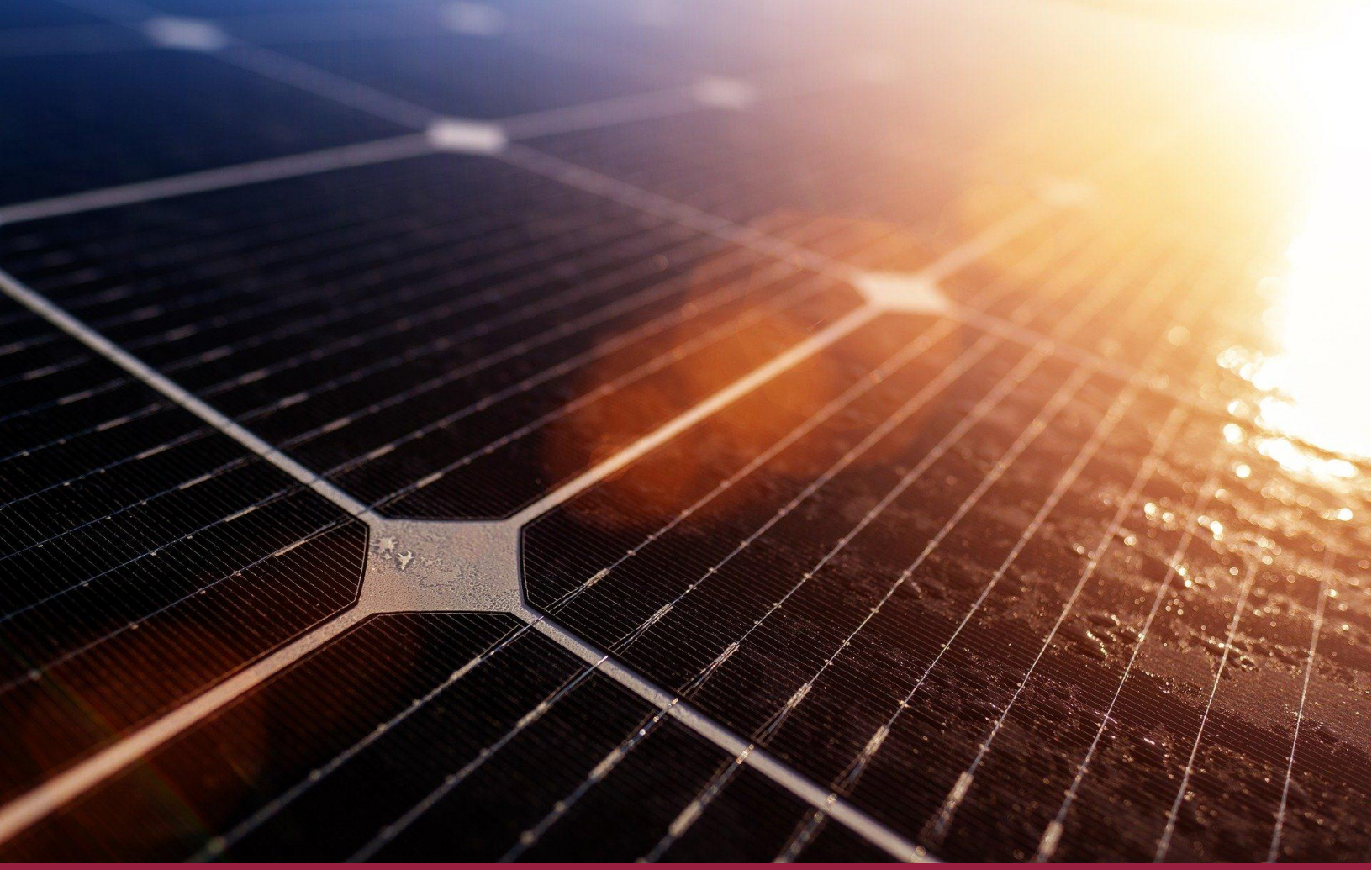

5.2. Use of storage technologies for ancillary services provision and its potential for climate change mitigation

Appendix E

Tables of emissions reduction by control area

October, 2020

MEDIO AMBIENTE
SECRETARÍA DE MEDIO AMBIENTE Y RECURSOS NATURALES
INECC
INSTITUTO NACIONAL DE ECOLOGÍA Y CAMBIO CLIMÁTICO
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Technology Roadmap and Mitigation Potential of Utility-scale Electricity Storage in Mexico

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Appendix E

Tables of emissions reduction by control area

E.1 Calculation of the Pollutant Emission Reduction Tables, by interpolation of data from the reference [E.1]

```
% Order in the following data
                Coal:   CO2 Emissions (Tons);
                        NOx Emissions (lbs);
                        SO2 Emissions (lbs);
                        Total Generation (MWh);

% Table 5.4 Kindle

Coal=[128858000 127345000
    154734000 151965000
    687351000 678176000
    129371386 127774000];

% Gas steam turbine: CO2 Emissions (Tons); NOx Emissions (lbs); % Total Generation (MWh);

% Table 5.7 Kindle
Gas_Steam_Turbine = [1122000   786000
                1854000   1253000
                1729000   1244000
                14415000  35431000];

% Combined cycle: % Table 5.9 Kindle

Combined_cycle = [45702000   39559000
            62442000   47874000
            112614883  95686000
            14415000  35431000];
```

```
% simple cycle: % Table 5.13 Kindle

Simple_cycle = [1335000   917000
                6094000   3993000
                1842674   1347996
                14415000  35431000];

% factor nivel pais (Figura 5.7 PRODESEN 2019)
Factor_pais = [0.092;  %carboelectrica
               0.132;  % steam
               0.510;  % ciclo combinado
               0.027]; % turbogas

% Northeast: Carboelectric, conventional thermal, combined cycle, turbo gas
% Tabla 5.1 (CFE) PRODESEN 2019.
Central = 7815*[0 0.132 0.51 0]; % MW
Oriental = 10488*[0 0.132 0.51 0]; %MW
Occidental = 8611*[0.092 0.132 0.51 0]; %MW
Noroeste = 3701*[0 0.132 0.51 0.027]; %MW
Norte = 2506*[0 0.132 0.51 0]; %MW
Noreste = 4800*[0.092 0.132 0.51 0.027]; %MW
Peninsular = 915*[0 0.132 0.51 0.027]; %MW

Gtotal_Mex=Central+Oriental+Occidental+Noroeste+Norte+Noreste+Peninsular;

% percentages
kl = 1;
   for jk = 1:4,
      Central(kl,jk) = Central(kl,jk)/Gtotal_Mex(jk);
       Oriental(kl,jk) = Oriental(kl,jk)/Gtotal_Mex(jk);
        Occidental(kl,jk) = Occidental(kl,jk)/Gtotal_Mex(jk);
         Noroeste(kl,jk) = Noroeste(kl,jk)/Gtotal_Mex(jk);
        Norte(kl,jk) = Norte(kl,jk)/Gtotal_Mex(jk);
```

```
    Noreste(kl,jk) = Noreste(kl,jk)/Gtotal_Mex(jk);
   Peninsular(kl,jk) = Peninsular(kl,jk)/Gtotal_Mex(jk);
end

% displacement of technologies in Mexico with insertion of 1700 MW of batteries (managed as renewable).
Carboelectric, conventional thermal, combined cycle, turbogas

SOx = [687351000-678176000 0 0 0]*17/65; proportion indicated on p. 42 of the report

CO2 = [128858000-127345000 1122000-786000 45702000-39559000 1335000-917000]*17/65;
NOx = [154734000-151965000 1854000-1253000 62442000-47874000 6094000-3993000]*17/65;
Deltagen=[1597386 485000 16928883 494678]*17/65;

% pounds to tons
% 1 pound = 0.000453592 tons;
SOx = SOx*0.000453592; % Tons
NOx = NOx*0.000453592; %Tons

% per control area

Central_SOx = Central.*SOx;
Oriental_SOx = Oriental.*SOx;
Occidental_SOx = Occidental.*SOx;
Noroeste_SOx = Noroeste.*SOx;
Norte_SOx = Norte.*SOx;
Noreste_SOx = Noreste.*SOx;
Peninsular_SOx = Peninsular.*SOx;

Central_CO2 = Central.*CO2;
Oriental_CO2 = Oriental.*CO2;
Occidental_CO2 = Occidental.*CO2;
Noroeste_CO2 = Noroeste.*CO2;
```

Norte_CO2 = Norte.*CO2;

Noreste_CO2 = Noreste.*CO2;

Peninsular_CO2 = Peninsular.*CO2;

Central_NOx = Central.*NOx;

Oriental_NOx = Oriental.*NOx;

Occidental_NOx = Occidental.*NOx;

Noroeste_NOx = Noroeste.*NOx;

Norte_NOx = Norte.*NOx;

Noreste_NOx = Noreste.*NOx;

Peninsular_NOx = Peninsular.*NOx;

Central_DG = Central.*Deltagen;

Oriental_DG = Oriental.*Deltagen;

Occidental_DG = Occidental.*Deltagen;

Noroeste_DG = Noroeste.*Deltagen;

Norte_DG = Norte.*Deltagen;

Noreste_DG = Noreste.*Deltagen;

Peninsular_DG = Peninsular.*Deltagen;

E.2 Estimation of carbon dioxide emissions

The CO_2 emissions from a fossil fuel power station can be estimated with the following formula [E.2]:

CO_2 emissions = capacity x capacity factor x heat rate x emission intensity x time

where,

Capacity: is the *nameplate capacity* or the maximum allowed output of the plant

Capacity factor or load factor: is a measure of the amount of power that a plant produces compared with the amount it would produce if operated at its rated capacity nonstop.

Heat rate: is thermal energy in/electrical energy out, emission intensity (also called emission factor) is the CO_2 emitted per unit of heat generated for a particular fuel.

Emission intensity: factor displayed in Table E.1.

As an example, a new 1500 MW supercritical lignite-fueled power station running on average at half its capacity might have annual CO_2 emissions estimated as:

= 1500MW x 0.5 x 100/40 x 101000 kg/TJ x 1year

= 1500MJ/s x 0.5 x 2.5 x 0.101 kg/MJ x 365x24x60x60s

= 1.5x103 x 5x10−1 x 2.5 x 1.01−1 x 3.1536x107 kg

= 59.7 x103-1-1+7 kg

= 5.97 Mt

Thus, the example power station is estimated to emit about six megatons of carbon dioxide each year.

Table E.1 Emission intensities. or Emissions Factors. The Intergovernmental Panel on Climate Change, (IPCC, 2006)

Emissions Factors		FE CO_2	FE CH_4	FE N_2O
Combustible		kg/MJ		
Coking Coal/Other Bituminous Coal	Hard coal	0.0946	0.000001	0.0000015
Lignite	Brown coal	0.101	0.000001	0.0000015
Residual Fuel Oil	fuel oil	0.0774	0.000003	0.0000006
Gas/Diesel Oil	other oil	0.0741	0.000003	0.0000006
Natural Gas	Gas	0.0561	0.000001	0.0000001

Table E.2 Emission intensities or Emissions Factors. [INEGyCEI]

Emissions Factors		FE CO_2	FE CH_4	FE N_2O
Combustible		kg/MJ		
Mix 1/3 to 2/3 of Coking or Bituminous Coal/Lignite	Coal	0.127907450	0.00000095	0.00000143
Residual Fuel Oil	Fuel oil	0.079450290	0.00000300	0.00000060
Natural Gas	Gas	0.057755930	0.00000100	0.00000010

Results presented only for 1,700 MW total reserve

Table E.3. Reduction estimation of CO_2 for the SIN emissions assuming the inclusion of energy storage technologies (1,700 MW) corresponding to the provision of ancillary services.

Method	IPCC	INEGyCEI	Kindle
Technology	kt CO2e		
Coal	419	530	396
Gas steam turbine	138	1,131	1,607
Combined cycle	1,146	242	109
Single cycle gas turbine	737	756	88
Internal combustion	58.0	57.0	1.4
Total	2,498	2,715	2,201

Table E.4 Reduction estimation in CO_2 emissions (Mtons) by control area and technology, Kindle

Method	Kindle					
Technology	Coal	Gas steam turbine	Combined cycle	Simple cycle	Internal combustion	Total
Control region	kt CO_2					
Central	0	18	323	0	0.0	341
Eastern	0	24	434	0	0.0	458
Western	254	19	356	0	0.0	630
Northwest	0	8	153	43	0.0	204
North	0	6	104	0	0.0	109
Northeast	142	11	199	56	0.0	407
Peninsular	0.0	2.1	38	11	0.0	51
BCS	0.0	0.5	0	0	1.4	2
Total	395.7	88.4	1,606.6	109.3	1.4	2,201

Table E5 Reduction estimation in CO_2 emissions (Mtons) by control area and technology, IPCC

Method	IPCC					
Technology	Coal	Gas steam turbine	Combined cycle	Simple cycle	Internal combustion	Total
Control region	kt CO_2					
Central	0.0	38.3	0.0	25.2	0.0	63.5
Eastern	0.0	194.7	149.4	33.5	0.0	377.6
Western	216.3	224.0	176.7	15.3	0.0	632.3
Northwest	0.0	73.0	98.7	2.2	0.0	174.0
North	0.0	51.9	164.7	5.6	0.0	222.2
Northeast	202.4	104.0	431.5	18.9	0.0	756.8
Peninsular	0.0	21.7	77.8	37.8	0.0	137.3
BCS	0.0	29.8	0.0	46.7	58.0	134.5
Total	**419**	**737**	**1,099**	**185**	**58**	**2,498**

Table E6 Reduction estimation in CO_2 emissions (Mtons) by control area and technology, INGyCEI

Method	INGyCEI					
Technology	Coal	Gas steam turbine	Combined cycle	Simple cycle	Internal combustion	Total per region
Control region	kt CO2e					
Central	0	39	0	26	0	65
Eastern	0	200	154	50	0	404
Western	274	230	182	23	0	708
Northwest	0	75	102	3	0	180
North	0	53	170	8	0	231
Northeast	256	107	444	28	0	835
Peninsular	0	22	80	57	0	159
BCS	0	29	0	46	57	132
Total	**530**	**756**	**1,131**	**242**	**57**	**2,715**