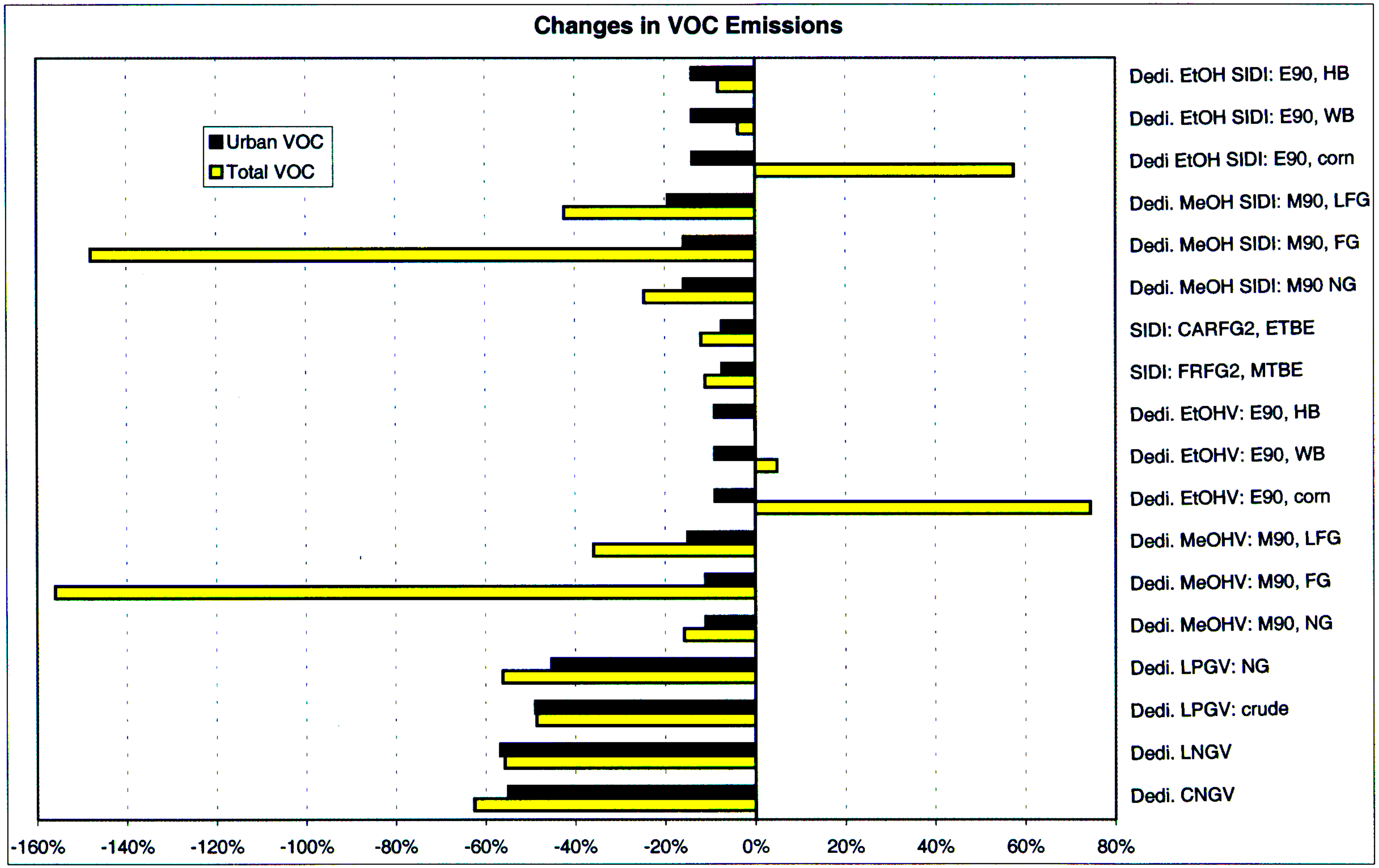

Figure 6.47 Changes in Fuel-Cycle Total and Urban VOC Emissions Relative to GVs Fueled with RFG: Long-Term SI and SIDI Vehicles

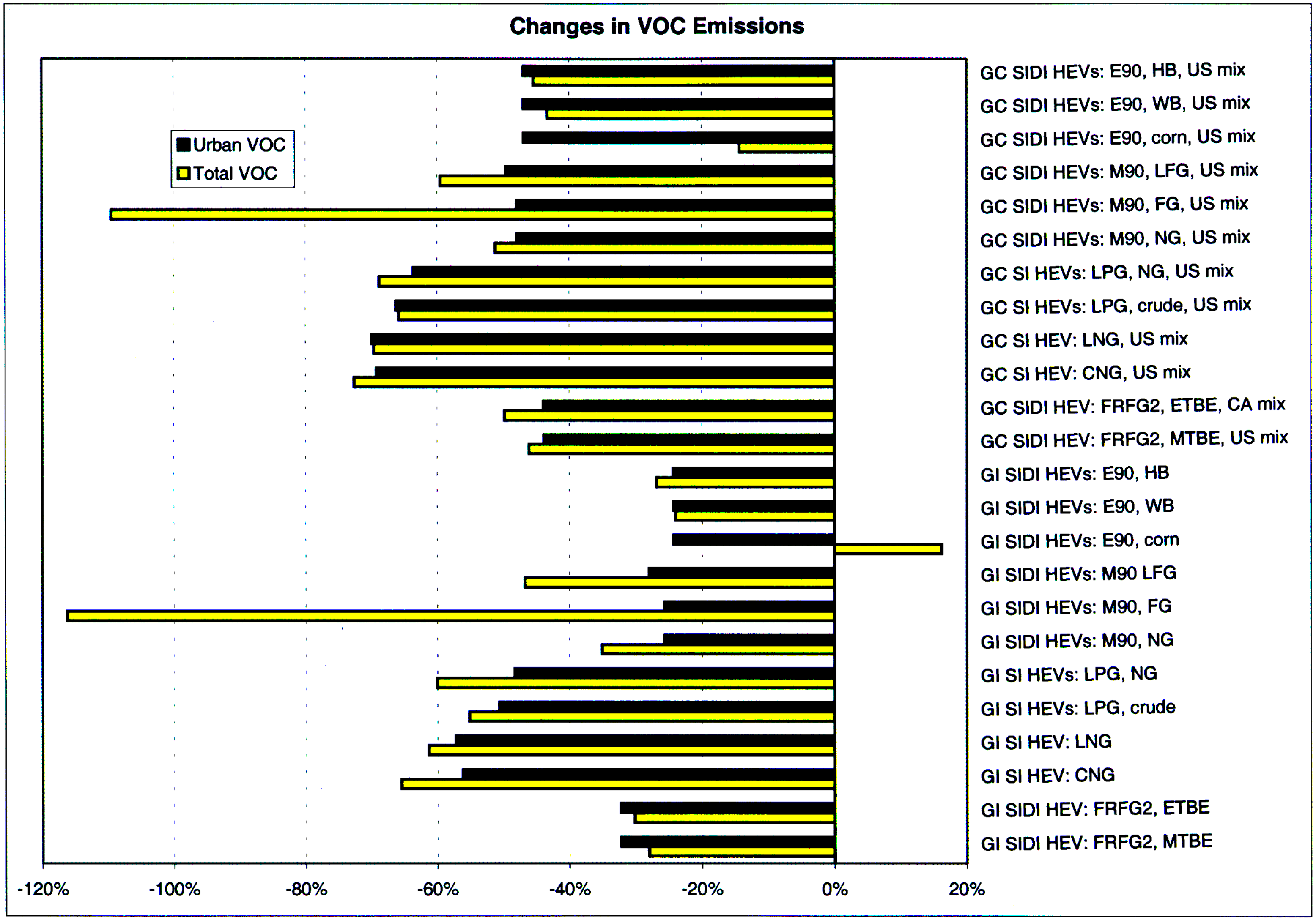

Figure 6.48 Changes in Fuel-Cycle Total and Urban VOC Emissions Relative to GVs Fueled with RFG: Long-Term SI and SIDI HEVs

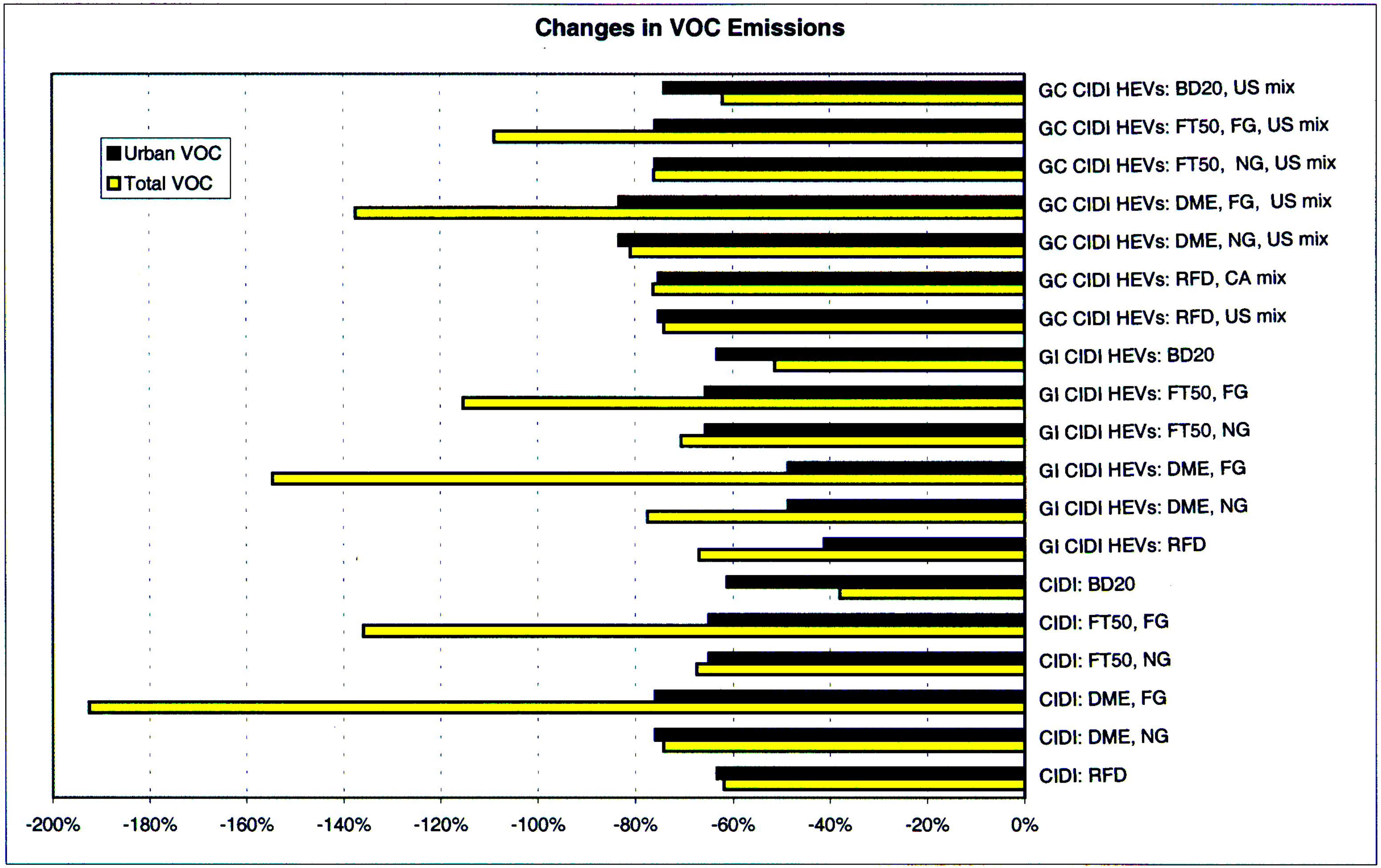

Figure 6.49 Changes in Fuel-Cycle Total and Urban VOC Emissions Relative to GVs Fueled with RFG: Long-Term CIDI Vehicles and CIDI HEVs

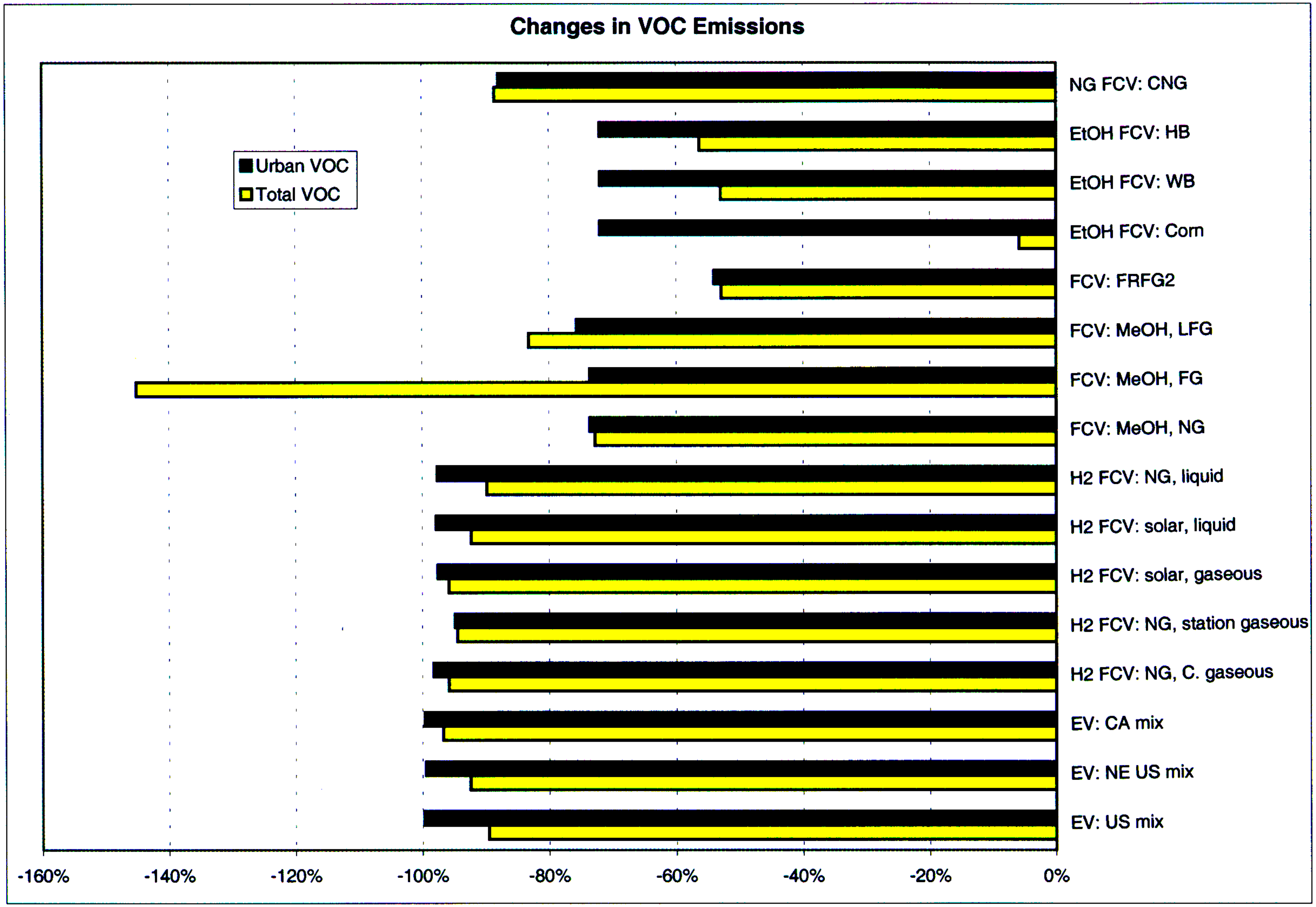

Figure 6.50 Changes in Fuel-Cycle Total and Urban VOC Emissions Relative to GVs Fueled with RFG: Long-Term EVs and FCVs

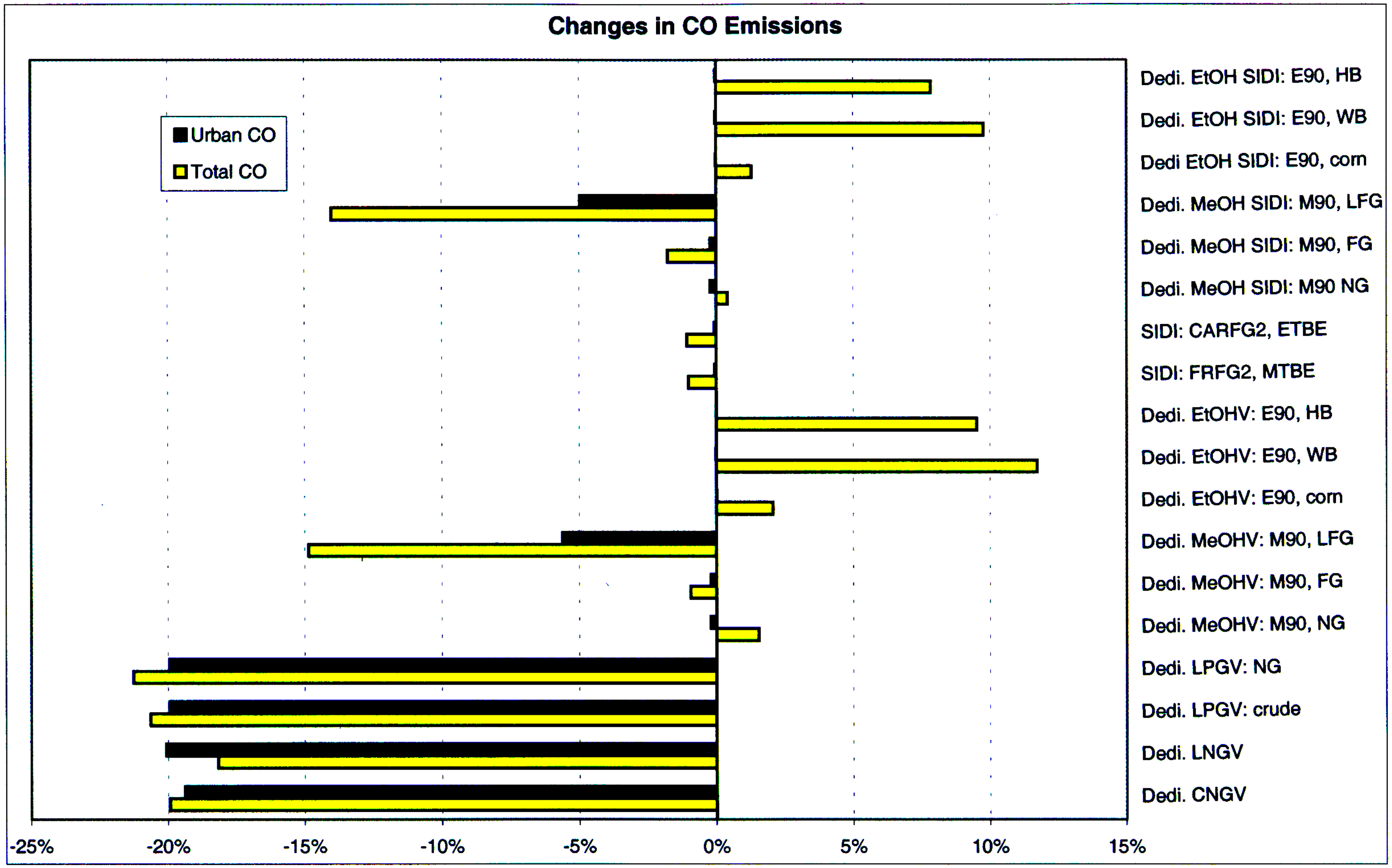

Figure 6.51 Changes in Fuel-Cycle Total and Urban CO Emissions Relative to GVs Fueled with RFG: Long-Term SI and SIDI Vehicles

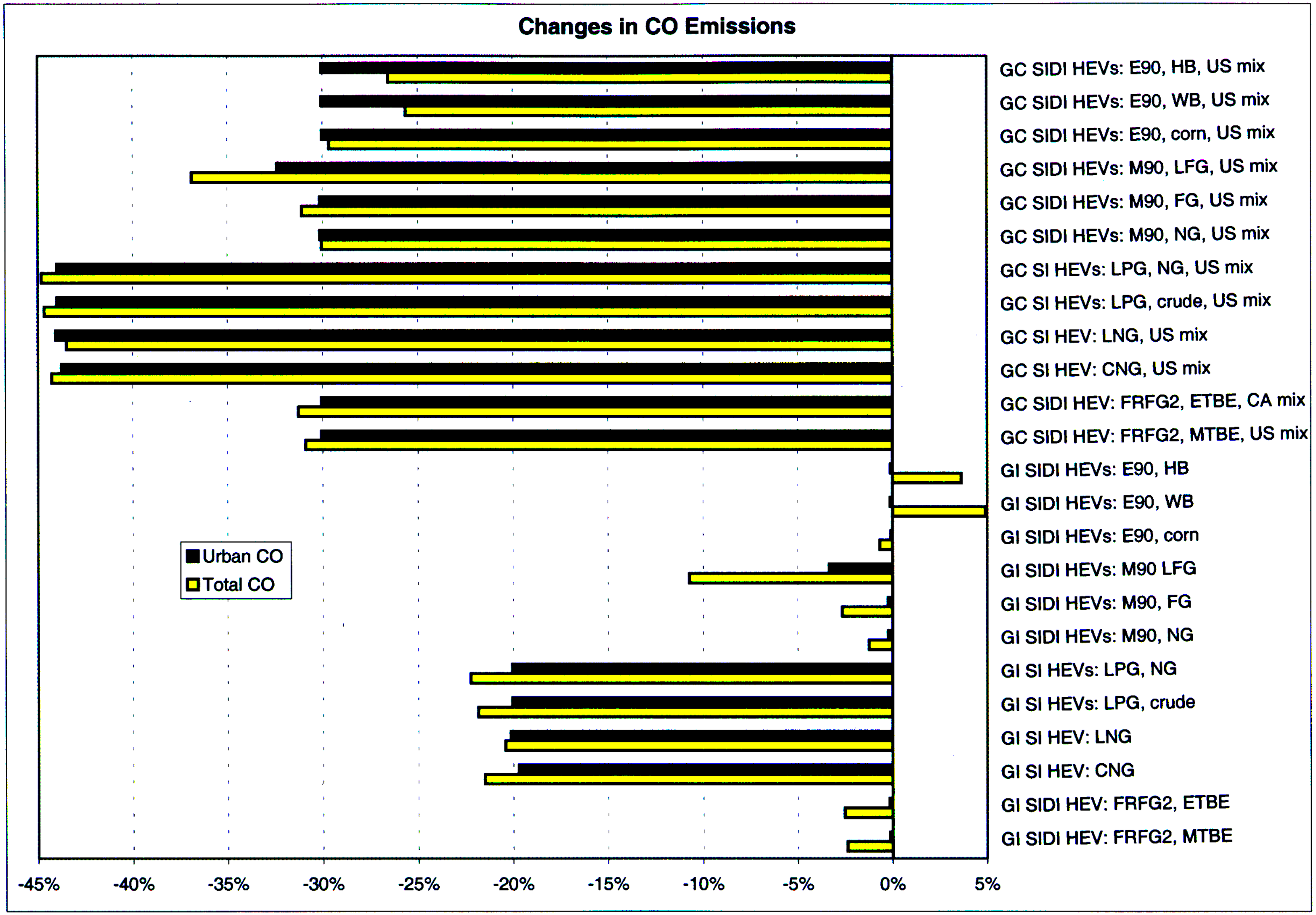

Figure 6.52 Changes in Fuel-Cycle Total and Urban CO Emissions Relative to GVs Fueled with RFG: Long-Term SI and SIDI HEVs

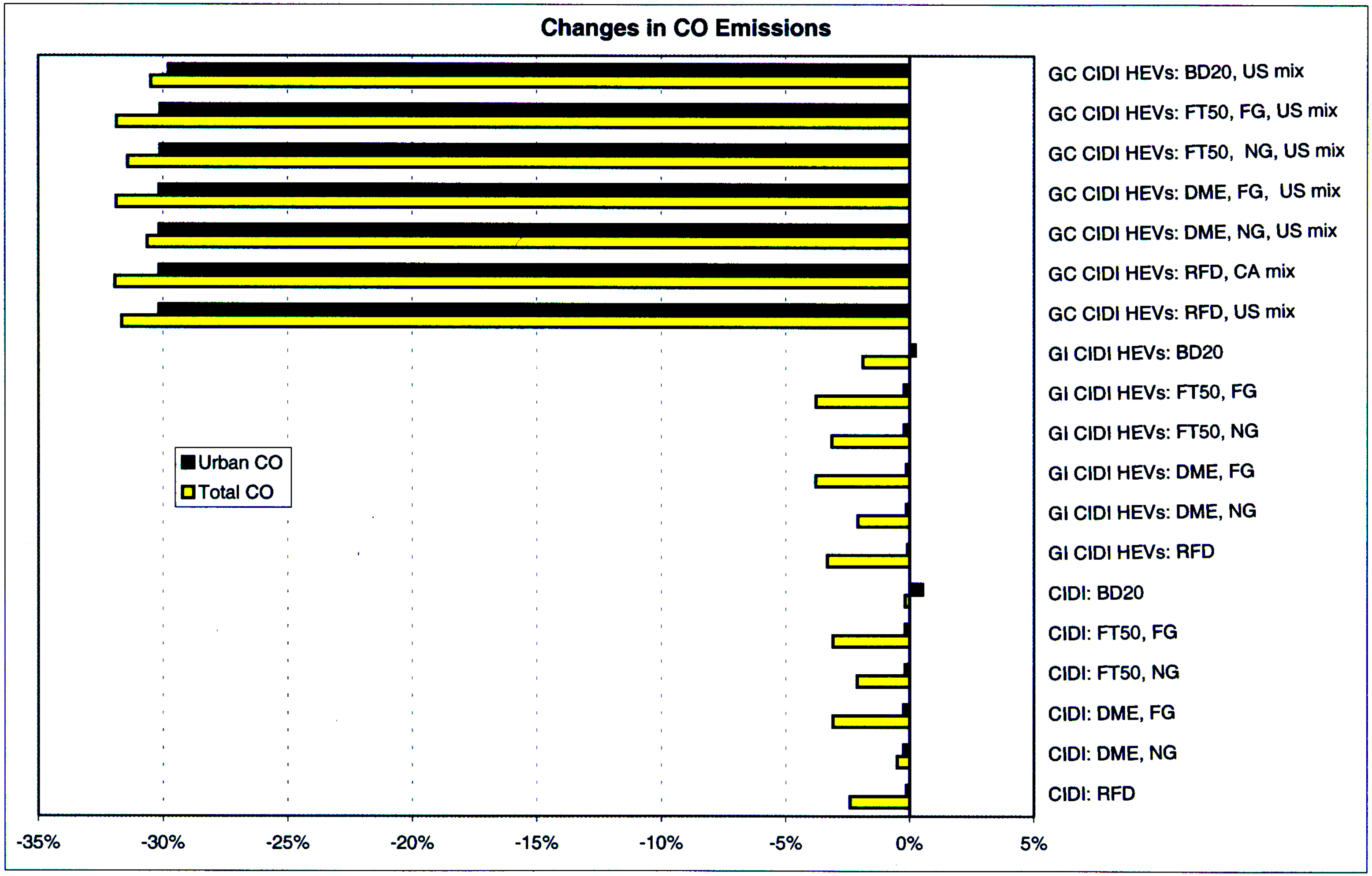

Figure 6.53 Changes in Fuel-Cycle Total and Urban CO Emissions Relative to GVs Fueled with RFG: Long-Term CIDI Vehicles and CIDI HEVs

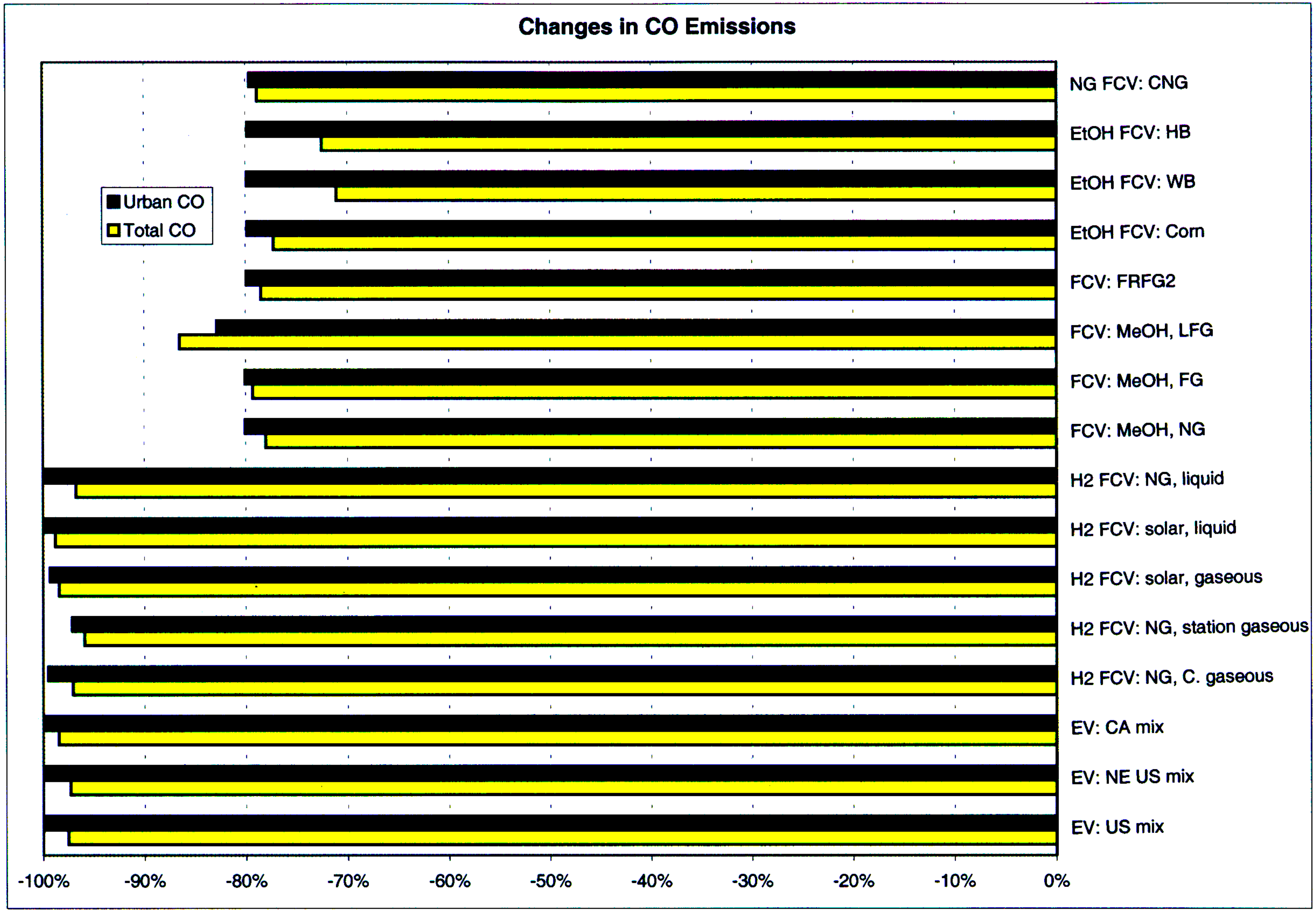

Figure 6.54 Changes in Fuel-Cycle Total and Urban CO Emissions Relative to GVs Fueled with RFG: Long-Term EVs and FCVs

Figure 6.52 shows that use of CNG, LNG, and LPG in SI HEVs achieves 20–40% reductions in total and urban CO emissions. Use of methanol and ethanol has little effect on CO emissions. The figure shows that GC HEVs achieve consistently higher CO emission reductions than GI HEVs.

Figure 6.53 presents CO emission changes for CIDI standalone and hybrid vehicles. Use of CIDI standalone vehicles and CIDI GI HEVs has little effect on CO emissions, especially urban CO emissions. GC HEVs achieve about 30% reductions in CO emissions. The reductions are from the miles traveled on grid electricity for these HEVs. Note that in our GREET simulations (see Section 5), we assume that 30% of the total VMT for GC HEVs are powered by grid electricity.

Figure 6.54 shows CO emission reductions by EVs and FCVs. EVs and H_2-fueled FCVs almost eliminate CO emissions; they are true zero-emission vehicles. FCVs powered with methanol, ethanol, gasoline, and CNG achieve about 80% reductions in CO emissions. The CO emission reductions by these fuels are lower because of emissions associated with on-board fuel processing.

Figures 6.55 through 6.58 present changes in total and urban NO_x emissions for the long-term technology options. Figure 6.55 shows that NO_x emissions for some of the SI and SIDI vehicle options may increase significantly. For example, total NO_x emissions from use of ethanol increase 100–200% because of emissions during farming (tractors and nitrification and denitrification of nitrogen fertilizer) and emissions associated with diesel locomotives and trucks for ethanol transportation and distribution. Use of CNG can result in increased total and urban NO_x emissions caused by emissions from NG compressors in CNG refueling stations (we assumed that one half of the compressors used are electric and the remainder are powered by NG). Use of LNG increases total NO_x emissions, primarily because of emissions from diesel locomotives and diesel trucks used for LNG transportation and distribution. Use of LPG and methanol reduces NO_x emissions slightly. Use of landfill gas-based methanol achieves large reductions because landfill gas burning is eliminated.

Figure 6.56 presents changes in NO_x emissions by SI and SIDI HEVs. The general patterns in NO_x emissions for these vehicle options are similar to those for SI and SIDI vehicles (as shown in Figure 6.55). That is, use of ethanol could increase total NO_x emissions and use of CNG could lead to increased urban NO_x emissions. For other fuels such as LPG, methanol, and RFG, use of HEVs results in moderate reductions in NO_x emissions. Large reductions are achieved with use of flared gas- and landfill gas-based methanol. Use of GC HEVs achieves greater NO_x emission reductions than use of GI HEVs.

Figure 6.57 shows changes in NO_x emissions by CIDI vehicles and CIDI HEVs. In general, these vehicle options have higher urban NO_x emissions than baseline GVs, except GC HEVs, which generate NO_x emissions at levels similar to those of baseline GVs. Most vehicle options reduce total NO_x emissions because the amount of emissions from petroleum refining is larger than the amount from producing these CI fuels.

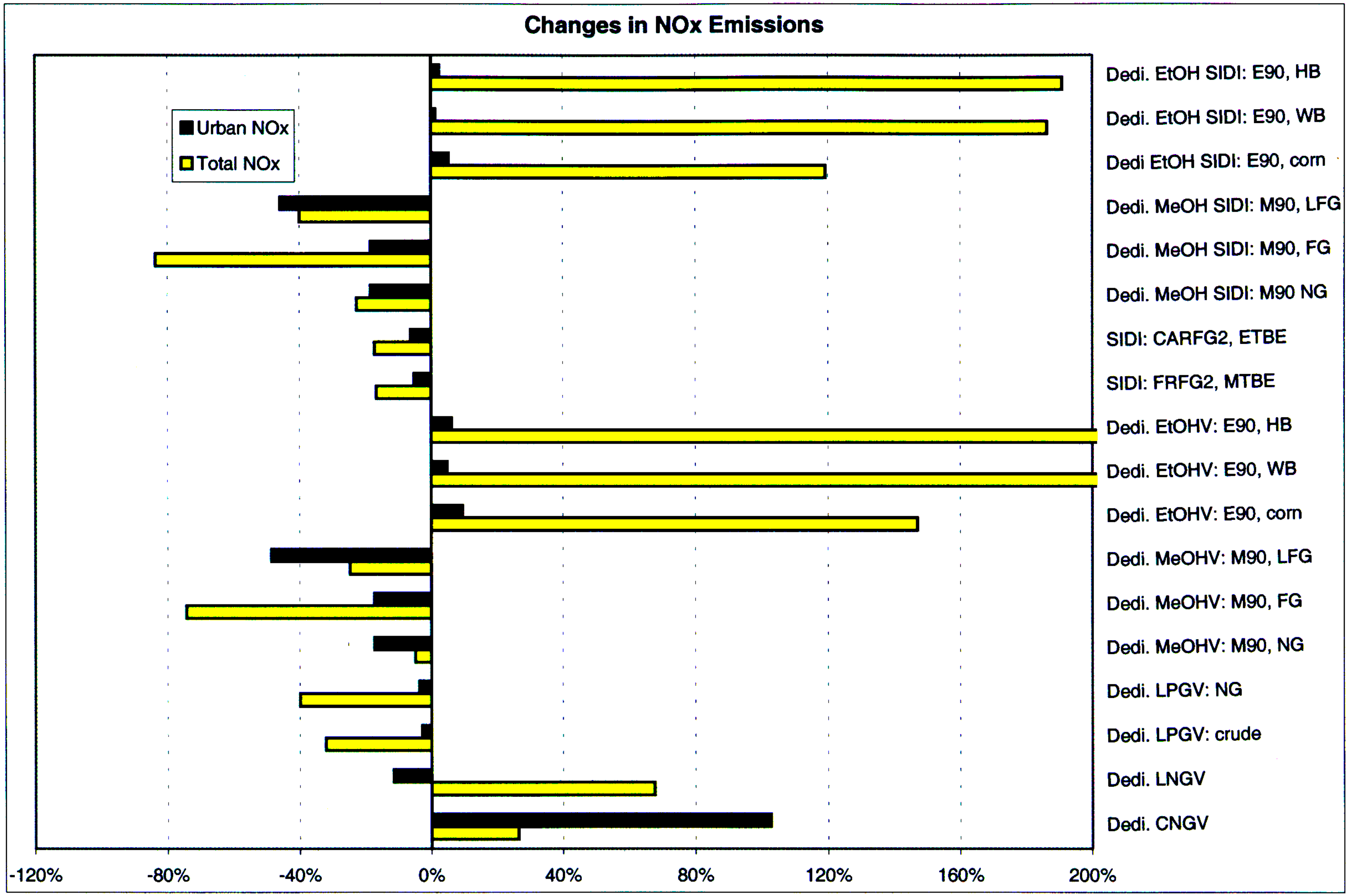

Figure 6.55 Changes in Fuel-Cycle Total and Urban NO_x Emissions Relative to GVs Fueled with RFG: Long-Term SI and SIDI Vehicles

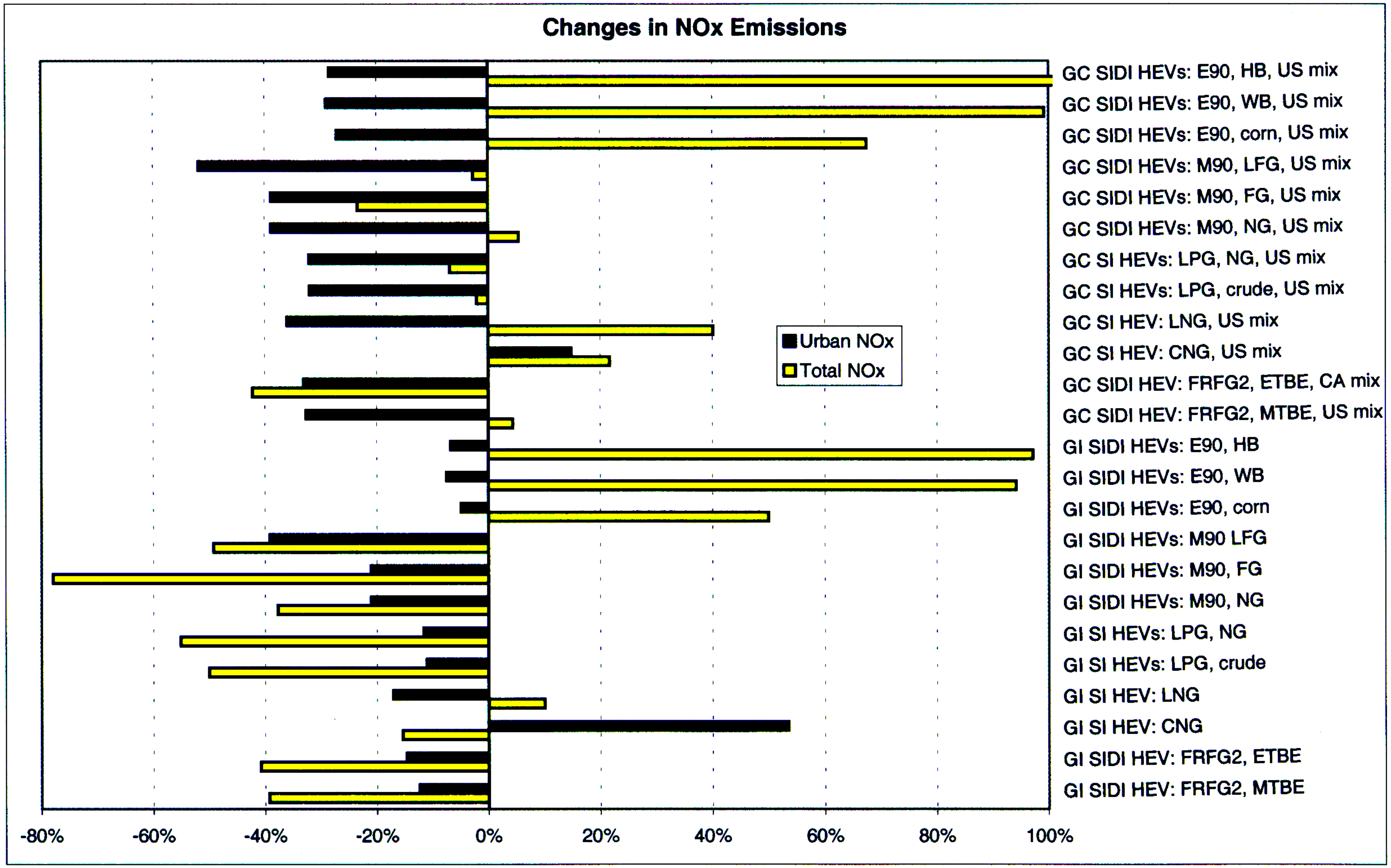

Figure 6.56 Changes in Fuel-Cycle Total and Urban NO_x Emissions Relative to GVs Fueled with RFG: Long-Term SI and SIDI HEVs

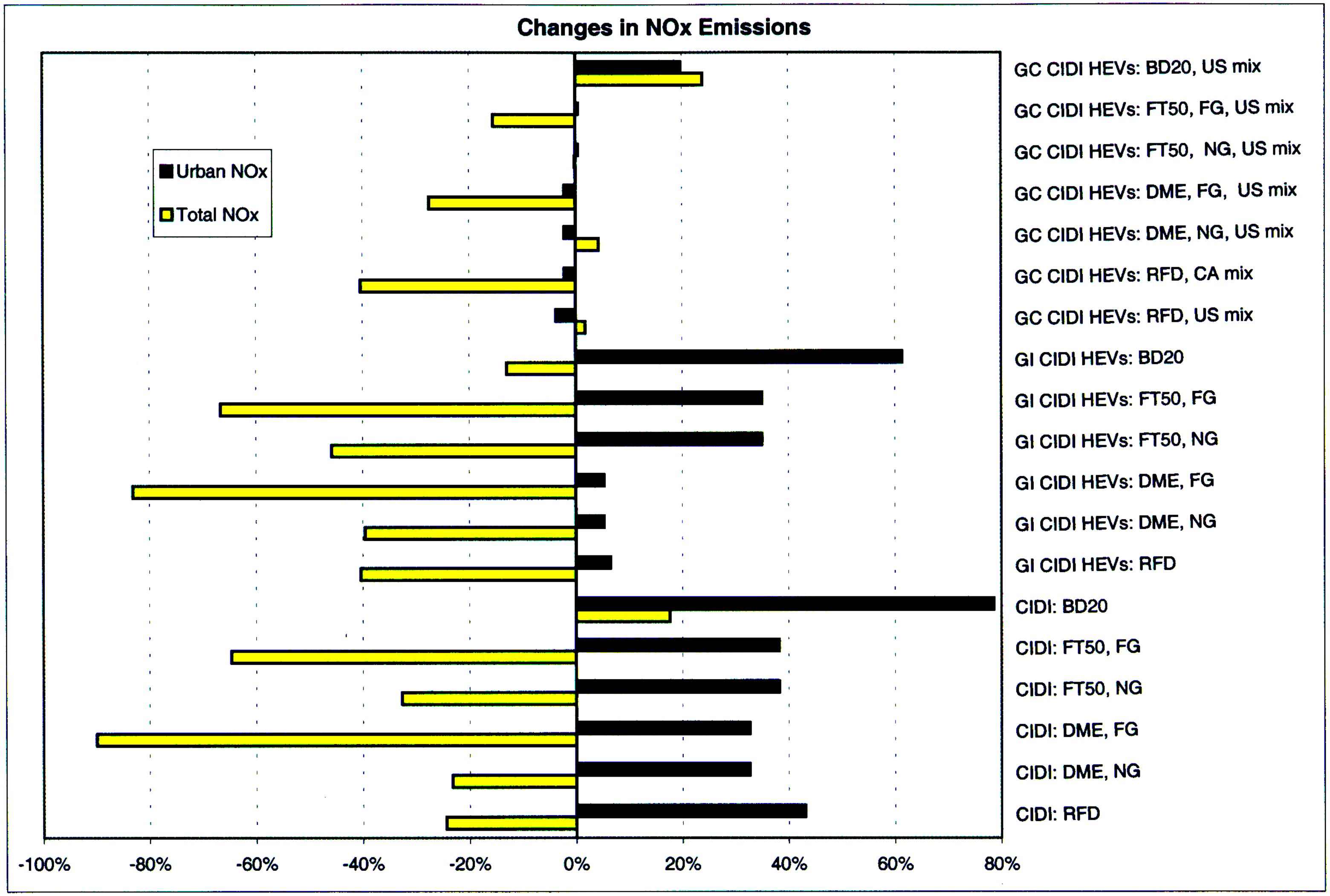

Figure 6.57 Changes in Fuel-Cycle Total and Urban NO_x Emissions Relative to GVs Fueled with RFG: Long-Term CIDI Vehicles and CIDI HEVs

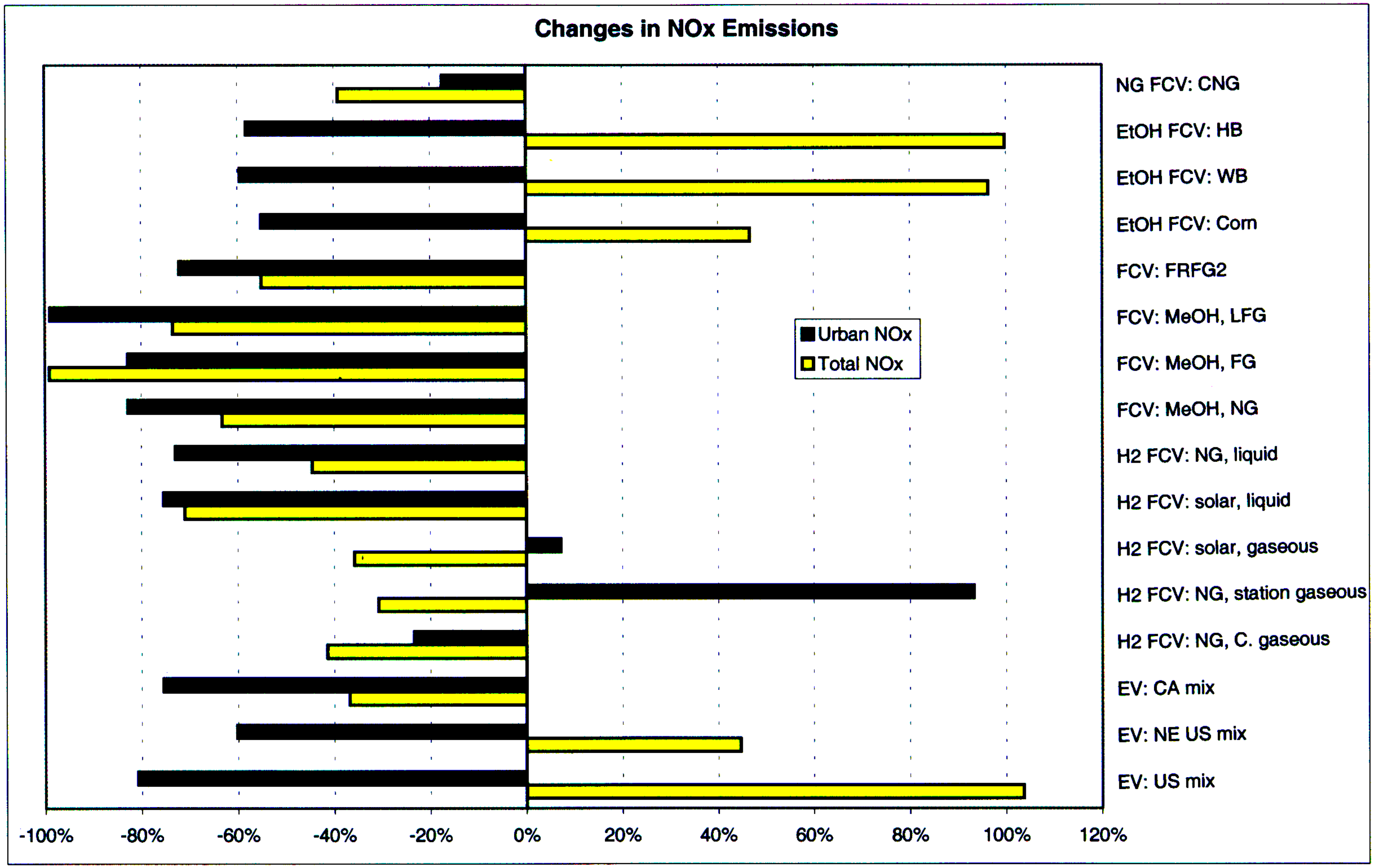

Figure 6.58 Changes in Fuel-Cycle Total and Urban NO_x Emissions Relative to GVs Fueled with RFG: Long-Term EVs and FCVs

Figure 6.58 presents changes in NO_x emissions for EVs and FCVs. With the U.S. and Northeast U.S. electric generation mix, use of EVs results in increases in total NO_x emissions, but decreases in urban NO_x emissions. With the California generation mix, EVs reduce both total and urban NO_x emissions. Of the FCV options, use of H_2 produced from NG at refueling stations (decentralized H_2 production) results in increases in urban emissions, because NO_x emissions from H_2 production at refueling stations occurs within urban areas. Use of ethanol increases total NO_x emissions because of high NO_x emissions during farming and ethanol production. Use of other fuels can achieve 60–80% reductions in urban NO_x emissions.

The results of changes in NO_x emissions demonstrate the increased importance of upstream emissions as regulations for vehicle tailpipe emissions are tightened. Even for clean vehicle technologies, such as CNGVs and H_2-fueled FCVs, urban NO_x emissions can be increased if the fuel used is produced within urban areas. Readers need to keep in mind that NO_x emissions from fuel production and compression calculated in GREET are estimated on the basis of current information, assumptions of the split between electric and gas compressors, and estimated emissions from gas compressors. When new information becomes available, the NO_x emission results could be different.

Figures 6.59 through 6.62 present changes in total and urban PM_{10} emissions for the long-term options. Note that vehicular PM_{10} emissions include tire- and brake-wear emissions as well as exhaust emissions. In fact, as tailpipe PM_{10} emissions are reduced (as more stringent PM standards for vehicles take effect), tire- and brake-wear emissions will account for a large share of total vehicle PM_{10} emissions. As Figure 6.59 shows, use of landfill gas-based methanol in SI and SIDI engines results in huge reductions in total and urban PM_{10} emissions because production of methanol from landfill gas eliminates PM_{10} emissions from landfill gas burning. On the other hand, use of corn-based ethanol causes large increases in total PM_{10} emissions (although urban PM_{10} emissions are reduced). The large increases are primarily caused by PM_{10} emissions during tillage for corn farming. Also, total PM_{10} emissions are increased to some extent by use of cellulosic ethanol. Use of CNG, LNG, LPG, and methanol from natural gas and flared gas results in moderate reductions in both total and urban PM_{10} emissions.

Figure 6.60 shows changes in PM_{10} emissions for SI and SIDI HEVs. The change patterns with these vehicles types are similar to those for SI and SIDI stand-alone applications (Figure 6.59).

Figure 6.61 presents changes in total and urban PM_{10} emissions for CIDI standalone and hybrid applications. As presented in Table 6.5, we assumed that passenger cars fueled with RFD will meet the PM standard of 0.01 g/mi for Tier 2 Bin 4, the same standard to which Tier 2 gasoline cars will be subject under Tier 2 Bin 3. Consequently, tailpipe PM_{10} emissions for gasoline engines and diesel engines are the same (see Table 6.4). Automakers are currently conducting intensive research and development to reduce diesel engine PM_{10} emissions. While it is conceivable for diesel cars to achieve PM_{10} emissions comparable to those of gasoline cars, diesel engines will face a tough challenge to reduce PM_{10} emissions to that level. On the other hand, we assumed that diesel LDT1 and LDT2 will meet the PM_{10} standard of 0.02 g/mi. Thus, diesel LDT1 and LDT2 will have PM_{10} emissions higher than those of gasoline LDT1 and

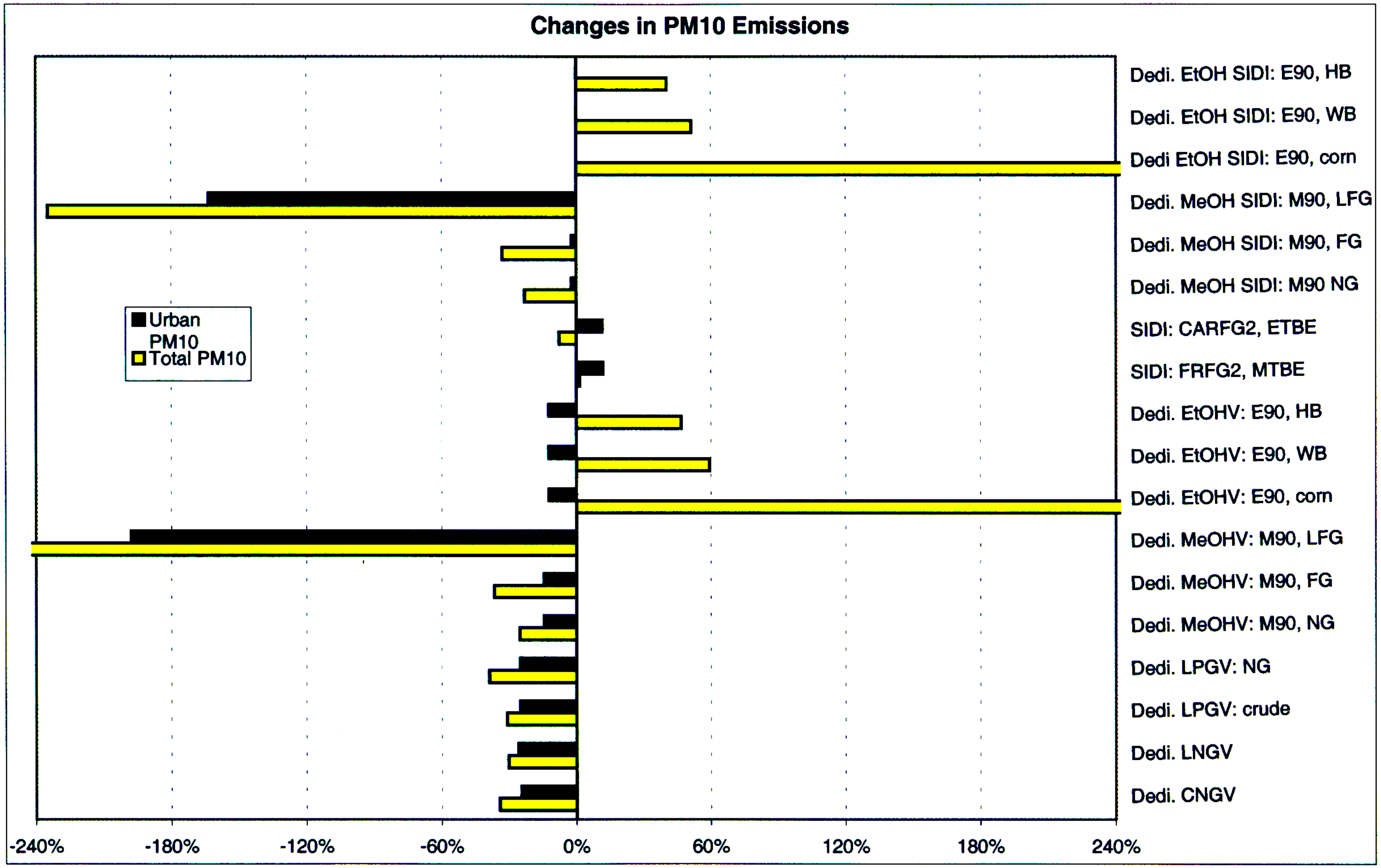

Figure 6.59 Changes in Fuel-Cycle Total and Urban PM_{10} Emissions Relative to GVs Fueled with RFG: Long-Term SI and SIDI Vehicles

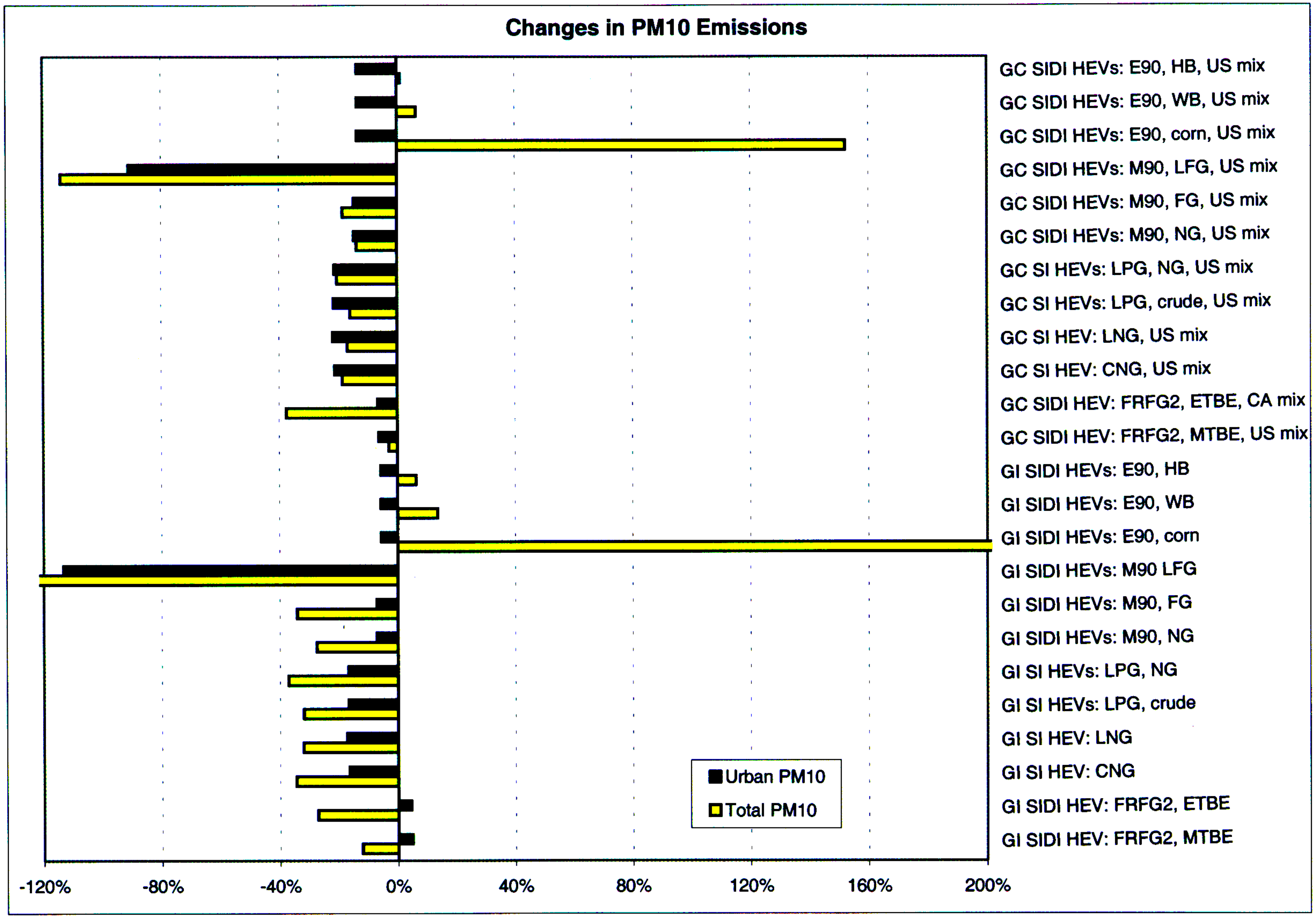

Figure 6.60 Changes in Fuel-Cycle Total and Urban PM_{10} Emissions Relative to GVs Fueled with RFG: Long-Term SI and SIDI HEVs

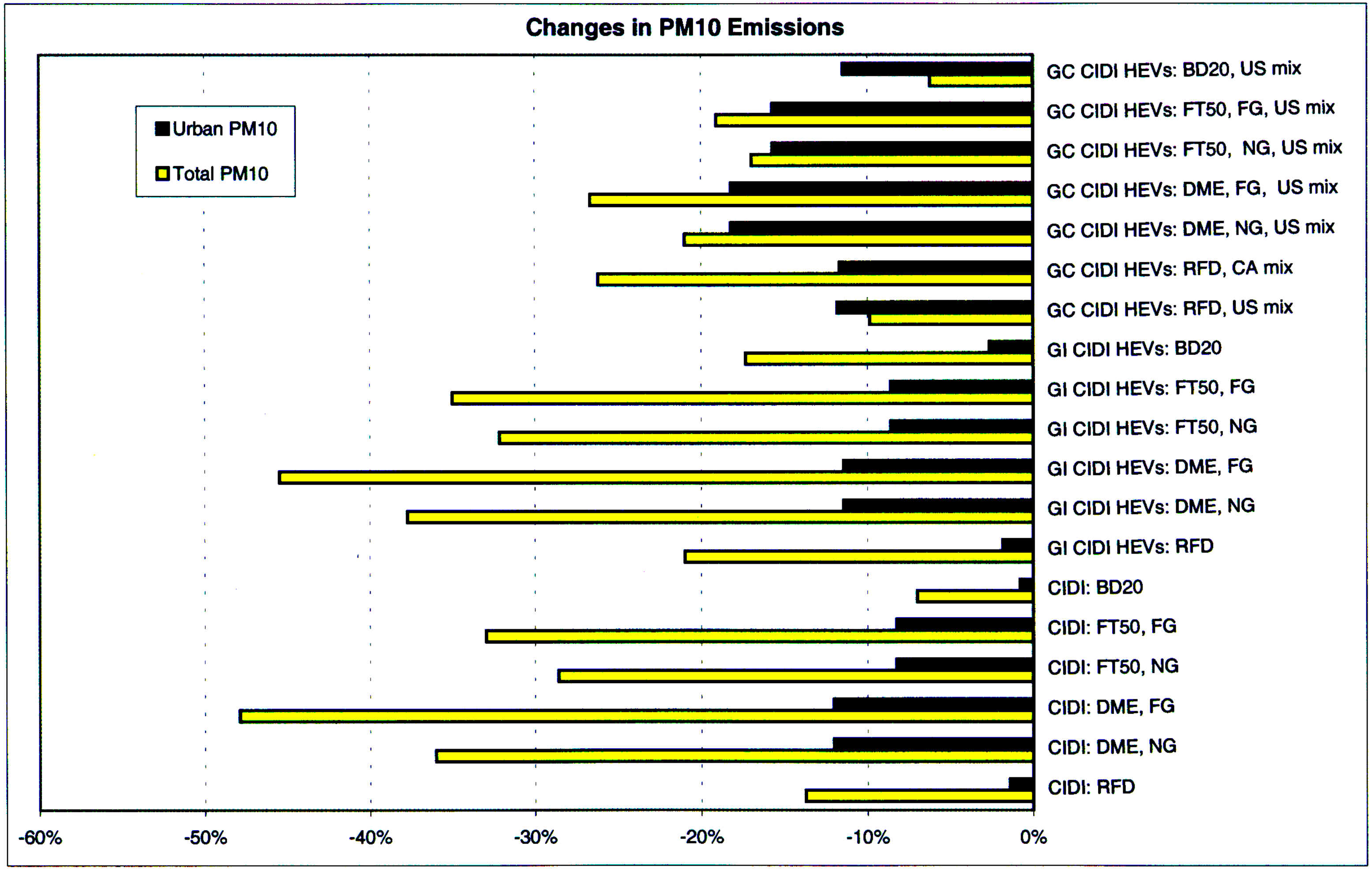

Figure 6.61 Changes in Fuel-Cycle Total and Urban PM_{10} Emissions Relative to GVs Fueled with RFG: Long-Term CIDI Vehicles and CIDI HEVs

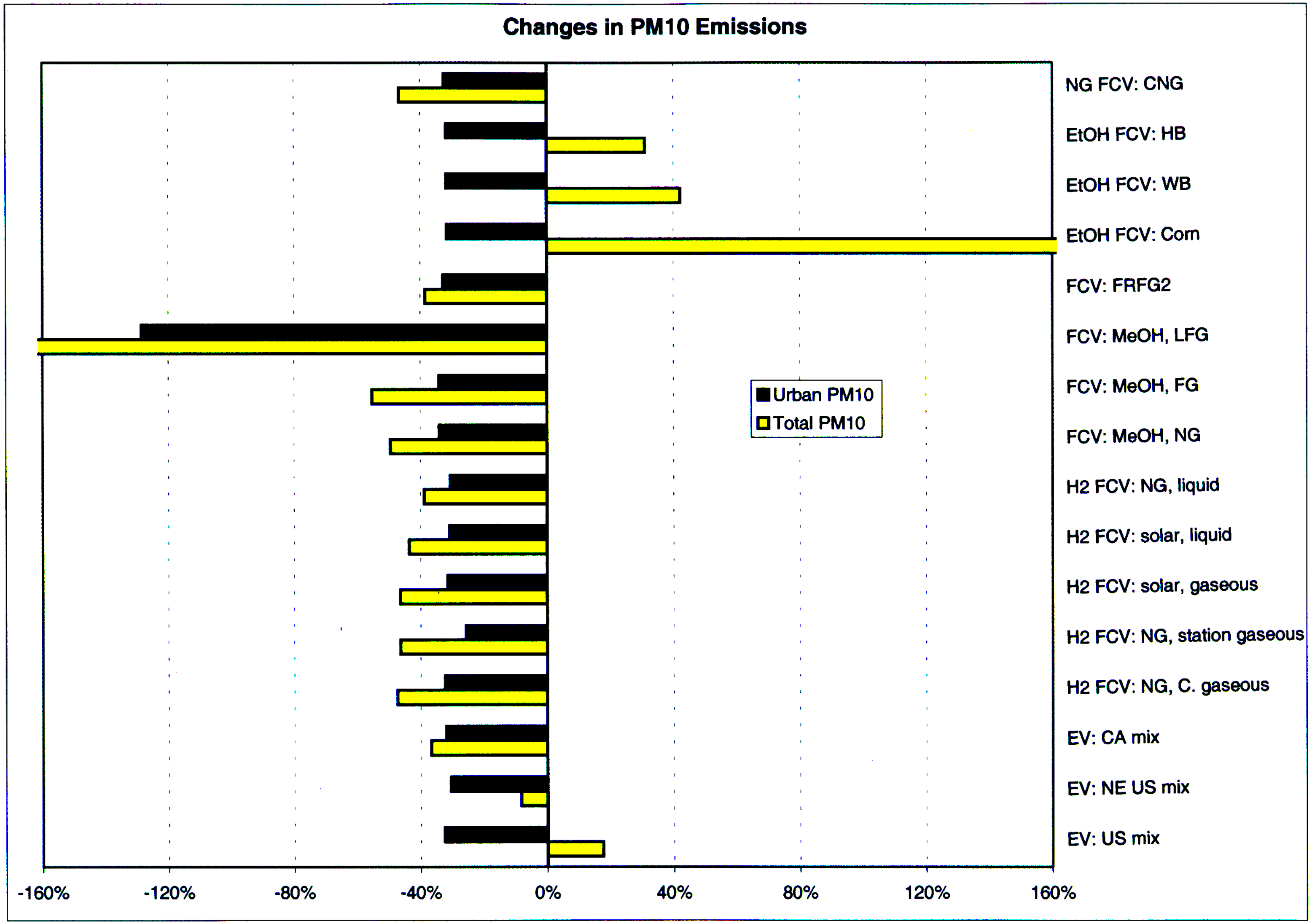

Figure 6.62 Changes in Fuel-Cycle Total and Urban PM_{10} Emissions Relative to GVs Fueled with RFG: Long-Term EVs and FCVs

LDT2, respectively. As Figure 6.61 shows, the CIDI vehicle technologies fueled by RFD, DME, FT50, and BD20 reduce both total and urban PM_{10} emissions. Urban PM_{10} emission reductions are 10–20% for most options.

Figure 6.62 shows PM_{10} emission reductions by EVs and FCVs. Total PM_{10} emissions are increased by use of EVs with the U.S. average electric generation mix and by use of ethanol-fueled FCVs. The increases are caused by high PM_{10} emissions in coal-fired power plants (over 50% of electricity is generated from coal in the United States) and from tillage during corn farming for ethanol. On the other hand, use of landfill gas-based methanol in FCVs results in huge PM_{10} emission reductions because PM_{10} emissions generated by landfill gas burning are eliminated. Other fuel options achieve 30–40% reductions in PM_{10} emissions.

Overall, reductions in PM_{10} emissions by new fuels and advanced vehicle technologies are smaller than researchers might expect, primarily because vehicle tire- and brake-wear PM emissions are included in GREET calculations. Vehicles within the same class have similar tire- and brake-wear emissions, which dilutes the effects of the fuels and vehicle technologies.

Figures 6.63 through 6.66 present total and urban SO_x emission changes for the long-term technologies. Figure 6.63 shows the results for SI and SIDI vehicles. Total SO_x emissions are noticeably increased by use of landfill gas-based methanol and corn-based ethanol. The increase for methanol is caused by the significant amount of electricity used for landfill gas-to-methanol production. Electricity generation produces SO_x emissions outside of urban areas, which is why landfill gas-based methanol still achieves a huge reduction in urban SO_x emissions. For corn-based ethanol, the increased SO_x emissions are the result of coal combustion in ethanol plants. Use of other fuel options generally results in over-80% reductions in urban SO_x emissions, except for RFG used in SIDI engines, where a moderate 20% reduction results from SIDI’s improved fuel economy.

Figure 6.64 presents changes in SO_x emissions for SI and SIDI HEVs. For total SO_x emissions, GC HEVs with the U.S. electric generation mix produce higher emissions than GI HEVs because of high SO_x emissions from coal-fired electric power plants. On the other hand, all the fuel and vehicle options achieve over-80% reductions in urban SO_x emissions, except for RFG, which achieves moderate reductions of 40–60%.

Figure 6.65 shows SO_x emission changes for CIDI vehicles and CIDI HEVs. GC HEVs have higher total SO_x emissions than GI HEVs or CIDI vehicles. Urban SO_x emissions from RFD-fueled CIDI vehicles are a little higher than those from baseline GVs. For urban SO_x emissions, use of DME achieves the largest reduction because DME does not contain sulfur. On the other hand, FT50 and BD20, which contain RFD, account for some SO_x emissions.

As Figure 6.66 shows, EVs and FCVs reduce urban SO_x emissions by over 90%. Total SO_x emissions are increased by EVs with the U.S. and Northeast U.S. electric generation mix because of SO_x emissions from coal and oil-fired electric power plants. Total SO_x emissions are increased by corn-based ethanol in FCVs because of SO_x emissions associated with coal combustion in ethanol plants.

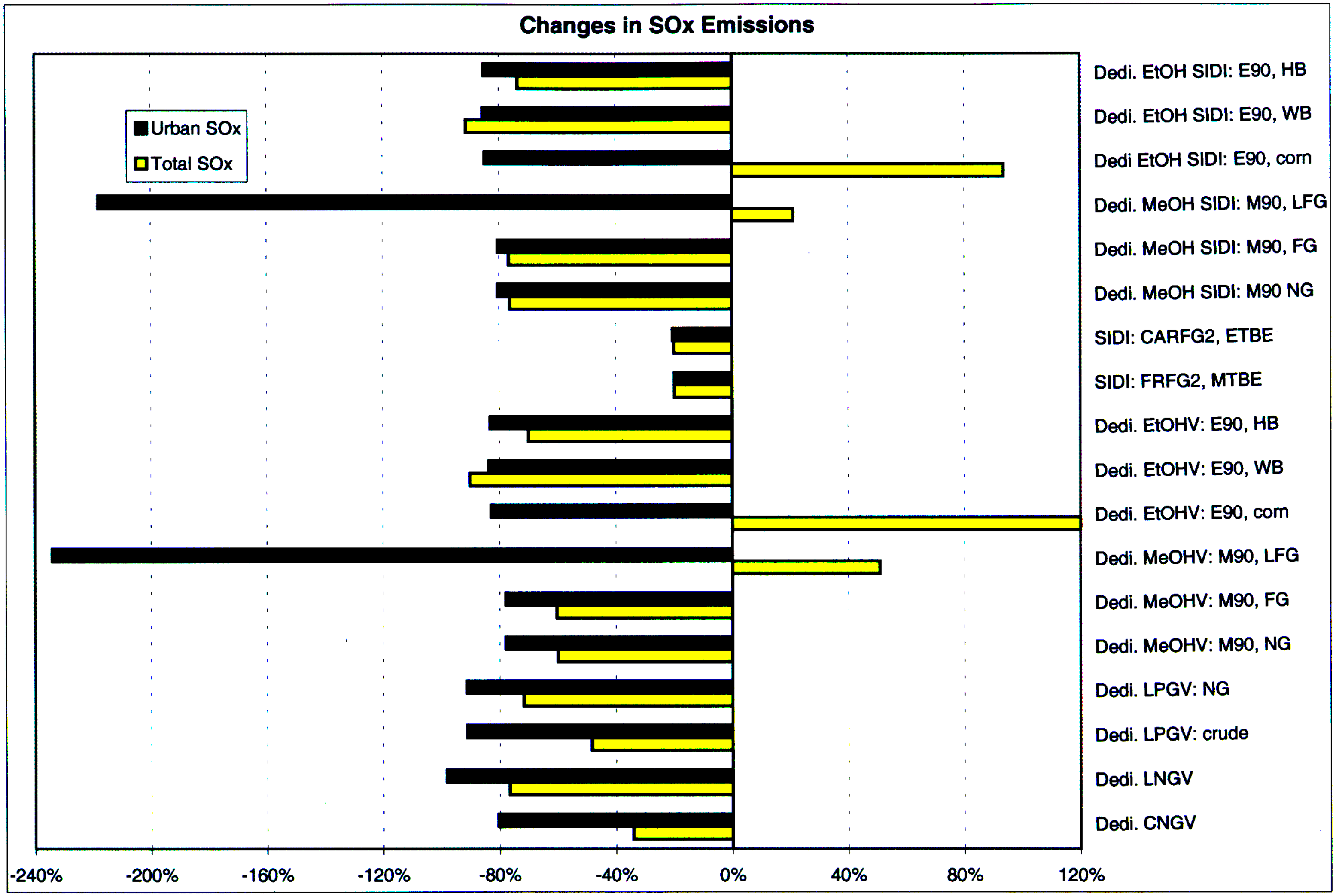

Figure 6.63 Changes in Fuel-Cycle Total and Urban SO_x Emissions Relative to GVs Fueled with RFG: Long-Term SI and SIDI Vehicles

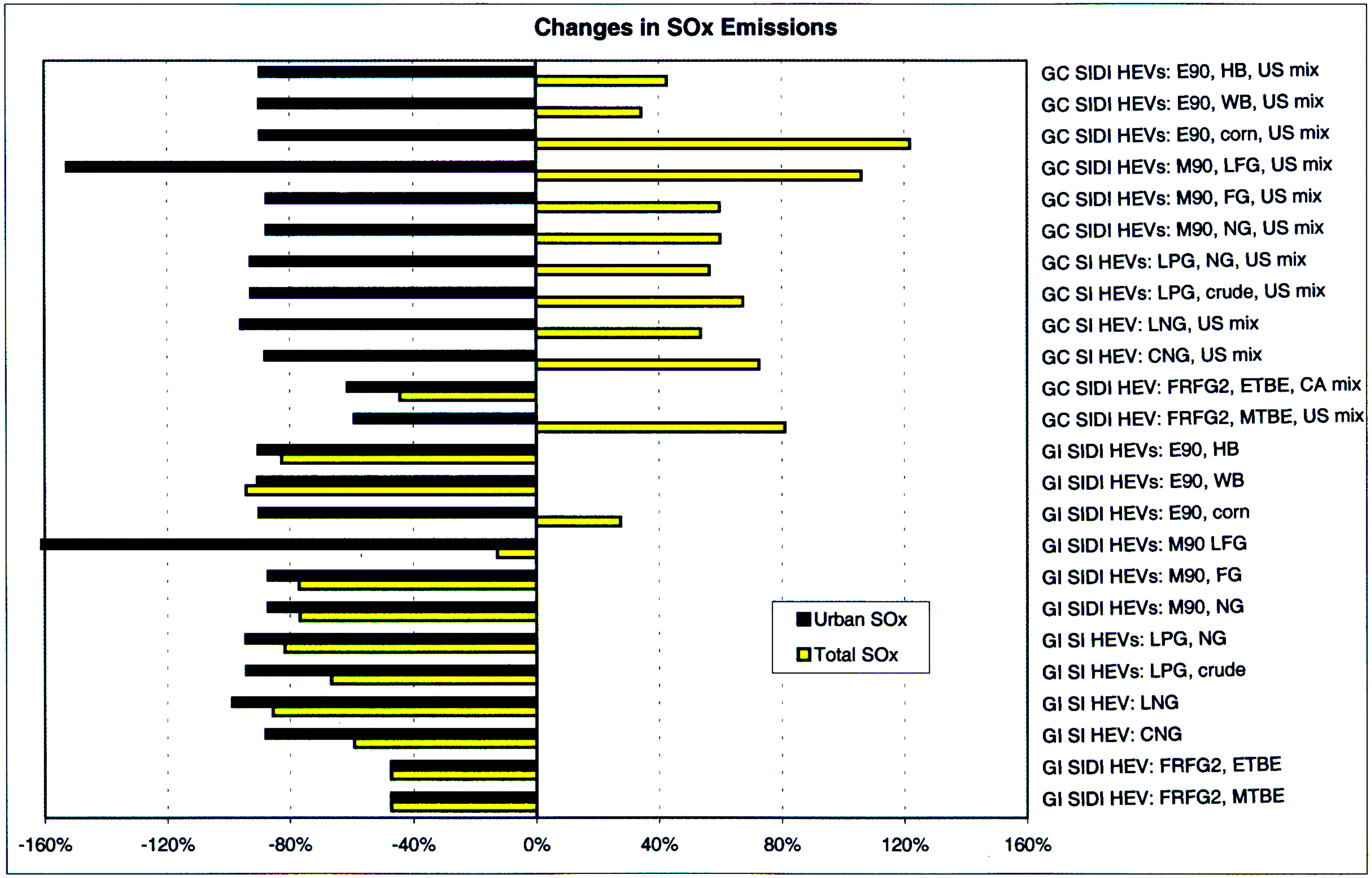

Figure 6.64 Changes in Fuel-Cycle Total and Urban SO_x Emissions Relative to GVs Fueled with RFG: Long-Term SI and SIDI HEVs

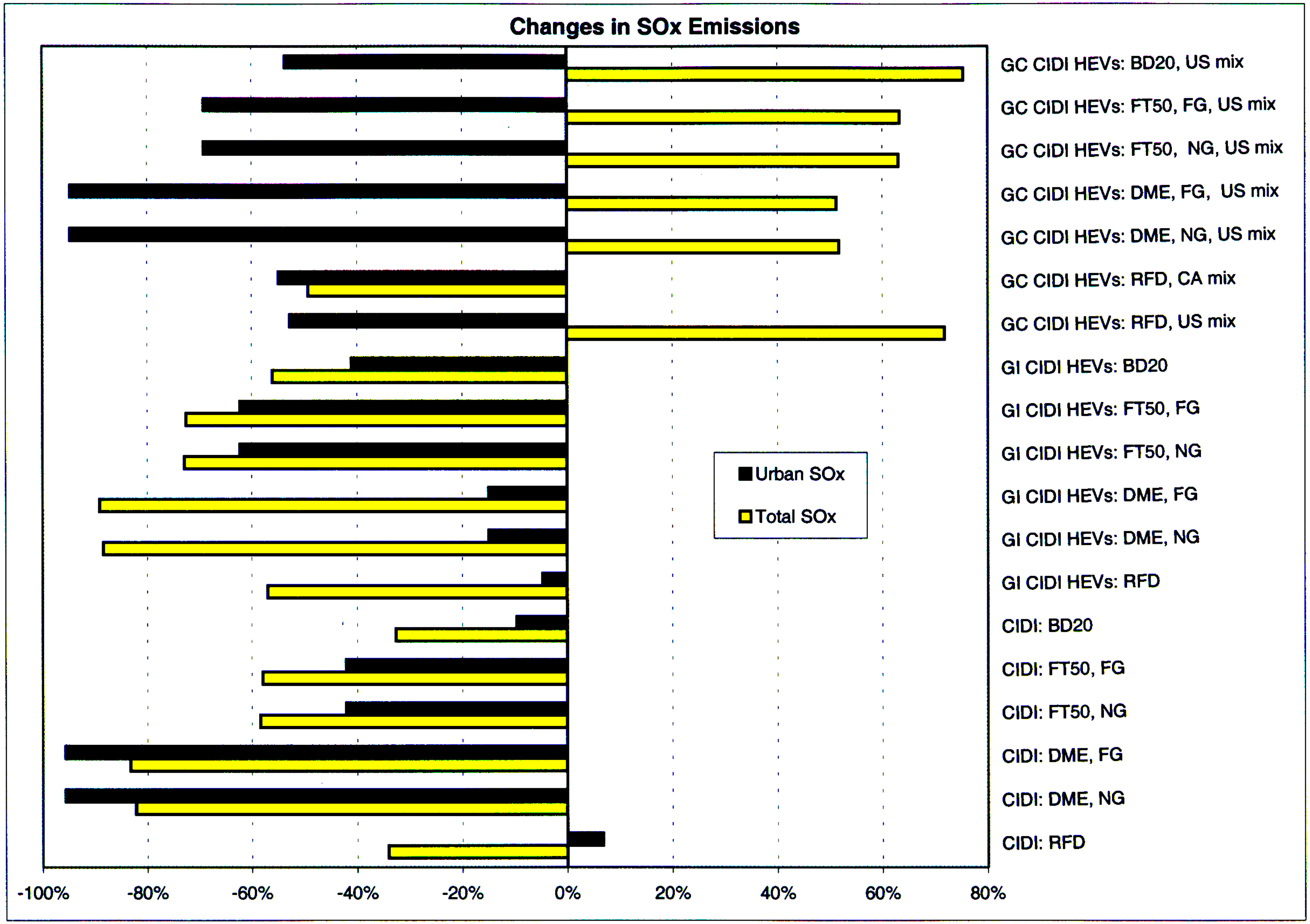

Figure 6.65 Changes in Fuel-Cycle Total and Urban SO_x Emissions Relative to GVs Fueled with RFG: Long-Term CIDI Vehicles and CIDI HEVs

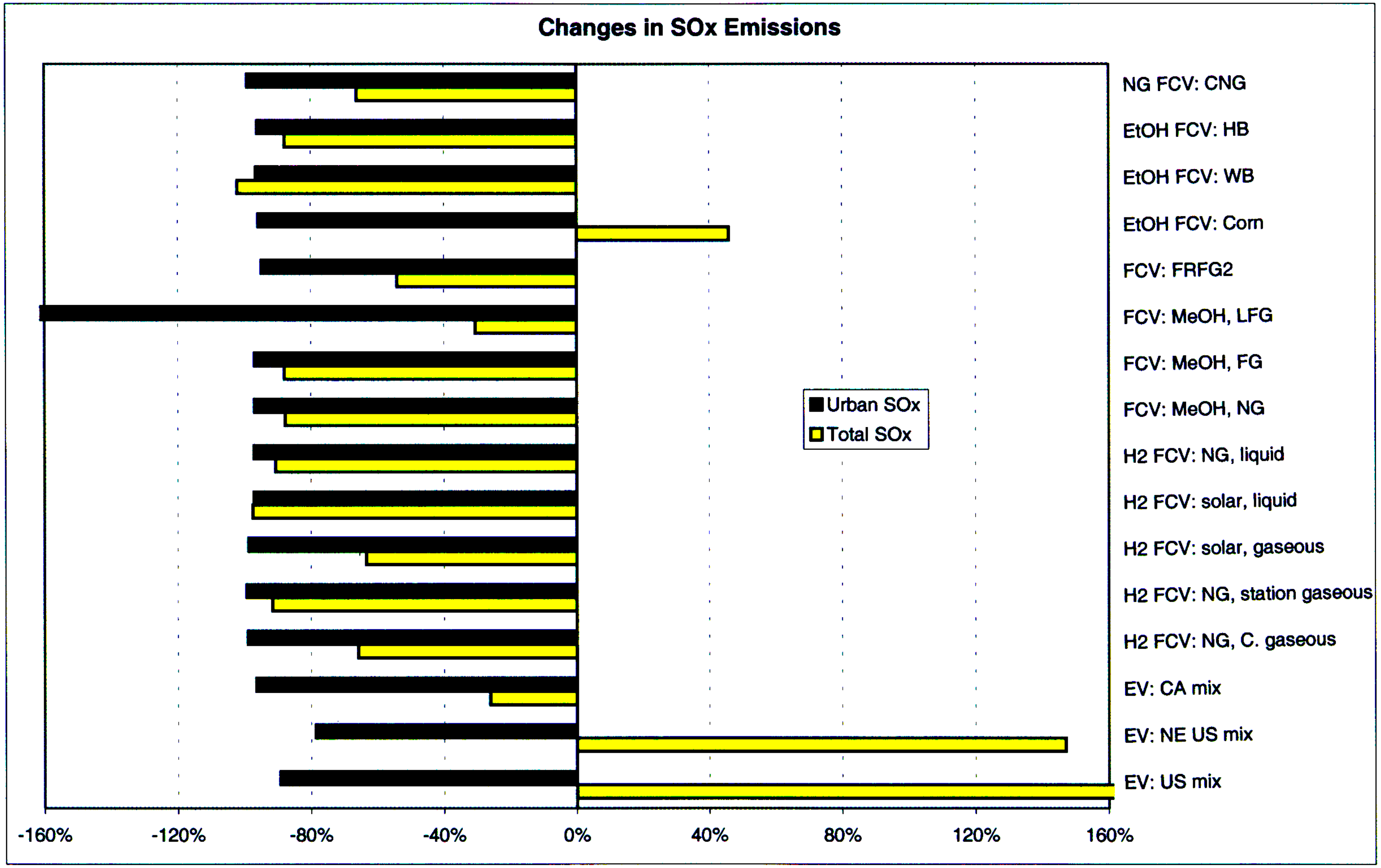

Figure 6.66 Changes in Fuel-Cycle Total and Urban SO_x Emissions Relative to GVs Fueled with RFG: Long-Term EVs and FCVs