How the Scenario Explorer Model Works
March 10, 2025

The model is quite simple (see Table 1):

1. Based on the “CO2 Emissions and Removals” from four sources, the model calculates the “Total Net CO2“, “Cumulative CO2”,” CO2 PPM Added/Year”, “CO2 PPM”, and “CO2 Radiative Forcing”.
2. The expected temperature increase is calculated based on a formula for a “climate factor” (“CF ratio of the temperature increase to the total radiative forcing): Temperature increase = “climate factor” * Total RF

Scenario Explorer Calculations				
Item		**Units**	**2050**	**2100**
CO2 Emissions and Removals				
Anthropogenic		GTCO2	30.00	5.00
Carbon Removal at the Source		GtCO2	0.00	0.00
Carbon Removal from Atmosphere		GtCO2	0.00	0.00
Feedbacks	(Formula if no data)	GtCO2e	9.00	17.00
CO2 Calculations				
Total Net CO2	(Sum)	GtCO2	39.00	22.00
Cumulative CO2	(Sum)	GtCO2	1215.00	2482.00
CO2 PPM Added/Year	(Formula)	PPM	1.85	-0.03
CO2 PPM	(Add)	PPM	497.00	504.00
CO2 Radiative Forcing	(Formula)	W/m-2	3.21	3.29
Radiative Forcing *(Includes the CO2 RF above)*				
CH4		W/m-2	0.61	0.59
N2O		W/m-2	0.28	0.38
Aerosol		W/m-2	-0.70	-0.50
Other Radiative Forcing		W/m-2	1.05	0.86
Albedo		W/m-2	0.00	0.00
Temperature Increase Calculations				
Total Radiative Forcing	(Sum)	W/m-2	4.41	4.62
Ratio “Temp Incr”/”Total RF” (Clim. Factor - “CF”)	(Formula)	°C/(W/m-2)	0.48	0.57
Temperature Increase	(CF * Total RF)	°C	2.15	2.63

Table 1. Calculating the Expected Temperature Increase

Scenario Data

The input data for most of the scenarios that can be analyzed with this program was derived from global climate models and include all of the “CO2 Emissions and Removals” elements (with the possible exception of feedbacks) and all of the “Radiative Forcing” elements, where the “Other Radiative Forcing” was calculated by subtracting the radiative forcings of CO2, CH4, N2O, and aerosols from the “Total Radiative Forcing”. (The data for the “SSP” and “AR6” scenarios was obtained from an IPCC spreadsheet and data for the “En-ROAD” scenario was obtained from running the En-Roads model).

The minimum requirement for a scenario is the specification of the CO2 emissions. The values for the other "emissions and removals" and the "radiative forcing elements" all have default values. The "Moderate" scenarios and "Simplified Net-Zero Emission Scenarios" are in this category. The "Mod" scenarios are based on the "Moderate" scenario and have one additional data element (SRM to reach 1.5°C, carbon removal to reach 1.5°C, and temperature acceleration).

Formulas Summary (details shown at the end)

1	Feedbacks	If a scenario does not have feedbacks, the model assumes that feedback emissions in 2025 will be 2 GTCO2 and will increase linearly to 2100. The 2100 value is determined by the expected temperature increase based on the cumulative non-feedback CO2 emissions in 2100 and is calculated by multiplying that number by 5 (the expected feedback emissions per degree of warming)
2	CO2 PPM Added/Year	If the "Total Net CO2" >=0 = 0.009993255 * $NetCO2^2$ + 0.252616086 * NetCO2- 10.6147928 + 4 * (yr - 2025) / 75 + 0.6 If the "Total Net CO2" <0 = -0.002194629 * $NetCO2^2$ + 0.485752274 * NetCO2 - 10.22581346
3	CO2 Radiative Forcing from CO2 PPM	= -7.2875E-06 * $CO2PPM^2$ + 0.018987517 * CO2PPM - 4.390914936
4	Climate Factor (CF) Temp Increase/Total RF	= (-2.07932167252698E-07 * YEAR * YEAR + 0.000871260688455337 * YEAR - 0.912804514777875) * CO2PPM + (0.0000636483061382873 * YEAR * YEAR - 0.266585156783745 * YEAR + 279.779588212216)

Table 2. Formulas Summary (see the spreadsheet https://scenexp.org/Documentation/SEFormulas.xlsx for details)

Calculations For RFs other than CO2 (when the scenario does not include RF values)

The values for RFs other than CO2 indicate how "aggressively" the other radiative forcing elements will be mitigated. An "aggressiveness value" of 1 to 10 is assigned to a scenario based the scenarios CO2 PPM in 2100 versus that of the SSP5-Baseline scenario (1,000 PPM) and the SSP1-19 scenario (392 PPM) (see Table 3.)

CO2 PPM in 2100									
1000	932	865	797	730	662	595	527	460	392
1	2	3	4	5	6	7	8	9	10
Aggressiveness Value									

Table 3

The Scenario Explorer calculates RF value proportionally to the SSP1-19 values and the SSP5-Baseline values based on an "aggressiveness value". For example, if the 2100 values for CH4 RF for the SSP1-19 and SSP5-Baseline scenarios are 0.15 and 0.93 respectively and the "aggressiveness value" is 5, the CH4 RF in 2100 is 0.5 (=0.15+(0.93-0.15)*((AggVal-1)/9))

Other Useful Formulas (see the spreadsheet https://scenexp.org/Documentation/SEFormulas.xlsx for details)

5	N2O RF from N2O ppb	= 0.003298327 * N2OPPB - 0.867763803
6	CH4 RF from CH4 ppb	= -5.98799E-08 * CH4PPB * CH4PPB + 0.000618751* CH4PPB - 0.389737122
7	CH4 Emissions to CH4 RF	= -1.2236E-06 * CH4Emiss * CH4Emiss +0.002191 * CH4Emiss + 0.010683 Not a particularly good correlation but it might be useful

Table 4

Formula Details

1. Feedbacks

Step 1 – Calculate the expected temperature increase based on cumulative net CO2 emissions (not including feedbacks)

IPCC CO2 Budget

	1.5	1.7	2
Post 2019	400	700	1150
Post 2024	200	500	950

Linear Coefficients

A	B
0.000667	1.366667

Formula: Temperature for feedback calculation = 0.000667 * Cum Co2 + 1.366667

Table 5

Step 2 – Calculate the expected feedback in 2100

- Assuming 2 GTCO2 from feedbacks in 2025, the IPCC estimate of 0.166 W/m-2 of warming appears to assume that feedbacks would be about 2 GTCO2/°C of warming in 2100
- Current feedbacks are about 3-5 GTCO2 for 1.3°C of warming, so about 3GTCO2 of feedback emissions on 2100 per °C
- The reduction carbon sinks in the Amazon and Arctic, amount to about 2 GTCO2/year, should also be considered as feedbacks
- Therefore 5 GTCO2 seems to be a reasonable estimate of the emissions from natural feedbacks per °C of warming

feedback in 2100 = Temperature for feedback calculation * 5

(“Expert” opinion would really be helpful!)

(see the “Feedback” tab in the spreadsheet https://scenexp.org/Documentation/SEFormulas.xlsx)
(see a “discussion” of feedbacks at https://scenexp.org/Documentation/More on Feedbacks from ChatGPT.pdf)

2. CO2 PPM Added/Year

The formula for “CO2 PPM Added/Year” was derived from En-Roads as the IPCC AR6 data that I had access to was not sufficient to develop such a formula.

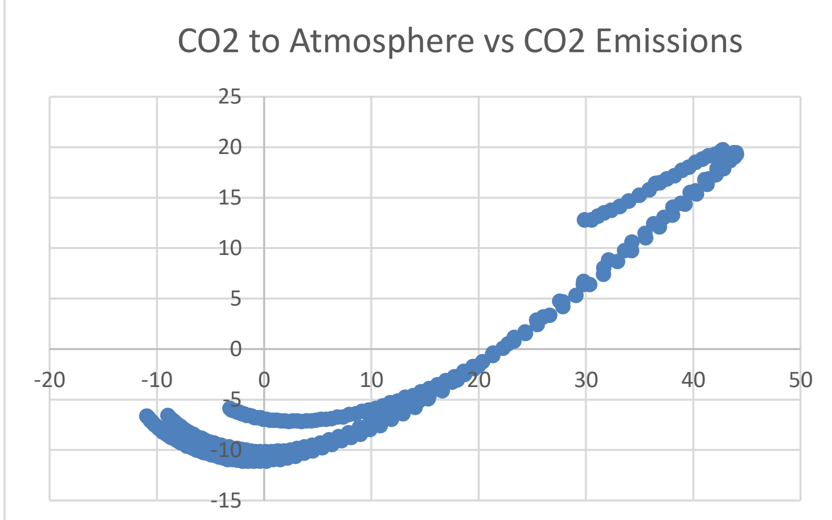
En-ROADs was used to create fourteen scenarios with temperature increases from 1.4°C to 4.0°C and the data copied to the spreadsheet at https://scenexp.org/Documentation/ENRoadsScenerioValues.xlsx. Table xx shows a “scatter plot” the “Net CO2 emissions” vs the “CO2 Added to the Atmosphere” for the scenarios with temperature increases of 1.4°C, 1.6°C, and 1.8°C.	

Table 6. Scatter plot” of “Net CO2 emissions” vs the “CO2 Added to the Atmosphere”

Selected data points in the above graph were used to create a polynomial function to be used when net emissions were greater than 0.

Coefficients for polynomial function (for emissions > 0)		
A	**B**	**C**
0.00999325	0.252616086	-10.6147928
Selected Data Points		**Calculated value**
-0.35	-10.153	-10.70198426
0.15	-10.153	-10.57667554
0.21	-11.0902	-10.56130272
9.86	-7.9662	-7.152457946
9.88	-7.2633	-7.143460287
10.4	-5.8575	-6.906715053
10.81	-7.5757	-6.716240113
10.88	-6.7947	-6.683384228
19.58	-1.9525	-1.837391728
19.96	-1.6401	-1.591246961
20.35	-1.2496	-1.335623726
29.75	6.4042	5.745190973
39.7	15.5419	-2.569595291
44	19.3	19.84725658

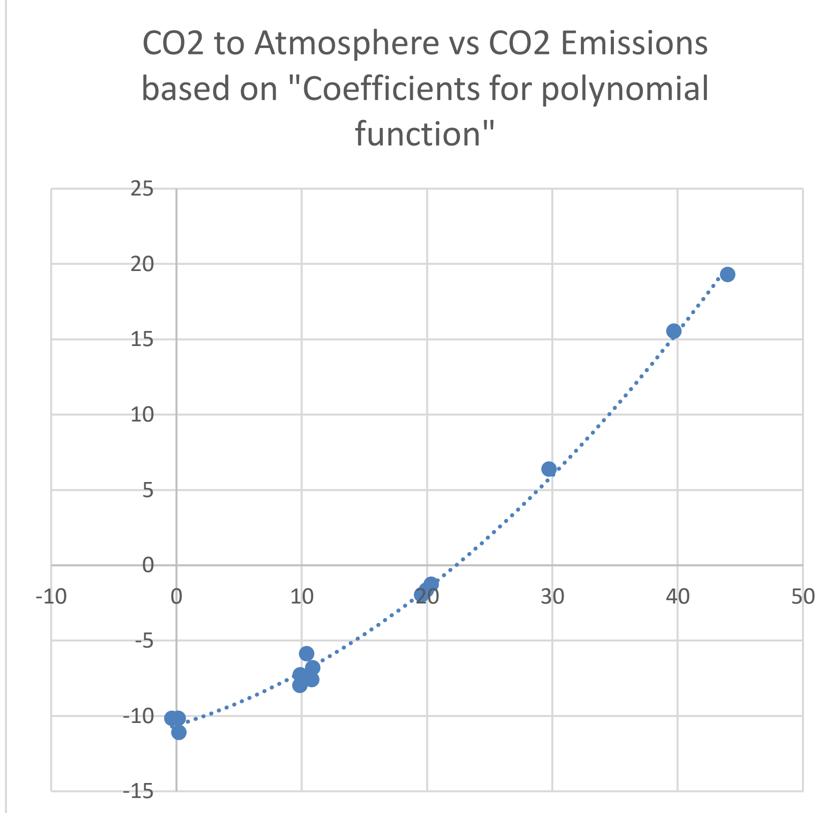


Table 7

The polynomial formula was a bit “off” when applied to scenarios with temperature increases less than 3.0°C (where the calculated value was off more as the year increased), but an adjustment of “4 * (year - 2025) / 75 + 0.6” resulted in a value that is almost always within 1 PPM of the scenario's value for scenarios with temperature increases under 3.0°C.

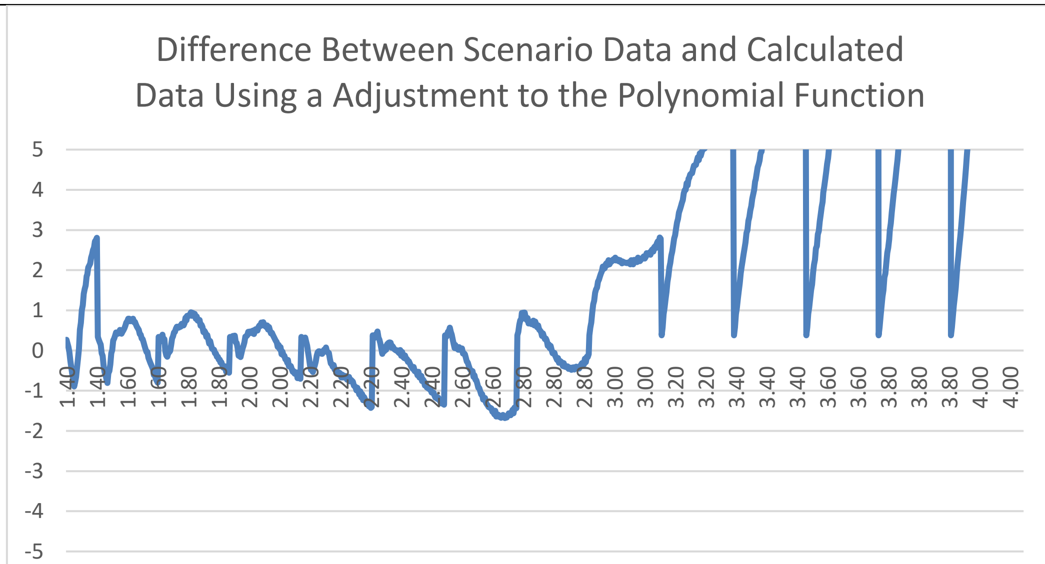


Table 8

The data in the “CO2 to Atmosphere vs CO2 Emissions” graph above do not really represent what happens when net emissions are less the zero. To compensate for this another polynomial function was created based on the two data points in the graph and an estimate that the atmospheric concentration of CO2 would be reduced by 40 GCTCO2 if 50 GTCO2 were removed from the atmosphere as oceans and land gave up some of the CO2 that was sequestered at higher concentrations of CO2.

The formula for net emissions less than zero does not do a good job of matching the En-Roads data, but I think the En-Roads calculations are erroneous.

Coefficients for polynomial function (for emissions < 0)		
A	**B**	**C**
-0.00219	0.485752	-10.22581
Data from graph used to create the polynomial function		**Calculated value**
-50	-40	-40
0.15	-10.153	-10.153
20.35	-1.2496	-1.2496

Table 9

3. **CO2 Radiative Forcing from CO2 PPM**

A scatter plot of CO2 RF from CO2PPM for 2040, 2050, and 2100

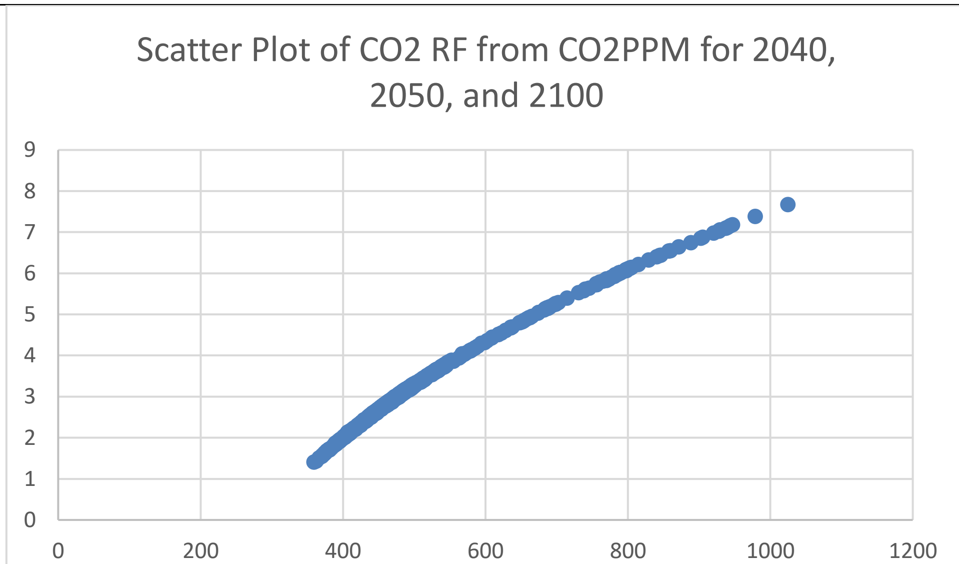


Table 10

4. **Climate Factor (CF) (the ratio of the temperature increase to the total RF)**

Data from the IPCC AR6 report was used to calculate the "Climate Factor" (=Temp/RF) (see Table XX for sample data)

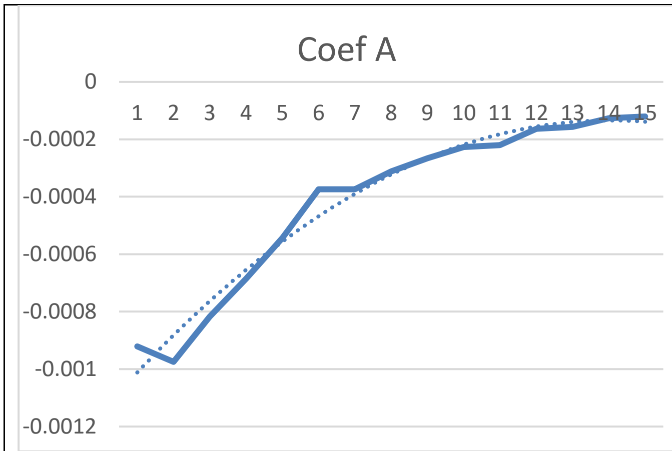
Data from IPCC AR6					Calculations		
Model Scenario ID	**Year**	**CO2 PPM**	**RF**	**Temp Increase**	**Climate Factor (Temp/RF)**	**Calculated CF Value**	**Difference**
572	2030	415.0418	2.9060	1.3931	0.4794	0.4796	0.0002
574	2030	420.5679	2.9918	1.4081	0.4707	0.4740	0.0033
407	2030	420.7796	2.9917	1.4102	0.4714	0.4738	0.0024
230	2030	422.1964	3.2164	1.4633	0.4549	0.4723	0.0174
229	2030	422.2136	3.2156	1.4629	0.4549	0.4723	0.0174
232	2030	422.2136	3.2156	1.4629	0.4549	0.4723	0.0174
425	2030	422.4094	3.0284	1.4183	0.4683	0.4721	0.0038
423	2030	422.4538	3.0309	1.4187	0.4681	0.4721	0.0040
676	2030	422.9494	3.1579	1.4550	0.4607	0.4716	0.0108

Table 11

For each year divisible by 5, the "A" and "B" coefficients for a linear equation relating the temperature increase to the total radiative forcing were derived.

Year	A	B
2030	-0.000921319	0.85085286
2035	-0.000974769	0.90201142
2040	-0.000817824	0.84894730
2045	-0.0006851	0.81353166
2050	-0.000543233	0.75888388
2055	-0.000373651	0.70512854
2060	-0.000373651	0.70512854
2065	-0.000311826	0.68610271
2070	-0.000266149	0.67275039
2075	-0.00022687	0.66025776
2080	-0.000219796	0.66603152
2085	-0.000163687	0.64041555
2090	-0.00015699	0.64802631
2095	-0.000126149	0.63347734
2100	-0.000120339	0.63985230

Table 12



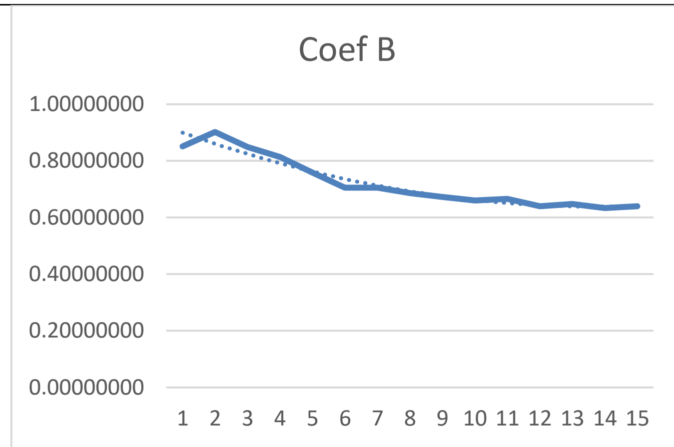


Table 13

Polynomial coefficients ("A", "B", and "C") for the above "A" and "B" coefficients were derived

	A	B	C
A	-2.06358E-07	0.000864732	-0.90603
B	6.29012E-05	-0.263486158	276.5668

The formula for calculating the "Climate Factor" (or "CF", the ratio of the temperature increase to the total radiative forcing) then becomes:

$$CF = (-2.07932167252698E{-}07 * YEAR * YEAR + 0.000871260688455337 * YEAR - 0.912804514777875) * CO2PPM + (0.0000636483061382873 * YEAR * YEAR - 0.266585156783745 * YEAR + 279.779588212216)$$

The formula works very well:

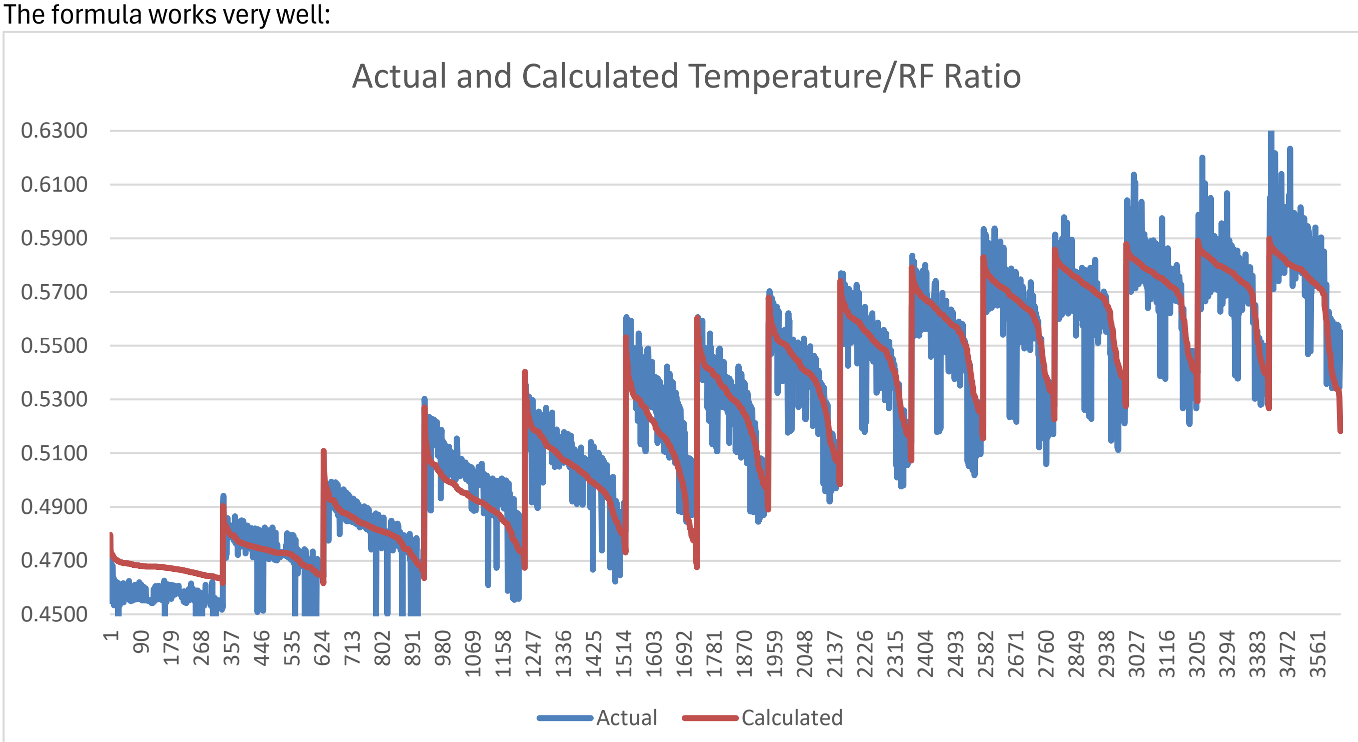


Table 14

Calculations For RFs other than CO2 (Details)

In order to avoid the need for a user to specify the radiative forcing for all forcing elements other that CO2, the Scenario Explorer calculates an “aggressiveness value” for as each scenario as it is evaluated, with 1 being the least aggressive and 10 being the most aggressive. The “aggressiveness value” is calculated based on the CO2 PPM value in 2100 for the scenario as it compares the CO2 PPM value for SSP1-19 and SSP5-Baseline. If the scenario's CO2 PPM value is close to those of SSP1-19 its "aggressiveness value" is set to 10, while if the scenario's CO2 PPM value is close to those of SSP5-Baseline its "aggressiveness value" is set to 1. For other values for CO2 PPM the "aggressiveness value" is set to value between 1 and 10 based proportionally. The user can override the "Default" value by checking the "Aggressiveness" checkbox to the right of the "Options" text on the "Scenario Explorer"

The "Aggressiveness value" = -0.014802632* CO2PPM in 2100 + 15.80263158

CO2 PPM in 2100									
1000	932	865	797	730	662	595	527	460	392
1	2	3	4	5	6	7	8	9	10
Aggressiveness Value									

Table 15

The Scenario Explorer calculates RF value proportionally to the SSP1-19 and SSP5-Baseline based on the "aggressiveness value". For example, the 2100 values for CH4 RF for the SSP1-19 and SSP5-Baseline scenarios are 0.15 and 0.93 respectively. For an value "aggressiveness", the CH4 RF in 2100 is 0.5 (=0.15+(0.93-0.15)*((AggVal-1)/9))

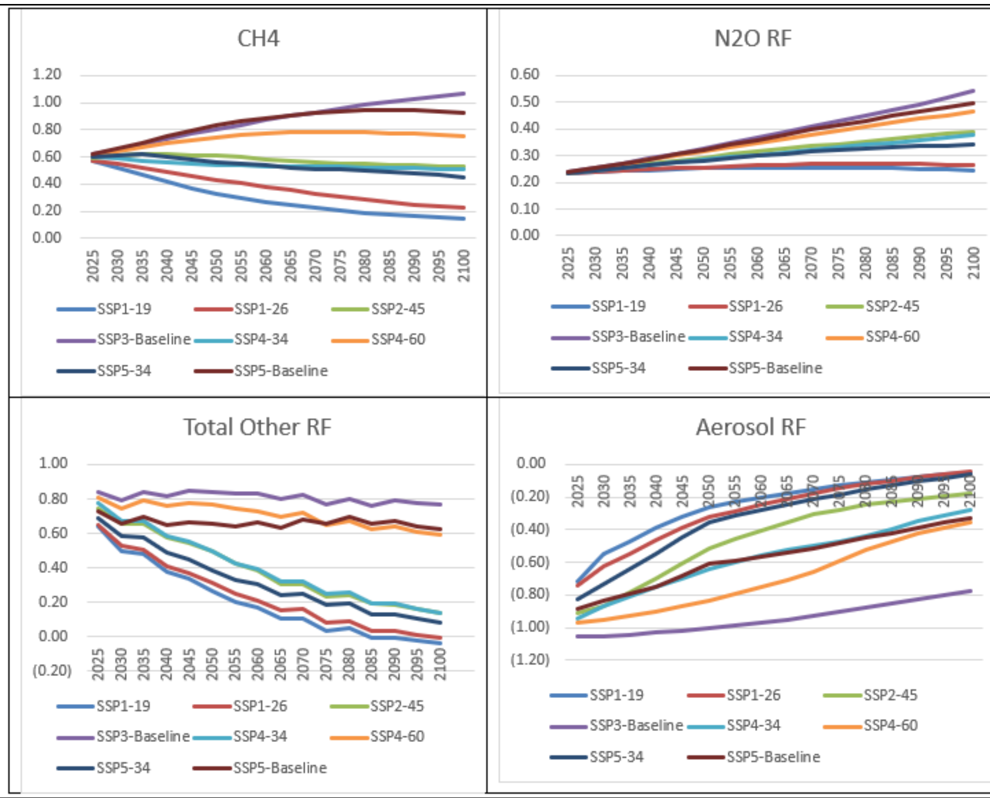


Table16

Cost Curves

The costs associated with a scenario are calculated based on a series of “cost curves”. The “Options” tab for the model shows the available curves and the current one selected. (The current curves are just a “wild guess”. “Expert” opinion is really need to derive a better series of curves and select a reasonable one for the model to use as a default.)

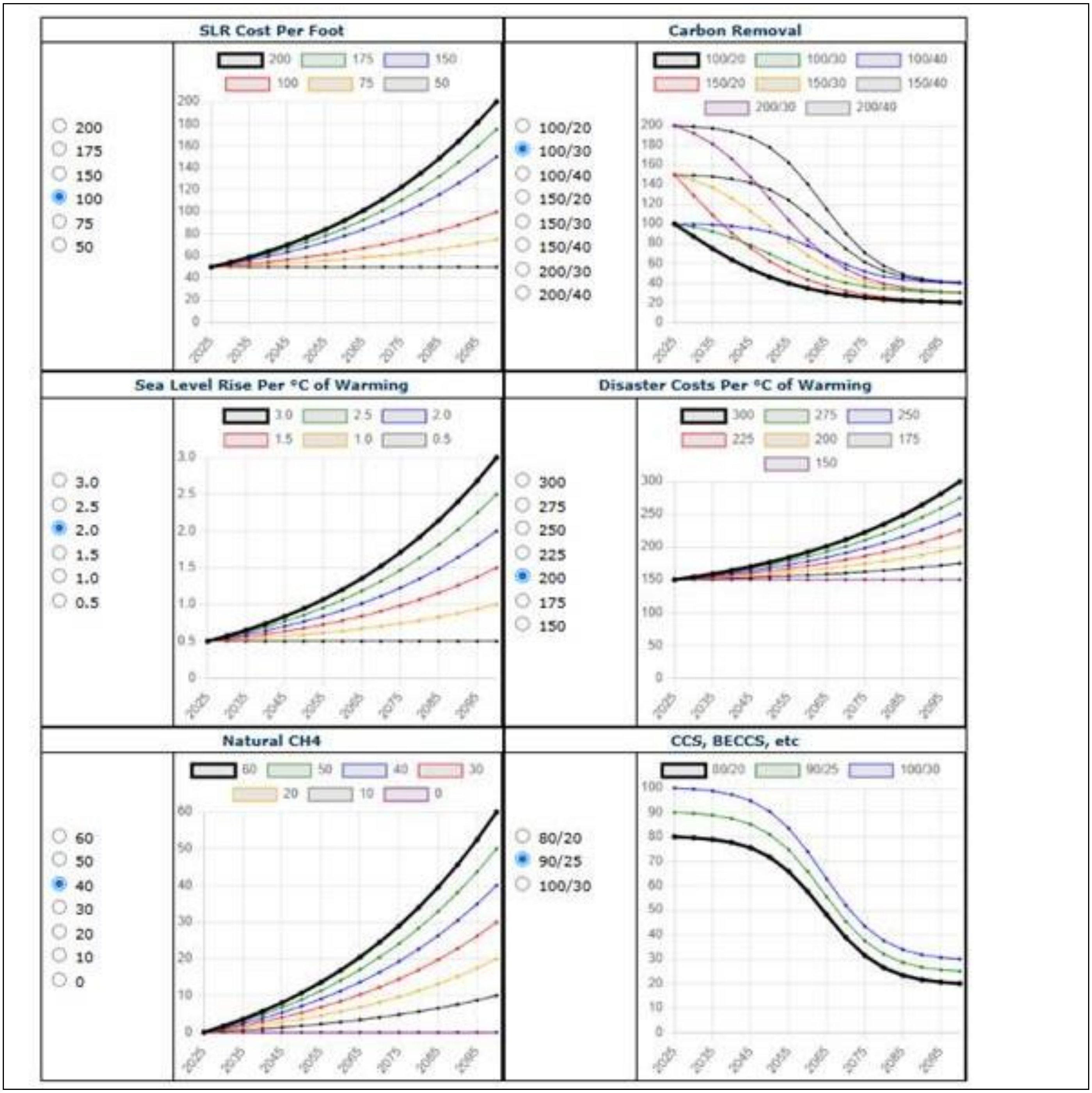


Table 17

Default cost curve values

Item	Units	Input Values														
		2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080	2085	2090	2095
Model Options - Select values on the 'Options' Tab																
CCS, BECCS, etc	$/Ton	90	90	89	88	85	81	75	66	55	45	37	32	29	27	26
Carbon Removal	$/Ton	100	97	92	86	78	69	60	52	45	40	36	34	32	31	30
Sea Level Rise Per °C	Feet	0.5	0.5	0.6	0.6	0.7	0.8	0.8	0.9	1.0	1.1	1.2	1.3	1.5	1.6	1.8
SLR Cost Per Foot	$B/Ft	50	51	53	55	57	59	61	64	67	70	74	78	83	88	94
Disaster Costs Per °C	$B/Yr	150	151	153	155	157	159	161	164	167	170	174	178	183	188	194

Table 18