residual\_emissions\_scenarios

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median\_and\_range <- function(data,grouping\_vars) {  
   
 data <- data %>%   
 group\_by\_at(grouping\_vars) %>%   
 summarise(median = signif(median(value),2),  
 percentile\_5th = signif(quantile(value, probs = c(0.05)),2),  
 percentile\_95th = signif(quantile(value, probs = c(0.95)),2)) %>%   
 mutate(value=paste0(median," [",percentile\_5th,"-",percentile\_95th,"]")) %>%   
 select(-median,-percentile\_5th,-percentile\_95th)  
   
}

## identify gases in the scenario data  
wd\_scenarios\_emissions <- data\_r1 %>%   
 ungroup() %>%   
 mutate(gas=ifelse(grepl("CO2",var),"CO2",NA)) %>%   
 mutate(gas=ifelse(grepl("CH4",var),"CH4",gas)) %>%   
 mutate(gas=ifelse(grepl("N2O",var),"N2O",gas)) %>%   
 mutate(gas=ifelse(grepl("F-Gases",var),"F-Gases",gas)) %>%   
 mutate(gas=ifelse(grepl("Kyoto Gases",var),"Kyoto Gases",gas)) %>%   
 select(-region)  
  
  
## join GWPs and calculate CO2e by sector  
wd\_scenarios\_emissions <- left\_join(wd\_scenarios\_emissions,cc\_gwps %>%   
 select(gas,gwp100\_ar6) %>%   
 mutate(gwp100\_ar6=ifelse(gas=="CH4",27,gwp100\_ar6)),by="gas")  
  
wd\_scenarios\_emissions <- wd\_scenarios\_emissions %>%   
 mutate(gwp100\_ar6=ifelse(unit=="Mt CO2-equiv/yr",1,gwp100\_ar6)) %>%   
 mutate(value=ifelse(unit=="kt N2O/yr",value/1000,value)) %>% # N2O is in kt, not Mt   
 mutate(value\_gwp=value\*gwp100\_ar6) %>%   
 select(-value,-gwp100\_ar6)  
  
  
## create unique scenario IDs  
wd\_scenarios\_emissions <- wd\_scenarios\_emissions %>%   
 mutate(id=paste0(model,"|",scenario)) %>%   
 select(id,everything()) %>%   
 arrange(id)  
  
  
## exclude scenarios based on whether they have semi-detailed sector data  
cc\_sectors <- read.xlsx("Data/scenario\_sector\_mapping.xlsx",sheet=2)  
cc\_scenarios <- left\_join(wd\_scenarios\_emissions,cc\_sectors %>% select(var) %>% mutate(include=1),by="var")  
cc\_scenarios <- cc\_scenarios %>%   
 ungroup() %>%   
 select(-unit,-gas) %>%   
 filter(year==2050) %>%   
 filter(include==1)  
cc\_scenarios <- spread(cc\_scenarios,var,value\_gwp)  
# Manually fill Emissions|CO2|Other as this is important for resolving totals in some scenarios, but isn't universally available  
cc\_scenarios <- cc\_scenarios %>%   
 mutate(`Emissions|CO2|Other`=ifelse(is.na(`Emissions|CO2|Other`),0,`Emissions|CO2|Other`))  
cc\_scenarios <- cc\_scenarios %>%   
 na.omit() %>%   
 select(id)  
  
wd\_scenarios\_emissions <- left\_join(wd\_scenarios\_emissions,cc\_scenarios %>% mutate(include=1),by="id") %>%   
 filter(include==1) %>%   
 select(-include)  
  
  
## rejoin the list of emissions sectors  
wd\_scenarios\_emissions <- left\_join(wd\_scenarios\_emissions,cc\_sectors,by=join\_by(var,gas))  
  
  
# infill the Emissions|CO2|Other sector  
wd\_co2\_other\_fix <- wd\_scenarios\_emissions %>%   
 ungroup() %>%   
 filter(var=="Emissions|CO2") %>%   
 select(id,model,scenario,category,unit,year)  
wd\_co2\_other\_fix <- left\_join(wd\_co2\_other\_fix,wd\_scenarios\_emissions %>%   
 ungroup() %>%   
 filter(var=="Emissions|CO2|Other") %>%  
 select(id,model,scenario,category,unit,year,value\_gwp),  
 by = join\_by(id, model, scenario, category, unit, year))  
wd\_co2\_other\_fix <- wd\_co2\_other\_fix %>%   
 mutate(var="Emissions|CO2|Other") %>%   
 mutate(value\_gwp=ifelse(is.na(value\_gwp),0,value\_gwp)) %>%   
 mutate(gas="CO2") %>%   
 mutate(sector="Other") %>%   
 mutate(subsector="Total")  
  
wd\_scenarios\_emissions <- wd\_scenarios\_emissions %>%   
 filter(var!="Emissions|CO2|Other")  
wd\_scenarios\_emissions <- rbind(wd\_scenarios\_emissions,wd\_co2\_other\_fix)  
  
blarg <- wd\_scenarios\_emissions %>% filter(id=="IMAGE 3.0|EN\_NPi2020\_1000") %>% filter(year==2050)  
  
## resolve sector and gas inconsistencies  
wd\_sector\_totals <- wd\_scenarios\_emissions %>%   
 ungroup() %>%   
 filter(subsector=="Total") %>%   
 group\_by(id,model,scenario,year,gas,sector) %>%   
 summarise(sector\_total=sum(value\_gwp))

## `summarise()` has grouped output by 'id', 'model', 'scenario', 'year', 'gas'.  
## You can override using the `.groups` argument.

wd\_gas\_totals <- wd\_scenarios\_emissions %>%   
 ungroup() %>%   
 filter(sector=="Total") %>%   
 group\_by(id,model,scenario,year,gas) %>%   
 summarise(gas\_total=sum(value\_gwp))

## `summarise()` has grouped output by 'id', 'model', 'scenario', 'year'. You can  
## override using the `.groups` argument.

###  
blarg <- wd\_scenarios\_emissions %>%   
 filter(!is.na(gas)) %>%   
 arrange(year,var)  
   
wd <- wd\_scenarios\_emissions %>%   
 filter(!is.na(sector)) %>%  
 filter(!is.na(subsector)) %>%  
 filter(subsector!="Total") %>%  
 group\_by(id,model,scenario,category,var,gas,sector,subsector,year) %>%  
 summarise(value\_gwp=sum(value\_gwp,na.rm=TRUE)) %>%   
 arrange(year,var)

## `summarise()` has grouped output by 'id', 'model', 'scenario', 'category',  
## 'var', 'gas', 'sector', 'subsector'. You can override using the `.groups`  
## argument.

# sector inconsistencies  
wd <- full\_join(wd,wd\_sector\_totals,  
 by = join\_by(id, model, scenario,year,gas,sector)) %>%   
 arrange(id,year,var)  
  
wd <- wd %>%  
 mutate(value\_gwp=ifelse(is.na(subsector),sector\_total,value\_gwp)) %>%  
 mutate(subsector=ifelse(is.na(subsector),"Other",subsector))  
  
residuals <- wd %>%  
 group\_by(id,model,scenario,year,gas,sector) %>%  
 summarise(value\_gwp=sum(value\_gwp),sector\_total=first(sector\_total)) %>%  
 mutate(value\_gwp=sector\_total-value\_gwp) %>%  
 mutate(subsector="Other") %>%  
 select(-sector\_total)# %>%

## `summarise()` has grouped output by 'id', 'model', 'scenario', 'year', 'gas'.  
## You can override using the `.groups` argument.

#filter(value\_gwp>0)  
  
wd <- rbind(wd,residuals)  
#   
# wd <- wd %>%   
# group\_by(id,model,scenario,category,year,gas,sector,subsector) %>%   
# summarise(value\_gwp=sum(value\_gwp))  
  
## gas inconsistencies  
wd <- left\_join(wd,wd\_gas\_totals,  
 by = join\_by(id, model, scenario, year, gas))  
  
  
residuals <- wd %>%  
 group\_by(id,model,scenario,year,gas) %>%  
 summarise(value\_gwp=sum(value\_gwp),gas\_total=first(gas\_total))%>%  
 mutate(value\_gwp=gas\_total-value\_gwp) %>%  
 mutate(sector="Other") %>%  
 select(-gas\_total) #%>%

## `summarise()` has grouped output by 'id', 'model', 'scenario', 'year'. You can  
## override using the `.groups` argument.

#filter(value\_gwp>0)  
  
wd <- rbind(wd,residuals)  
wd <- wd %>%   
 arrange(id,year,gas,sector)  
  
## tidy up naming conventions  
  
wd\_scenarios\_emissions <- wd %>%   
 mutate(var=ifelse(sector=="Other",paste0(gas,"|",sector),paste0(gas,"|",sector,"|",subsector))) %>%   
 mutate(var=ifelse(var=="F-Gases|F-Gases|Other","F-Gases",var)) %>%   
 mutate(var=ifelse(var=="CO2|AFOLU|Other","CO2|AFOLU",var)) %>%   
 mutate(var=ifelse(var=="N2O|AFOLU|Other","N2O|AFOLU",var)) %>%   
 mutate(var=ifelse(var=="CH4|Energy|Other","CH4|Energy",var)) %>%   
 mutate(var=ifelse(var=="CO2|Industrial processes|Other","CO2|Industrial processes",var)) %>%   
 mutate(var=ifelse(gas=="F-Gases","F-Gases",var)) %>%  
 mutate(var=ifelse(gas=="Kyoto Gases","Kyoto Gases",var)) %>%   
 mutate(subsector=ifelse(is.na(subsector),"Other",subsector)) %>%   
 mutate(sector=ifelse(gas=="F-Gases","F-Gases",sector)) %>%   
 mutate(sector=ifelse(gas=="Kyoto Gases","Total",sector))  
  
wd\_scenarios\_emissions <- wd\_scenarios\_emissions %>%   
 group\_by(id,model,scenario) %>%   
 mutate(category=first(category))  
  
wd\_scenarios\_emissions <- wd\_scenarios\_emissions %>%   
 group\_by(id,model,scenario,category,year,var,gas,sector,subsector) %>%   
 summarise(value\_gwp=sum(value\_gwp,na.rm=TRUE))

## `summarise()` has grouped output by 'id', 'model', 'scenario', 'category',  
## 'year', 'var', 'gas', 'sector'. You can override using the `.groups` argument.

## save the updated list of sectors  
cc\_sectors <- wd\_scenarios\_emissions %>%   
 ungroup() %>%   
 select(gas,sector,subsector,var) %>%   
 distinct()

## check if the bottom-up estimated totals equal the original reporting  
  
check\_co2 <- wd\_scenarios\_emissions %>%   
 group\_by(id,year,gas) %>%   
 summarise(value=sum(value\_gwp,na.rm=TRUE))

## `summarise()` has grouped output by 'id', 'year'. You can override using the  
## `.groups` argument.

check\_co2\_native <- data\_r1 %>%   
 filter(var %in% c("Emissions|CO2",  
 "Emissions|CH4",  
 "Emissions|N2O",  
 "Emissions|F-Gases")) %>%  
 mutate(id=paste0(model,"|",scenario)) %>%  
 ungroup() %>%  
 select(id,year,var,value\_native=value)  
  
check\_co2\_native <- check\_co2\_native %>%   
 mutate(gas=ifelse(grepl("CO2",var),"CO2",NA)) %>%   
 mutate(gas=ifelse(grepl("CH4",var),"CH4",gas)) %>%   
 mutate(gas=ifelse(grepl("N2O",var),"N2O",gas)) %>%   
 mutate(gas=ifelse(grepl("F-Gases",var),"F-Gases",gas))  
  
check\_co2\_native <- check\_co2\_native %>%   
 mutate(value\_native=ifelse(gas=="CH4",value\_native\*27,value\_native)) %>%   
 mutate(value\_native=ifelse(gas=="N2O",(value\_native\*273.0)/1000,value\_native))  
   
  
check\_co2 <- left\_join(check\_co2,check\_co2\_native %>% select(-var))

## Joining with `by = join\_by(id, year, gas)`

check\_co2 <- check\_co2 %>%   
 mutate(difference=value-value\_native) %>%   
 filter(abs(difference)>1)  
  
  
  
## Check for major discrepancies between the reconstructed sectors and the Kyoto gas total  
check\_kyoto <- wd\_scenarios\_emissions %>%  
 filter(gas!="Kyoto Gases") %>%  
 group\_by(id,year) %>%  
 summarise(recalculated\_net\_emissions=sum(value\_gwp,na.rm=TRUE))

## `summarise()` has grouped output by 'id'. You can override using the `.groups`  
## argument.

check\_kyoto <- left\_join(check\_kyoto,wd\_scenarios\_emissions %>%   
 ungroup %>%   
 filter(gas=="Kyoto Gases") %>%   
 filter(sector=="Total") %>%   
 select(id,year,native\_net\_emissions=value\_gwp),  
 by = join\_by(id,year))  
  
check\_kyoto <- check\_kyoto %>%  
 mutate(difference=recalculated\_net\_emissions-native\_net\_emissions) %>%  
 mutate(difference\_abs=abs(difference))  
  
check\_kyoto <- left\_join(check\_kyoto,cc\_scenarios %>% select(id) %>% mutate(include=1)) %>%   
 filter(include==1) %>%   
 select(-include)

## Joining with `by = join\_by(id)`

check\_kyoto <- check\_kyoto %>%  
 group\_by(year) %>%  
 summarise(median=signif(median(difference\_abs),2),  
 percentile\_5th = signif(quantile(difference\_abs, probs = c(0.05)),2),  
 percentile\_95th = signif(quantile(difference\_abs, probs = c(0.95)),2))

## filter scenarios  
wd\_scenarios\_removals <- data\_r1 %>%   
 ungroup() %>%   
 mutate(id=paste0(model,"|",scenario)) %>%   
 select(id,everything(),-region,-unit) %>%   
 rename(value\_gwp=value) %>%   
 arrange(id)  
  
wd\_scenarios\_removals <- left\_join(wd\_scenarios\_removals,cc\_scenarios %>% mutate(include=1),by="id") %>%   
 filter(include==1) %>%   
 select(-include)  
  
  
## identify relevant sectors  
cc\_removals <- read.xlsx("Data/scenario\_sector\_mapping.xlsx",sheet=3)  
wd\_scenarios\_removals <- left\_join(wd\_scenarios\_removals,cc\_removals %>% mutate(include=1),by="var")  
wd\_scenarios\_removals <- wd\_scenarios\_removals %>%   
 filter(include==1) %>%   
 select(-include)  
  
  
## subtract CCS|Biomass|industrial processes from CCS|Biomass, so that the former aren't double counted when allocated to the process sector  
wd\_scenarios\_removals <- spread(wd\_scenarios\_removals,var,value\_gwp)  
wd\_scenarios\_removals <- wd\_scenarios\_removals %>%  
 mutate(`Carbon Sequestration|CCS|Biomass|Industrial Processes`=ifelse(is.na(`Carbon Sequestration|CCS|Biomass|Industrial Processes`),0,`Carbon Sequestration|CCS|Biomass|Industrial Processes`)) %>%   
 mutate(`Carbon Sequestration|CCS|Biomass`=`Carbon Sequestration|CCS|Biomass`-`Carbon Sequestration|CCS|Biomass|Industrial Processes`)  
  
  
## merge the other removal categories  
wd\_scenarios\_removals <- wd\_scenarios\_removals %>%   
 rowwise() %>%   
 mutate(`Carbon Sequestration|Other`= sum(`Carbon Sequestration|Direct Air Capture`,  
 `Carbon Sequestration|Enhanced Weathering`,  
 `Carbon Sequestration|Feedstocks`,  
 `Carbon Sequestration|Other`,na.rm = TRUE))  
  
  
## update the scenario inclusion list to exclude scenarios without land use removals reporting   
cc\_scenarios <- anti\_join(cc\_scenarios,wd\_scenarios\_removals %>% filter(is.na(`Carbon Sequestration|Land Use`)) %>% select(id))

## Joining with `by = join\_by(id)`

## tidy up   
wd\_scenarios\_removals <- gather(wd\_scenarios\_removals,var,value\_gwp,`Carbon Sequestration|CCS|Biomass`:`Carbon Sequestration|Other`) %>%   
 filter(var %in% c("Carbon Sequestration|CCS|Biomass",  
 "Carbon Sequestration|CCS|Biomass|Industrial Processes",  
 "Carbon Sequestration|Land Use",  
 "Carbon Sequestration|Other"))  
  
  
## join data to main dataset  
wd\_scenarios\_emissions <- rbind(wd\_scenarios\_emissions,wd\_scenarios\_removals) %>%   
 arrange(id,year,var)  
  
  
## check whats going on with IMAGE / Industrial process CCS  
# check\_ind <- wd\_scenarios\_emissions %>%  
# filter(id=="IMAGE 3.2|SSP1\_SPA1\_19I\_D\_LB") %>%  
# filter(var %in% c("CO2|Industrial processes",  
# "Carbon Sequestration|CCS|Biomass|Industrial Processes",  
# "CO2|Other"))  
#   
# ggplot(check\_ind,aes(x=year,y=value,color=var)) +  
# geom\_path()  
  
  
## calculate gross emissions by sector   
wd <- spread(wd\_scenarios\_emissions %>%   
 ungroup() %>%   
 select(id,model,scenario,category,year,var,value\_gwp),var,value\_gwp)  
  
wd <- wd %>%   
 mutate(`CO2|Energy|Supply`=`CO2|Energy|Supply`+`Carbon Sequestration|CCS|Biomass`) %>%   
 mutate(`CO2|AFOLU`=`CO2|AFOLU`+`Carbon Sequestration|Land Use`) %>%   
 mutate(`CO2|Other`=`CO2|Other`+`Carbon Sequestration|Other`) %>%   
 mutate(`CO2|Other`=`CO2|Other`+`Carbon Sequestration|CCS|Biomass|Industrial Processes`)  
  
wd <- gather(wd,var,value,-id,-model,-scenario,-category,-year)  
wd <- left\_join(wd,cc\_sectors,by="var")  
wd <- wd %>%   
 select(id,model,scenario,category,var,gas,sector,subsector,year,value) %>%   
 arrange(id,year,var)  
  
  
## source the net zero years from scenario metadata  
cc\_netzero <- read.xlsx("Data/AR6\_Scenarios\_Database\_metadata\_indicators\_v1.1\_1.xlsx",sheet=2) %>%   
 mutate(id=paste0(Model,"|",Scenario)) %>%   
 select(id,net\_zero\_CO2=`Year.of.netzero.CO2.emissions.(Harm-Infilled).Table.SPM2`,  
 net\_zero\_GHG=`Year.of.netzero.GHG.emissions.(Harm-Infilled).Table.SPM2`)  
cc\_netzero <- left\_join(cc\_netzero,cc\_scenarios %>% mutate(include=1),by="id") %>%   
 filter(include==1) %>%   
 select(-include)  
  
wd <- left\_join(wd,cc\_netzero,by="id")  
  
  
## exclude the scenarios that don't reach net zero by 2100 and tidy up  
wd <- wd %>%   
 filter(!is.na(net\_zero\_CO2)) %>%   
 arrange(id,year) %>%   
 mutate(value=value/1000)  
  
no\_scenarios <- wd %>%   
 select(id) %>%  
 distinct()  
  
  
## simplify the model names  
  
wd\_scenarios\_emissions <- wd %>%   
 mutate(model=ifelse(grepl("IMAGE",model),"IMAGE",model)) %>%   
 mutate(model=ifelse(grepl("MESSAGE",model),"MESSAGE",model)) %>%   
 mutate(model=ifelse(grepl("REMIND",model),"REMIND",model))  
  
  
wd\_scenarios\_emissions$category <- as.factor(wd\_scenarios\_emissions$category)  
wd\_scenarios\_emissions$category <- fct\_relevel(wd\_scenarios\_emissions$category,"C3","C2","C1")  
  
  
wd\_scenarios\_emissions$gas <- as.factor(wd\_scenarios\_emissions$gas)  
wd\_scenarios\_emissions$gas <- fct\_relevel(wd\_scenarios\_emissions$gas,"CO2","CH4","N2O","F-Gases")  
  
  
wd\_scenarios\_emissions$sector <- as.factor(wd\_scenarios\_emissions$sector)  
wd\_scenarios\_emissions$sector <- fct\_relevel(wd\_scenarios\_emissions$sector,"Energy","AFOLU","Industrial processes","F-Gases","Other")

wd\_check <- wd\_scenarios\_emissions %>%   
 filter(gas=="CO2") %>%   
 group\_by(id,year,net\_zero\_CO2) %>%   
 summarise(value=sum(value,na.rm=TRUE))

## `summarise()` has grouped output by 'id', 'year'. You can override using the  
## `.groups` argument.

wd\_check <- left\_join(wd\_check,wd\_scenarios\_emissions %>%   
 filter(grepl("Carbon Sequestration",var)) %>%   
 group\_by(id,year) %>%   
 summarise(removals=sum(value,na.rm=TRUE)))

## `summarise()` has grouped output by 'id'. You can override using the `.groups`  
## argument.  
## Joining with `by = join\_by(id, year)`

wd\_check <- wd\_check %>%   
 mutate(totals=value-removals)  
  
####  
wd\_check <- left\_join(wd\_check,data\_r1 %>%   
 ungroup() %>%   
 mutate(id=paste0(model,"|",scenario)) %>%  
 filter(var=="Emissions|CO2") %>%  
 mutate(value=value/1000) %>%   
 select(id,year,native\_co2=value),  
 by = join\_by(id, year))  
  
wd\_check <- wd\_check %>%   
 mutate(difference=totals-native\_co2)  
  
wd\_check <- left\_join(wd\_check,data\_r1 %>%   
 ungroup() %>%   
 mutate(id=paste0(model,"|",scenario)) %>%  
 filter(var=="AR6 climate diagnostics|Infilled|Emissions|CO2") %>%  
 mutate(value=value/1000) %>%   
 select(id,year,infilled\_co2=value),  
 by = join\_by(id, year))  
  
wd\_check\_years <- wd\_check %>%   
 filter(totals<0) %>%   
 group\_by(id) %>%   
 summarise(native\_net\_zero\_CO2=first(year))  
  
wd\_check <- left\_join(wd\_check,wd\_check\_years)

## Joining with `by = join\_by(id)`

wd\_scenarios\_emissions <- left\_join(wd\_scenarios\_emissions,wd\_check\_years,by="id")  
wd\_scenarios\_emissions <- wd\_scenarios\_emissions %>%   
 mutate(native\_net\_zero\_CO2=ifelse(is.na(native\_net\_zero\_CO2),2100,native\_net\_zero\_CO2))  
  
wd\_check <- wd\_scenarios\_emissions %>%   
 select(id,native\_net\_zero\_CO2,net\_zero\_CO2) %>%   
 distinct() %>%   
 mutate(difference=native\_net\_zero\_CO2-net\_zero\_CO2) %>%   
 mutate(group="group") %>%   
 group\_by(group) %>%   
 summarise(median=signif(median(difference),2),  
 percentile\_5th = signif(quantile(difference, probs = c(0.05)),2),  
 percentile\_95th = signif(quantile(difference, probs = c(0.95)),2))

## any scenarios where final gross emissions by sector are still negative?  
  
check <- wd\_scenarios\_emissions %>%  
 # mutate(include=ifelse(year==net\_zero\_CO2,1,0)) %>%   
 # filter(include==1) %>%   
 filter(year==2100) %>%   
 filter(var=="CO2|AFOLU") %>%   
 filter(value<0) %>%   
 select(id,model,var,value) %>%   
 mutate(group="blarg")  
  
check <- median\_and\_range(check,"group")

colors=c("#e6550d","#3182bd","#31a354")  
  
## gross CO2 emissions at net zero CO2  
wd\_totals\_co2 <- wd\_scenarios\_emissions %>%   
 filter(var!="Kyoto Gases") %>%   
 filter(!grepl("Carbon Sequestration",var)) %>%   
 filter(gas=="CO2") %>%   
 mutate(value=ifelse(is.na(value),0,value)) %>%   
 mutate(include=ifelse(native\_net\_zero\_CO2==year,1,0)) %>%   
 filter(include==1) %>%   
 group\_by(id,category,year) %>%   
 summarise(value=sum(value)) %>%   
 mutate(var="CO2")

## `summarise()` has grouped output by 'id', 'category'. You can override using  
## the `.groups` argument.

## gross GHG emissions at net zero CO2  
wd\_totals\_ghg <- wd\_scenarios\_emissions %>%   
 filter(var!="Kyoto Gases") %>%   
 filter(!grepl("Carbon Sequestration",var)) %>%   
 mutate(value=ifelse(is.na(value),0,value)) %>%   
 mutate(include=ifelse(native\_net\_zero\_CO2==year,1,0)) %>%   
 filter(include==1) %>%   
 group\_by(id,category,year) %>%   
 summarise(value=sum(value)) %>%   
 mutate(var="GHG")

## `summarise()` has grouped output by 'id', 'category'. You can override using  
## the `.groups` argument.

## join  
wd\_totals <- rbind(wd\_totals\_co2,wd\_totals\_ghg) %>%   
 select(id,category,year,var,value) %>%   
 arrange(var,desc(category))  
  
  
# labels  
wd\_totals <- wd\_totals %>%   
 mutate(category=as.character(category)) %>%   
 mutate(category=ifelse(grepl("C1",category),"C1: Below 1.5°C",category)) %>%   
 mutate(category=ifelse(grepl("C2",category),"C2: Below 1.5°C with overshoot",category)) %>%   
 mutate(category=ifelse(grepl("C3",category),"C3: Below 2°C",category)) %>%   
 mutate(category=as.factor(category))  
  
wd\_totals$category <- fct\_relevel(wd\_totals$category,  
 "C3: Below 2°C",  
 "C2: Below 1.5°C with overshoot",  
 "C1: Below 1.5°C")   
  
  
## plot CO2  
p1 <- wd\_totals %>%   
 filter(var=="CO2") %>%   
 ggplot(.,aes(x=value,fill=category)) +  
 geom\_density(alpha=0.3,color='#636363') +  
 scale\_x\_continuous(limits=c(0,30),breaks=c(0,5,10,15,20,25,30)) +  
 scale\_fill\_manual(values=colors) +  
 theme(axis.title = element\_blank(),  
 axis.ticks = element\_blank(),  
 axis.text = element\_blank(),  
 panel.border = element\_rect(color='#636363',fill=NA),  
 panel.background = element\_blank(),  
 panel.grid.major.y = element\_blank(),  
 panel.grid.major.x = element\_line(color='#f0f0f0'),  
 legend.position = "none",  
 plot.background = element\_blank(),  
 plot.margin = margin(0,0,0,0,"cm"),  
 plot.title = element\_text(color='#636363',size = 14,face = 'bold'),  
 plot.subtitle = element\_text(color='#636363')) +  
 labs(title=bquote(bold("a. Residual"~CO[2]\*" emissions at net zero")),  
 subtitle=bquote("Gt"~CO[2]\*"e/yr"))

## Scale for fill is already present.  
## Adding another scale for fill, which will replace the existing scale.

p2 <- wd\_totals %>%   
 filter(var=="CO2") %>%   
 ggplot(.,aes(x=value,y=category,fill=category)) +  
 geom\_point(shape=21,size=3,alpha=0.4,color="#636363") +  
 scale\_y\_discrete(labels = function(x) str\_wrap(x, width = 17)) +  
 scale\_fill\_manual(values=colors) +  
 theme\_wl() +  
 theme(legend.position="none",  
 axis.title = element\_blank(),  
 plot.margin = margin(0,0,0,0,"cm")) +  
 scale\_x\_continuous(limits=c(0,30),breaks=c(0,5,10,15,20,25,30))

## Scale for fill is already present.  
## Adding another scale for fill, which will replace the existing scale.

## Warning: The `size` argument of `element\_line()` is deprecated as of ggplot2 3.4.0.  
## ℹ Please use the `linewidth` argument instead.  
## This warning is displayed once every 8 hours.  
## Call `lifecycle::last\_lifecycle\_warnings()` to see where this warning was  
## generated.

## Warning: The `size` argument of `element\_rect()` is deprecated as of ggplot2 3.4.0.  
## ℹ Please use the `linewidth` argument instead.  
## This warning is displayed once every 8 hours.  
## Call `lifecycle::last\_lifecycle\_warnings()` to see where this warning was  
## generated.

## plot GHG  
p3 <- wd\_totals %>%   
 filter(var=="GHG") %>%   
 ggplot(.,aes(x=value,fill=category)) +  
 geom\_density(alpha=0.3,color='#636363') +  
 scale\_x\_continuous(limits=c(0,30),breaks=c(0,5,10,15,20,25,30)) +  
 scale\_fill\_manual(values=colors) +  
 theme(axis.title = element\_blank(),  
 axis.ticks = element\_blank(),  
 axis.text = element\_blank(),  
 panel.border = element\_rect(color='#636363',fill=NA),  
 panel.background = element\_blank(),  
 panel.grid.major.y = element\_blank(),  
 panel.grid.major.x = element\_line(color='#f0f0f0'),  
 legend.position = "none",  
 plot.background = element\_blank(),  
 plot.margin = margin(0,0,0,0,"cm"),  
 plot.title = element\_text(color='#636363',size = 14,face = 'bold'),  
 plot.subtitle = element\_text(color='#636363')) +  
 labs(title=bquote(bold("b. Residual GHG emissions at net zero")),  
 subtitle=bquote("Gt"~CO[2]\*"e/yr"))

## Scale for fill is already present.  
## Adding another scale for fill, which will replace the existing scale.

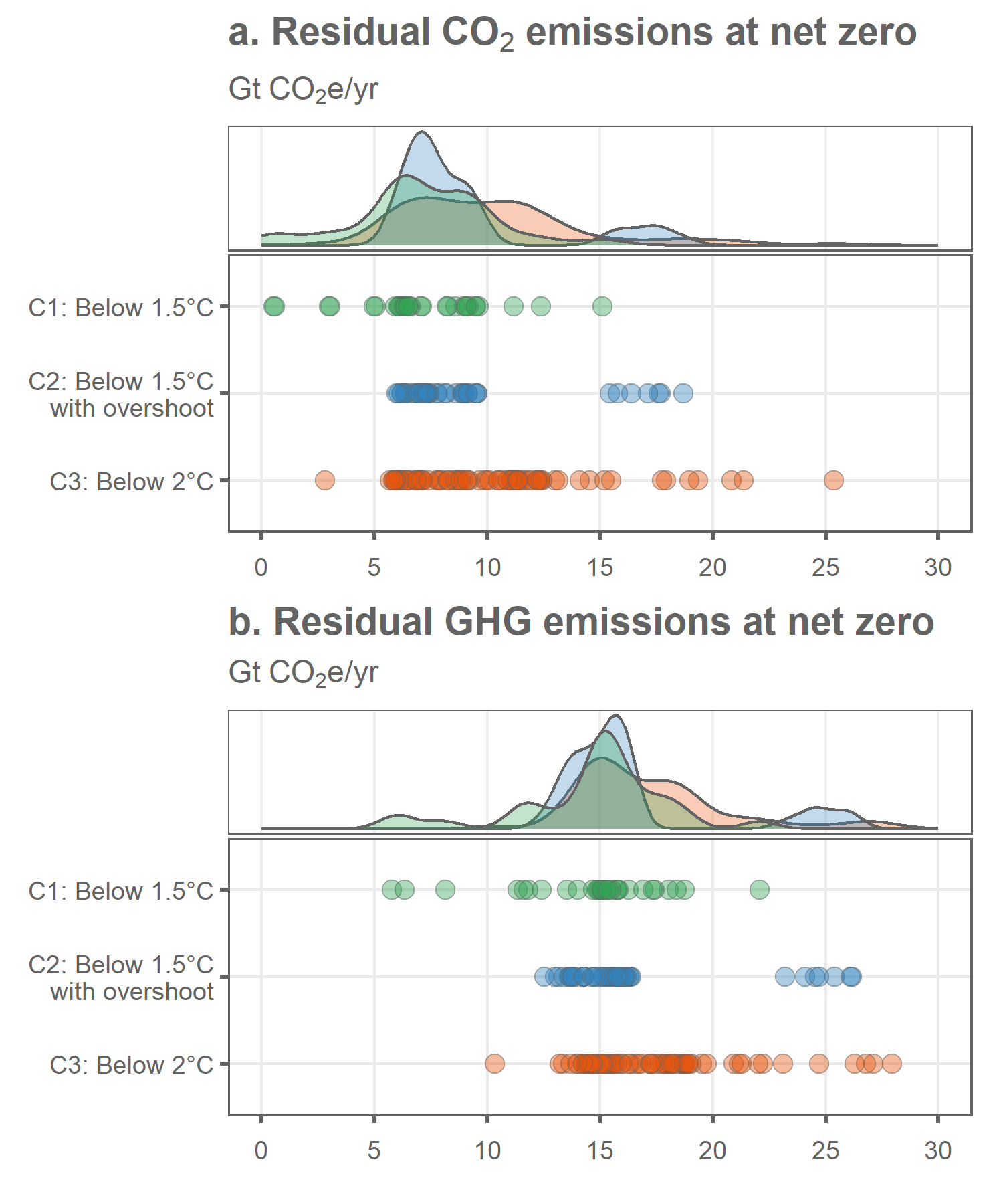
p4 <- wd\_totals %>%   
 filter(var=="GHG") %>%   
 ggplot(.,aes(x=value,y=category,fill=category)) +  
 geom\_point(shape=21,size=3,alpha=0.4,color="#636363") +  
 scale\_y\_discrete(labels = function(x) str\_wrap(x, width = 17)) +  
 scale\_fill\_manual(values=colors) +  
 theme\_wl() +  
 theme(legend.position="none",  
 axis.title = element\_blank(),  
 plot.margin = margin(0,0,0,0,"cm")) +  
 scale\_x\_continuous(limits=c(0,30),breaks=c(0,5,10,15,20,25,30))

## Scale for fill is already present.  
## Adding another scale for fill, which will replace the existing scale.

p1/plot\_spacer()/p2/p3/plot\_spacer()/p4 + plot\_layout(heights=c(1.8,-0.5,4,1.8,-0.5,4))

## Warning: Removed 2 rows containing non-finite values (`stat\_density()`).

## Warning: Removed 2 rows containing missing values (`geom\_point()`).



## save plot data  
addWorksheet(wb\_figures,"fig\_1\_total\_residual")  
writeData(wb\_figures, sheet = "fig\_1\_total\_residual",  
 wd\_totals, colNames = T, rowNames = F)

## summary of scenario totals  
wd\_totals\_summary <- median\_and\_range(wd\_totals,c("var","category"))

## `summarise()` has grouped output by 'var'. You can override using the `.groups`  
## argument.

wd\_totals\_summary <- left\_join(wd\_totals\_summary,wd\_totals %>%   
 group\_by(var,category) %>%   
 summarise(n=n(),  
 year\_median = signif(median(year),4),  
 year\_5th = signif(quantile(year, probs = c(0.05)),4),  
 year\_95th = signif(quantile(year, probs = c(0.95)),4)) %>%   
 mutate(year=paste0(year\_median," [",year\_5th,"-",year\_95th,"]")) %>%   
 select(var,category,year,n),by = join\_by(var, category))

## `summarise()` has grouped output by 'var'. You can override using the `.groups`  
## argument.

wd\_totals\_summary <- rbind(wd\_totals\_summary,  
 left\_join(median\_and\_range(wd\_totals,"var"),wd\_totals %>%   
 group\_by(var) %>%   
 summarise(n=n(),year\_median = signif(median(year),4),  
 year\_5th = signif(quantile(year, probs = c(0.05)),4),  
 year\_95th = signif(quantile(year, probs = c(0.95)),4)) %>%   
 mutate(year=paste0(year\_median," [",year\_5th,"-",year\_95th,"]")) %>%   
 select(var,year,n),by = join\_by(var)) %>%   
 mutate(category="all"))  
  
  
## calculate reductions and join  
wd\_total\_reductions <- wd\_scenarios\_emissions %>%   
 mutate(include=ifelse(native\_net\_zero\_CO2==year,1,0)) %>%   
 mutate(include=ifelse(year==2020,1,include)) %>%   
 filter(include==1) %>%   
 filter(gas=="CO2") %>%   
 group\_by(id,gas,category,year) %>%   
 summarise(value=sum(value,na.rm=TRUE))

## `summarise()` has grouped output by 'id', 'gas', 'category'. You can override  
## using the `.groups` argument.

wd\_total\_reductions <- rbind(wd\_total\_reductions,wd\_scenarios\_emissions %>%   
 mutate(include=ifelse(native\_net\_zero\_CO2==year,1,0)) %>%   
 mutate(include=ifelse(year==2020,1,include)) %>%   
 filter(include==1) %>%   
 filter(var!="Kyoto Gases") %>%   
 filter(!grepl("Carbon Sequestration",var)) %>%   
 group\_by(id,category,year) %>%   
 summarise(value=sum(value,na.rm=TRUE)) %>%   
 mutate(gas="GHG"))

## `summarise()` has grouped output by 'id', 'category'. You can override using  
## the `.groups` argument.

wd\_total\_reductions <- wd\_total\_reductions %>%   
 group\_by(id,gas,category) %>%   
 summarise(rel\_change=(first(value)-last(value))/first(value)) %>%   
 mutate(rel\_change=rel\_change\*100)

## `summarise()` has grouped output by 'id', 'gas'. You can override using the  
## `.groups` argument.

wd\_total\_reductions\_summary <- median\_and\_range(wd\_total\_reductions %>% mutate(value=rel\_change),c("gas","category"))

## `summarise()` has grouped output by 'gas'. You can override using the `.groups`  
## argument.

wd\_total\_reductions\_summary <- rbind(wd\_total\_reductions\_summary,  
 median\_and\_range(wd\_total\_reductions %>% mutate(value=rel\_change),c("gas")) %>%   
 mutate(category="all"))  
  
wd\_total\_reductions\_summary <- wd\_total\_reductions\_summary %>%   
 mutate(category=as.character(category)) %>%   
 mutate(category=ifelse(grepl("C1",category),"C1: Below 1.5°C",category)) %>%   
 mutate(category=ifelse(grepl("C2",category),"C2: Below 1.5°C with overshoot",category)) %>%   
 mutate(category=ifelse(grepl("C3",category),"C3: Below 2°C",category)) %>%   
 mutate(category=as.factor(category))  
  
wd\_totals\_summary <- left\_join(wd\_totals\_summary %>% rename(residual=value,gas=var),  
 wd\_total\_reductions\_summary %>% rename(reductions=value),  
 by = join\_by(gas,category))  
  
  
wd\_totals\_summary <- gather(wd\_totals\_summary,var,value,residual,reductions)  
wd\_totals\_summary <- wd\_totals\_summary %>%   
 ungroup() %>%   
 mutate(var=paste0(gas,"\_",var)) %>%   
 select(-gas)  
wd\_totals\_summary <- spread(wd\_totals\_summary,var,value)  
wd\_totals\_summary <- wd\_totals\_summary %>%   
 select(category,n,year,CO2\_residual,CO2\_reductions,GHG\_residual,GHG\_reductions)  
  
addWorksheet(wb\_analysis,"total\_residual\_at\_nz")  
writeData(wb\_analysis, sheet = "total\_residual\_at\_nz",  
 wd\_totals\_summary, colNames = T, rowNames = F)  
  
  
## standard deviations  
  
wd\_sd\_summary <- wd\_totals %>%   
 group\_by(category,var) %>%   
 summarise(year\_median = signif(median(year),4),  
 year\_5th = signif(quantile(year, probs = c(0.05)),4),  
 year\_95th = signif(quantile(year, probs = c(0.95)),4),  
 year\_sd = signif(sd(year),2),  
 value\_median = signif(median(value),2),  
 value\_5th = signif(quantile(value, probs = c(0.05)),2),  
 value\_95th = signif(quantile(value, probs = c(0.95)),2),  
 value\_sd = signif(sd(value),2)) %>%   
 mutate(year=paste0(year\_median," [",year\_5th,"-",year\_95th,"]")) %>%   
 mutate(value=paste0(value\_median," [",value\_5th,"-",value\_95th,"]")) %>%   
 select(category,var,year,year\_sd,value,value\_sd)

## `summarise()` has grouped output by 'category'. You can override using the  
## `.groups` argument.

wd\_sd\_table <- spread(wd\_sd\_summary %>% select(-value\_sd),var,value)  
wd\_sd\_table <- left\_join(wd\_sd\_table,spread(wd\_sd\_summary %>% select(-value),var,value\_sd) %>% select(category,CO2\_sd=CO2,GHG\_sd=GHG))

## Joining with `by = join\_by(category)`

wd\_sd\_table <- wd\_sd\_table %>%   
 arrange(desc(category)) %>%   
 select(category,year,year\_sd,CO2\_residual=CO2,CO2\_sd,GHG\_residual=GHG,GHG\_sd)

## how many scenarios were excluded?  
total\_scenarios <- data\_r1 %>%   
 ungroup() %>%   
 select(model,scenario,category) %>%   
 distinct() %>%   
 group\_by(category) %>%   
 summarise(n=n())  
  
  
## what is the range of non-CO2 GHG emissions at net zero in C1-C3 scenarios ?  
non\_CO2 <- wd\_scenarios\_emissions %>%   
 filter(var!="Kyoto Gases") %>%   
 filter(!grepl("Carbon Sequestration",var)) %>%   
 mutate(value=ifelse(is.na(value),0,value)) %>%   
 mutate(include=ifelse(native\_net\_zero\_CO2==year,1,0)) %>%   
 filter(include==1) %>%  
 filter(gas!="CO2") %>%   
 group\_by(id,category,year) %>%   
 summarise(value=sum(value)) %>%   
 mutate(var="GHG")

## `summarise()` has grouped output by 'id', 'category'. You can override using  
## the `.groups` argument.

non\_CO2 <- median\_and\_range(non\_CO2,"var")  
  
  
## how many scenarios adjust 2020 emissions for COVID?  
covid <- wd\_scenarios\_emissions %>%   
 filter(year==2020) %>%   
 select(id,category) %>%   
 distinct()  
cc\_expl <- read.xlsx('Data/AR6\_Scenarios\_Database\_metadata\_indicators\_v1.1\_1.xlsx',sheet=2)  
covid <- left\_join(covid,cc\_expl %>% mutate(id=paste0(Model,"|",Scenario)) %>% select(id,COVID),by = join\_by(id)) %>%   
 group\_by(COVID) %>%   
 summarise(n=n())  
  
  
##

blarg <- wd\_scenarios\_emissions %>%   
 filter(year %in% c(2020,2100)) %>%   
 filter(var!="Kyoto Gases") %>%   
 filter(!grepl("Carbon Sequestration",var)) %>%   
 group\_by(id,category,year) %>%   
 summarise(value=sum(value,na.rm=TRUE)) %>%   
 mutate(gas="GHG")

## `summarise()` has grouped output by 'id', 'category'. You can override using  
## the `.groups` argument.

blarg <- blarg %>%   
 group\_by(id,gas,category) %>%   
 summarise(level=last(value),  
 rel\_change=(first(value)-last(value))/first(value)) %>%   
 mutate(rel\_change=rel\_change\*100)

## `summarise()` has grouped output by 'id', 'gas'. You can override using the  
## `.groups` argument.

blarg <- median\_and\_range(blarg %>% mutate(value=rel\_change),c("gas","category"))

## `summarise()` has grouped output by 'gas'. You can override using the `.groups`  
## argument.

## emissions by gas at NZ  
wd\_gases <- wd\_scenarios\_emissions %>%   
 filter(var!="Kyoto Gases") %>%   
 filter(!grepl("Carbon Sequestration",var)) %>%   
 mutate(value=ifelse(is.na(value),0,value)) %>%   
 mutate(include=ifelse(native\_net\_zero\_CO2==year,1,0)) %>%   
 filter(include==1) %>%   
 group\_by(id,model,scenario,category,year,gas) %>%   
 summarise(value=sum(value,na.rm=TRUE))

## `summarise()` has grouped output by 'id', 'model', 'scenario', 'category',  
## 'year'. You can override using the `.groups` argument.

## emissions by sector at NZ  
wd\_sectors <- wd\_scenarios\_emissions %>%   
 filter(var!="Kyoto Gases") %>%   
 filter(!grepl("Carbon Sequestration",var)) %>%   
 mutate(value=ifelse(is.na(value),0,value)) %>%   
 mutate(include=ifelse(native\_net\_zero\_CO2==year,1,0)) %>%   
 filter(include==1) %>%   
 mutate(sector=as.character(sector)) %>%   
 mutate(sector=ifelse(sector %in% c("Industrial processes","F-Gases","Other"),"Other (Industrial processes, F-gases, other)",sector)) %>%   
 group\_by(id,model,scenario,category,year,sector) %>%   
 summarise(value=sum(value,na.rm=TRUE))

## `summarise()` has grouped output by 'id', 'model', 'scenario', 'category',  
## 'year'. You can override using the `.groups` argument.

## energy by fuel type at NZ  
wd\_fuels <- data\_r1 %>%   
 ungroup() %>%   
 mutate(id=paste0(model,"|",scenario)) %>%   
 select(-region,-unit) %>%   
 filter(var %in% c("Primary Energy",  
 "Primary Energy|Fossil|w/ CCS",  
 "Primary Energy|Coal|w/o CCS",  
 "Primary Energy|Gas|w/o CCS",  
 "Primary Energy|Oil|w/o CCS"))  
  
wd\_fuels <- left\_join(wd\_fuels,wd\_check\_years,by="id") %>%   
 filter(!is.na(native\_net\_zero\_CO2)) %>%   
 mutate(include=ifelse(native\_net\_zero\_CO2==year,1,0)) %>%   
 #mutate(include=ifelse(year==2050,1,0)) %>%   
 filter(include==1) %>%   
 select(-include)  
  
wd\_fuels <- spread(wd\_fuels,var,value)  
wd\_fuels <- wd\_fuels %>%   
 mutate(`Primary Energy|Renewable & nuclear`=`Primary Energy`-  
 `Primary Energy|Fossil|w/ CCS`-  
 `Primary Energy|Coal|w/o CCS` -  
 `Primary Energy|Gas|w/o CCS` -  
 `Primary Energy|Oil|w/o CCS`)  
  
wd\_fuels <- gather(wd\_fuels,var,value,`Primary Energy`:`Primary Energy|Renewable & nuclear`) %>%   
 filter(var!="Primary Energy")  
  
wd\_fuels <- left\_join(wd\_fuels,data.frame(var=c("Primary Energy|Renewable & nuclear",  
 "Primary Energy|Fossil|w/ CCS",  
 "Primary Energy|Coal|w/o CCS",  
 "Primary Energy|Gas|w/o CCS",  
 "Primary Energy|Oil|w/o CCS"),  
 fuel=c("Renewables, biomass & nuclear",  
 "Fossil with CCS",  
 "Coal",  
 "Gas",  
 "Oil")),by="var")  
  
wd\_fuels$fuel <- as.factor(wd\_fuels$fuel)  
wd\_fuels$fuel <- fct\_relevel(wd\_fuels$fuel,"Renewables, biomass & nuclear","Fossil with CCS","Oil","Gas","Coal")  
  
wd\_fuels$category <- as.factor(wd\_fuels$category)  
wd\_fuels$category <- fct\_relevel(wd\_fuels$category,"C3","C2","C1")  
  
wd\_fuels <- wd\_fuels %>%   
 mutate(model=ifelse(grepl("IMAGE",model),"IMAGE",model)) %>%   
 mutate(model=ifelse(grepl("REMIND",model),"REMIND",model)) %>%   
 mutate(model=ifelse(grepl("MESSAGE",model),"MESSAGE",model))  
  
  
  
## data summaries  
## at this point we ignore C1-C3 really  
wd\_gases\_summary <- median\_and\_range(wd\_gases,c("model","gas"))

## `summarise()` has grouped output by 'model'. You can override using the  
## `.groups` argument.

wd\_gases\_summary <- rbind(wd\_gases\_summary,  
 median\_and\_range(wd\_gases,"gas") %>% mutate(model="all"))  
wd\_gases\_summary <- spread(wd\_gases\_summary,gas,value) %>%   
 arrange(model)  
  
wd\_sectors\_summary <- median\_and\_range(wd\_sectors,c("model","sector"))

## `summarise()` has grouped output by 'model'. You can override using the  
## `.groups` argument.

wd\_sectors\_summary <- rbind(wd\_sectors\_summary,  
 median\_and\_range(wd\_sectors,"sector") %>% mutate(model="all"))  
wd\_sectors\_summary <- spread(wd\_sectors\_summary,sector,value) %>%   
 arrange(model)  
  
wd\_fuels\_extra\_vars <- spread(wd\_fuels %>% select(-var),fuel,value) %>%   
 mutate(`Fossil total`=Oil+Coal+Gas) %>%   
 mutate(Total=`Fossil total`+`Renewables, biomass & nuclear`+`Fossil with CCS`)  
wd\_fuels\_extra\_vars <- gather(wd\_fuels\_extra\_vars,fuel,value,`Renewables, biomass & nuclear`:Total)  
  
wd\_fuels\_summary <- median\_and\_range(wd\_fuels\_extra\_vars,c("model","fuel"))

## `summarise()` has grouped output by 'model'. You can override using the  
## `.groups` argument.

wd\_fuels\_summary <- rbind(wd\_fuels\_summary,  
 median\_and\_range(wd\_fuels\_extra\_vars,"fuel") %>% mutate(model="all"))  
wd\_fuels\_summary$fuel <- as.factor(wd\_fuels\_summary$fuel)  
wd\_fuels\_summary$fuel <- fct\_relevel(wd\_fuels\_summary$fuel,"Coal","Oil","Gas","Fossil total","Fossil with CCS","Renewables, biomass & nuclear","Total")  
wd\_fuels\_summary <- spread(wd\_fuels\_summary,fuel,value) %>%   
 arrange(model)  
  
addWorksheet(wb\_analysis,"gas\_residual\_at\_nz")  
addWorksheet(wb\_analysis,"sector\_residual\_at\_nz")  
addWorksheet(wb\_analysis,"fuel\_at\_nz")  
writeData(wb\_analysis, sheet = "gas\_residual\_at\_nz",  
 wd\_gases\_summary, colNames = T, rowNames = F)  
writeData(wb\_analysis, sheet = "sector\_residual\_at\_nz",  
 wd\_sectors\_summary, colNames = T, rowNames = F)  
writeData(wb\_analysis, sheet = "fuel\_at\_nz",  
 wd\_fuels\_summary, colNames = T, rowNames = F)

## what about primary energy supply if we compare across the same year??  
  
wd\_fuels\_check <- data\_r1 %>%   
 ungroup() %>%   
 mutate(id=paste0(model,"|",scenario)) %>%   
 select(-region,-unit) %>%   
 filter(var %in% c("Primary Energy",  
 "Primary Energy|Fossil|w/ CCS",  
 "Primary Energy|Coal|w/o CCS",  
 "Primary Energy|Gas|w/o CCS",  
 "Primary Energy|Oil|w/o CCS"))  
  
wd\_fuels\_check <- left\_join(wd\_fuels\_check,cc\_scenarios %>% mutate(include=1)) %>%   
 filter(year %in% c(2050,2075,2100)) %>%   
 filter(include==1) %>%   
 select(-include)

## Joining with `by = join\_by(id)`

wd\_fuels\_check <- spread(wd\_fuels\_check,var,value)  
wd\_fuels\_check <- wd\_fuels\_check %>%   
 mutate(`Primary Energy|Renewable & nuclear`=`Primary Energy`-  
 `Primary Energy|Fossil|w/ CCS`-  
 `Primary Energy|Coal|w/o CCS` -  
 `Primary Energy|Gas|w/o CCS` -  
 `Primary Energy|Oil|w/o CCS`)  
  
wd\_fuels\_check <- gather(wd\_fuels\_check,var,value,`Primary Energy`:`Primary Energy|Renewable & nuclear`) %>%   
 filter(var!="Primary Energy")  
  
wd\_fuels\_check <- left\_join(wd\_fuels\_check,data.frame(var=c("Primary Energy|Renewable & nuclear",  
 "Primary Energy|Fossil|w/ CCS",  
 "Primary Energy|Coal|w/o CCS",  
 "Primary Energy|Gas|w/o CCS",  
 "Primary Energy|Oil|w/o CCS"),  
 fuel=c("Renewables, biomass & nuclear",  
 "Fossil with CCS",  
 "Coal",  
 "Gas",  
 "Oil")),by="var")  
  
wd\_fuels\_check <- wd\_fuels\_check %>%   
 mutate(model=ifelse(grepl("IMAGE",model),"IMAGE",model)) %>%   
 mutate(model=ifelse(grepl("REMIND",model),"REMIND",model)) %>%   
 mutate(model=ifelse(grepl("MESSAGE",model),"MESSAGE",model)) %>%   
 filter(year==2050)  
  
wd\_fuels\_check\_totals <- wd\_fuels\_check   
  
wd\_fuels\_check <- median\_and\_range(wd\_fuels\_check,c("model","var"))

## `summarise()` has grouped output by 'model'. You can override using the  
## `.groups` argument.

wd\_fuels\_check\_totals <- median\_and\_range(wd\_fuels\_check\_totals,c("var"))  
wd\_fuels\_check <- rbind(wd\_fuels\_check,wd\_fuels\_check\_totals %>% mutate(model="all"))  
  
wd\_fuels\_check <- spread(wd\_fuels\_check,var,value)  
  
addWorksheet(wb\_analysis,"fuel\_at\_2050")  
writeData(wb\_analysis, sheet = "fuel\_at\_2050",  
 wd\_fuels\_check, colNames = T, rowNames = F)

p1 <- wd\_gases %>% ggplot(.,aes(x=id,y=value,fill=gas)) +  
 geom\_bar(stat="identity",color="#969696") +  
 facet\_nested(.~model + fct\_rev(category),scales="free\_x",space="free",switch = "x",  
 nest\_line = element\_line(linetype = 1,color='#636363')) +  
 theme\_wl() +  
 scale\_y\_continuous(limits=c(0,28),breaks=c(0,5,10,15,20,25)) +  
 #scale\_fill\_manual(values=colors[1:4]) +  
 scale\_fill\_brewer(palette="Greens") +  
 theme(axis.title = element\_blank(),  
 axis.text.x = element\_blank(),  
 axis.ticks.x = element\_blank(),  
 panel.grid.major.x = element\_blank(),  
 legend.position="bottom",  
 legend.title=element\_blank(),  
 legend.background = element\_blank(),  
 legend.margin = margin(t=-5),  
 strip.background = element\_blank(),  
 panel.spacing.x=unit(0.4, "lines"),  
 panel.border = element\_blank(),  
 strip.text = element\_text(color='#636363'),) +  
 labs(title="a. Residual GHG emissions at net zero by gas",  
 subtitle=bquote("Gt"~CO[2]\*"e/yr"))

## Scale for fill is already present.  
## Adding another scale for fill, which will replace the existing scale.

wd\_sectors$sector <- as.factor(wd\_sectors$sector)  
wd\_sectors$sector <- fct\_relevel(wd\_sectors$sector,"Energy","AFOLU","Other (Industrial processes, F-gases, other)")  
  
p2 <- wd\_sectors %>% ggplot(.,aes(x=id,y=value,fill=sector)) +  
 geom\_bar(stat="identity",color="#969696") +  
 facet\_nested(.~model + fct\_rev(category),scales="free\_x",space="free",switch = "x",  
 nest\_line = element\_line(linetype = 1,color='#636363')) +  
 theme\_wl() +  
 scale\_y\_continuous(limits=c(0,28),breaks=c(0,5,10,15,20,25)) +  
 scale\_fill\_brewer(palette="Blues") +  
 theme(axis.title = element\_blank(),  
 axis.text.x = element\_blank(),  
 axis.ticks.x = element\_blank(),  
 panel.grid.major.x = element\_blank(),  
 legend.position="bottom",  
 legend.title=element\_blank(),  
 legend.background = element\_blank(),  
 legend.margin = margin(t=-5),  
 strip.background = element\_blank(),  
 panel.spacing.x=unit(0.4, "lines"),  
 panel.border = element\_blank(),  
 strip.text = element\_text(color='#636363'),  
 strip.clip = element\_blank()  
 ) +  
 labs(title="b. Residual GHG emissions at net zero by sector",  
 subtitle=bquote("Gt"~CO[2]\*"e/yr"))

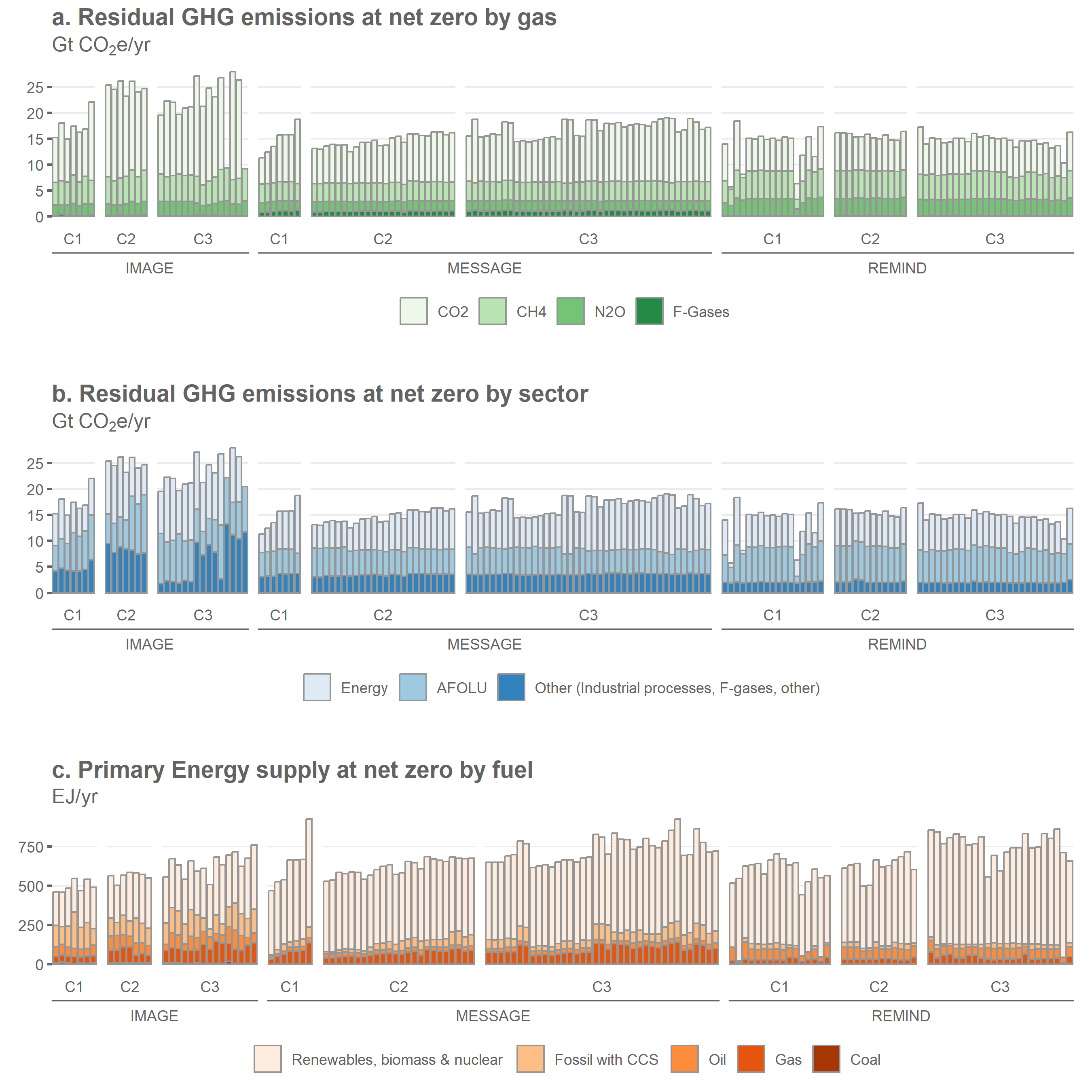
## Scale for fill is already present.  
## Adding another scale for fill, which will replace the existing scale.

p3 <- wd\_fuels %>% ggplot(.,aes(x=id,y=value,fill=fuel)) +  
 geom\_bar(stat="identity",color="#969696") +  
 facet\_nested(.~model + fct\_rev(category),scales="free\_x",space="free",switch = "x",  
 nest\_line = element\_line(linetype = 1,color='#636363')) +  
 theme\_wl() +  
 scale\_fill\_brewer(palette="Oranges") +  
 theme(axis.title = element\_blank(),  
 axis.text.x = element\_blank(),  
 axis.ticks.x = element\_blank(),  
 panel.grid.major.x = element\_blank(),  
 legend.position="bottom",  
 legend.title=element\_blank(),  
 legend.background = element\_blank(),  
 legend.margin = margin(t=-5),  
 strip.background = element\_blank(),  
 panel.spacing.x=unit(0.4, "lines"),  
 panel.border = element\_blank(),  
 strip.text = element\_text(color='#636363'),  
 strip.clip = element\_blank()  
 ) +  
 labs(title="c. Primary Energy supply at net zero by fuel",  
 subtitle=bquote("EJ/yr"))

## Scale for fill is already present.  
## Adding another scale for fill, which will replace the existing scale.

p1/plot\_spacer()/p2/plot\_spacer()/p3 + plot\_layout(heights=c(5,1,5,1,5))

## Warning: Removed 2 rows containing missing values (`geom\_bar()`).  
## Removed 2 rows containing missing values (`geom\_bar()`).



## save plot data  
addWorksheet(wb\_figures,"fig\_2a\_gases")  
addWorksheet(wb\_figures,"fig\_2b\_sectors")  
addWorksheet(wb\_figures,"fig\_2c\_fuels")  
  
writeData(wb\_figures, sheet = "fig\_2a\_gases",spread(wd\_gases,gas,value)   
 %>% arrange(model,desc(category),scenario), colNames = T, rowNames = F)  
writeData(wb\_figures, sheet = "fig\_2b\_sectors",spread(wd\_sectors,sector,value)  
 %>% arrange(model,desc(category),scenario), colNames = T, rowNames = F)  
writeData(wb\_figures, sheet = "fig\_2c\_fuels",spread(wd\_fuels %>% select(-fuel),var,value) %>%   
 select(-native\_net\_zero\_CO2,-native\_net\_zero\_CO2) %>%   
 select(id,model,scenario,category,year,everything()) %>%   
 arrange(model,desc(category),scenario), colNames = T, rowNames = F)

## get the scenario data  
wd\_subsectors <- wd\_scenarios\_emissions %>%  
 filter(var!="Kyoto Gases") %>%  
 filter(!grepl("Carbon Sequestration",var)) %>%  
 mutate(value=ifelse(is.na(value),0,value)) %>%  
 mutate(include=ifelse(native\_net\_zero\_CO2==year,1,0)) %>%  
 mutate(include=ifelse(year==2020,1,include)) %>%   
 filter(include==1) %>%  
 group\_by(id,model,category,year,sector,var) %>%  
 summarise(value=sum(value,na.rm=TRUE))

## `summarise()` has grouped output by 'id', 'model', 'category', 'year',  
## 'sector'. You can override using the `.groups` argument.

## generate median scenarios for each  
  
wd\_subsectors\_total <- wd\_subsectors %>%   
 mutate(model="All") %>%   
 mutate(year=ifelse(year!=2020,2050,year)) %>% #2050 here is just a fake year to merge all the nz years  
 group\_by(model,year,sector,var) %>%  
 summarise(percentile\_5th = quantile(value, probs = c(0.05)),  
 percentile\_95th = quantile(value, probs = c(0.95)),  
 std=sd(value),  
 value=median(value,na.rm=TRUE)) %>%   
 mutate(model="All")

## `summarise()` has grouped output by 'model', 'year', 'sector'. You can override  
## using the `.groups` argument.

wd\_subsectors <- wd\_subsectors %>%   
 mutate(year=ifelse(year!=2020,2050,year)) %>% #2050 here is just a fake year to merge all the nz years  
 group\_by(model,year,sector,var) %>%  
 summarise(percentile\_5th = quantile(value, probs = c(0.05)),  
 percentile\_95th = quantile(value, probs = c(0.95)),  
 std=sd(value),  
 value=median(value,na.rm=TRUE))

## `summarise()` has grouped output by 'model', 'year', 'sector'. You can override  
## using the `.groups` argument.

## calculate relative and absolute changes for each model and variable  
wd\_subsectors <- rbind(wd\_subsectors,wd\_subsectors\_total)  
wd\_subsectors <- wd\_subsectors %>%   
 group\_by(model,sector,var) %>%   
 mutate(change\_rel = (first(value)-last(value))/first(value)) %>%   
 mutate(change\_rel\_5th = (first(percentile\_5th)-last(percentile\_5th))/first(percentile\_5th)) %>%   
 mutate(change\_rel\_95th = (first(percentile\_95th)-last(percentile\_95th))/first(percentile\_95th)) %>%   
 mutate(change\_rel=-round(change\_rel\*100,0)) %>%   
 mutate(change\_rel\_5th=-round(change\_rel\_5th\*100,0)) %>%   
 mutate(change\_rel\_95th=-round(change\_rel\_95th\*100,0))  
  
  
## rebase the data so that totals in 2020 vs "2050" are shown  
wd\_subsectors <- wd\_subsectors %>%   
 group\_by(model,sector,var) %>%   
 mutate(value\_rebased=first(value)-last(value)) %>%   
 mutate(value\_rebased=ifelse(year==2050,value,value\_rebased))  
  
wd\_subsectors <- wd\_subsectors %>%  
 mutate(value\_rebased=ifelse(value\_rebased<0,0,value\_rebased))  
  
wd\_subsectors$year = as.factor(wd\_subsectors$year)  
wd\_subsectors$year <- fct\_relevel(wd\_subsectors$year,"2020","2050")  
  
p1 <- wd\_subsectors %>%   
 filter(model!="All") %>%   
 filter(sector=="Energy") %>%   
 mutate(var=gsub("\\|Energy","",var)) %>%   
 ggplot(.,aes(x=value\_rebased,y=reorder(var,value\_rebased),alpha=year)) +  
 geom\_col(color='#636363',fill="#8da0cb") +  
 geom\_errorbar(data=wd\_subsectors %>%  
 filter(model!="All") %>%   
 filter(year==2050) %>%  
 filter(sector=="Energy") %>%  
 mutate(var=gsub("\\|Energy","",var)),inherit.aes = FALSE,  
 aes(xmin=percentile\_5th,xmax=percentile\_95th,y=reorder(var,value\_rebased)),  
 width=0.3) +  
 geom\_text(data=wd\_subsectors %>%  
 filter(model!="All") %>%   
 filter(sector=="Energy") %>%  
 mutate(var=gsub("\\|Energy","",var)) %>%   
 group\_by(model,var,change\_rel) %>%  
 summarise(value=sum(value\_rebased)),  
 inherit.aes = FALSE,aes(x=value+1,y=var,  
 label=ifelse(change\_rel<0,  
 paste0(change\_rel,"%"),  
 paste0("+",change\_rel,"%"))),  
 hjust=0,size=3) +  
 scale\_x\_continuous(expand = expansion(mult = c(0.05, 0.25))) +  
 scale\_alpha\_discrete(range=c(0.3,1)) +  
 scale\_fill\_brewer(palette="Blues") +  
 facet\_grid(.~model) +  
 theme\_wl() +  
 theme(legend.position="none",  
 axis.title=element\_blank(),  
 panel.grid.major.y = element\_blank()) +  
 labs(title="a. Energy sector emissions from 2020 to net zero",  
 subtitle=bquote("Gt"~CO[2]\*"e/yr"))

## `summarise()` has grouped output by 'model', 'var'. You can override using the  
## `.groups` argument.

## Warning: Using alpha for a discrete variable is not advised.

## Scale for fill is already present.  
## Adding another scale for fill, which will replace the existing scale.

p2 <- wd\_subsectors %>%  
 filter(model!="All") %>%   
 filter(sector=="AFOLU") %>%   
 mutate(var=gsub("\\|AFOLU","",var)) %>%   
 ggplot(.,aes(x=value\_rebased,y=reorder(var,value\_rebased),alpha=year)) +  
 geom\_col(color='#636363',fill="#66c2a5") +  
 geom\_errorbar(data=wd\_subsectors %>%  
 filter(model!="All") %>%   
 filter(year==2050) %>%  
 filter(sector=="AFOLU") %>%   
 mutate(var=gsub("\\|AFOLU","",var)),inherit.aes = FALSE,  
 aes(xmin=percentile\_5th,xmax=percentile\_95th,y=reorder(var,value\_rebased)),  
 width=0.3) +  
 geom\_text(data=wd\_subsectors %>%  
 filter(model!="All") %>%   
 filter(sector=="AFOLU") %>%  
 mutate(var=gsub("\\|AFOLU","",var)) %>%   
 group\_by(model,var,change\_rel) %>%  
 summarise(value=sum(value\_rebased)),  
 inherit.aes = FALSE,aes(x=value+1.2,y=var,  
 label=ifelse(change\_rel<0,  
 paste0(change\_rel,"%"),  
 paste0("+",change\_rel,"%"))),  
 hjust=0,size=3) +  
 scale\_x\_continuous(expand = expansion(mult = c(0.05, 0.25))) +  
 scale\_alpha\_discrete(range=c(0.3,1)) +  
 #scale\_fill\_brewer(palette="Greens") +  
 facet\_grid(.~model) +  
 theme\_wl() +  
 theme(legend.position="none",  
 axis.title=element\_blank(),  
 panel.grid.major.y = element\_blank()) +  
 labs(title="b. AFOLU sector emissions from 2020 to net zero",  
 subtitle=bquote("Gt"~CO[2]\*"e/yr"))

## `summarise()` has grouped output by 'model', 'var'. You can override using the  
## `.groups` argument.

## Warning: Using alpha for a discrete variable is not advised.

p3 <- wd\_subsectors %>%   
 filter(model!="All") %>%   
 filter(sector!="Energy") %>%   
 filter(sector!="AFOLU") %>%   
 mutate(var=gsub("\\|Other","",var)) %>%   
 mutate(var=ifelse(var=="CO2","CO2|Other",var)) %>%   
 ggplot(.,aes(x=value\_rebased,y=reorder(var,value\_rebased),alpha=year)) +  
 geom\_col(color='#636363',fill="#fc8d62") +  
 geom\_errorbar(data=wd\_subsectors %>%  
 filter(model!="All") %>%   
 filter(year==2050) %>%   
 filter(sector!="Energy") %>%   
 filter(sector!="AFOLU") %>%   
 mutate(var=gsub("\\|Other","",var)) %>%   
 mutate(var=ifelse(var=="CO2","CO2|Other",var)),inherit.aes = FALSE,  
 aes(xmin=percentile\_5th,xmax=percentile\_95th,y=reorder(var,value\_rebased)),  
 width=0.3) +  
 geom\_text(data=wd\_subsectors %>%  
 filter(model!="All") %>%   
 filter(sector!="Energy") %>%  
 filter(sector!="AFOLU") %>%  
 mutate(var=gsub("\\|Other","",var)) %>%  
 mutate(var=ifelse(var=="CO2","CO2|Other",var)) %>%  
 group\_by(model,var,change\_rel) %>%  
 summarise(value=sum(value\_rebased)),  
 inherit.aes = FALSE,aes(x=value+0.4,y=var,  
 label=ifelse(change\_rel<0,  
 paste0(change\_rel,"%"),  
 paste0("+",change\_rel,"%"))),  
 hjust=0,size=3) +  
 scale\_x\_continuous(expand = expansion(mult = c(0.05, 0.25))) +  
 scale\_alpha\_discrete(range=c(0.3,1)) +  
 scale\_fill\_brewer(palette="Oranges") +  
 facet\_grid(.~model) +  
 theme\_wl() +  
 theme(legend.position="none",  
 axis.title=element\_blank(),  
 panel.grid.major.y = element\_blank()) +  
 labs(title="c. Other sector emissions from 2020 to net zero",  
 subtitle=bquote("Gt"~CO[2]\*"e/yr"))

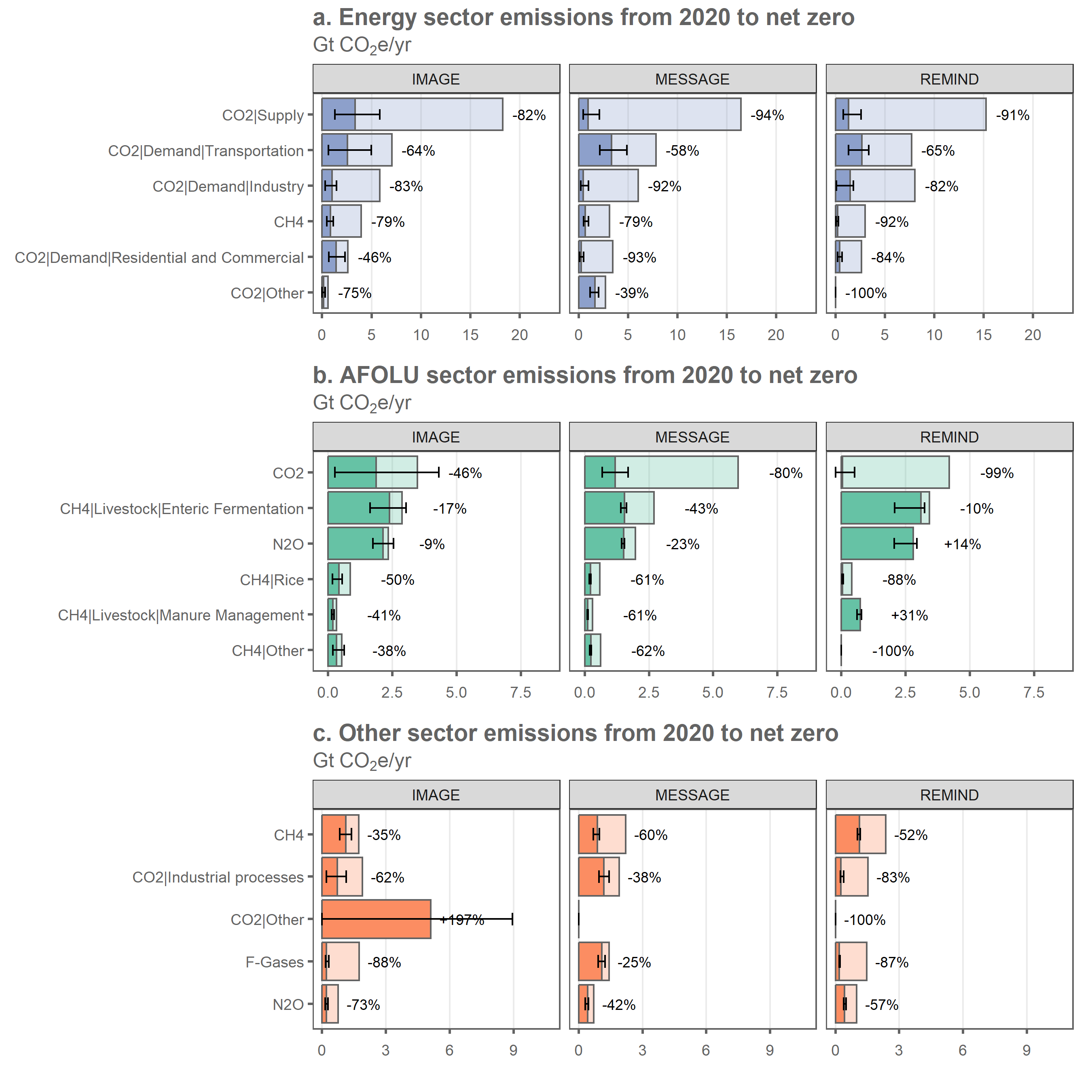
## `summarise()` has grouped output by 'model', 'var'. You can override using the  
## `.groups` argument.

## Warning: Using alpha for a discrete variable is not advised.

## Scale for fill is already present.  
## Adding another scale for fill, which will replace the existing scale.

p1 / p2 / p3

## Warning: Removed 1 rows containing missing values (`geom\_text()`).



## save plot data  
addWorksheet(wb\_figures,"fig\_3\_subsectors")  
  
  
writeData(wb\_figures, sheet = "fig\_3\_subsectors",  
 wd\_subsectors %>%   
 select(sector,model,var,year,value\_rebased,percentile\_5th,percentile\_95th) %>%  
 arrange(sector,model,var,year) %>%   
 mutate(year=ifelse(year==2050,"Net Zero","2020")),  
 colNames = T, rowNames = F)

wd\_subsectors\_summary <- wd\_subsectors %>%   
 ungroup() %>%   
 filter(year==2050) %>%   
 mutate(sector=as.character(sector)) %>%   
 mutate(sector=ifelse(sector=="F-Gases","Other",sector)) %>%   
 mutate(sector=ifelse(sector=="Industrial processes","Other",sector)) %>%   
 mutate(change\_rel\_5th=ifelse(percentile\_5th==0,-100,change\_rel\_5th)) %>%   
 mutate(value=paste0(signif(value,2)," [",signif(percentile\_5th,2),"-",signif(percentile\_95th,2),"]")) %>%   
 mutate(change\_rel=paste0(change\_rel," [",change\_rel\_5th," to ",change\_rel\_95th,"]")) %>%   
 select(model,sector,var,value,change\_rel)  
  
wd\_subsectors\_summary$sector <- as.factor(wd\_subsectors\_summary$sector)  
wd\_subsectors\_summary$sector <- fct\_relevel(wd\_subsectors\_summary$sector,  
 "AFOLU","Energy","Other")  
  
wd\_subsectors\_summary <- cbind(spread(wd\_subsectors\_summary %>%   
 mutate(model=paste0(model,"\_level")) %>%   
 select(-change\_rel),model,value),  
 spread(wd\_subsectors\_summary %>%   
 mutate(model=paste0(model,"\_reduction")) %>%   
 select(-value),model,change\_rel) %>%   
 select(-sector,-var)) %>%   
 arrange(sector,var)  
  
  
addWorksheet(wb\_analysis,"subsector\_residual\_at\_nz")  
writeData(wb\_analysis, sheet = "subsector\_residual\_at\_nz",  
 wd\_subsectors\_summary, colNames = T, rowNames = F)

wd\_pca <- wd\_scenarios\_emissions %>%  
 filter(var!="Kyoto Gases") %>%  
 filter(!grepl("Carbon Sequestration",var)) %>%  
 mutate(value=ifelse(is.na(value),0,value)) %>%  
 mutate(include=ifelse(native\_net\_zero\_CO2==year,1,0)) %>%   
 filter(include==1) %>%  
 group\_by(id,model,var) %>%  
 summarise(value=sum(value,na.rm=TRUE))

## `summarise()` has grouped output by 'id', 'model'. You can override using the  
## `.groups` argument.

wd\_pca <- spread(wd\_pca,var,value)  
pca <- prcomp(wd\_pca %>% ungroup() %>% select(-id,-model),scale=TRUE)  
wd\_pca <- cbind(wd\_pca %>% select(id,model),pca$x)  
pca\_variance <-get\_eigenvalue(pca)$variance.percent  
sum(pca\_variance[1:2])

## [1] 75.01983

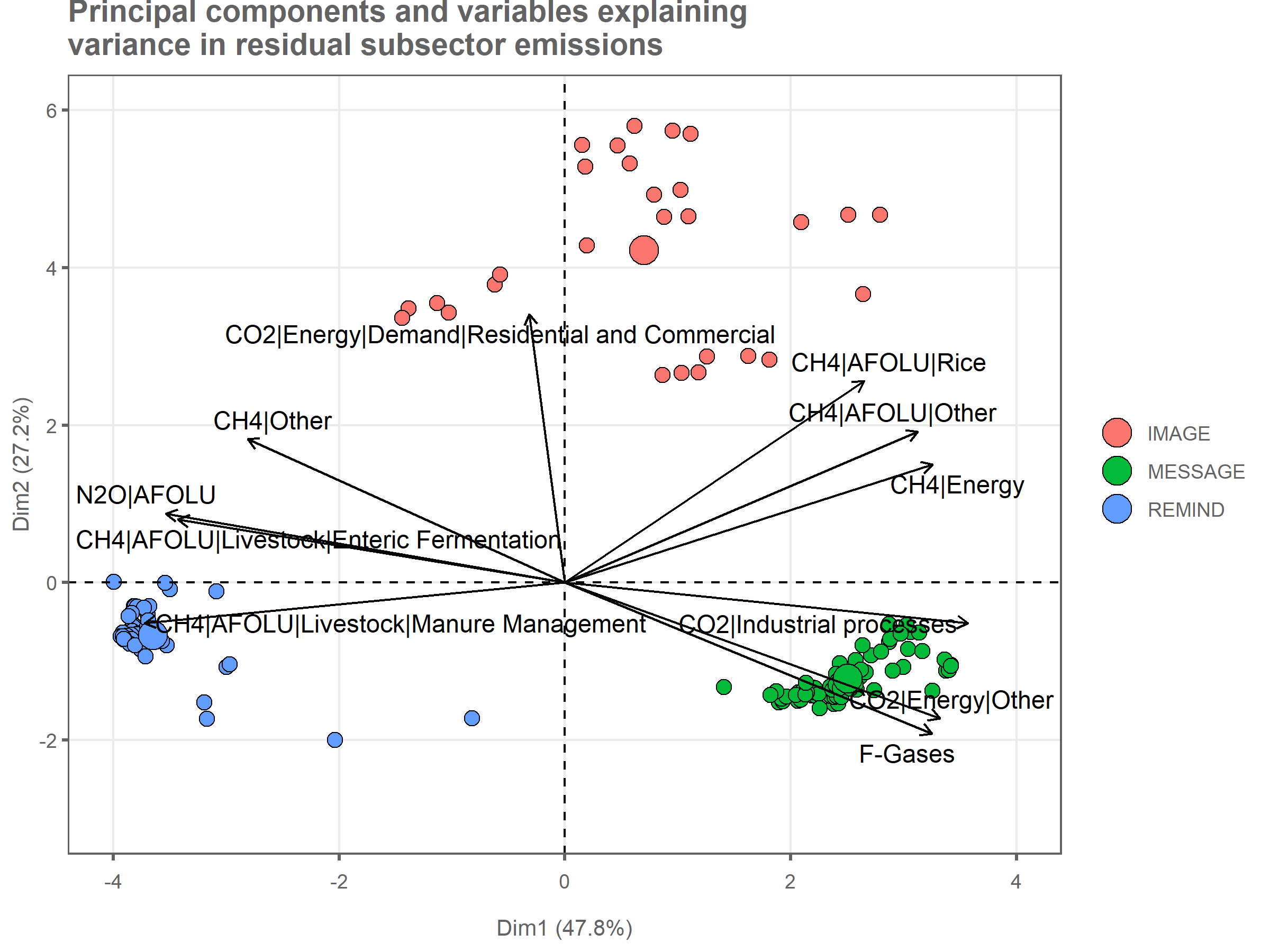
# colors=c("#e6550d","#3182bd","#31a354")  
# wd\_pca %>% ggplot(.,aes(x=PC1,y=PC2,fill=model)) +  
# geom\_point(shape=21,size=3,alpha=0.6) +  
# theme\_wl() +  
# scale\_fill\_manual(values=colors) +  
# theme(legend.title=element\_blank()) +  
# labs(title=paste0("Principal components explaining ",signif(sum(pca\_variance[1:2]),2), "% of residual\nsubsector emissions variance"))  
  
  
fviz\_pca\_biplot(pca,   
 geom.ind = "point",  
 pointshape = 21,  
 pointsize = 3,  
 fill.ind = wd\_pca$model,  
 col.ind = "black",  
 select.var = list(contrib= 12),  
 col.var = "black",  
 repel = TRUE # Avoid label overplotting  
 ) +   
 theme\_wl() +  
 xlim(-4,4) +  
 ylim(-3,6) +  
 theme(legend.title=element\_blank()) +  
 labs(title=paste0("Principal components and variables explaining\nvariance in residual subsector emissions"))

## Warning: Removed 1 rows containing non-finite values (`stat\_mean()`).

## Warning: Removed 1 rows containing missing values (`geom\_point()`).

## Warning: Removed 1 rows containing missing values (`geom\_text\_repel()`).

## Warning: Removed 1 rows containing missing values (`geom\_segment()`).



# fviz\_contrib(pca,  
# choice = "var",  
# axes = 1:2,  
# fill="#3182bd") +  
# coord\_flip() +  
# theme(axis.text.x = element\_text(angle = 0,hjust=0.5),  
# axis.title.y = element\_blank())

# wd\_clusters <- wd\_scenarios\_emissions %>%  
# filter(var!="Kyoto Gases") %>%  
# filter(!grepl("Carbon Sequestration",var)) %>%  
# mutate(value=ifelse(is.na(value),0,value)) %>%  
# mutate(include=ifelse(native\_net\_zero\_CO2==year,1,0)) %>%  
# filter(include==1) %>%  
# group\_by(id,category,var) %>%  
# summarise(value=sum(value,na.rm=TRUE))  
#   
# wd\_clusters <- spread(wd\_clusters,var,value) %>%  
# ungroup()  
#   
# cc\_clusters = wd\_clusters %>%  
# select(id) %>%   
# mutate(no\_clusters=NA) %>%   
# mutate(value=NA)  
#   
# for(x in 3:6) {  
#   
# wd\_cluster\_summary <- kmeans(scale(wd\_clusters %>% select(-id,-category)),x,nstart=25)  
#   
# blarg <- cbind(cc\_clusters %>% select(id),value=wd\_cluster\_summary$cluster) %>%   
# mutate(no\_clusters=x)  
# cc\_clusters <- rbind(cc\_clusters,blarg)  
#   
# }  
#   
# cc\_clusters <- left\_join(cc\_clusters %>% filter(!is.na(no\_clusters)),wd\_pca %>% select(id,model,PC1,PC2))  
# cc\_clusters <- cc\_clusters %>%   
# mutate(label=paste0(no\_clusters," Clusters"))  
#   
# cc\_clusters$value <- as.factor(cc\_clusters$value)  
#   
#   
# cc\_clusters %>% ggplot(.,aes(x=PC1,y=PC2,fill=model)) +  
# geom\_point(shape=21,size=3,alpha=0.6) +  
# theme\_wl() +  
# facet\_wrap(.~label) +  
# #theme(legend.position="none") +  
# labs(title=paste0("Principal components explaining ",signif(sum(pca\_variance[1:2]),2), "% of residual subsector emissions variance"))

cc\_expl <- read.xlsx('Data/AR6\_Scenarios\_Database\_metadata\_indicators\_v1.1\_1.xlsx',sheet=2)  
cc\_expl <- cc\_expl %>%  
 mutate(id=paste0(Model,"|",Scenario)) %>%   
 select(id,Policy\_category,Policy\_category\_name,Project\_study,reference=`Literature.Reference.(if.applicable)`,  
 Ssp\_family,Technology\_category\_name)  
  
## explanatory factors vs. total residual?  
wd\_expl <- left\_join(wd\_scenarios\_emissions,cc\_expl,by="id") %>%   
 mutate(include=ifelse(year==native\_net\_zero\_CO2,1,0)) %>%   
 filter(include==1) %>%   
 select(-include) %>%   
 filter(var!="Kyoto Gases") %>%   
 filter(!is.na(subsector))  
  
wd\_expl <- wd\_expl %>%   
 group\_by(id,model,category,Policy\_category,Policy\_category\_name,Project\_study,reference,  
 Ssp\_family,Technology\_category\_name) %>%   
 summarise(value=sum(value,na.rm=TRUE)) %>%  
 mutate(Ssp\_family=as.character(Ssp\_family)) %>%   
 mutate(Ssp\_family=ifelse(Ssp\_family=="1","SSP1",Ssp\_family)) %>%  
 mutate(Ssp\_family=ifelse(Ssp\_family=="2","SSP2",Ssp\_family)) %>%   
 mutate(Ssp\_family=as.factor(Ssp\_family))

## `summarise()` has grouped output by 'id', 'model', 'category',  
## 'Policy\_category', 'Policy\_category\_name', 'Project\_study', 'reference',  
## 'Ssp\_family'. You can override using the `.groups` argument.

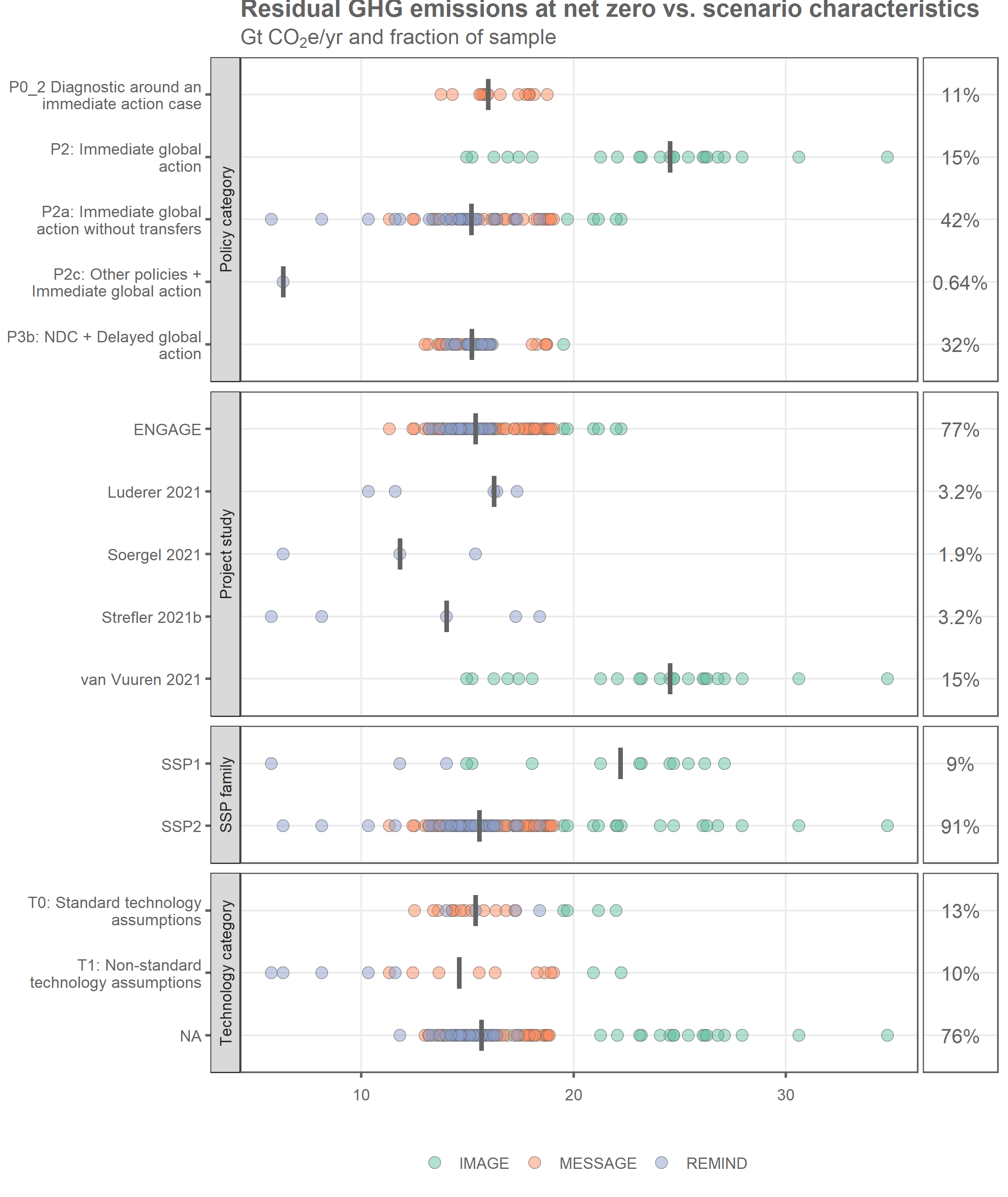
wd\_expl <- wd\_expl %>%   
 ungroup() %>%   
 select(-category,-Policy\_category,-reference)  
wd\_expl <- gather(wd\_expl,key,var,-id,-value,-model)

## Warning: attributes are not identical across measure variables; they will be  
## dropped

p1 <- wd\_expl %>%   
 ggplot(.,aes(x=value,y=var)) +  
 geom\_point(shape=21,size=3,alpha=0.5,color="#636363",aes(fill=model)) +  
 stat\_summary(fun=median,geom="crossbar", color="#636363",width=0.5,show.legend = FALSE) +  
 facet\_grid(key~.,scales="free\_y",space="free",switch="y",  
 labeller=as\_labeller(c(Policy\_category\_name="Policy category",  
 Project\_study="Project study",  
 Ssp\_family="SSP family",  
 Technology\_category\_name="Technology category"))) +  
 scale\_y\_discrete(limits=rev,labels = function(x) str\_wrap(x, width = 25)) +  
 theme\_wl() +  
 theme(legend.position="bottom",  
 legend.title=element\_blank(),  
 axis.title = element\_blank(),  
 strip.text = element\_text(color="#252525"),  
 plot.margin = margin(0,0,0,0,"cm"),) +  
 labs(title="Residual GHG emissions at net zero vs. scenario characteristics",  
 subtitle=bquote("Gt"~CO[2]\*"e/yr and fraction of sample"))  
  
  
## how many scenarios are from the ENGAGE project?  
wd\_expl\_totals <- wd\_expl %>%   
 group\_by(key,var) %>%   
 summarise(n=n(),  
 fraction=n/length(no\_scenarios$id)) %>%   
 mutate(fraction=signif(fraction\*100,2))

## `summarise()` has grouped output by 'key'. You can override using the `.groups`  
## argument.

p2 <- wd\_expl\_totals %>% ggplot(.,aes(x="% of sample",y=var,label=paste0(fraction,"%"))) +  
 geom\_text(size=4,color="#636363") +  
 facet\_grid(key~.,scales="free\_y",space="free") +  
 scale\_y\_discrete(limits=rev) +  
 theme\_wl() +  
 theme(legend.position="none",  
 axis.title = element\_blank(),  
 axis.text = element\_blank(),  
 plot.background = element\_blank(),  
 strip.background = element\_blank(),  
 strip.text = element\_blank(),  
 axis.ticks = element\_blank(),  
 panel.grid.major.x = element\_blank(),  
 plot.margin = margin(0,0,0,0,"cm"),  
 axis.text.x = element\_blank())  
  
  
p1 + p2 + plot\_layout(widths=c(9,1))



wd\_expl <- median\_and\_range(wd\_expl,c("key","var"))

## `summarise()` has grouped output by 'key'. You can override using the `.groups`  
## argument.

wd\_expl <- left\_join(wd\_expl,wd\_expl\_totals)

## Joining with `by = join\_by(key, var)`

addWorksheet(wb\_analysis,"explanatory\_vars")  
writeData(wb\_analysis, sheet = "explanatory\_vars",  
 wd\_expl, colNames = T, rowNames = F)

# pd <- pd %>%   
# mutate(include=ifelse(year==2020,1,0)) %>%   
# mutate(include=ifelse(year==net\_zero\_CO2,1,include)) %>%   
# mutate(include=ifelse(year==2100,1,include)) %>%   
# filter(include==1)  
  
  
  
# pd <- wd\_scenarios\_emissions %>%   
# filter(var!="Kyoto Gases") %>%   
# filter(!grepl("Carbon Sequestration",var)) %>%   
# mutate(include=ifelse(year>=net\_zero\_CO2,1,0)) %>%   
# filter(include==1) %>%   
# group\_by(id,model,scenario,category,year,net\_zero\_CO2) %>%   
# summarise(value=sum(value,na.rm=TRUE)) #%>%   
# group\_by(id,model,scenario,category) %>%   
# summarise(emissions\_nz=first(value),  
# emissions\_2100=last(value))  
  
  
  
# pd <- gather(pd,var,value,-id,-category)  
#   
# pd %>% filter(var=="change\_rel") %>% ggplot(.,aes(x=value,y=category,fill=category)) +  
# geom\_point(shape=21,size=3,alpha=0.6,color="#636363") +  
# theme\_wl() +  
# theme(legend.position="none",  
# axis.title = element\_blank(),  
# plot.margin = margin(0,0,0,0,"cm"))  
  
#   
#   
# pd %>% ggplot(.,aes(x=emissions\_2100,y=emissions\_nz))+  
# geom\_abline(intercept=0,color="#636363") +  
# geom\_point(shape=21,size=3,alpha=0.6,color="#636363",aes(fill=category)) +  
# geom\_text(data=data.frame(emissions\_nz=c(6,5),  
# emissions\_2100=c(5,6),  
# label=c("Decrease","Increase")),  
# aes(label=label),  
# color="#636363",  
# angle=35,  
# hjust=0) +  
# facet\_wrap(.~category) +  
# theme\_wl() +  
# theme(legend.title=element\_blank()) +  
# xlim(5,25) +  
# ylim(5,25) +  
# ylab("GHG emissions at net-zero") +  
# xlab("GHG emissions at 2100") +  
# labs(title="Residual GHG emissions after net-zero",  
# subtitle="GtCO2e/yr")  
#   
#   
# pd <- wd\_scenarios\_emissions %>%   
# filter(var!="Kyoto Gases") %>%   
# filter(!grepl("Carbon Sequestration",var)) %>%   
# group\_by(id,model,scenario,category,year,net\_zero\_CO2) %>%   
# summarise(value=sum(value,na.rm=TRUE))  
#   
# pd %>% ggplot(.,aes(x=year,y=value,group=id,color=model)) +  
# geom\_line() +  
# facet\_grid(category~model) +  
# theme\_wl() +  
# theme(legend.position="none") +  
# scale\_y\_continuous(limits=c(0,60),breaks=c(0,10,20,30,40,50,60))

wd\_standards <- wd\_scenarios\_emissions %>%   
 filter(var!="Kyoto Gases")%>%   
 filter(!grepl("Carbon Sequestration",var)) %>%   
 mutate(include=ifelse(year==native\_net\_zero\_CO2,1,0)) %>%  
 mutate(include=ifelse(year==2020,1,include)) %>%   
 filter(include==1) %>%   
 select(-include)  
  
wd\_standards <- wd\_standards %>%   
 mutate(mapping=ifelse(sector=="AFOLU","AFOLU",NA)) %>%   
 mutate(mapping=ifelse(var=="CO2|Energy|Supply","Power",mapping)) %>%   
 mutate(mapping=ifelse(var=="CO2|Energy|Demand|Industry","Cement/Iron and Steel",mapping)) %>%   
 mutate(mapping=ifelse(var=="CO2|Industrial processes","Cement/Iron and Steel",mapping)) %>%   
 mutate(mapping=ifelse(var=="CO2|Energy|Demand|Residential and Commercial","Buildings",mapping))  
  
## cross-sector total (everything excl. AFOLU)  
wd\_standards\_total <- wd\_scenarios\_emissions %>%   
 filter(var!="Kyoto Gases")%>%   
 filter(!grepl("Carbon Sequestration",var)) %>%   
 mutate(include=ifelse(year==native\_net\_zero\_CO2,1,0)) %>%  
 mutate(include=ifelse(year==2020,1,include)) %>%   
 filter(include==1) %>%   
 select(-include)  
  
wd\_standards\_total <- wd\_standards\_total %>%   
 mutate(mapping=ifelse(sector!="AFOLU","Total",NA))  
  
wd\_standards <- rbind(wd\_standards,wd\_standards\_total) %>%   
 filter(!is.na(mapping)) %>%   
 group\_by(id,category,year,mapping) %>%   
 summarise(value=sum(value,na.rm=TRUE))

## `summarise()` has grouped output by 'id', 'category', 'year'. You can override  
## using the `.groups` argument.

wd\_standards <- wd\_standards %>%   
 group\_by(id,category,mapping) %>%   
 mutate(rel\_change=(first(value)-last(value))/first(value)) %>%   
 mutate(rel\_change=rel\_change\*100)  
  
wd\_standards <- median\_and\_range(wd\_standards %>% select(id,category,sector=mapping,value=rel\_change),c("sector","category"))

## `summarise()` has grouped output by 'sector'. You can override using the  
## `.groups` argument.

wd\_standards$category <- fct\_relevel(wd\_standards$category,"C1","C2","C3")  
wd\_standards <- spread(wd\_standards,category,value)  
  
addWorksheet(wb\_analysis,"scenarios\_vs\_standards")  
writeData(wb\_analysis, sheet = "scenarios\_vs\_standards",  
 wd\_standards, colNames = T, rowNames = F)

## get the scenario data  
wd\_subsectors <- wd\_scenarios\_emissions %>%  
 filter(var!="Kyoto Gases") %>%  
 filter(!grepl("Carbon Sequestration",var)) %>%  
 mutate(value=ifelse(is.na(value),0,value)) %>%  
 mutate(include=ifelse(native\_net\_zero\_CO2==year,1,0)) %>%  
 mutate(include=ifelse(year==2020,1,include)) %>%   
 filter(include==1) %>%  
 group\_by(id,model,category,year,sector,var) %>%  
 summarise(value=sum(value,na.rm=TRUE))

## `summarise()` has grouped output by 'id', 'model', 'category', 'year',  
## 'sector'. You can override using the `.groups` argument.

## new sector aggregation  
aggregation <- read.xlsx("Data/cc\_aggregation\_socdr.xlsx")  
wd\_subsectors <- left\_join(wd\_subsectors,aggregation)

## Joining with `by = join\_by(sector, var)`

wd\_subsectors <- wd\_subsectors %>%   
 group\_by(id,model,year,colour,aggregation) %>%   
 summarise(value=sum(value,na.rm=TRUE))

## `summarise()` has grouped output by 'id', 'model', 'year', 'colour'. You can  
## override using the `.groups` argument.

## generate median scenarios for each  
  
wd\_subsectors <- wd\_subsectors %>%   
 mutate(year=ifelse(year!=2020,2050,year)) %>% #2050 here is just a fake year to merge all the nz years  
 group\_by(year,colour,aggregation) %>%  
 summarise(percentile\_5th = quantile(value, probs = c(0.05)),  
 percentile\_95th = quantile(value, probs = c(0.95)),  
 std=sd(value),  
 value=median(value,na.rm=TRUE))

## `summarise()` has grouped output by 'year', 'colour'. You can override using  
## the `.groups` argument.

## calculate relative and absolute changes for each model and variable  
wd\_subsectors <- wd\_subsectors %>%   
 group\_by(colour,aggregation) %>%   
 mutate(change\_rel = (first(value)-last(value))/first(value)) %>%   
 mutate(change\_rel\_5th = (first(percentile\_5th)-last(percentile\_5th))/first(percentile\_5th)) %>%   
 mutate(change\_rel\_95th = (first(percentile\_95th)-last(percentile\_95th))/first(percentile\_95th)) %>%   
 mutate(change\_rel=-round(change\_rel\*100,0)) %>%   
 mutate(change\_rel\_5th=-round(change\_rel\_5th\*100,0)) %>%   
 mutate(change\_rel\_95th=-round(change\_rel\_95th\*100,0))  
  
  
## rebase the data so that totals in 2020 vs "2050" are shown  
wd\_subsectors <- wd\_subsectors %>%   
 group\_by(colour,aggregation) %>%   
 mutate(value\_rebased=first(value)-last(value)) %>%   
 mutate(value\_rebased=ifelse(year==2050,value,value\_rebased))  
  
wd\_subsectors <- wd\_subsectors %>%  
 mutate(value\_rebased=ifelse(value\_rebased<0,0,value\_rebased))  
  
wd\_subsectors$year = as.factor(wd\_subsectors$year)  
wd\_subsectors$year <- fct\_relevel(wd\_subsectors$year,"2020","2050")  
  
wd\_subsectors$colour = as.factor(wd\_subsectors$colour)  
wd\_subsectors$colour <- fct\_relevel(wd\_subsectors$colour,"Energy","AFOLU","Other")  
  
blarg <- wd\_subsectors %>%  
 filter(year==2020) %>%   
 arrange(desc(colour),value)  
blarg$levels = 1  
blarg$levels = cumsum(blarg$levels)  
wd\_subsectors <- left\_join(wd\_subsectors,blarg)

## Joining with `by = join\_by(year, colour, aggregation, percentile\_5th,  
## percentile\_95th, std, value, change\_rel, change\_rel\_5th, change\_rel\_95th,  
## value\_rebased)`

wd\_subsectors$aggregation <- fct\_reorder(wd\_subsectors$aggregation,wd\_subsectors$levels)

## Warning: `fct\_reorder()` removing 11 missing values.  
## ℹ Use `.na\_rm = TRUE` to silence this message.  
## ℹ Use `.na\_rm = FALSE` to preserve NAs.

p1 <- wd\_subsectors %>%   
 filter(aggregation!="Other") %>%   
 ggplot(.,aes(x=value\_rebased,y=aggregation,alpha=year,fill=colour)) +  
 geom\_col(color='#636363') +  
 geom\_errorbar(data=wd\_subsectors %>%  
 filter(aggregation!="Other") %>%   
 filter(year==2050),inherit.aes = FALSE,  
 aes(xmin=percentile\_5th,xmax=percentile\_95th,y=aggregation),  
 width=0.3) +  
 geom\_text(data=wd\_subsectors %>%  
 filter(aggregation!="Other") %>%   
 group\_by(aggregation,change\_rel) %>%  
 summarise(value=sum(value\_rebased)),  
 inherit.aes = FALSE,aes(x=value+1,y=aggregation,  
 label=ifelse(change\_rel<0,  
 paste0(change\_rel,"%"),  
 paste0("+",change\_rel,"%"))),  
 hjust=0,size=3) +  
 scale\_x\_continuous(expand = expansion(mult = c(0.05, 0.25))) +  
 scale\_alpha\_discrete(range=c(0.3,1)) +  
 theme\_wl() +  
 theme(legend.position="none",  
 axis.title=element\_blank(),  
 panel.grid.major.y = element\_blank()) +  
 labs(title="Emissions by sector from 2020 to net zero CO2",  
 subtitle=bquote("Gt"~CO[2]\*"e/yr"))

## `summarise()` has grouped output by 'aggregation'. You can override using the  
## `.groups` argument.

## Warning: Using alpha for a discrete variable is not advised.

## get the scenario data  
wd\_gases <- wd\_scenarios\_emissions %>%  
 filter(var!="Kyoto Gases") %>%  
 filter(gas!="F-Gases") %>%   
 filter(!grepl("Carbon Sequestration",var)) %>%  
 mutate(value=ifelse(is.na(value),0,value)) %>%  
 mutate(include=ifelse(native\_net\_zero\_CO2==year,1,0)) %>%  
 mutate(include=ifelse(year==2020,1,include)) %>%   
 filter(include==1) %>%  
 group\_by(id,model,category,year,gas) %>%  
 summarise(value=sum(value,na.rm=TRUE))

## `summarise()` has grouped output by 'id', 'model', 'category', 'year'. You can  
## override using the `.groups` argument.

## generate median scenarios  
  
wd\_gases <- wd\_gases %>%   
 mutate(year=ifelse(year!=2020,2050,year)) %>% #2050 here is just a fake year to merge all the nz years  
 group\_by(year,gas) %>%  
 summarise(percentile\_5th = quantile(value, probs = c(0.05)),  
 percentile\_95th = quantile(value, probs = c(0.95)),  
 std=sd(value),  
 value=median(value,na.rm=TRUE))

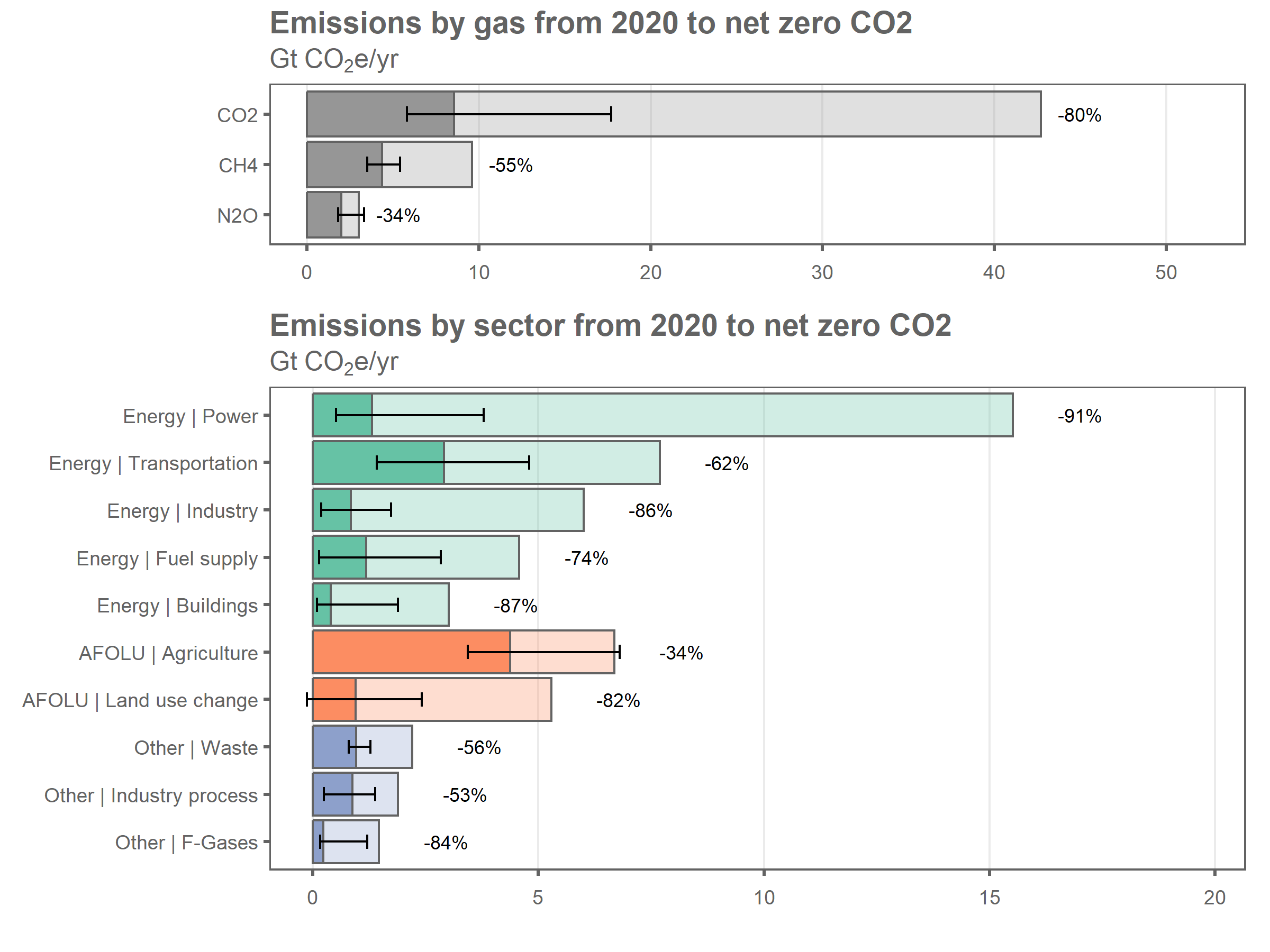
## `summarise()` has grouped output by 'year'. You can override using the  
## `.groups` argument.

## calculate relative and absolute changes for each model and variable  
wd\_gases <- wd\_gases %>%   
 group\_by(gas) %>%   
 mutate(change\_rel = (first(value)-last(value))/first(value)) %>%   
 mutate(change\_rel\_5th = (first(percentile\_5th)-last(percentile\_5th))/first(percentile\_5th)) %>%   
 mutate(change\_rel\_95th = (first(percentile\_95th)-last(percentile\_95th))/first(percentile\_95th)) %>%   
 mutate(change\_rel=-round(change\_rel\*100,0)) %>%   
 mutate(change\_rel\_5th=-round(change\_rel\_5th\*100,0)) %>%   
 mutate(change\_rel\_95th=-round(change\_rel\_95th\*100,0))  
  
  
## rebase the data so that totals in 2020 vs "2050" are shown  
wd\_gases <- wd\_gases %>%   
 group\_by(gas) %>%   
 mutate(value\_rebased=first(value)-last(value)) %>%   
 mutate(value\_rebased=ifelse(year==2050,value,value\_rebased))  
  
wd\_gases <- wd\_gases %>%  
 mutate(value\_rebased=ifelse(value\_rebased<0,0,value\_rebased))  
  
wd\_gases$year = as.factor(wd\_gases$year)  
wd\_gases$year <- fct\_relevel(wd\_gases$year,"2020","2050")  
  
wd\_gases$gas <- fct\_relevel(wd\_gases$gas,"F-Gases","N2O","CH4","CO2")  
  
  
p2 <- wd\_gases %>%   
 ggplot(.,aes(x=value\_rebased,y=gas,alpha=year,fill=gas)) +  
 geom\_col(color='#636363',fill='#969696') +  
 geom\_errorbar(data=wd\_gases %>%  
 filter(year==2050),inherit.aes = FALSE,  
 aes(xmin=percentile\_5th,xmax=percentile\_95th,y=gas),  
 width=0.3) +  
 geom\_text(data=wd\_gases %>%  
 group\_by(gas,change\_rel) %>%  
 summarise(value=sum(value\_rebased)),  
 inherit.aes = FALSE,aes(x=value+1,y=gas,  
 label=ifelse(change\_rel<0,  
 paste0(change\_rel,"%"),  
 paste0("+",change\_rel,"%"))),  
 hjust=0,size=3) +  
 scale\_x\_continuous(expand = expansion(mult = c(0.05, 0.25))) +  
 scale\_alpha\_discrete(range=c(0.3,1)) +  
 theme\_wl() +  
 theme(legend.position="none",  
 axis.title=element\_blank(),  
 panel.grid.major.y = element\_blank()) +  
 labs(title="Emissions by gas from 2020 to net zero CO2",  
 subtitle=bquote("Gt"~CO[2]\*"e/yr"))

## `summarise()` has grouped output by 'gas'. You can override using the `.groups`  
## argument.

## Warning: Using alpha for a discrete variable is not advised.

p2 / p1 + plot\_layout(heights=c(2,6))



#   
# addWorksheet(wb\_analysis,"recalcd\_vs\_native\_net\_emissions")  
# writeData(wb\_analysis, sheet = "recalcd\_vs\_native\_net\_emissions",  
# test\_residual %>% select(-difference\_abs), colNames = T, rowNames = F)  
  
  
saveWorkbook(wb\_figures,"Results/residual-emissions-ERL-figure-data.xlsx",overwrite=T)  
saveWorkbook(wb\_analysis,"Results/residual-emissions-ERL-analysis.xlsx",overwrite=T)  
  
  
write.csv(wd\_scenarios\_emissions %>%  
 filter(var!="Kyoto Gases") %>%  
 filter(!grepl("Carbon Sequestration",var)),  
 file="Results/residual-emissions-ERL-processed-data.csv",sep=";")

## Warning in write.csv(wd\_scenarios\_emissions %>% filter(var != "Kyoto Gases")  
## %>% : Versuch ignoriert 'sep' zu setzen