Supplemental Material

This file contains additional statistical analysis of ESP v2.0 model results. The statistical metrics used are listed in Table S1. Mean Difference (MD) is a calculation of the average difference in emissions, *e*, between scenarios *A* and *B*, for a source category, *s*, over grid cells *i*=1 to *n*, where *n* is the set of grid cells. MD equals 0 over the full grid if each scenario uses the same emission growth factors. MD is useful in examining the sign and magnitude of difference for a subset of cells, such as those representing urban or rural land use. Mean Absolute Difference (MAD) is similar, but provides an indication in the emissions differences independent of the sign of those differences. Normalized Mean Absolute Difference (NMAD) calculates the ratio of MAD to the corresponding average grid cell value.

The primary metric used within the main body of the paper was Fractional Difference (FD). FD is a measure of the difference between two cells. FD is a symmetric metric ranging from -200% to +200%. A value of 67% for FD represents that e_A is larger than e_B by a factor of two, while an FD of 0 means that values are the same. The mean FD (MFD) provides information about the magnitude and variability of differences between two gridded inventories. The final two metrics are useful for understanding grid cell-level variation across grid cells from one result to another. Root Mean Square Difference (RMSD) is a measure of the standard deviation of grid cell differences between two model results. Normalized RMSD divides this value by the average grid cell value.

In Table S2, a number of these metrics are applied to evaluate grid-cell changes when disaggregating from the regional growth factors (*FutureRegGF)* to county-level growth factors (*Future)*. On average, NMAD shows grid cell emission values change from 3.6% to 13%, depending on species. The greatest variation is in CO and NOx. Differences between species are a function of their predominant source categories and whether the emissions from those source categories are affected by population shifts. NOx and CO are particularly highly correlated with population since transportation is responsible for a large component of the emissions of both.

Table S3 evaluates grid cell-level differences, *Future* minus *Future05Surr*. These metrics are correlated with the linkage between emissions and changing spatial surrogates. NMAD shows the greatest changes in VOC and CO emissions, each nearly 7%. In contrast, NMAD for SO_2 emissions is less than 1%. SO_2 emissions are mostly from power plants, which are grown in place.

Tables S4 and S5 provide additional insights into shifting emissions. In Table S4, MD is shown by species, calculated as the values for *Future* minus those of *FutureRegGF*. The table corresponds to Figure 10 in the text. The data are stratified by ranges of population density, and the number of cells within each range are shown. Overall, MD equals zero across all grid cell ranges for each pollutant, but stratification allows a more detailed assessment of changes in various density ranges. For example, the results for NOx show that using county-level emission growth factors increases emissions in grid cells with populations greater than 10,000. Emissions grid cells with projected populations less than 10,000 decrease. Growing emissions in place thus would not account for urban and suburban expansion into surrounding counties, nor would it capture emission changes from migration away from rural counties.

Table S5 shows the effects of adjusting future surrogates by subtracting results from *Future05Surr* from those of *Future*. The values correspond to Figure 12. The results indicate that updating surrogates decreases emissions from the most and least dense grid cells, while increasing emissions from cells in between. Note that both these results used to create this table include the updated regional-to-county mapping. Differences could be expected to be particularly great in large western counties with urban expansion. Expansion of urban areas would be represented in higher emissions in surrounding counties. Expansion of these emissions into urban and suburban grid cells would not occur without updates to spatial surrogates.

An additional file is also included in this Supplemental Information. The file "example_spatial_calculations.xlxs" demonstrates how county-level emission growth factors are developed from regional emission growth factors and population changes.

Table S1. Equations of statistical metrics used to compare differences of the Future Run from the two SF Runs for selected pollutants.

Metric	**Equation**
Mean Difference (MD**)**	$\frac{1}{n}\sum_{i=1}^{n}\left(e_A(i,s)-e_B(i,s)\right)$
Mean Absolute Difference (MAD)	$\frac{1}{n}\sum_{i=1}^{n}\left\|e_A(i,s)-e_B(i,s)\right\|$
Normalized Mean Absolute Difference (NMAD)	$\frac{MAD}{\frac{1}{n}\sum_{i=1}^{n}e_B(i,s)}$
Fractional Difference (FD)	$2*\left[\frac{e_A(i,s)-e_B(i,s)}{e_A(i,s)+e_B(i,s)}\right]*100$
Mean Fractional Difference (MFD)	$\frac{2}{n}\sum_{i=1}^{n}\frac{e_A(i,s)-e_B(i,s)}{e_A(i,s)+e_B(i,s)}$
Root Mean Square Difference (RMSD)	$\left[\frac{1}{n}\sum_{i=1}^{n}\left(e_A(i,s)-e_B(i,s)\right)^2\right]^{1/2}$
Normalized RMSD (NRMSD)	$\frac{RMSD}{\frac{1}{n}\sum_{i=1}^{n}e_A(i,s)}$

Table S2. Domain-wide 2050 annual emission difference metrics due to using regional rather than county-specific growth factors, *Future* minus *FutureRegGF*.

Future Run vs. Region-Factor SF Run				
Speceis	MAD	NMAD (%)	RMSD	NRMSD (%)
NOX	11.79	9.57	118.18	95.97
SO2	3.23	12.71	27.74	109.28
CO	73.01	8.08	443.41	49.09
PM10	2.37	6.73	14.69	41.63
PM25	1.77	6.78	9.25	35.34
VOC	11.93	3.57	52.66	15.75

Table S3. Domain-wide 2050 annual emission difference metrics due to using ICLUS 2005 surrogates rather than 2050, *Future* minus *Future05Surr*.

Future Run vs. 2005-Surrogate SF Run				
Speceis	MAD	NMAD (%)	RMSD	NRMSD (%)
NOX	4.66	3.78	26.72	21.70
SO2	0.09	0.36	0.51	2.02
CO	58.88	6.52	346.65	38.36
PM10	1.64	4.65	7.13	20.23
PM25	1.37	5.23	5.43	20.77
VOC	23.11	6.91	200.22	59.86

Table S4. 2050 Mean difference (MD) of annual emissions (ton) due to using regional rather than county-specific growth factors, stratified by grid cell population at 2050 (POP50 – 2050 population per grid cell, GRIDS – the number of grid cells), *Future* minus *FutureRegGF*.

POP50	NOx	SO2	CO	VOC	PM25	PM10	GRIDS
< 1k	-0.54	-0.09	-3.01	-0.78	-0.08	-0.10	116702
1k-5k	-5.41	-1.79	-35.46	-5.80	-1.11	-1.43	12425
5k-10k	-4.51	-2.99	-37.13	-1.03	-1.14	-1.69	2937
10k-30k	0.85	-2.98	-15.97	8.36	0.36	-0.19	2779
30k-50k	2.30	0.74	31.95	21.54	3.10	3.68	796
50k-80k	19.90	6.54	160.30	37.84	5.30	5.51	537
80k-130k	58.12	17.58	281.36	59.26	11.18	15.02	411
130k-200k	67.33	27.64	643.96	99.96	15.52	22.31	323
>=200k	265.44	87.88	1611.19	195.29	29.67	43.03	331

Table S5. Mean difference (MD) of 2050 yearly total emissions (ton) due to using ICLUS 2005 surrogates rather than 2050, stratified by grid cell population at 2050 (POP50, 2050 population per grid cell, GRIDS, number of grid cells) , *Future* minus *Future05Surr*.

POP50	NOx	SO2	CO	VOC	PM25	PM10	GRIDS
< 1k	-0.01	0.00	-0.13	-0.01	-0.01	-0.01	116702
1k-5k	0.16	0.00	2.99	1.90	-0.03	-0.02	12425
5k-10k	2.27	0.05	46.31	25.01	0.99	1.28	2937
10k-30k	8.57	0.16	140.83	92.51	2.28	2.59	2779
30k-50k	13.38	0.21	145.08	5.17	1.40	1.68	796
50k-80k	12.87	0.22	102.92	-56.99	0.47	0.05	537
80k-130k	1.50	0.01	-126.63	-160.95	-2.38	-2.53	411
130k-200k	-35.86	-0.65	-552.74	-286.33	-6.04	-6.54	323
>=200k	-115.52	-1.99	-1478.57	-507.59	-17.51	-21.62	331