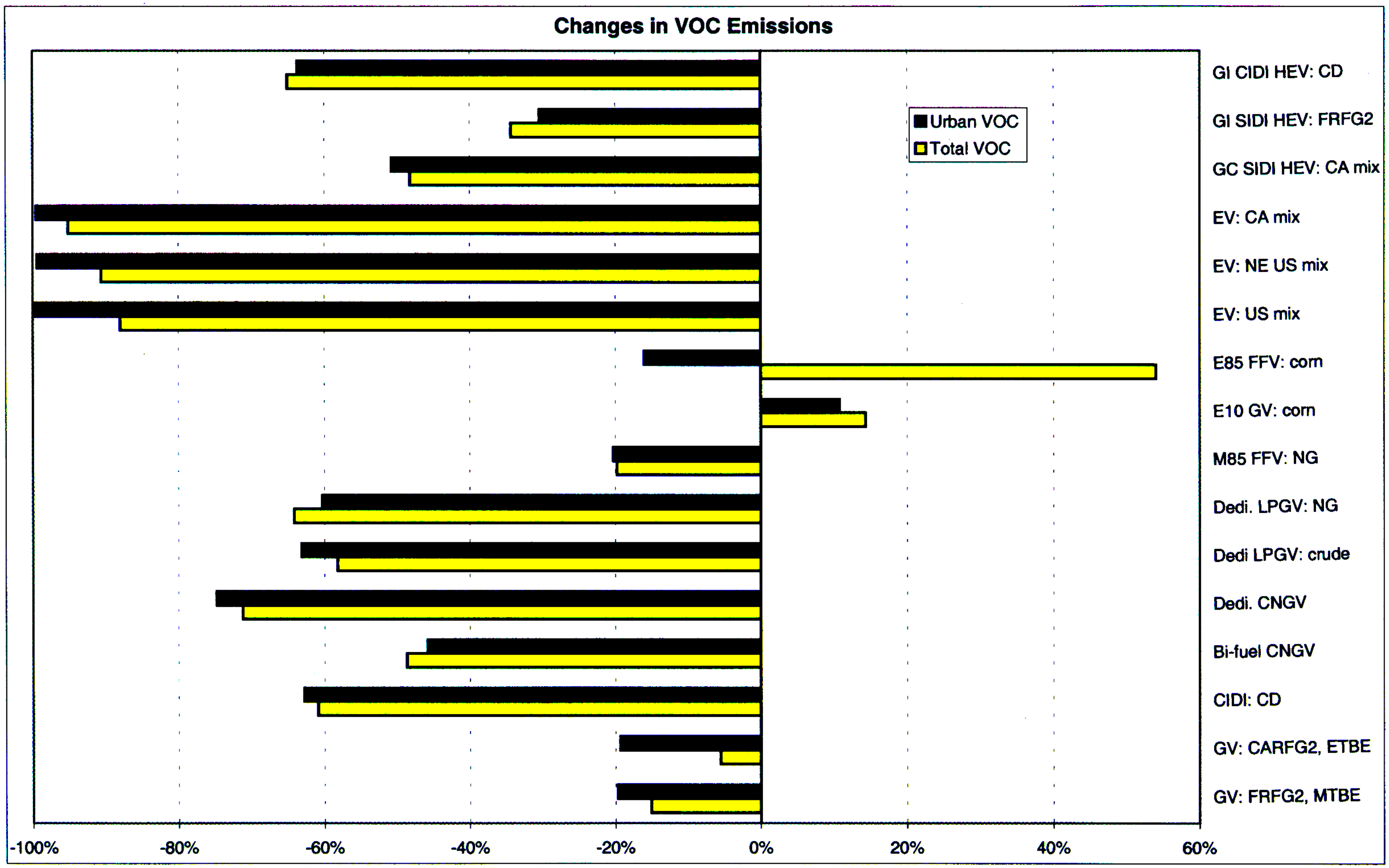

Figure 6.27 Changes in Fuel-Cycle CO Emissions Relative to GVs Fueled with CG: Near-Term Technologies

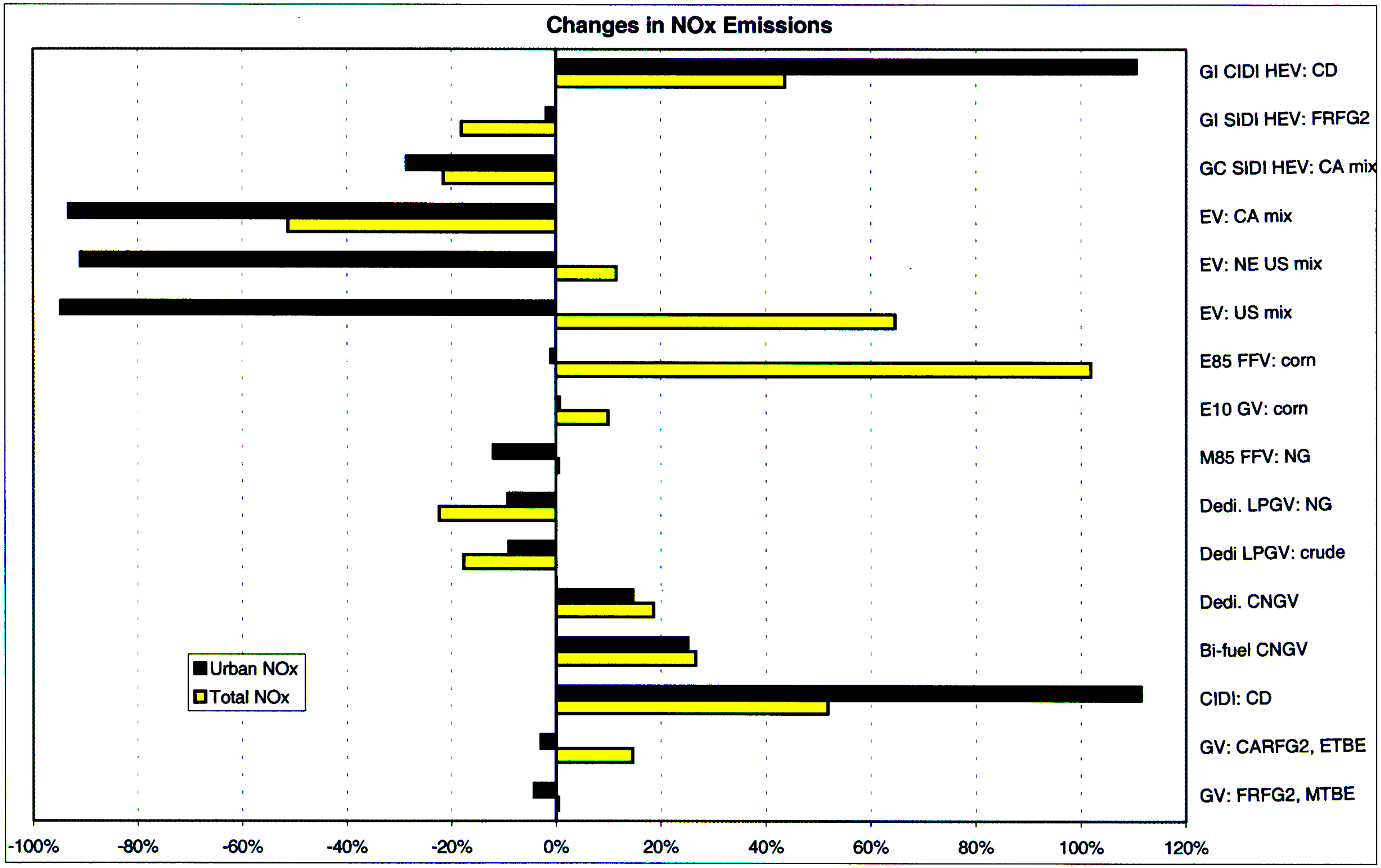

Figure 6.28 Changes in Fuel-Cycle NO_x Emissions Relative to GVs Fueled with CG: Near-Term Technologies