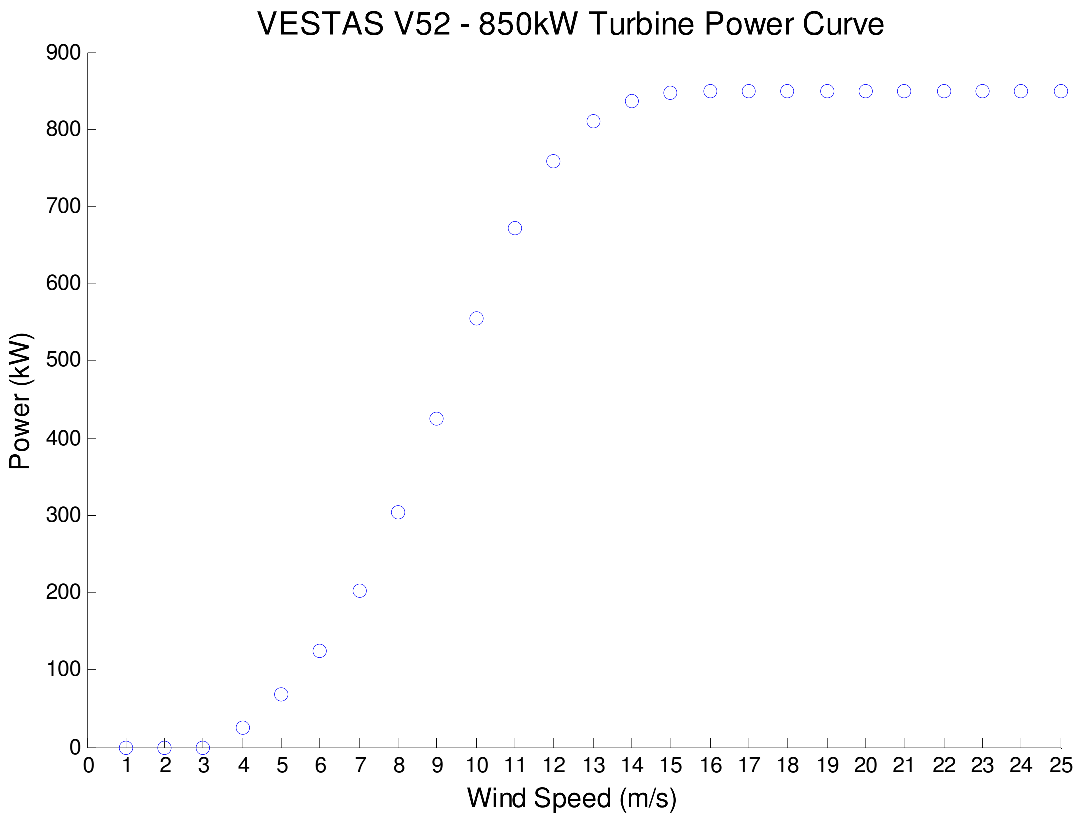
APPENDICES

APPENDIX A

POWER CURVE VALUES OF THE REFERENCE TURBINE

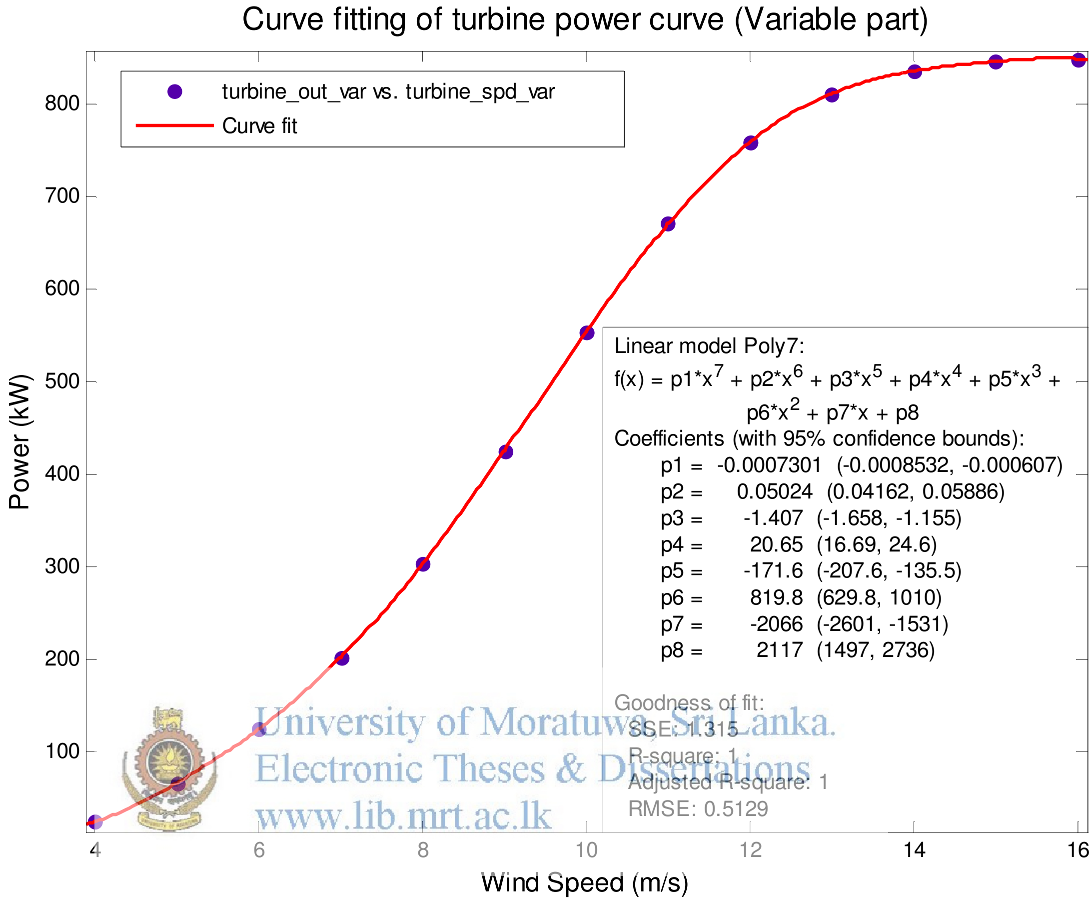
Turbine	VESTAS V52 – 850kW
Rotor Diameter	52m
Cut-in wind speed	4 m/s
Nominal wind speed	16 m/s
Stop wind speed	25 m/s
Area swept	2,124 m^2

Wind Speed (m/s)	**Power (kW)**
1	0
2	0
3	0
4	25.5
5	67.4
6	125
7	203
8	304
9	425
10	554
11	671
12	759
13	811
14	836
15	846
16	849
17	850
18	850
19	850
20	850
21	850
22	850
23	850
24	850
25	850


VESTAS V52 - 850kW Turbine Power Curve
Power (kW)
Wind Speed (m/s)
0
100
200
300
400
500
600
700
800
900
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

APPENDIX B

CURVE FITTING OF REFERENCE TURBINE POWER CURVE



APPENDIX C

MATLAB CODE OF WIND POWER OUTPUT MODEL

```
%==========Wind Power Output Model==================================

clear
data = xlsread('man.xls');
dates = data(:, 1);
%times = data(:,2);
windspd_ms = data(:, 2);

filtered_spds = windspd_ms(windspd_ms>=0);
filtered_dates = dates(windspd_ms>=0);
%filtered_times = times(windspd_ms>=0);

initial_spds = filtered_spds;
twr_height_corrected_spds = initial_spds * ((65/40)^ 0.1);% tower
height correction, roughness is assumed to be 0.1

spd_ms = twr_height_corrected_spds;

%==================================================================
%Month and Hour selection from the wind speed measurement time stamp

date_string = num2str(filtered_dates);
%time_string = num2str(filtered_times);
%dt_string = strcat(date_string,time_string);
hour_string = date_string(:,9:10); % peak hour selection
month_string = date_string(:,5:6); % month selection for monthly
capacity factor calculation

for i = 1:length(hour_string)
    hour_double(i) = str2double(hour_string(i,:));
end

for k = 1:length(month_string)
    month_double(k) = str2double(month_string(k,:));
end

%==================================================================
%Peak wind value selection from the valid wind speed data set

peak_wind = spd_ms(hour_double>=18 & hour_double <=22); % Wind
speeds during peak times
%hist(peak_wind, 18), xlabel('Wind Speed m/s'),ylabel('Frequency');
peak_dates = filtered_dates(hour_double>=18 & hour_double <=22);

%Peak wind speeds in January
peak_wind_jan = spd_ms(month_double==01 & hour_double>=18 &
hour_double <=22);
peak_dates_jan = filtered_dates(month_double==01 & hour_double>=18 &
hour_double <=22);
```

```
%Peak wind speeds in February
peak_wind_feb = spd_ms(month_double==02 & hour_double>=18 &
hour_double <=22);
peak_dates_feb = filtered_dates(month_double==02 & hour_double>=18 &
hour_double <=22);
%Peak wind speeds in March
peak_wind_mar = spd_ms(month_double==03 & hour_double>=18 &
hour_double <=22);
peak_dates_mar = filtered_dates(month_double==03 & hour_double>=18 &
hour_double <=22);
%Peak wind speeds in April
peak_wind_apr = spd_ms(month_double==04 & hour_double>=18 &
hour_double <=22);
peak_dates_apr = filtered_dates(month_double==04 & hour_double>=18 &
hour_double <=22);
%Peak wind speeds in May
peak_wind_may = spd_ms(month_double==05 & hour_double>=18 &
hour_double <=22);
peak_dates_may = filtered_dates(month_double==05 & hour_double>=18 &
hour_double <=22);
%Peak wind speeds in June
peak_wind_june = spd_ms(month_double==06 & hour_double>=18 &
hour_double <=22);
peak_dates_june = filtered_dates(month_double==06 & hour_double>=18
& hour_double <=22);
%Peak wind speeds in July
peak_wind_july = spd_ms(month_double==07 & hour_double>=18 &
hour_double <=22);
peak_dates_july = filtered_dates(month_double==07 & hour_double>=18
& hour_double <=22);
%Peak wind speeds in August
peak_wind_aug = spd_ms(month_double==08 & hour_double>=18 &
hour_double <=22);
peak_dates_aug = filtered_dates(month_double==08 & hour_double>=18 &
hour_double <=22);
%Peak wind speeds in September
peak_wind_sep = spd_ms(month_double==09 & hour_double>=18 &
hour_double <=22);
peak_dates_sep = filtered_dates(month_double==09 & hour_double>=18 &
hour_double <=22);
%Peak wind speeds in October
peak_wind_oct = spd_ms(month_double==10 & hour_double>=18 &
hour_double <=22);
peak_dates_oct = filtered_dates(month_double==10 & hour_double>=18 &
hour_double <=22);
%Peak wind speeds in November
peak_wind_nov = spd_ms(month_double==11 & hour_double>=18 &
hour_double <=22);
peak_dates_nov = filtered_dates(month_double==11 & hour_double>=18 &
hour_double <=22);
%Peak wind speeds in December
peak_wind_dec = spd_ms(month_double==12 & hour_double>=18 &
hour_double <=22);
peak_dates_dec = filtered_dates(month_double==12 & hour_double>=18 &
hour_double <=22);

%===================================================================
```

```
%Wind turbine powe curve data of Vestas V52 850kW turbine
turbine_pc = xlsread ('vestasv52_850.xls'); %W.Tur power curve data
turbine_spd = turbine_pc (:,1);
turbine_out = turbine_pc (:,2);
turbine_spd_var = turbine_pc (4:16,1);%variable part of power curve
turbine_out_var = turbine_pc (4:16,2);
%scatter(turbine_spd,turbine_pc(:,2)); %Scatter plot of power curve
%====================================================================
%Discrete points of the power curve is fitted to a polynomial curve
to determine the variable power output of the turbine (When wind spd
is between Vcut-in and Vrated)

coeff = polyfit(turbine_spd_var,turbine_out_var,7);%coefficients of
the polynomial fit of turbine power curve
%scatter(turbine_spd_var,turbine_out_var);
p1 = coeff(1,1);
p2 = coeff(1,2);
p3 = coeff(1,3);
p4 = coeff(1,4);
p5 = coeff(1,5);
p6 = coeff(1,6);
p7 = coeff(1,7);
p8 = coeff(1,8);%These coefficients are used in the var_coeff Func.
%====================================================================
%Wind Power calculation during peak hours (Annual)_Wind Park
for j=1:length(peak_wind)
peak_hourly_wind_power (j,:) = power_func(peak_wind(j));%Wind power
during peak hours in MW
end

%Monthly wind power calculation during peak hours
for jan=1:length(peak_wind_jan) %January
peak_hourly_wind_power_jan (jan,:) =
power_func(peak_wind_jan(jan));%Wind Pwr during peak hours_MW_Jan
end
for feb=1:length(peak_wind_feb) %February
peak_hourly_wind_power_feb (feb,:) =
power_func(peak_wind_feb(feb));%Wind Pwr during peak hours_MW_Feb
end
for mar=1:length(peak_wind_mar) %March
peak_hourly_wind_power_mar (mar,:) =
power_func(peak_wind_mar(mar));% Wind Pwr during peak hours_MW_Mar
end
for apr=1:length(peak_wind_apr) %April
peak_hourly_wind_power_apr (apr,:) =
power_func(peak_wind_apr(apr));% Wind Pwr during peak hours_MW_Apr
end
for may=1:length(peak_wind_may) %May
peak_hourly_wind_power_may (may,:) =
power_func(peak_wind_may(may));% Wind Pwr during peak hours_MW_May
end
for june=1:length(peak_wind_june) %June
peak_hourly_wind_power_june (june,:) =
power_func(peak_wind_june(june));% Wind Pwr during peak hours_MW_Jun
end
for july=1:length(peak_wind_july) %July
```

```
peak_hourly_wind_power_july (july,:) =
power_func(peak_wind_july(july));% Wind Pwr during peak hours_MW_Jul
end
for aug=1:length(peak_wind_aug) %August
peak_hourly_wind_power_aug (aug,:) =
power_func(peak_wind_aug(aug));% Wind Pwr during peak hours_MW_Aug
end
for sep=1:length(peak_wind_sep) %September
peak_hourly_wind_power_sep (sep,:) =
power_func(peak_wind_sep(sep));% Wind Pwr during peak hours_MW_Sep
end
for oct=1:length(peak_wind_oct) %October
peak_hourly_wind_power_oct (oct,:) =
power_func(peak_wind_oct(oct));% Wind Pwr during peak hours_MW_Oct
end
for nov=1:length(peak_wind_nov) %November
peak_hourly_wind_power_nov (nov,:) =
power_func(peak_wind_nov(nov));% Wind Pwr during peak hours_MW_Nov
end
for dec=1:length(peak_wind_dec) %December
peak_hourly_wind_power_dec (dec,:) =
power_func(peak_wind_dec(dec));% Wind Pwr during peak hours_MW_Dec
end
%===================================================================
%Peak Period Capacity Factor calculation (Capacity Credit)
annual_avg_peak_wind_power = mean(peak_hourly_wind_power);
annual_cap_factor = (annual_avg_peak_wind_power/100.3)*100;

%Monthly Peak Period Capacity Factor calculation
avg_peak_wind_power_jan = mean(peak_hourly_wind_power_jan); %Jan
cap_factor_jan = (avg_peak_wind_power_jan/100.3)*100;
avg_peak_wind_power_feb = mean(peak_hourly_wind_power_feb); %Feb
cap_factor_feb = (avg_peak_wind_power_feb/100.3)*100;
avg_peak_wind_power_mar = mean(peak_hourly_wind_power_mar); %Mar
cap_factor_mar = (avg_peak_wind_power_mar/100.3)*100;
avg_peak_wind_power_apr = mean(peak_hourly_wind_power_apr); %Apr
cap_factor_apr = (avg_peak_wind_power_apr/100.3)*100;
avg_peak_wind_power_may = mean(peak_hourly_wind_power_may); %May
cap_factor_may = (avg_peak_wind_power_may/100.3)*100;
avg_peak_wind_power_june = mean(peak_hourly_wind_power_june); %Jun
cap_factor_june = (avg_peak_wind_power_june/100.3)*100;
avg_peak_wind_power_july = mean(peak_hourly_wind_power_july); %Jul
cap_factor_july = (avg_peak_wind_power_july/100.3)*100;
avg_peak_wind_power_aug = mean(peak_hourly_wind_power_aug); %Aug
cap_factor_aug = (avg_peak_wind_power_aug/100.3)*100;
avg_peak_wind_power_sep = mean(peak_hourly_wind_power_sep); %Sept
cap_factor_sep = (avg_peak_wind_power_sep/100.3)*100;
avg_peak_wind_power_oct = mean(peak_hourly_wind_power_oct); %Oct
cap_factor_oct = (avg_peak_wind_power_oct/100.3)*100;
avg_peak_wind_power_nov = mean(peak_hourly_wind_power_nov); %Nov
cap_factor_nov = (avg_peak_wind_power_nov/100.3)*100;
avg_peak_wind_power_dec = mean(peak_hourly_wind_power_dec); %Dec
cap_factor_dec = (avg_peak_wind_power_dec/100.3)*100;

monthly_cap_factors (1,:) = cap_factor_jan;
monthly_cap_factors (2,:) = cap_factor_feb;
monthly_cap_factors (3,:) = cap_factor_mar;
```

```
monthly_cap_factors (4,:) = cap_factor_apr;
monthly_cap_factors (5,:) = cap_factor_may;
monthly_cap_factors (6,:) = cap_factor_june;
monthly_cap_factors (7,:) = cap_factor_july;
monthly_cap_factors (8,:) = cap_factor_aug;
monthly_cap_factors (9,:) = cap_factor_sep;
monthly_cap_factors (10,:) = cap_factor_oct;
monthly_cap_factors (11,:) = cap_factor_nov;
monthly_cap_factors (12,:) = cap_factor_dec;
%bar(monthly_cap_factors); Monthly cap. contribution from wind plant

%===================================================================
% Annual energy production calculation

for en=1:length(spd_ms)
hourly_pwr (en,:)  = power_func(spd_ms(en));%Hourly wind power in MW
for filtered out wind speeds
end

eng_production = trapz (hourly_pwr); % Energy production in MWh
% If aggregated losses are 15%
expected_eng_prod = (eng_production * 0.85)/1000; %Expected annual
energy production in GWh

%===================================================================
%Monthly energy production calculation

wind_jan = spd_ms(month_double==01); %January
for jani=1:length(wind_jan)
    hourly_pwr_jan (jani,:) = power_func(wind_jan(jani));
end
eng_production_jan = trapz (hourly_pwr_jan);
expected_eng_prod_jan = (eng_production_jan * 0.85)/1000; %GWh
wind_feb = spd_ms(month_double==02); %February
for febi=1:length(wind_feb)
    hourly_pwr_feb (febi,:) = power_func(wind_feb(febi));
end
eng_production_feb = trapz (hourly_pwr_feb);
expected_eng_prod_feb = (eng_production_feb * 0.85)/1000;
wind_mar = spd_ms(month_double==03); %March
for mari=1:length(wind_mar)
    hourly_pwr_mar (mari,:) = power_func(wind_mar(mari));
end
eng_production_mar = trapz (hourly_pwr_mar);
expected_eng_prod_mar = (eng_production_mar * 0.85)/1000;
wind_apr = spd_ms(month_double==04); %April
for apri=1:length(wind_apr)
    hourly_pwr_apr (apri,:) = power_func(wind_apr(apri));
end
eng_production_apr = trapz (hourly_pwr_apr);
expected_eng_prod_apr = (eng_production_apr * 0.85)/1000;
wind_may = spd_ms(month_double==05); %May
for mayi=1:length(wind_may)
    hourly_pwr_may (mayi,:) = power_func(wind_may(mayi));
end
eng_production_may = trapz (hourly_pwr_may);
expected_eng_prod_may = (eng_production_may * 0.85)/1000;
```

```
wind_june = spd_ms(month_double==06); %June
for junei=1:length(wind_june)
    hourly_pwr_june (junei,:) = power_func(wind_june(junei));
end
eng_production_june = trapz (hourly_pwr_june);
expected_eng_prod_june = (eng_production_june * 0.85)/1000;
wind_july = spd_ms(month_double==07); %July
for julyi=1:length(wind_july)
    hourly_pwr_july (julyi,:) = power_func(wind_july(julyi));
end
eng_production_july = trapz (hourly_pwr_july);
expected_eng_prod_july = (eng_production_july * 0.85)/1000;
wind_august = spd_ms(month_double==08); %August
for augusti=1:length(wind_august)
    hourly_pwr_august (augusti,:) =
power_func(wind_august(augusti));
end
eng_production_august = trapz (hourly_pwr_august);
expected_eng_prod_august = (eng_production_august * 0.85)/1000;
wind_sep = spd_ms(month_double==09); %September
for sepi=1:length(wind_sep)
    hourly_pwr_sep (sepi,:) = power_func(wind_sep(sepi));
end
eng_production_sep = trapz (hourly_pwr_sep);
expected_eng_prod_sep = (eng_production_sep * 0.85)/1000;
wind_oct = spd_ms(month_double==10); %October
for octi=1:length(wind_oct)
    hourly_pwr_oct (octi,:) = power_func(wind_oct(octi));
end
eng_production_oct = trapz (hourly_pwr_oct);
expected_eng_prod_oct = (eng_production_oct * 0.85)/1000;
wind_nov = spd_ms(month_double==11); %November
for novi=1:length(wind_nov)
    hourly_pwr_nov (novi,:) = power_func(wind_nov(novi));
end
eng_production_nov = trapz (hourly_pwr_nov);
expected_eng_prod_nov = (eng_production_nov * 0.85)/1000;
wind_dec = spd_ms(month_double==12); %December
for deci=1:length(wind_dec)
    hourly_pwr_dec (deci,:) = power_func(wind_dec(deci));
end
eng_production_dec = trapz (hourly_pwr_dec);
expected_eng_prod_dec = (eng_production_dec * 0.85)/1000;

monthly_eng_prod (1,:) = expected_eng_prod_jan;
monthly_eng_prod (2,:) = expected_eng_prod_feb;
monthly_eng_prod (3,:) = expected_eng_prod_mar;
monthly_eng_prod (4,:) = expected_eng_prod_apr;
monthly_eng_prod (5,:) = expected_eng_prod_may;
monthly_eng_prod (6,:) = expected_eng_prod_june;
monthly_eng_prod (7,:) = expected_eng_prod_july;
monthly_eng_prod (8,:) = expected_eng_prod_august;
monthly_eng_prod (9,:) = expected_eng_prod_sep;
monthly_eng_prod (10,:) = expected_eng_prod_oct;
monthly_eng_prod (11,:) = expected_eng_prod_nov;
monthly_eng_prod (12,:) = expected_eng_prod_dec;
%bar(monthly_eng_prod); Monthly energy production of wind park
```

```
%====================Power Function=================================

function [wind_power] = power_func(x)

if x<=3 || x>=26
    wind_power = 0;

elseif x>=17 && x<=25
    wind_power = 850*118;%Wind power in MW

else
    wind_power = (var_coeff(x)*118)/1000;%Wind power in MW
end
end

%====================Coefficients of polynomial====================
function [var_pwr] = var_coeff(x)

       p1 =  -0.000730103444883633;
       p2 =   0.050242948056187;
       p3 =  -1.406879944953474;
       p4 =   20.645523570313510;
       p5 =  -1.715904264728373e+02;
       p6 =   8.198030199834666e+02;
       p7 =  -2.066155295423886e+03;
       p8 =   2.116667132848899e+03;

       var_pwr = p1*x^7 + p2*x^6 + p3*x^5 + p4*x^4 + p5*x^3 + p6*x^2
+ p7*x + p8;
end

%===========================================End=====================
```

APPENDIX D

BASE LOAD DEMAND FORECAST OF THE CEB UP TO YEAR 2030

Year	Demand (GWh)	Growth Rate (%)	Gross Losses (%)	Generation (GWh)	Growth Rate (%)	Peak (MW)
2010	9190	8.9	14.4	10740	8.7	2170
2011	10036	9.2	14.3	11715	9.1	2356
2012	10698	6.6	14.2	12464	6.4	2503
2013	11402	6.6	14.9	13402	7.5	2688
2014	12149	6.6	15.1	14315	6.8	2853
2015	12941	6.5	15.1	15238	6.4	3035
2016	13773	6.4	15.1	16220	6.4	3211
2017	14630	6.2	14.8	17168	5.8	3397
2018	15530	6.2	14.6	18188	5.9	3604
2019	16481	6.1	14.4	19257	5.9	3820
2020	17489	6.1	14.3	20397	5.9	4051
2021	18563	6.1	14.6	21741	6.6	4258
2022	19708	6.2	14.4	23019	5.9	4513
2023	20932	6.2	14.3	24436	6.2	4796
2024	22242	6.3	14.2	25922	6.1	5092
2025	23647	6.3	14.2	27559	6.3	5418
2026	25153	6.4	14.1	29284	6.3	5684
2027	26768	6.4	14.1	31149	6.4	6051
2028	28503	6.5	14.0	33142	6.4	6443
2029	30365	6.5	14.0	35308	6.5	6869
2030	32367	6.6	14.0	37615	6.5	7323
Source: Long Term Generation Expansion Plan 2011-2025, CEB						

APPENDIX E

DETAILS OF THE CANDIDATE THERMAL PLANTS USED IN THE WASP RUNS

Type of Power Plant	Economic Life	FOR (%)	Total Construction Cost (US$/kW)	Fixed O&M Cost (US$/kW-Month)	Variable O&M Cost (US$/MWh)
150 MW Oil fired steam plants	30 Years	2.74	1512.4	0.940	5.15
300 MW Oil fired steam plants	30 Years	2.74	1278.4	0.659	2.58
300 MW Coal fired steam plants	30 Years	2.74	1542.0	0.704	2.76
35MW Auto diesel fired gas turbines	20 Years	8.0	737.4	0.638	5.12
75MW Auto diesel fired gas turbines	20 Years	8.0	602.5	0.549	4.38
105MW Auto diesel fired gas turbines	20 Years	8.0	501.3	0.483	3.83
150MW Auto diesel fired Combined cycle plants	30 Years	8.0	1070.0	0.484	4.15
300MW Auto diesel fired Combined cycle plants	30 Years	8.0	864.3	0.365	3.13
Source: Long Term Generation Expansion Plan 2011-2025, CEB					

APPENDIX F

STANDARD DEVIATION VALUES OF CAPITAL, FUEL, O&M AND CO_2 COSTS

	Construction	Fuel	O&M	CO_2
Coal	0.23	0.14	0.054	0.26
Oil	0.23	0.25	0.242	0.26
Gas	0.15	0.19	0.105	0.26
Hydro	0.1	0	0.153	0
Wind	0.05	0	0.08	0
Biomass	0.2	0.18	0.108	0
Source: Awerbuch and Yang (2007) [55]				

APPENDIX G

CORRELATION COEFFICIENTS OF FUEL, O&M AND CO_2 COSTS

1. Fuel and CO_2 Correlation Coefficients

	Coal	Oil	Gas	Biomass	CO_2
Coal	1	0.27	0.47	-0.38	-0.49
Oil	0.27	1	0.49	-0.17	0.19
Gas	0.47	0.49	1	-0.44	0.68
Biomass	-0.38	-0.17	-0.44	1	0
CO_2	-0.49	0.19	0.68	0	1
Source: Awerbuch and Yang (2007) [55]					

2. O&M Correlation Coefficients

Technology	Coal	Gas	Oil	Hydro	Wind	Biomass
Coal	1	0.25	-0.18	0.03	-0.22	0.18
Gas	0.25	1	0.09	-0.04	0	0.32
Oil	-0.18	0.09	1	-0.27	-0.58	0.01
Hydro	0.03	-0.04	-0.27	1	0.29	-0.18
Wind	-0.22	0	-0.58	0.29	1	-0.18
Biomass	0.18	0.32	0.01	-0.18	-0.18	1
Source: Awerbuch and Yang (2007) [55]						

APPENDIX H

MATLAB CODE OF MVPT ANALYSIS MODEL

```
%============Mean Variance Portfolio Theory Analysis================
clear;
%==========Calculation of Technology Risks===========================
% fractional weights of cost components with CO2 cost
      %Cap        Fuel      O&M       CO2
FW1= [0.2747     0.4089    0.0444    0.2719        %Coal
      0.0885     0.7996    0.0254    0.0865        %Oil
      0.1734     0.6636    0.0486    0.1144        %Gas
      0.9808     0.0000    0.0192    0.0000        %Hydro
      0.8402     0.0000    0.1598    0.0000        %Wind
      0.2228     0.7306    0.0465    0.0000];      %Biomass
SQRFW1 = realpow(FW1,2);

 % fractional weights of cost components without CO2 cost
      %Cap        Fuel     O&M      CO2
FW2= [0.3774     0.5617   0.0610   0.0000          %Coal
      0.0968     0.8754   0.0278   0.0000          %Oil
      0.1958     0.7493   0.0549   0.0000          %Gas
      0.9808     0.0000   0.0192   0.0000          %Hydro
      0.8402     0.0000   0.1598   0.0000          %Wind
      0.2228     0.7306   0.0465   0.0000];        %Biomass
SQRFW2 = realpow(FW2,2);

 % Technology standard deviations of Cost Components
        %Cap       Fuel     O&M      CO2
STDCC=  [0.23      0.14     0.054    0.26      %Coal
        0.23      0.25     0.242    0.26      %Oil
        0.15      0.19     0.105    0.26      %Gas
        0.10      0        0.153    0         %Hydro
        0.05      0        0.08     0         %Wind
        0.20      0.18     0.108    0];       %Biomass
SQRSTDCC = realpow(STDCC,2);
%===================================================================
%Tech risk WITH CO2 - TR1
INT1= bsxfun(@times,SQRFW1,SQRSTDCC);

%Fuel and CO2 Correlation
FCO2Corr= [-0.49
            0.19
            0.68
            0
            0
            0];
X1= FW1(:,2);
X2= FW1(:,4);
X3= STDCC(:,2);
X4= STDCC(:,4);
X5= bsxfun(@times,X1,X2);
X6= bsxfun(@times,X3,X4);
X7= bsxfun(@times,X5,X6);
X8= bsxfun(@times,X7,FCO2Corr);
X9= 2*X8; %Correlation element array
```

```
X10 = INT1(1,:); %Tech risk with CO2 - COAL
X11 = sum(X10);
X12 = X11+X9(1,1);
TRCOAL=sqrt(X12); %Technology risk of coal
X13 = INT1(2,:); %Tech risk with CO2 - OIL
X14 = sum(X13);
X15 = X14+X9(2,1);
TROIL=sqrt(X15); %Technology risk of oil
X16 = INT1(3,:); %Tech risk with CO2 - GAS
X17 = sum(X16);
X18 = X17+X9(3,1);
TRGAS=sqrt(X18); %Technology risk of gas
X19 = INT1(4,:); %Tech risk with CO2 - HYDRO
X20 = sum(X19);
X21 = X20+X9(4,1);
TRHYDRO=sqrt(X21); %Technology risk of hydro
X22 = INT1(5,:); %Tech risk with CO2 - WIND
X23 = sum(X22);
X24 = X23+X9(5,1);
TRWIND=sqrt(X24); %Technology risk of wind
X25 = INT1(6,:); %Tech risk with CO2 - BIOMASS
X26 = sum(X25);
X27 = X26+X9(6,1);
TRDENDRO=sqrt(X27); %Technology risk of Biomass
%================End of Tech risk WITH CO2==========================
%===================================================================
%Tech risk WITHOUT CO2 - TR3
INT2= bsxfun(@times,SQRFW2,SQRSTDCC);
%No Fuel and CO2 Correlation
YX10 = INT2(1,:); %Tech risk without CO2 - COAL
YX11 = sum(YX10);
YTRCOAL=sqrt(YX11); %Technology risk of coal
YX13 = INT2(2,:); %Tech risk without CO2 - OIL
YX14 = sum(YX13);
YTROIL=sqrt(YX14); %Technology risk of oil
YX16 = INT2(3,:); %Tech risk without CO2 - GAS
YX17 = sum(YX16);
YTRGAS=sqrt(YX17); %Technology risk of gas
YX19 = INT2(4,:); %Tech risk without CO2 - HYDRO
YX20 = sum(YX19);
YTRHYDRO=sqrt(X20); %Technology risk of hydro
YX22 = INT2(5,:); %Tech risk without CO2 - WIND
YX23 = sum(YX22);
YTRWIND=sqrt(YX23); %Technology risk of wind
YX24 = INT2(6,:); %Tech risk without CO2 - BIOMASS
YX25 = sum(YX24);
YTRDENDRO=sqrt(YX25); %Technology risk of Biomass
%===============End of Tech risk WITHOUT CO2========================
TR1=[TRCOAL TROIL TRGAS TRHYDRO TRWIND TRDENDRO]; %Technology stds
with CO2 cost risk for new plants
TR3=[YTRCOAL YTROIL YTRGAS YTRHYDRO YTRWIND YTRDENDRO]; %Technology
stds without CO2 cost risk for new plants
%===============End of Calculation of Technology risks==============
%===Calculation of Correlation coefficients between technologies====
%====Correlations between technologies with CO2 costs===============
C1 =     [0.23     0        0.23    0
          0        0.14     0       0
          0.054    0        0.054   0
```

```
        0        0       0       0.26];%Stds of Coal
C2 =    [0.2747      0         0.2747      0
         0           0.4089    0           0
         0.0444      0         0.0444      0
         0           0         0           0.2719];%Weights of Coal
O1 =    [0.23      0        0.242    0
         0         0.25     0        0
         0.23      0        0.242    0
         0         0        0        0.26];%Stds of Oil
O2 =    [0.0885      0         0.0254     0
         0           0.7996    0          0
         0.0885      0         0.0254     0
         0           0         0          0.0865];%Weights of Oil
G1 =    [0.15      0        0.105    0
         0         0.19     0        0
         0.15      0        0.105    0
         0         0        0        0.26];%Stds of Gas
G2 =    [0.1734      0         0.0486     0
         0           0.6636    0          0
         0.1734      0         0.0486     0
         0           0         0          0.1144];%Weights of Gas

% Correlation between Coal and Oil
          %Cap     %Fuel     %O&M     %CO2
CO =      [0.7       0         0.1      0     %Capital
           0         0.27      0        0     %Fuel
           0.1       0         -0.18    0     %O&M
           0         0         0        1];   %CO2
CO1= bsxfun(@times,CO,C1);
CO2= bsxfun(@times,CO1,O1);
CO3= bsxfun(@times,CO2,C2);
CO4= bsxfun(@times,CO3,O2);
CO5= sum(CO4);
CO6= sum(CO5);
CorCO= CO6/(TRCOAL*TROIL); % Tech. Corr. Coeff. between Coal and Oil

% Correlation between Coal and Gas
          %Cap     %Fuel     %O&M     %CO2
CG =      [0.7       0         0.1      0     %Capital
           0         0.47      0        0     %Fuel
           0.1       0         0.25     0     %O&M
           0         0         0        1];   %CO2
CG1= bsxfun(@times,CG,C1);
CG2= bsxfun(@times,CG1,G1);
CG3= bsxfun(@times,CG2,C2);
CG4= bsxfun(@times,CG3,G2);
CG5= sum(CG4);
CG6= sum(CG5);
CorCG= CG6/(TRCOAL*TRGAS); % Tech. Corr. Coeff. between Coal and Gas

% Correlation between Coal and Hydro
          %Cap     %Fuel     %O&M     %CO2
CH =      [0.1       0         0.1      0     %Capital
           0         0         0        0     %Fuel
           0.1       0         0.03     0     %O&M
           0         0         0        0];   %CO2
```

```
H1 =       [0.1        0        0.153    0
            0          0        0        0
            0.1        0        0.153    0
            0          0        0        0];%Stds of Hydro
H2 =       [0.9808       0        0.0192     0
            0            0        0          0
            0.9808       0        0.0192     0
            0            0        0          0];%Weights of Hydro
CH1= bsxfun(@times,CH,C1);
CH2= bsxfun(@times,CH1,H1);
CH3= bsxfun(@times,CH2,C2);
CH4= bsxfun(@times,CH3,H2);
CH5= sum(CH4);
CH6= sum(CH5);
CorCH= CH6/(TRCOAL*TRHYDRO); % Tech. Corr. Coeff. btwn Coal & Hydro

% Correlation between Coal and Wind
            %Cap      %Fuel      %O&M     %CO2
CW =       [0.1       0          0.1      0     %Capital
            0         0          0        0     %Fuel
            0.1       0          -0.22    0     %O&M
            0         0          0        0];   %CO2
W1 =       [0.05       0         0.08     0
            0          0         0        0
            0.05       0         0.08     0
            0          0         0        0];%Stds of Wind
W2 =       [0.8402       0         0.1598     0
            0            0         0          0
            0.8402       0         0.1598     0
            0            0         0          0];%Weights of Wind
CW1= bsxfun(@times,CW,C1);
CW2= bsxfun(@times,CW1,W1);
CW3= bsxfun(@times,CW2,C2);
CW4= bsxfun(@times,CW3,W2);
CW5= sum(CW4);
CW6= sum(CW5);
CorCW= CW6/(TRCOAL*TRWIND); % Tech. Corr. Coeff. btwn Coal & Wind

% Correlation between Coal and Biomass
            %Cap      %Fuel      %O&M     %CO2
CD =       [0.1       0          0.1      0     %Capital
            0         -0.38      0        0     %Fuel
            0.1       0          0.18     0     %O&M
            0         0          0        0];   %CO2

D1 =       [0.2        0         0.108    0
            0          0.18      0        0
            0.2        0         0.108    0
            0          0         0        0];%Stds of Biomass
D2 =       [0.2228       0          0.0465     0
            0            0.7306     0          0
            0.2228       0          0.0465     0
            0            0          0          0];%Weights of Biomass
CD1= bsxfun(@times,CD,C1);
CD2= bsxfun(@times,CD1,D1);
CD3= bsxfun(@times,CD2,C2);
CD4= bsxfun(@times,CD3,D2);
```

```
CD5= sum(CD4);
CD6= sum(CD5);
CorCD= CD6/(TRCOAL*TRDENDRO); % Tech.Corr.Coeff. Btwn Coal & Biomass

% Correlation between Oil and Gas
           %Cap     %Fuel     %O&M     %CO2
OG =      [0.7      0         0.1      0     %Capital
           0        0.49      0        0     %Fuel
           0.1      0         0.09     0     %O&M
           0        0         0        1];   %CO2
O3 = O1';
O4 = O2';
OG1= bsxfun(@times,OG,O3);
OG2=bsxfun(@times,OG1,G1);
OG3=bsxfun(@times,OG2,O4);
OG4=bsxfun(@times,OG3,G2);
OG5= sum(OG4);
OG6= sum(OG5);
CorOG= OG6/(TROIL*TRGAS); % Tech.Corr.Coeff. between Oil and Gas

% Correlation between Oil and Hydro
           %Cap     %Fuel     %O&M     %CO2
OH =      [0.1      0         0.1      0     %Capital
           0        0         0        0     %Fuel
           0.1      0         -0.27    0     %O&M
           0        0         0        0];   %CO2
OH1= bsxfun(@times,OH,O3);
OH2=bsxfun(@times,OH1,H1);
OH3=bsxfun(@times,OH2,O4);
OH4=bsxfun(@times,OH3,H2);
OH5= sum(OH4);
OH6= sum(OH5);
CorOH= OH6/(TROIL*TRHYDRO); % Tech.Corr.Coeff. between Oil and Hydro

% Correlation between Oil and Wind
           %Cap     %Fuel     %O&M     %CO2
OW =      [0.1      0         0.1      0     %Capital
           0        0         0        0     %Fuel
           0.1      0         -0.58    0     %O&M
           0        0         0        0];   %CO2
OW1= bsxfun(@times,OW,O3);
OW2=bsxfun(@times,OW1,W1);
OW3=bsxfun(@times,OW2,O4);
OW4=bsxfun(@times,OW3,W2);
OW5= sum(OW4);
OW6= sum(OW5);
CorOW= OW6/(TROIL*TRWIND); % Tech.Corr.Coeff.between Oil and Wind

% Correlation between Oil and Biomass
           %Cap     %Fuel     %O&M     %CO2
OD =      [0.1      0         0.1      0     %Capital
           0        -0.17     0        0     %Fuel
           0.1      0         0.01     0     %O&M
           0        0         0        0];   %CO2
OD1= bsxfun(@times,OD,O3);
OD2= bsxfun(@times,OD1,D1);
OD3= bsxfun(@times,OD2,O4);
```

```
OD4= bsxfun(@times,OD3,D2);
OD5= sum(OD4);
OD6= sum(OD5);
CorOD= OD6/(TROIL*TRDENDRO); % Tech.Corr.Coeff. btwn Oil and Biomass

% Correlation between Gas and Hydro
           %Cap    %Fuel     %O&M    %CO2
GH =      [0.1      0         0.1     0     %Capital
           0        0         0       0     %Fuel
           0.1      0         -0.04   0     %O&M
           0        0         0       0];   %CO2
G3 = G1';
G4 = G2';
GH1= bsxfun(@times,GH,G3);
GH2=bsxfun(@times,GH1,H1);
GH3=bsxfun(@times,GH2,G4);
GH4=bsxfun(@times,GH3,H2);
GH5= sum(GH4);
GH6= sum(GH5);
CorGH= GH6/(TRGAS*TRHYDRO); % Tech.Corr.Coeff. btwn Gas and Hydro

% Correlation between Gas and Wind
           %Cap    %Fuel     %O&M    %CO2
GW =      [0.1      0         0.1     0     %Capital
           0        0         0       0     %Fuel
           0.1      0         0       0     %O&M
           0        0         0       0];   %CO2
GW1= bsxfun(@times,GW,G3);
GW2=bsxfun(@times,GW1,W1);
GW3=bsxfun(@times,GW2,G4);
GW4=bsxfun(@times,GW3,W2);
GW5= sum(GW4);
GW6= sum(GW5);
CorGW= GW6/(TRGAS*TRWIND); % Tech.Corr.Coeff. between Gas and Wind


% Correlation between Gas and Biomass
           %Cap    %Fuel     %O&M    %CO2
GD =      [0.1      0         0.1     0     %Capital
           0        -0.44     0       0     %Fuel
           0.1      0         0.32    0     %O&M
           0        0         0       0];   %CO2
GD1= bsxfun(@times,GD,G3);
GD2=bsxfun(@times,GD1,D1);
GD3=bsxfun(@times,GD2,G4);
GD4=bsxfun(@times,GD3,D2);
GD5= sum(GD4);
GD6= sum(GD5);
CorGD= GD6/(TRGAS*TRDENDRO); % Tech.Corr.Coeff. btwn Gas and Biomass

% Correlation between Hydro and Wind
           %Cap    %Fuel     %O&M    %CO2
HW =      [0.1      0         0.1     0     %Capital
           0        0         0       0     %Fuel
           0.1      0         0.29    0     %O&M
           0        0         0       0];   %CO2
```

```
H3 = H1';
H4 = H2';
HW1= bsxfun(@times,HW,H3);
HW2= bsxfun(@times,HW1,W1);
HW3= bsxfun(@times,HW2,H4);
HW4= bsxfun(@times,HW3,W2);
HW5= sum(HW4);
HW6= sum(HW5);
CorHW= HW6/(TRHYDRO*TRWIND); % Tech.Corr.Coeff. btwn Hydro and Wind

% Correlation between Hydro and Biomass
           %Cap     %Fuel      %O&M     %CO2
HD =       [0.1       0         0.1      0      %Capital
            0         0         0        0      %Fuel
            0.1       0         -0.18    0      %O&M
            0         0         0        0];    %CO2
HD1= bsxfun(@times,HD,H3);
HD2= bsxfun(@times,HD1,D1);
HD3= bsxfun(@times,HD2,H4);
HD4= bsxfun(@times,HD3,D2);
HD5= sum(HD4);
HD6= sum(HD5);
CorHD= HD6/(TRHYDRO*TRDENDRO); % Tech.Corr.Coeff. btwn Hyd. & BMS.

% Correlation between Wind and Biomass
           %Cap     %Fuel      %O&M     %CO2
WD =       [0.1       0         0.1      0      %Capital
            0         0         0        0      %Fuel
            0.1       0         -0.18    0      %O&M
            0         0         0        0];    %CO2
W3 = W1';
W4 = W2';
WD1= bsxfun(@times,WD,W3);
WD2= bsxfun(@times,WD1,D1);
WD3= bsxfun(@times,WD2,W4);
WD4= bsxfun(@times,WD3,D2);
WD5= sum(WD4);
WD6= sum(WD5);
CorWD= WD6/(TRWIND*TRDENDRO); % Tech.Corr.Coeff. bten Wind & Biomass

%====End of Correlations between technologies with CO2 costs========
%====Correlations between technologies without CO2 costs============

XC1 =      [0.23      0        0.23     0
            0         0.14     0        0
            0.054     0        0.054    0
            0         0        0        0];%Stds of Coal
XC2 =     [0.3774       0          0.3774     0
           0            0.5617     0          0
           0.0610       0          0.0610     0
           0            0          0          0];%Weights of Coal
XO1 =     [0.23       0        0.242    0
           0          0.25     0        0
           0.23       0        0.242    0
           0          0        0        0];%Stds of Oil
XO2 =     [0.0968       0          0.0278     0
           0            0.8754     0          0
```

```
            0.0968      0          0.0278     0
            0           0          0          0];%Weights of Oil
XG1 =      [0.15       0         0.105    0
            0          0.19      0        0
            0.15       0         0.105    0
            0          0         0        0];%Stds of Gas
XG2 =      [0.1958      0          0.0549     0
            0           0.7493     0          0
            0.1958      0          0.0549     0
            0           0          0          0];%Weights of Gas

% Correlation between Coal and Oil without CO2
             %Cap      %Fuel      %O&M     %CO2
XCO =       [0.7        0          0.1       0     %Capital
             0          0.27       0         0     %Fuel
             0.1        0          -0.18     0     %O&M
             0          0          0         0];   %CO2
XCO1= bsxfun(@times,XCO,XC1);
XCO2= bsxfun(@times,XCO1,XO1);
XCO3= bsxfun(@times,XCO2,XC2);
XCO4= bsxfun(@times,XCO3,XO2);
XCO5= sum(XCO4);
XCO6= sum(XCO5);
XCorCO= XCO6/(YTRCOAL*YTROIL); %TCorrCoeff btwn Coal&Oil W/O CO2

% Correlation between Coal and Gas without CO2
             %Cap      %Fuel      %O&M     %CO2
XCG =       [0.7        0          0.1       0     %Capital
             0          0.47       0         0     %Fuel
             0.1        0          0.25      0     %O&M
             0          0          0         0];   %CO2
XCG1= bsxfun(@times,XCG,XC1);
XCG2= bsxfun(@times,XCG1,XG1);
XCG3= bsxfun(@times,XCG2,XC2);
XCG4= bsxfun(@times,XCG3,XG2);
XCG5= sum(XCG4);
XCG6= sum(XCG5);
XCorCG= XCG6/(YTRCOAL*YTRGAS); % TCorrCoeff btwn Coa&Gas W/O CO2

% Correlation between Coal and Hydro without CO2
             %Cap      %Fuel      %O&M     %CO2
XCH =       [0.1        0          0.1       0     %Capital
             0          0          0         0     %Fuel
             0.1        0          0.03      0     %O&M
             0          0          0         0];   %CO2
XH1 = H1;
XH2 = H2;
XCH1= bsxfun(@times,XCH,XC1);
XCH2= bsxfun(@times,XCH1,XH1);
XCH3= bsxfun(@times,XCH2,XC2);
XCH4= bsxfun(@times,XCH3,XH2);
XCH5= sum(XCH4);
XCH6= sum(XCH5);
XCorCH= XCH6/(YTRCOAL*YTRHYDRO);%TCorrCoeff btwn Coal&Hyd W/O CO2
```

```
% Correlation between Coal and Wind without CO2
            %Cap     %Fuel      %O&M     %CO2
XCW =      [0.1       0          0.1       0     %Capital
             0        0          0         0     %Fuel
             0.1      0          -0.22     0     %O&M
             0        0          0         0];   %CO2
XW1 = W1;
XW2 = W2;
XCW1= bsxfun(@times,XCW,XC1);
XCW2= bsxfun(@times,XCW1,XW1);
XCW3= bsxfun(@times,XCW2,XC2);
XCW4= bsxfun(@times,XCW3,XW2);
XCW5= sum(XCW4);
XCW6= sum(XCW5);
XCorCW= XCW6/(YTRCOAL*YTRWIND);%TCorrCoeff btwn Coal&Wind W/O CO2

% Correlation between Coal and Biomass without CO2
            %Cap     %Fuel      %O&M     %CO2
XCD =      [0.1       0          0.1       0     %Capital
             0        -0.38      0         0     %Fuel
             0.1      0          0.18      0     %O&M
             0        0          0         0];   %CO2
XD1 = D1;
XD2 = D2;
XCD1= bsxfun(@times,XCD,XC1);
XCD2= bsxfun(@times,XCD1,XD1);
XCD3= bsxfun(@times,XCD2,XC2);
XCD4= bsxfun(@times,XCD3,XD2);
XCD5= sum(XCD4);
XCD6= sum(XCD5);
XCorCD= XCD6/(YTRCOAL*YTRDENDRO);%TCorrCoeff btwn Coal&BMS W/O CO2
% Correlation between Oil and Gas without CO2
            %Cap     %Fuel      %O&M     %CO2
XOG =      [0.7       0          0.1       0     %Capital
             0        0.49       0         0     %Fuel
             0.1      0          0.09      0     %O&M
             0        0          0         0];   %CO2
XO3 = XO1';
XO4 = XO2';
XOG1= bsxfun(@times,XOG,XO3);
XOG2= bsxfun(@times,XOG1,XG1);
XOG3= bsxfun(@times,XOG2,XO4);
XOG4= bsxfun(@times,XOG3,XG2);
XOG5= sum(XOG4);
XOG6= sum(XOG5);
XCorOG= XOG6/(YTROIL*YTRGAS);%TCorrCoeff btwn Oil&Gas W/O CO2

% Correlation between Oil and Hydro without CO2
            %Cap     %Fuel      %O&M     %CO2
XOH =      [0.1       0          0.1       0     %Capital
             0        0          0         0     %Fuel
             0.1      0          -0.27     0     %O&M
             0        0          0         0];   %CO2
XOH1= bsxfun(@times,XOH,XO3);
XOH2= bsxfun(@times,XOH1,XH1);
XOH3= bsxfun(@times,XOH2,XO4);
XOH4= bsxfun(@times,XOH3,XH2);
```

```
XOH5= sum(XOH4);
XOH6= sum(XOH5);
XCorOH= XOH6/(YTROIL*YTRHYDRO);%TCorrCoeff btwn Oil&Hydro W/O CO2

% Correlation between Oil and Wind without CO2
            %Cap     %Fuel      %O&M     %CO2
XOW =      [0.1       0          0.1      0     %Capital
            0         0          0        0     %Fuel
            0.1       0          -0.58    0     %O&M
            0         0          0        0];   %CO2
XOW1= bsxfun(@times,XOW,XO3);
XOW2= bsxfun(@times,XOW1,XW1);
XOW3= bsxfun(@times,XOW2,XO4);
XOW4= bsxfun(@times,XOW3,XW2);
XOW5= sum(XOW4);
XOW6= sum(XOW5);
XCorOW= XOW6/(YTROIL*YTRWIND);%TCorrCoeff btwn Oil&Wind W/O CO2

% Correlation between Oil and Biomass without CO2
            %Cap     %Fuel      %O&M     %CO2
XOD =      [0.1       0          0.1      0     %Capital
            0         -0.17      0        0     %Fuel
            0.1       0          0.01     0     %O&M
            0         0          0        0];   %CO2
XOD1= bsxfun(@times,XOD,XO3);
XOD2= bsxfun(@times,XOD1,XD1);
XOD3= bsxfun(@times,XOD2,XO4);
XOD4= bsxfun(@times,XOD3,XD2);
XOD5= sum(XOD4);
XOD6= sum(XOD5);
XCorOD= XOD6/(YTROIL*YTRDENDRO);%TCorrCoeff btwn Oil&BMS W/O CO2
```



```
% Correlation between Gas and Hydro without CO2
            %Cap     %Fuel      %O&M     %CO2
XGH =      [0.1       0          0.1      0     %Capital
            0         0          0        0     %Fuel
            0.1       0          -0.04    0     %O&M
            0         0          0        0];   %CO2
XG3 = XG1';
XG4 = XG2';
XGH1= bsxfun(@times,XGH,XG3);
XGH2= bsxfun(@times,XGH1,XH1);
XGH3= bsxfun(@times,XGH2,XG4);
XGH4= bsxfun(@times,XGH3,XH2);
XGH5= sum(XGH4);
XGH6= sum(XGH5);
XCorGH= XGH6/(YTRGAS*YTRHYDRO);%TCorrCoeff btwn Gas&Hydro W/O CO2

% Correlation between Gas and Wind without CO2
            %Cap     %Fuel      %O&M     %CO2
XGW =      [0.1       0          0.1      0     %Capital
            0         0          0        0     %Fuel
            0.1       0          0        0     %O&M
            0         0          0        0];   %CO2
XGW1= bsxfun(@times,XGW,XG3);
XGW2= bsxfun(@times,XGW1,XW1);
XGW3= bsxfun(@times,XGW2,XG4);
```

```
XGW4= bsxfun(@times,XGW3,XW2);
XGW5= sum(XGW4);
XGW6= sum(XGW5);
XCorGW= XGW6/(YTRGAS*YTRWIND);%TCorrCoeff btwn Gas&Wind W/O CO2

% Correlation between Gas and Biomass without CO2
           %Cap     %Fuel     %O&M     %CO2
XGD =     [0.1      0         0.1      0     %Capital
           0        -0.44     0        0     %Fuel
           0.1      0         0.32     0     %O&M
           0        0         0        0];   %CO2
XGD1= bsxfun(@times,XGD,XG3);
XGD2= bsxfun(@times,XGD1,XD1);
XGD3= bsxfun(@times,XGD2,XG4);
XGD4= bsxfun(@times,XGD3,XD2);
XGD5= sum(XGD4);
XGD6= sum(XGD5);
XCorGD= XGD6/(YTRGAS*YTRDENDRO);%TCorrCoeff btwn Gas&Biomass W/O CO2

% Correlation between Hydro and Wind without CO2
           %Cap     %Fuel     %O&M     %CO2
XHW =     [0.1      0         0.1      0     %Capital
           0        0         0        0     %Fuel
           0.1      0         0.29     0     %O&M
           0        0         0        0];   %CO2
XH3 = XH1';
XH4 = XH2';
XHW1= bsxfun(@times,XHW,XH3);
XHW2= bsxfun(@times,XHW1,XW1);
XHW3= bsxfun(@times,XHW2,XH4);
XHW4= bsxfun(@times,XHW3,XW2);
XHW5= sum(XHW4);
XHW6= sum(XHW5);
XCorHW= XHW6/(YTRHYDRO*YTRWIND);%TCorrCoeff btwn Hydro&Wind W/O CO2

% Correlation between Hydro and Biomass without CO2
           %Cap     %Fuel     %O&M     %CO2
XHD =     [0.1      0         0.1      0     %Capital
           0        0         0        0     %Fuel
           0.1      0         -0.18    0     %O&M
           0        0         0        0];   %CO2
XHD1= bsxfun(@times,XHD,XH3);
XHD2= bsxfun(@times,XHD1,XD1);
XHD3= bsxfun(@times,XHD2,XH4);
XHD4= bsxfun(@times,XHD3,XD2);
XHD5= sum(XHD4);
XHD6= sum(XHD5);
XCorHD= XHD6/(YTRHYDRO*YTRDENDRO);%TCorrCoeff btwn Hydro&BMS W/O CO2

% Correlation between Wind and Biomass without CO2
           %Cap     %Fuel     %O&M     %CO2
XWD =     [0.1      0         0.1      0     %Capital
           0        0         0        0     %Fuel
           0.1      0         -0.18    0     %O&M
           0        0         0        0];   %CO2
XW3 = XW1';
XW4 = XW2';
```

```
XWD1= bsxfun(@times,XWD,XW3);
XWD2= bsxfun(@times,XWD1,XD1);
XWD3= bsxfun(@times,XWD2,XW4);
XWD4= bsxfun(@times,XWD3,XD2);
XWD5= sum(XWD4);
XWD6= sum(XWD5);
XCorWD= XWD6/(YTRWIND*YTRDENDRO);%TCorrCoeff btwn Wind&BMS W/O CO2

%===End of Correlations between technologies without CO2 costs======
%Tech Correlation coefficients with CO2 cost
TCC = [1        CorCO     CorCG     CorCH     CorCW     CorCD
       CorCO    1         CorOG     CorOH     CorOW     CorOD
       CorCG    CorOG     1         CorGH     CorGW     CorGD
       CorCH    CorOH     CorGH     1         CorHW     CorHD
       CorCW    CorOW     CorGW     CorHW     1         CorWD
       CorCD    CorOD     CorGD     CorHD     CorWD     1];
%Tech Correlation coefficients without CO2 cost
XTCC = [1        XCorCO    XCorCG    XCorCH    XCorCW    XCorCD
        XCorCO   1         XCorOG    XCorOH    XCorOW    XCorOD
        XCorCG   XCorOG    1         XCorGH    XCorGW    XCorGD
        XCorCH   XCorOH    XCorGH    1         XCorHW    XCorHD
        XCorCW   XCorOW    XCorGW    XCorHW    1         XCorWD
        XCorCD   XCorOD    XCorGD    XCorHD    XCorWD    1];
%End of Calculation of Correlation coefficients between technologies

%=======MVPT Analysis of 2025 Generation Mix========================
D = diag(TR1);
XD = diag(TR3);
COV=D*TCC*D; %covariance matrix (with CO2)
XCOV=XD*XTCC*XD; %covariance matrix (without CO2)

         %Coal     Oil      Gas     Hydro   Wind    Biomass
LCOE =  [93.29   198.98   92.11   97.60   137.16  136.92]; %LCOE
XLCOE = [67.92   181.76   81.57   97.60   137.16  136.92]; %LOCE
without CO2 cost

%=============Scenario (1) with CO2 Cost============================
RTN = 1./LCOE;%Return (with CO2 cost)
bounds = [0.065  0  0  0.18  0.005  0; 0.815  0.75  0.75  0.30  0.10
0.10];% Upper and lower bounds of technologies
[risk,returns,wts] = frontcon(RTN,COV,5000,[],bounds);
cost = 1./returns;
%plot(risk*100,cost);%Efficient frontier
hold on;
portwts_ceb = [0.709458  0.011106   0.0000  0.249637   0.01372
0.016079];%CEB Energy Mix 2025_with CO2
[risk_ceb,ret_ceb] = portstats(RTN,COV,portwts_ceb);
cost_ceb = 1./ret_ceb;
%scatter(risk_ceb*100,cost_ceb);
hold on;
yportwts_ceb = [0.146112    0.396694    0.000000    0.437776
0.011233    0.008184];%CEB Energy Mix 2012_with CO2
[yrisk_ceb,yret_ceb] = portstats(RTN,COV,yportwts_ceb);
ycost_ceb = 1./yret_ceb;
%scatter(yrisk_ceb*100,ycost_ceb);
hold on;
%scatter(TR1*100,LCOE);%Individual technology cost and risk
```

```
portwts1 = wts(4231,:);%Same risk portfolio_2025 mix
[risk1,ret1] = portstats(RTN,COV,portwts1);
cost1 = 1./ret1;
%scatter(risk1*100,cost1);
hold on;
portwts2 = wts(3535,:);% Same cost less risk portfolio_2025mix
[risk2,ret2] = portstats(RTN,COV,portwts2);
cost2 = 1./ret2;
%scatter(risk2*100,cost2);
hold on;
portwts3 = wts(1,:);% Least risk portfolio
[risk3,ret3] = portstats(RTN,COV,portwts3);
cost3 = 1./ret3;
%scatter(risk3*100,cost3);
hold on;
portwts4 = wts(5000,:);% Least cost portfolio
[risk4,ret4] = portstats(RTN,COV,portwts4);
cost4 = 1./ret4;
%scatter(risk4*100,cost4);
hold on;
portwts5 = wts(4847,:);% Same risk less cost portfolio_2012mix
[risk5,ret5] = portstats(RTN,COV,portwts5);
cost5 = 1./ret5;
%scatter(risk5*100,cost5);
hold on;
%Cost risk matrix of scenario 1
Cost_risk_1 = [cost_ceb   risk_ceb*100      %CEB 2025
               ycost_ceb  yrisk_ceb*100     %CEB 2012
               cost3      risk3*100         %A1
               cost2      risk2*100         %B1
               cost1      risk1*100         %C1
               cost4      risk4*100         %D1
               cost5      risk5*100];       %E1
efportwts = 100*[portwts1        %Same risk_2025
                 portwts2        %Same cost_2025
                 portwts3        %Least risk_2025
                 portwts4        %Least cost_2025
                 portwts5];      %Same risk_2012

%=============End of Scenario (1)===================================
%=============Scenario (2) without CO2 Cost=========================

XRTN = 1./XLCOE;% Return (Without CO2 Cost)
[xrisk,xreturns,xwts] = frontcon(XRTN,XCOV,5000,[],bounds);
xcost = 1./xreturns;
%plot(xrisk*100,xcost);%Efficient frontier
hold on;
xportwts_ceb = [0.709458  0.011106  0.0000  0.249637   0.01372
0.016079];%CEB Energy Mix 2025
[xrisk_ceb,xret_ceb] = portstats(XRTN,XCOV,xportwts_ceb);
xcost_ceb = 1./xret_ceb;
%scatter(xrisk_ceb*100,xcost_ceb);
hold on;
xxportwts_ceb = [0.146112   0.396694   0.000000   0.437776
0.011233   0.008184];%CEB Energy Mix 2012
[xxrisk_ceb,xxret_ceb] = portstats(XRTN,XCOV,xxportwts_ceb);
xxcost_ceb = 1./xxret_ceb;
```

```
%scatter(xxrisk_ceb*100,xxcost_ceb);
hold on;
%scatter(TR3*100,XLCOE);
xportwts1 = xwts(4066,:);%Same risk portfolio_2025 mix
[xrisk1,xret1] = portstats(XRTN,XCOV,xportwts1);
xcost1 = 1./xret1;
%scatter(xrisk1*100,xcost1);
hold on;
xportwts2 = xwts(3878,:);% Same cost less risk portfolio_2025mix
[xrisk2,xret2] = portstats(XRTN,XCOV,xportwts2);
xcost2 = 1./xret2;
%scatter(xrisk2*100,xcost2);
hold on;
xportwts3 = xwts(1,:);% Least risk portfolio
[xrisk3,xret3] = portstats(XRTN,XCOV,xportwts3);
xcost3 = 1./xret3;
%scatter(xrisk3*100,xcost3);
hold on;
xportwts4 = xwts(5000,:);% Least cost portfolio
[xrisk4,xret4] = portstats(XRTN,XCOV,xportwts4);
xcost4 = 1./xret4;
%scatter(xrisk4*100,xcost4);
hold on;
%Cost risk matrix of scenario 2
Cost_risk_2 = [xcost_ceb   xrisk_ceb*100      %CEB 2025
               xxcost_ceb  xxrisk_ceb*100     %CEB 2012
               xcost3      xrisk3*100         %A2
               xcost2      xrisk2*100         %B2
               xcost1      xrisk1*100         %C2
               xcost4      xrisk4*100];       %D2
xefportwts = 100*[xportwts1           %Same risk_2025
                  xportwts2           %Same cost_2025
                  xportwts3           %Least risk_2025
                  xportwts4];         %Least cost_2025

%==============End of Scenario (2)==================================

%=========End of Mean Variance Portfolio Theory Analysis============
```

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