```
clc;
clear all;

% Large container characteristics
DWT(1)=189766; %tonnes
P(1)=56380; %power kw
HFO(1)=27923000; %kg
EFF(1)=0.5;
NM(1)=99770;  %distance
Tank(1)=15142;
TEU(1)=20182


% Small container characteristics
DWT(2)=30000;
P(2)=13500;
HFO(2)=13507000;
EFF(2)=0.42;
NM(2)=75381;
Tank(2)=1800;%litre
TEU(2)= 2500

% Fuels lower heating values  MJ/kg
LHV_D=42.5;
LHV_HFO=40.2;
LHV_A=18.8;
LHV_H=119.6;

% fuels density
Rho_D=825;
Rho_A=682;
Rho_H=71;

% HRF characteristics
%  %mass concentration
H_MC = xlsread('C:\Payam1\MATLAB\H2.xlsx','sheet1','G8');
A_MC = xlsread('C:\Payam1\MATLAB\H2.xlsx','sheet1','H8');


%Boil-off rate coefficient
BOG_A=0.025;
BOG_H=0.52;

% GHG conversion factors
CF_CO2=3.206;  %kg/kgF
CF_CH4=0.01;    %g/kWh
CF_BC=0.005;
CF_N2O_min=0.06;
CF_N2O_ave1=0.3;
CF_N2O_ave2=0.78;
```

```
% GWP coefficients
GWP_CO2=1;
GWP_CH4=28;
GWP_BC=900;
GWP_N2O=265;

% WTT Average emission factor for Diesel, Brown ammonia, grey, blue and green
WTT_D=723;
WTT_AN=3008;
WTT_AS=1880;
WTT_AB=846;
WTT_AG=150;

% WTT Min/Max emission factor
WTT_AN_min=1200;
WTT_AS_min=1400;
WTT_AB_min=400;
WTT_AG_min=60;

WTT_AN_max=4220;
WTT_AS_max=3600;
WTT_AB_max=1400;
WTT_AG_max=480;

% Engine capital cost large and Small container
C_E=[505,720,720,720,790;350,500,500,500,600];

% installation factor
Install_E=0.1;

% Capital cost for cracker
C_CR=50; %$/kW

% fuel PRICE indexes 2020  $/t
FP_D=635;
FP_AS=320;
FP_AB=360;
FP_AG=670;
FP_HS=1480;
FP_HB=2160;
FP_HG=5160;

% Capital cost for fuel storage tanks
T_D=965;
T_A=600;
T_H=2212;

% O&M cost index
OM_E=[2.5,2.5,2.5,2.5,4.5];  %engine
OM_T=0.01; %tank
OM_R=0.01; %cracker
```

```
carbon=0;  %carbon tax $/t

Numbers_all = [];
DWTT_all = [];
NMM_all = [];
Sum_EEDI=[];


for i=1:5
SC(i)=(i-1)*0.25;
end

for i=1:2
%       F_to_P(i)=HFO(i)*LHV_HFO*EFF(i)/(3.6*P(i))
        E(i)=HFO(i)*LHV_HFO;
 for j=1:5
%       fuel gravimetric consumption
    D(i,j)=E(i)*(1-SC(j))/LHV_D; %kg
    A(i,j)=(SC(j)*E(i)/(LHV_H+A_MC*LHV_A/H_MC))*100/10.65;
    BOG(i,j)=A(i,j)*BOG_A;
    TF(i,j)=D(i,j)+A(i,j)+BOG(i,j);
    SFC(i,j)=TF(i,j)*1000/(E(i)*EFF(i)/3.6);

% fuel volumetric consumption
   DV(i,j)=D(i,j)/Rho_D;
   AV(i,j)=A(i,j)/Rho_A;
   TFV(i,j)=DV(i,j)+AV(i,j);
%    Ammonia volume fraction
   AVF(i,j)=AV(i,j)/TFV(i,j);
   DVF(i,j)=DV(i,j)/TFV(i,j);
 end
end


for i=1:2
 for j=1:5
    CO2(i,j)=D(i,j)*CF_CO2*1000;
    CH4(i,j)=(E(i)*EFF(i)/3.6)*(1-SC(j))*CF_CH4*GWP_CH4 ;
    BC(i,j)=(E(i)*EFF(i)/3.6)*(1-SC(j))*CF_BC*GWP_BC ;
    if j==1
    N2O_min(i,j)=(E(i)*EFF(i)/3.6)*(CF_N2O_min/2)*GWP_N2O;
    else
     N2O_min(i,j)=(E(i)*EFF(i)/3.6)*(CF_N2O_min)*GWP_N2O;
    end
    if j==1
    N2O_ave(i,j)=(E(i)*EFF(i)/3.6)*(CF_N2O_min/2)*GWP_N2O;
    else if j==5
    N2O_ave(i,j)=(E(i)*EFF(i)/3.6)*(SC(j))*(CF_N2O_ave2/2)*GWP_N2O;
    else
      N2O_ave(i,j)=(E(i)*EFF(i)/3.6)*(SC(j))*(CF_N2O_ave1)*GWP_N2O;
```

```
    end
    end
    TTW_ave(i,j)=(CO2(i,j)+CH4(i,j)+BC(i,j)+N2O_ave(i,j))/1e06;
    TTW_min(i,j)=(CO2(i,j)+CH4(i,j)+BC(i,j)+N2O_min(i,j))/1e06;
%     EEDI based on TTW g/t.NM
    EEDI(i,j)=TTW_ave(i,j)*1e06/(DWT(i)*NM(i));
 end
end
min_EEDI_L=EEDI(1,1)-EEDI(1,3);
min_EEDI_S=EEDI(2,1)-EEDI(2,3);

for k=2:10
    range1 = strcat('A', num2str(k));
    Numbers = xlsread('C:\Payam1\MATLAB\EEDI1.xlsx', 'sheet1', range1);
    Numbers_all = [Numbers_all; Numbers];

    range2 = strcat('B', num2str(k));
    DWTT = xlsread('C:\Payam1\MATLAB\EEDI1.xlsx', 'sheet1', range2);
    DWTT_all = [DWTT_all; DWTT];

    range3 = strcat('C', num2str(k));
    NMM = xlsread('C:\Payam1\MATLAB\EEDI1.xlsx', 'sheet1', range3);
    NMM_all = [NMM_all; NMM];
end

Sum_Num=0;
Sum_NDN=0;
for i=1:9
Sum_NDN=Sum_NDN+Numbers_all(i)*DWTT_all(i)* NMM_all(i);
Sum_Num=Sum_Num+Numbers_all(i);
end
DWTL_ave=(Sum_NDN)/(Sum_Num);

Sum_EEDI=0;
for i=1:9
if i<=3
Sum_EEDI=Sum_EEDI+Numbers_all(i)*min_EEDI_S;
else
Sum_EEDI=Sum_EEDI+Numbers_all(i)*min_EEDI_L;
end
end

EEDI_ave=(Sum_EEDI)/(Sum_Num);
Total_EEDI=(EEDI_ave*DWTL_ave*0.7*Sum_Num)/1e12;
Global_EEDI=236;
EEDI_frac=Total_EEDI/Global_EEDI;

for i=1:2
 for j=1:5

    WTT_N(i,j)=(D(i,j)*(WTT_D)+A(i,j)*(WTT_AN))/1e06;
```

```
    WTT_S(i,j)=(D(i,j)*(WTT_D)+A(i,j)*(WTT_AS))/1e06;
    WTT_B(i,j)=(D(i,j)*(WTT_D)+A(i,j)*(WTT_AB))/1e06;
    WTT_G(i,j)=(D(i,j)*(WTT_D)+A(i,j)*(WTT_AG))/1e06;
%WTW=WTT+TTW
    WTW_N(i,j)=WTT_N(i,j)+TTW_ave(i,j);
    WTW_S(i,j)=WTT_S(i,j)+TTW_ave(i,j);
    WTW_B(i,j)=WTT_B(i,j)+TTW_ave(i,j);
    WTW_G(i,j)=WTT_G(i,j)+TTW_ave(i,j);

    %Relative WTW
    if i==1
    R_WTW_N(i,j)=WTW_N(i,j)/WTW_N(1,1);
     R_WTW_S(i,j)=WTW_S(i,j)/WTW_S(1,1);
      R_WTW_B(i,j)=WTW_B(i,j)/WTW_B(1,1);
       R_WTW_G(i,j)=WTW_G(i,j)/WTW_G(1,1);
    else
      R_WTW_N(i,j)=WTW_N(i,j)/WTW_N(2,1);
      R_WTW_S(i,j)=WTW_S(i,j)/WTW_S(2,1);
      R_WTW_B(i,j)=WTW_B(i,j)/WTW_B(2,1);
       R_WTW_G(i,j)=WTW_G(i,j)/WTW_G(2,1);
    end

    %Reduction by considering the minimum TTW
    WTW_N_min(i,j)=WTT_N(i,j)+TTW_min(i,j);
    WTW_S_min(i,j)=WTT_S(i,j)+TTW_min(i,j);
    WTW_B_min(i,j)=WTT_B(i,j)+TTW_min(i,j);
    WTW_G_min(i,j)=WTT_G(i,j)+TTW_min(i,j);

    WTW_N_R(i,j)=(WTW_N(i,j)-WTW_N_min(i,j))/WTW_N(i,j);
    WTW_S_R(i,j)=(WTW_S(i,j)-WTW_S_min(i,j))/WTW_S(i,j);
    WTW_B_R(i,j)=(WTW_B(i,j)-WTW_B_min(i,j))/WTW_B(i,j);
    WTW_N_G(i,j)=(WTW_G(i,j)-WTW_G_min(i,j))/WTW_G(i,j);

%error bars for WTW considerring Relative WTW
if i==1
WTW_N_ER_min(i,j)=((D(i,j)*(WTT_D)+A(i,j)*(WTT_AN_min))/1e06+TTW_ave(i,j))/WTW_N(1,1);
WTW_S_ER_min(i,j)=((D(i,j)*(WTT_D)+A(i,j)*(WTT_AS_min))/1e06+TTW_ave(i,j))/WTW_N(1,1);
WTW_B_ER_min(i,j)=((D(i,j)*(WTT_D)+A(i,j)*(WTT_AB_min))/1e06+TTW_ave(i,j))/WTW_N(1,1);
WTW_G_ER_min(i,j)=((D(i,j)*(WTT_D)+A(i,j)*(WTT_AG_min))/1e06+TTW_ave(i,j))/WTW_N(1,1);

WTW_N_ER_max(i,j)=((D(i,j)*(WTT_D)+A(i,j)*(WTT_AN_max))/1e06+TTW_ave(i,j))/WTW_N(1,1);
WTW_S_ER_max(i,j)=((D(i,j)*(WTT_D)+A(i,j)*(WTT_AS_max))/1e06+TTW_ave(i,j))/WTW_N(1,1);
WTW_B_ER_max(i,j)=((D(i,j)*(WTT_D)+A(i,j)*(WTT_AB_max))/1e06+TTW_ave(i,j))/WTW_N(1,1);
WTW_G_ER_max(i,j)=((D(i,j)*(WTT_D)+A(i,j)*(WTT_AG_max))/1e06+TTW_ave(i,j))/WTW_N(1,1);

else
WTW_N_ER_min(i,j)=((D(i,j)*(WTT_D)+A(i,j)*(WTT_AN_min))/1e06+TTW_ave(i,j))/WTW_N(2,1);
WTW_S_ER_min(i,j)=((D(i,j)*(WTT_D)+A(i,j)*(WTT_AS_min))/1e06+TTW_ave(i,j))/WTW_N(2,1);
WTW_B_ER_min(i,j)=((D(i,j)*(WTT_D)+A(i,j)*(WTT_AB_min))/1e06+TTW_ave(i,j))/WTW_N(2,1);
WTW_G_ER_min(i,j)=((D(i,j)*(WTT_D)+A(i,j)*(WTT_AG_min))/1e06+TTW_ave(i,j))/WTW_N(2,1);
```

```
WTW_N_ER_max(i,j)=((D(i,j)*(WTT_D)+A(i,j)*(WTT_AN_max))/1e06+TTW_ave(i,j))/WTW_N(2,1);
WTW_S_ER_max(i,j)=((D(i,j)*(WTT_D)+A(i,j)*(WTT_AS_max))/1e06+TTW_ave(i,j))/WTW_N(2,1);
WTW_B_ER_max(i,j)=((D(i,j)*(WTT_D)+A(i,j)*(WTT_AB_max))/1e06+TTW_ave(i,j))/WTW_N(2,1);
WTW_G_ER_max(i,j)=((D(i,j)*(WTT_D)+A(i,j)*(WTT_AG_max))/1e06+TTW_ave(i,j))/WTW_N(2,1);
end

%EEDI based on WTW g/t.NM
EEDI_B(i,j)=WTW_B(i,j)*1e06/(DWT(i)*NM(i));
EEDI_G(i,j)=WTW_G(i,j)*1e06/(DWT(i)*NM(i));

 end
end

min_EEDI_B_L=EEDI_B(1,1)-EEDI_B(1,3);
min_EEDI_B_S=EEDI_B(2,1)-EEDI_B(2,3);
min_EEDI_G_L=EEDI_G(1,1)-EEDI_G(1,3);
min_EEDI_G_S=EEDI_G(2,1)-EEDI_G(2,3);

Sum_EEDI_B=0;
Sum_EEDI_G=0;
for i=1:9
if i<=3
Sum_EEDI_B=Sum_EEDI_B+Numbers_all(i)*min_EEDI_B_S;
Sum_EEDI_G=Sum_EEDI_G+Numbers_all(i)*min_EEDI_G_S;
else
Sum_EEDI_B=Sum_EEDI_B+Numbers_all(i)*min_EEDI_B_L;
Sum_EEDI_G=Sum_EEDI_G+Numbers_all(i)*min_EEDI_G_L;
end
end

EEDI_ave_B=(Sum_EEDI_B)/(Sum_Num);
EEDI_ave_G=(Sum_EEDI_G)/(Sum_Num);

Total_EEDI_B=(EEDI_ave_B*DWTL_ave*0.7*Sum_Num)/1e12; %Million tonnes
Total_EEDI_G=(EEDI_ave_G*DWTL_ave*0.7*Sum_Num)/1e12;

% ECONOMIC ANALYSIS
for i=1:2
 for j=1:5
%      Capital cost (CC)
%      Engine CC
CC_E(i,j)=C_E(i,j)*P(i);   %$
Ins_E(i,j)=Install_E*CC_E(i,j);

% storage tank CC

Tankk(i,j)=(TFV(i,j)/(HFO(i)/Rho_D))*Tank(i);
CC_Tankk(i,j)=Tankk(i,j)*(AVF(i,j)*T_A+DVF(i,j)*T_D);

% cracker CC
CC_CR(i,j)=P(i)*C_CR*SC(j);
```

```
CAPEX(i,j)=(CC_E(i,j)+Ins_E(i,j)+CC_Tankk(i,j)+3*CC_CR(i,j))/1e06; %million $

% O&M costs
OM_EE(i,j)=CC_E(i,j)*OM_E(j)*0.01; %$
OM_cracker(i,j)=CC_CR(i,j)*0.01;
OM_tank(i,j)=CC_Tankk(i,j)*0.01;
OPEX(i,j)=(OM_EE(i,j)+OM_cracker(i,j)+OM_tank(i,j))*20/1e06;  %million $
 end
end
CAPEX;
OPEX;
% fuel costs
for i=1:2
 for j=1:5
        FUELEX_S(i,j)=20*(D(i,j)*FP_D+A(i,j)*FP_AS)/1e09; %million $
        FUELEX_B(i,j)=20*(D(i,j)*FP_D+A(i,j)*FP_AB)/1e09;
        FUELEX_G(i,j)=20*(D(i,j)*FP_D+A(i,j)*FP_AG)/1e09;

%         Relative fuel cost
        if i==1
        RFC_S(i,j)=FUELEX_S(i,j)/FUELEX_S(1,1);
        RFC_B(i,j)=FUELEX_B(i,j)/FUELEX_B(1,1);
        RFC_G(i,j)=FUELEX_G(i,j)/FUELEX_G(1,1);
        else
        RFC_S(i,j)=FUELEX_S(i,j)/FUELEX_S(2,1);
        RFC_B(i,j)=FUELEX_B(i,j)/FUELEX_B(2,1);
        RFC_G(i,j)=FUELEX_G(i,j)/FUELEX_G(2,1);
        end
   ENVEX(i,j)=(carbon*TTW_ave(i,j))*20/1e06;

   total_S(i,j)=CAPEX(i,j)+FUELEX_S(i,j)+OPEX(i,j)+ENVEX(i,j); %million $
   total_B(i,j)=CAPEX(i,j)+FUELEX_B(i,j)+OPEX(i,j)+ENVEX(i,j);
   total_G(i,j)=CAPEX(i,j)+FUELEX_G(i,j)+OPEX(i,j)+ENVEX(i,j);

   if i==1
   MAC_S(i,j)=1e06*(total_S(i,j)-total_S(1,1))/(20*abs(TTW_ave(i,j)-TTW_ave(1,1)))
   MAC_B(i,j)=1e06*(total_B(i,j)-total_B(1,1))/(20*abs(TTW_ave(i,j)-TTW_ave(1,1)))
   MAC_G(i,j)=1e06*(total_G(i,j)-total_G(1,1))/(20*abs(TTW_ave(i,j)-TTW_ave(1,1)))
   else
   MAC_S(i,j)=1e06*(total_S(i,j)-total_S(2,1))/(20*abs(TTW_ave(i,j)-TTW_ave(2,1)))
   MAC_B(i,j)=1e06*(total_B(i,j)-total_B(2,1))/(20*abs(TTW_ave(i,j)-TTW_ave(2,1)))
   MAC_G(i,j)=1e06*(total_G(i,j)-total_G(2,1))/(20*abs(TTW_ave(i,j)-TTW_ave(2,1)))
   end
 end
end
 MAC_S
    for j=1:5
       Sum_MAC_S(j)=0;
       Sum_MAC_B(j)=0;
       Sum_MAC_G(j)=0;
       for i=1:9
```

```
        if i<=3
Sum_MAC_S(j)=Sum_MAC_S(j)+Numbers_all(i)*MAC_S(2,j);
Sum_MAC_B(j)=Sum_MAC_B(j)+Numbers_all(i)*MAC_B(2,j);
Sum_MAC_G(j)=Sum_MAC_G(j)+Numbers_all(i)*MAC_G(2,j);
        else
Sum_MAC_S(j)=Sum_MAC_S(j)+Numbers_all(i)*MAC_S(1,j);
Sum_MAC_B(j)=Sum_MAC_B(j)+Numbers_all(i)*MAC_B(1,j);
Sum_MAC_G(j)=Sum_MAC_G(j)+Numbers_all(i)*MAC_G(1,j);
        end
        Ave_MAC_S(j)=Sum_MAC_S(j)/Sum_Num;
        Ave_MAC_B(j)=Sum_MAC_B(j)/Sum_Num;
        Ave_MAC_G(j)=Sum_MAC_G(j)/Sum_Num;
    end
 end


%Proper dual-fuel percentage and ammonia sources combination
syms x
equ1=TTW_ave(1,1)*1000000/2==(E(1)*(1-x)/LHV_D)*CF_CO2*1000+(E(1)*EFF(1)/3.6)*(1-x)↙
*CF_CH4*GWP_CH4+(E(1)*EFF(1)/3.6)*(1-x)*CF_BC*GWP_BC+(E(1)*EFF(1)/3.6)*(x)*(CF_N2O_ave1)↙
*GWP_N2O
equ2=TTW_ave(2,1)*1000000/2==(E(2)*(1-x)/LHV_D)*CF_CO2*1000+(E(2)*EFF(2)/3.6)*(1-x)↙
*CF_CH4*GWP_CH4+(E(2)*EFF(2)/3.6)*(1-x)*CF_BC*GWP_BC+(E(2)*EFF(2)/3.6)*(x)*(CF_N2O_ave1)↙
*GWP_N2O
S1=double(solve(equ1));
S2=double(solve(equ2));

syms y z1 z2 z3 z4 z5 z6 z7 z8
xx=0.6
%WTW=WTT+TTW
equ3=WTW_N(1,1)*1000*0.7==(E(1)*(1-xx)/LHV_D)*(WTT_D)/1000+(y/1000)*(xx*E(1)/↙
(LHV_H+A_MC*LHV_A/H_MC))*100/10.65+TTW_ave(1,1)*1000/2;
equ4=WTW_N(2,1)*1000*0.7==(E(2)*(1-xx)/LHV_D)*(WTT_D)/1000+(y/1000)*(xx*E(2)/↙
(LHV_H+A_MC*LHV_A/H_MC))*100/10.65+TTW_ave(2,1)*1000/2;
S3=double(solve(equ3)); %g/kg
S4=double(solve(equ4));

% Blue and grey percentage for envoironmental
equ5=S3==(z1*WTT_AS)+((1-z1)*WTT_AG);
equ6=S4==(z2*WTT_AB)+((1-z2)*WTT_AG);
S5=double(solve(equ5)); %g/kg
S6=double(solve(equ6));

%Blue and grey percentage for envoironmental
for k=1:2
D(k)=E(k)*(1-xx)/LHV_D; %kg
A(k)=(xx*E(k)/(LHV_H+A_MC*LHV_A/H_MC))*100/10.65;
DV(k)=D(k)/(Rho_D);
AV(k)=A(k)/(Rho_A);
TFV(k)=DV(k)+AV(k);
AVF(k)=AV(k)/TFV(k);
```

```
DVF(k)=DV(k)/TFV(k);
Tankk(k)=(TFV(k)/(HFO(k)/Rho_D))*Tank(k)
CC_Tankk(k)=Tankk(k)*(AVF(k)*T_A+DVF(k)*T_D)
CC_CR(k)=P(k)*C_CR*xx
CAPEX(k)= 3*CC_CR(k)+CC_Tankk(k)+CC_E(k,2)+Ins_E(k,2)  %$
end
CAPEX(2)
carbon*TTW_ave(2,1)/2
0.01*CC_Tankk(2)
0.01*CC_CR(2)
equ7=total_S(1,1)*1000000==CAPEX(1)+20*(2.5*CC_E(1,2)/100+0.01*CC_Tankk(1)+3*0.01*CC_CR↙
(1)+carbon*TTW_ave(1,1)/2+ D(1)*FP_D/1000)+20*A(1)*z3/1000;
equ8=total_S(2,1)*1000000==CAPEX(2)+20*(2.5*CC_E(2,2)/100+0.01*CC_Tankk(2)+3*0.01*CC_CR↙
(2)+carbon*TTW_ave(2,1)/2+ D(2)*FP_D/1000)+20*A(2)*z4/1000;
S7=double(solve(equ7));
S8=double(solve(equ8));
equ9=S8==(z7*FP_AS)+(1-z7)*FP_AG;
equ10=S8==(z8*FP_AB)+(1-z8)*FP_AG;
S9=double(solve(equ9));
S10=double(solve(equ10));
```