Supplementary Materials

Contents

Supplementary materials for farm-level analysis *3*

Table 1 Detailed farm-level quantitative data for each state 3

Supplementary materials for flight-level analysis *4*

Table 2 Detailed short-range flight-level quantitative data for each origin state 4

Table 3 Detailed medium-range flight-level quantitative data for each origin state 6

Table 4 Detailed long-range flight-level quantitative data for each origin state 8

Table 5 Detailed short-range flight-level quantitative data for each destination state 9

Table 6 Detailed medium-range flight-level quantitative data for each destination state 11

Table 7 Detailed long-range flight-level quantitative data for each destination state 13

Supplementary materials for flight schedule optimization *14*

Table 8 Optimized farm-level quantitative data for each state 14

Table 9 Optimized short-range flight-level quantitative data for each origin state 15

Table 10 Optimized medium-range flight-level quantitative data for each origin state 17

Table 11 Optimized long-range flight-level quantitative data for each origin state 19

Table 12 Optimized short-range flight-level quantitative data for each destination state 20

Table 13 Optimized medium-range flight-level quantitative data for each destination state 22

Table 14 Optimized long-range flight-level quantitative data for each destination state 24

Supplementary materials for farm-and-flight selection optimization *25*

Table 15 Detailed quantitative data for each solar farm and flight market penetration rate 25

Table 16 System parameters 28

Table 17 Notation for optimization 29

Figure 1 10% Solar farm selection across different flight market penetration rates 31

Figure 2 20% Solar farm selection across different flight market penetration rates 33

Figure 3 30% Solar farm selection across different flight market penetration rates 35

Figure 4 40% Solar farm selection across different flight market penetration rates 37

Figure 5 50% Solar farm selection across different flight market penetration rates 39

Figure 6 60% Solar farm selection across different flight market penetration rates 41

Figure 7 70% Solar farm selection across different flight market penetration rates 43

Figure 8 80% Solar farm selection across different flight market penetration rates 45

Figure 9 90% Solar farm selection across different flight market penetration rates 47

Figure 10 100% Solar farm selection across different flight market penetration rates..... 49

Figure 11 10% Flight selection across different solar farm market penetration rates 51

Figure 12 20% Flight selection across different solar farm market penetration rates 53

Figure 13 30% Flight selection across different solar farm market penetration rates 55

Figure 14 40% Flight selection across different solar farm market penetration rates 57

Figure 15 50% Flight selection across different solar farm market penetration rates 59

Figure 16 60% Flight selection across different solar farm market penetration rates 61

Figure 17 70% Flight selection across different solar farm market penetration rates 63

Figure 18 80% Flight selection across different solar farm market penetration rates 65

Figure 19 90% Flight selection across different solar farm market penetration rates 67

Figure 20 100% Flight selection across different solar farm market penetration rates 69

Supplementary materials for case study..... 70

Note 1 Solar farm case study 70

Figure 21 Location and power transfer range of the selected solar farm in the solar farm case study 70

Figure 22 Flights supported by the selected solar farm in the solar farm case study 71

Figure 23 Energy supplied by the selected solar farm in the solar farm case study 72

Note 2 Flight case study 73

Figure 24 Selected flight and associated solar farms in the flight case study 73

Figure 25 Power received by the selected flight in the flight case study 74

Supplementary materials for farm-level analysis

Table 1 Detailed farm-level quantitative data for each state

State	CO2 Reduction (kg)	Fuel Cost Saving ($)	Total Capacity (MW)	Total Cost Saving ($)
AL	556974.2657	112878.8373	256.76986	218703.9478
AR	876300.7793	173863.672	404.61088	340360.82
AZ	3017590.654	588157.7422	1645.53446	1161499.967
CA	17181113.66	3305289.062	6431.68858	6569700.657
CO	1561134.509	305504.6171	697.46016	602120.1737
FL	8909972.495	1869012.351	1695.06584	3561907.125
GA	4082156.589	836149.9182	1402.273	1611759.67
IA	464332.918	95946.34634	125.00532	184169.6008
ID	125733.3259	25591.68148	157.20628	49481.0134
IL	1193829.439	242271.8002	387.46052	469099.3935
IN	1518178.529	273582.4831	521.15204	562036.4036
LA	81183.21991	15671.7725	87.02766	31096.58428
MI	1041404.032	215962.615	247.55984	413829.381
MN	49703.78104	9905.506331	62.25778	19349.22473
MS	540647.1784	112234.5774	198.93006	214957.5413
MT	38925.22086	8197.913744	67.30136	15593.70571
NC	4880328.908	1019063.718	723.1281	1946326.21
NM	872322.0105	175269.5494	463.5394	341010.7314
NV	3530085.419	689993.0423	1923.84938	1360709.272
OH	2564415.477	500633.0263	772.44572	987871.9668
OK	50672.7783	10500.49116	42.3656	20128.31903
OR	30948.67192	6005.713342	86.8029	11885.96101
PA	615774.8352	130405.9671	59.97754	247403.1858
SC	2400951.603	504176.4466	438.37744	960357.2511
SD	119388.3351	24889.58036	92.6355	47573.36403
TN	626481.4339	128455.4216	146.68454	247486.894
TX	8723495.937	1612672.469	7530.43948	3270136.697
UT	1605029.542	331368.0006	988.9374	636323.6136
VA	5279426.642	1074306.708	930.11296	2077397.77
WA	23512.79787	4523.616762	89.545	8991.048357
WI	1077429.417	219769.6721	582.71876	424481.2613
WY	283544.8799	57624.76251	94.46618	111498.2897
Total	73922989.28	14679879.08	29353.32954	28725247.04

Supplementary materials for flight-level analysis

Table 2 Detailed short-range flight-level quantitative data for each origin state

State	CO2 Reduction (kg)	Fuel Cost Saving ($)	Total Flight Distance (km)	Total Cost Saving ($)
AL	168146.2728	34683.14837	161847.8395	66630.94021
AR	138385.8711	25795.44393	197253.2868	52088.75944
AZ	4189951.736	808463.4117	1667854.673	1604554.241
CA	9832867.87	1904761.316	4991633.304	3773006.211
CO	1119132.741	217690.3106	1906250.742	430325.5314
CT	15183.29889	3190.866431	49490.30048	6075.693219
FL	5495562.797	1141485.394	5264828.763	2185642.326
GA	2618849.25	539195.6575	2904654.649	1036777.015
IA	30279.83613	6049.742618	77870.71346	11802.91148
ID	287805.1762	58567.61732	305358.4421	113250.6008
IL	991065.2073	196076.3371	1781766.266	384378.7265
IN	386511.7842	77032.364	678974.9194	150469.603
KS	39986.40663	8119.165974	94813.35585	15716.58323
KY	671936.6856	132689.5143	790433.3276	260357.4845
LA	91054.93404	18363.41717	280719.6249	35663.85464
MA	223511.6179	46470.4525	482799.6549	88937.6599
MD	525144.9357	108319.1152	715545.9291	208096.653
ME	10924.80964	2237.617848	42942.88959	4313.331679
MI	522082.0838	107054.3497	549669.7019	206249.9456
MN	387879.9394	79092.21685	665841.3674	152789.4053
MO	477942.4384	94848.1677	923258.8702	185657.231
MS	29193.09572	5912.38287	57822.79337	11459.07106
MT	29896.99899	6125.302781	128358.1259	11805.73259
NC	2367572.774	487340.7179	2469009.606	937179.5449
ND	5359.637324	1120.976007	16564.75131	2139.307098
NE	22625.32918	4241.721616	89404.18972	8540.534161
NH	9084.21581	1892.154919	31939.30858	3618.155923
NJ	329332.0758	67304.96745	487333.2531	129878.0618
NM	84023.64916	15606.71237	200097.0648	31571.20571
NV	1453948.181	285128.4666	894159.0761	561378.621
NY	1105325.76	225181.9272	1589797.225	435193.8216
OH	421231.6216	84659.44191	577458.1014	164693.45

OK	90474.38392	17477.83349	210482.5512	34667.96643
OR	287290.293	57692.01566	424675.1686	112277.1713
PA	955958.825	195817.4471	1023450.556	377449.6239
RI	33218.95772	6807.882149	67024.23758	13119.48411
SC	902554.0225	185184.4717	755011.0801	356669.736
SD	56329.96627	11457.33541	98538.51269	22160.029
TN	805536.9081	157192.7688	1204865.767	310244.7814
TX	4444388.834	846438.1564	5134003.054	1690872.035
UT	920550.5197	181328.6186	765891.8365	356233.2173
VA	1619673.523	331424.5131	1713832.216	639162.4825
VT	4652.495899	986.4673226	15968.46086	1870.441543
WA	52345.3774	10416.95059	100768.6257	20362.57229
WI	218817.8531	44331.51061	361516.9508	85906.90271
WV	9710.556568	2030.791075	10500.41871	3875.796823
WY	21092.91863	4213.383014	9130.132271	8221.037554
Total	44504394.46	8847500.544	42971411.68	17303335.49

Table 3 Detailed medium-range flight-level quantitative data for each origin state

State	CO2 Reduction (kg)	Fuel Cost Saving ($)	Total Flight Distance (km)	Total Cost Saving ($)
AK	13029.9127	2420.18599	26445.59432	4895.869403
AL	12385.7938	2606.89588	59825.7942	4960.196702
AR	31847.21453	6398.17754	62411.66192	12449.14831
AZ	610839.9084	117448.821	3206394.898	233508.4033
CA	4776210.706	919490.426	11297080.66	1826970.46
CO	700956.6675	142876.708	3288854.437	276058.4749
CT	76825.26381	15753.9198	211603.8983	30350.71996
FL	6013781.964	1230850.76	10551920.14	2373469.332
GA	362339.548	71178.7256	1638366.143	140023.2397
IA	46538.25056	9496.17407	149812.3127	18338.44168
ID	5900.957404	1164.50144	40909.29876	2285.683343
IL	1674288.454	336073.217	3965382.467	654188.0231
IN	205710.3154	41600.665	441843.7706	80685.62493
KS	881.0626347	187.638072	10617.98379	355.0399731
KY	77102.03417	15925.6083	297777.0383	30574.99483
LA	119671.8322	22763.1817	382970.928	45500.82982
MA	300735.2509	61018.0931	1210896.967	118157.7908
MD	367793.1617	71894.539	1115510.969	141775.2398
ME	25242.91017	5271.83057	50978.4427	10067.9835
MI	769881.0538	157732.709	1750753.943	304010.1093
MN	432194.9672	86358.9712	1545104.361	168476.015
MO	342343.2444	69034.7653	772977.9052	134079.9817
MT	13792.02028	2499.53176	79628.77544	5120.015616
NC	230152.4488	45425.0481	1608809.308	89154.01337
ND	38802.34341	7632.481	57132.37281	15004.92625
NE	34107.50834	6631.06117	133155.1803	13111.48776
NH	47361.4662	9887.9459	80616.4514	18886.62447
NJ	904704.9583	183073.519	2594875.3	354967.4613
NM	19375.99677	3886.24845	91843.36637	7567.687835
NV	701930.3065	132761.08	3161807.297	266127.8382
NY	1425794.577	288792.958	4733235.829	559693.9274
OH	338906.7611	68593.026	954481.8198	132985.3106
OK	37119.29758	7568.85968	119511.0743	14621.52622
OR	175637.7671	34882.4916	718286.1487	68253.66739

PA	697359.7441	141411.385	2085238.617	273909.7359
PR	82544.23968	16743.8814	370152.8388	32427.2869
RI	30720.56564	6410.78244	46286.30062	12247.68991
SC	34045.61024	7074.98506	136231.1613	13543.651
SD	16180.137	3263.04303	44200.56414	6337.269058
TN	110005.5205	22450.2462	696493.2375	43351.29507
TX	4423062.384	841718.866	8284300.56	1682100.719
UT	220600.4678	43652.1856	1249313.65	85566.27451
VA	563874.5256	109107.782	2342380.366	216243.9418
VI	4909.851747	1019.59547	44622.33805	1952.467303
VT	4878.738095	1009.82227	9832.244605	1936.78251
WA	778192.5829	154560.137	2623194.999	302416.7274
WI	196796.5039	39079.7414	371682.0701	76471.07714
WY	3167.931564	586.028677	11791.04258	1187.935674
Total	28100524.73	5567269.24	74727542.52	10906368.94

Table 4 Detailed long-range flight-level quantitative data for each origin state

State	CO2 Reduction (kg)	Fuel Cost Saving ($)	Total Flight Distance (km)	Total Cost Saving ($)
AK	2488.444018	456.7315035	34915.18983	929.535867
AZ	68018.39379	13314.95713	252268.6408	26238.45195
CA	240593.6908	48109.31062	2029368.281	93822.11186
CO	20303.30596	4214.759684	219141.8177	8072.387817
FL	195044.7423	40364.99245	662165.4219	77423.49348
GA	4770.048017	965.3859836	50570.95872	1871.695107
HI	213726.4253	41993.71398	1613437.069	82601.73479
IL	4071.745415	856.8027279	101319.5417	1630.434357
MA	128346.3209	25154.61687	965075.4017	49540.41784
MI	10592.81331	2192.430699	50209.4714	4205.065228
MN	4849.152223	976.7405839	44620.21629	1898.079506
NJ	51874.39547	10693.95519	432805.9826	20550.09033
NV	49916.48493	9263.819867	305057.1058	18747.952
NY	77087.39411	15903.34471	652807.0702	30549.94959
OR	17100.01996	3544.467927	126087.481	6793.471719
PA	22943.44323	4730.920073	132803.275	9090.174287
PR	7731.834638	1596.936058	30747.0198	3065.984639
TX	39026.06583	7563.606892	206019.5158	14978.5594
UT	5530.220758	1157.494972	129176.6583	2208.236916
VA	5739.744481	1175.893618	46281.83359	2266.445069
WA	129093.9036	26964.65329	432622.8312	51492.49496
Total	1298848.589	261195.5348	8517500.783	507976.7667

Table 5 Detailed short-range flight-level quantitative data for each destination state

State	CO2 Reduction (kg)	Fuel Cost Saving ($)	Total Flight Distance (km)	Total Cost Saving ($)
AL	165791.2486	34198.59216	159032.4673	65698.9294
AR	137581.5049	25657.03196	200032.9798	51797.5179
AZ	4260289.625	821729.4809	1658866.678	1631184.51
CA	9899450.39	1918945.137	5013493.331	3799840.711
CO	1134053.146	220849.3605	1905491.815	436319.4582
CT	13707.90202	2878.874464	49526.29996	5483.375849
FL	5496295.757	1141697.217	5279980.894	2185993.411
GA	2722214.825	560934.9882	2868443.919	1078155.805
IA	44631.62343	8919.993571	94530.25084	17400.00202
ID	250885.076	51077.09327	300901.0323	98745.2577
IL	1164118.272	230157.1075	1812281.798	451339.5792
IN	397101.1297	79159.62369	682786.8474	154608.8383
KS	35135.07522	7103.966017	94725.27169	13779.63031
KY	664727.8426	131788.9374	794502.4002	258087.2275
LA	88117.98668	17746.63602	281816.17	34489.05349
MA	187795.3465	39034.28468	479190.3355	74715.40052
MD	492167.667	101426.7178	712987.028	194938.5746
ME	7855.292871	1610.813737	41501.98382	3103.319383
MI	526027.9848	107770.1432	556572.8204	207715.4603
MN	392931.5477	79954.94895	655201.0464	154611.943
MO	516460.5794	102431.0885	923744.7689	200558.5986
MS	28404.42108	5757.486455	58388.31092	11154.32646
MT	27834.01855	5671.578271	127654.384	10960.0418
NC	2385363.595	491826.6205	2465784.119	945045.7036
ND	5326.98744	1113.920083	16564.75131	2126.047696
NE	24522.13728	4571.2616	90724.11007	9230.467683
NH	10886.564	2239.426709	27767.16933	4307.87387
NJ	301421.8257	61564.52501	473286.2652	118834.6719
NM	88204.96042	16333.30884	203201.701	33092.25132
NV	1460393.173	286102.7105	888272.7836	563577.4134
NY	951084.5991	193756.5857	1583537.323	374462.6596
OH	410205.8206	82522.75372	574329.7229	160461.8596
OK	83833.29321	16142.38835	204478.295	32070.71406
OR	285714.8774	57403.99698	424492.5891	111689.8237

PA	886836.763	181698.661	1023182.454	350197.646
RI	29053.93581	5964.524232	67376.04555	11484.77204
SC	943469.0317	193677.9229	753769.477	372937.0389
SD	53557.46415	10903.9579	99278.86642	21079.87609
TN	804285.8521	157949.9409	1208295.626	310764.2528
TX	4492193.97	855983.6998	5156527.198	1709500.554
UT	879545.7007	173122.6411	761646.8995	340236.3242
VA	1451977.89	296970.3121	1691581.191	572846.1112
VT	5356.606713	1135.98937	17196.80401	2153.744646
WA	56340.22691	11226.95411	100768.6257	21931.59723
WI	215290.0398	43515.29145	368066.2842	84420.39902
WV	9547.429747	1996.802981	10500.41871	3810.814633
WY	16403.45864	3275.246375	9130.132271	6391.903517
Total	44504394.46	8847500.544	42971411.68	17303335.49

Table 6 Detailed medium-range flight-level quantitative data for each destination state

State	CO2 Reduction (kg)	Fuel Cost Saving ($)	Total Flight Distance (km)	Total Cost Saving ($)
AK	14458.00423	2673.87397	26445.59432	5420.894771
AL	11303.86686	2380.07	59825.7942	4527.804702
AR	37649.95512	7553.00341	60676.16231	14706.49488
AZ	661563.9886	127029.893	3194896.047	252727.0506
CA	5117099.05	984888.216	11247249.92	1957137.036
CO	776607.1567	158040.447	3304091.978	305595.8065
CT	65392.31863	13408.445	209907.6008	25832.98557
FL	5795978.176	1187418.71	10524056.93	2288654.565
GA	330272.6229	64855.7944	1641494.185	127607.5927
IA	53827.65233	10999.0896	179359.2456	21226.34355
ID	7038.825836	1378.12381	40909.29876	2715.500721
IL	1792666.587	360970.516	3946551.139	701577.1679
IN	202460.7212	41214.3851	433275.7513	79681.9221
KS	755.8521301	160.971435	8848.319821	304.5833397
KY	78610.59499	16281.8658	302071.0267	31217.8789
LA	104962.9745	19989.3352	400858.0324	39932.30035
MA	259281.7582	52558.1021	1194569.631	101821.6362
MD	339133.7864	66383.9076	1141999.745	130819.327
ME	21760.07617	4546.1687	53290.94992	8680.583173
MI	756646.3691	155047.177	1769184.017	298809.9873
MN	454295.72	90964.627	1555316.413	177280.8138
MO	366105.2545	74075.614	774883.2157	143635.6124
MT	15500.87576	2812.72703	79628.77544	5757.893426
NC	207237.4961	40971.3336	1625669.454	80346.45783
ND	41061.85647	8102.24612	57132.37281	15903.99885
NE	34303.9937	6685.53876	133155.1803	13203.29756
NH	35854.06818	7486.8089	78769.79208	14299.08186
NJ	823445.2441	166814.229	2588062.323	323268.8251
NM	17692.82508	3556.06544	95420.90005	6917.702207
NV	788713.7683	149238.563	3129358.163	299094.1789
NY	1282302.36	259797.489	4774410.427	503434.9374
OH	332477.067	67432.6	952560.2831	130603.2428
OK	45658.26528	9312.50571	119261.3394	17987.57612
OR	199294.3633	39514.6915	717246.0747	77380.62052

PA	636269.4818	129136.891	2084384.098	250028.0927
PR	71923.55804	14597.0514	366552.7214	28262.52742
RI	27285.00771	5694.22351	46286.30062	10878.37497
SC	29936.25716	6224.57337	134941.8033	11912.46223
SD	18183.61381	3668.11622	45737.13711	7123.002841
TN	103057.7167	21078.8212	684038.2314	40659.78737
TX	4341918.694	827475.311	8295408.762	1652439.863
UT	254337.664	50456.6465	1260447.808	98780.80266
VA	503627.754	97391.7208	2343735.943	193080.994
VI	4829.245089	985.844408	47062.68486	1903.400975
VT	4700.934331	972.582465	9832.244605	1865.759988
WA	819994.8766	162863.803	2600333.353	318662.8296
WI	209586.6412	41535.3023	376554.3182	81356.76414
WY	3459.78923	645.220209	11791.04258	1302.580163
Total	28100524.73	5567269.24	74727542.52	10906368.94

Table 7 Detailed long-range flight-level quantitative data for each destination state

State	CO2 Reduction (kg)	Fuel Cost Saving ($)	Total Flight Distance (km)	Total Cost Saving ($)
AK	2658.278412	474.813415	34915.18983	979.8863134
AZ	72264.01353	14159.65942	266368.8147	27889.82199
CA	282698.0575	56632.00917	2037595.184	110344.6401
CO	20983.28511	4354.560254	224616.1459	8341.384425
FL	162054.344	33526.09583	662165.4219	64316.42119
GA	4963.295445	1005.660571	50570.95872	1948.686705
HI	218494.8554	42975.82029	1588355.206	84489.84281
IL	3738.542858	786.909139	101319.5417	1497.232282
MA	112544.0561	22001.34148	965075.4017	43384.71214
MI	9519.596081	1971.936616	50209.4714	3780.659872
MN	4259.423837	857.9520805	44620.21629	1667.242609
NJ	43568.73606	8981.05893	428709.1339	17259.11878
NV	48356.78469	8958.964393	313835.6348	18146.75348
NY	61253.73738	12637.43599	640693.4477	24275.64609
OR	20835.83581	4321.983864	126087.481	8280.792668
PA	20471.70767	4220.057673	132803.275	8109.68213
PR	6680.341719	1380.58667	30747.0198	2649.851597
TX	35898.49014	6962.311785	206019.5158	13783.02491
UT	5578.712307	1168.066594	133889.0584	2228.021932
VA	5279.592992	1073.802625	46281.83359	2076.925294
WA	156746.9019	32744.50804	432622.8312	62526.4194
Total	1298848.589	261195.5348	8517500.783	507976.7667

Supplementary materials for flight schedule optimization

Table 8 Optimized farm-level quantitative data for each state

State	CO2 Reduction (kg)	Fuel Cost Saving ($)	Total Capacity (MW)	Total Cost Saving ($)
AL	590888.8987	119730.385	256.76986	218703.9478
AR	958284.9953	190233.856	404.61088	340360.82
AZ	3341398.39	651905.8682	1645.53446	1161499.967
CA	20210641.5	3886158.717	6431.68858	6569700.657
CO	1813628.458	356524.0727	697.46016	602120.1737
FL	10012124.05	2101133.314	1695.06584	3561907.125
GA	4620450.936	947334.7055	1402.273	1611759.67
IA	511118.6428	105630.2619	125.00532	184169.6008
ID	130747.654	26618.22557	157.20628	49481.0134
IL	1322906.652	268762.7412	387.46052	469099.3935
IN	1771079.128	316538.8521	521.15204	562036.4036
LA	83914.63349	16204.84833	87.02766	31096.58428
MI	1207171.772	250516.2177	247.55984	413829.381
MN	49860.72881	9937.363886	62.25778	19349.22473
MS	578662.8211	120139.5068	198.93006	214957.5413
MT	39998.3834	8424.058678	67.30136	15593.70571
NC	5605825.058	1171097.436	723.1281	1946326.21
NM	939428.4715	189003.2949	463.5394	341010.7314
NV	3927545.089	768361.3328	1923.84938	1360709.272
OH	2984329.539	583587.6031	772.44572	987871.9668
OK	51648.1439	10702.98494	42.3656	20128.31903
OR	31141.25868	6043.283976	86.8029	11885.96101
PA	749436.3365	158812.8572	59.97754	247403.1858
SC	2698151.333	566794.8983	438.37744	960357.2511
SD	125451.2954	26161.79435	92.6355	47573.36403
TN	711072.6325	145903.889	146.68454	247486.894
TX	9578100.281	1764791.789	7530.43948	3270136.697
UT	1680087.431	347005.5675	988.9374	636323.6136
VA	6262096.466	1274196.735	930.11296	2077397.77
WA	23795.60128	4578.728061	89.545	8991.048357
WI	1137555.232	232179.5868	582.71876	424481.2613
WY	309311.207	62853.31246	94.46618	111498.2897
Total	84057853.02	16687868.09	29353.32954	32658860.16

Table 9 Optimized short-range flight-level quantitative data for each origin state

State	CO2 Reduction (kg)	Fuel Cost Saving ($)	Total Flight Distance (km)	Total Cost Saving ($)
AL	180742.2978	37292.9092	162786.2969	71633.94579
AR	161199.3612	29396.69452	197857.2492	60024.57315
AZ	4801321.44	924877.3379	1673223.507	1837128.412
CA	11577648.85	2243854.031	5030501.057	4443607.312
CO	1253723.205	243967.8993	1920389.353	482175.3082
CT	18372.60887	3861.421328	52927.85756	7352.217013
FL	6269104.549	1302881.855	5285335.471	2494011.719
GA	2965195.29	610544.437	2959880.78	1173931.542
IA	34309.63821	6863.486412	79575.98994	13382.31767
ID	305785.5764	62251.63872	307472.5089	120350.8982
IL	1154937.783	228067.4418	1875720.425	447505.6206
IN	456206.5867	90783.29006	682276.176	177462.5415
KS	46650.45775	9515.132094	94813.35585	18378.71907
KY	778747.1263	153801.355	800029.1204	301763.309
LA	99638.16323	20094.99153	287366.5047	39026.24254
MA	256721.1158	53417.45027	482799.6548	102194.4623
MD	612038.3985	126234.1227	722123.7532	242521.4184
ME	13328.08753	2732.458246	44251.08849	5264.794877
MI	583654.2038	119615.7124	570815.2138	230510.0111
MN	413540.1144	84364.38912	670854.906	162937.0109
MO	536466.2289	106375.3642	925951.7876	208303.9477
MS	30816.69727	6240.713141	57822.79337	12095.88562
MT	31265.5352	6369.152201	128358.1259	12309.60389
NC	2682458.365	551925.1311	2551423.254	1061592.22
ND	5544.736254	1160.170473	16564.75131	2213.670361
NE	26539.51037	4927.19071	91483.12788	9969.697679
NH	13481.14421	2777.908294	31939.30858	5339.325695
NJ	388800.1654	79553.94946	511530.2313	153425.9809
NM	87740.03639	16257.84705	206306.3373	32928.45396
NV	1653983.315	324650.6047	911222.6398	638907.4345
NY	1328150.225	270680.6716	1682111.708	523029.2144
OH	484246.6322	97587.27602	580245.7493	189594.1361
OK	112860.081	21960.53212	245647.7943	43403.94751
OR	312147.0289	62704.17238	425695.5764	122012.1079

PA	1110831.15	227620.1236	1029604.401	438678.0421
RI	38296.73591	7838.299406	67024.23758	15114.67923
SC	1041947.972	213411.9079	757991.5972	411382.0225
SD	58535.92923	11918.80134	98538.51269	23040.6279
TN	888352.1354	172953.0076	1235518.748	341739.9133
TX	4914407.65	935474.8403	5172963.998	1869212.294
UT	971124.7021	191134.4672	776717.3338	375648.1606
VA	1877139.281	383860.4831	1745531.868	740516.9464
VT	5989.796789	1270.324509	15968.46086	2408.385898
WA	58000.71214	11545.73176	100768.6257	22565.86706
WI	234186.7488	47246.59777	365530.8582	91742.08005
WV	11380.16721	2378.889489	10500.41871	4541.121259
WY	21553.4504	4306.405269	9130.132271	8401.560844
Total	50909110.99	10118548.62	43653092.65	19791279.7

Table 10 Optimized medium-range flight-level quantitative data for each origin state

State	CO2 Reduction (kg)	Fuel Cost Saving ($)	Total Flight Distance (km)	Total Cost Saving ($)
AK	14823.93633	2747.870696	26445.59432	5564.418598
AL	15437.4528	3252.902729	59825.7942	6186.018762
AR	37013.84336	7436.100025	62411.66192	14468.73026
AZ	660053.1393	127026.0828	3212901.446	252436.1793
CA	5357094.918	1030411.815	11374653.69	2048259.849
CO	776276.3062	157786.6416	3422065.188	305279.1398
CT	90132.26639	18499.0134	211603.8983	35624.14402
FL	6811622.881	1394708.202	10669171.15	2688916.549
GA	402997.2173	79212.20259	1696882.63	155781.6739
IA	50775.73602	10377.16413	153106.2117	20024.55398
ID	6606.870445	1284.186288	40909.29876	2539.491673
IL	1901233.333	381354.8527	3984278.237	742589.1859
IN	227488.0185	46030.16397	441843.7706	89252.88749
KS	881.0625629	187.6379857	10617.98379	355.0398727
KY	88643.08722	18326.24983	304597.1035	35168.4364
LA	132353.8231	25155.90682	416677.9449	50303.13321
MA	351187.0731	71267.60311	1263435.877	137993.147
MD	420677.3742	82125.6213	1125835.8	162054.3224
ME	28094.10898	5868.466281	50978.4427	11206.34699
MI	884756.5643	181267.961	1773826.538	349371.7082
MN	485010.3513	96951.66416	1557848.092	189103.6309
MO	378521.8484	76340.88375	786530.3887	148260.0349
MT	14904.9159	2706.608689	79628.77544	5538.542709
NC	254188.5685	49957.10283	1655582.154	98252.93085
ND	40344.44881	7941.611742	57132.37281	15607.05702
NE	36220.46677	7051.03674	133155.1803	13932.92543
NH	52692.63011	11003.86352	80616.4514	21015.46324
NJ	1039315.423	210445.4873	2626028.975	407915.4176
NM	20284.80962	4074.640878	93632.13321	7928.754706
NV	770176.6811	145923.1242	3215570.85	292256.6936
NY	1676913.695	339542.283	4874553.398	658155.8851
OH	386556.4577	78199.62421	954481.8198	151645.3512
OK	44689.09356	9092.722779	125570.723	17583.65056
OR	189894.6508	37647.21444	718286.1487	73727.19809

PA	799535.1146	162061.6674	2106826.828	313973.3392
PR	90911.0275	18399.15139	370152.8388	35672.24662
RI	35774.02049	7467.453925	46286.30062	14264.51782
SC	39419.16936	8202.111602	144412.4817	15691.75378
SD	17074.8701	3446.61857	44200.56414	6690.843888
TN	121678.1929	24892.53977	718039.9013	48011.39642
TX	4974249.634	945125.0501	8369909.647	1890232.481
UT	240028.0554	47452.13252	1257184.521	93057.46305
VA	648009.791	124595.5315	2349200.006	247717.3918
VI	5892.486979	1183.613322	44622.33805	2303.185848
VT	6272.587022	1301.027596	9832.244605	2492.81913
WA	850615.7853	168943.402	2639558.358	330560.4012
WI	225543.6216	44671.62135	371682.0701	87524.90945
WY	3256.389156	601.0626928	11791.04258	1219.776632
Total	31706123.8	6279547.496	75744384.87	12303711.02

Table 11 Optimized long-range flight-level quantitative data for each origin state

State	CO2 Reduction (kg)	Fuel Cost Saving ($)	Total Flight Distance (km)	Total Cost Saving ($)
AK	2735.995545	496.6881169	34915.18983	1016.52727
AZ	87072.86846	17047.09443	261668.7567	33590.93943
CA	276056.7879	55148.08847	2029368.281	107598.8782
CO	21493.90241	4466.940521	219141.8177	8550.781978
FL	206366.5021	42698.07976	662165.4219	81907.71516
GA	5325.427435	1077.73341	50570.95872	2089.564623
HI	229209.8621	45000.32607	1618137.127	88550.19987
IL	4170.838793	877.8279864	101319.5417	1670.287357
MA	148764.5721	29068.44513	965075.4017	57333.71383
MI	11018.02329	2282.79107	50209.4714	4376.215496
MN	4849.152223	976.7405839	44620.21629	1898.079506
NJ	59545.19674	12284.22141	432805.9826	23597.8088
NV	54503.11118	10089.51408	305057.1058	20445.10521
NY	88691.08435	18309.54496	652807.0702	35160.85098
OR	18218.39567	3780.272162	126087.481	7241.76734
PA	25811.1904	5318.204739	132803.275	10222.33092
PR	8753.733998	1812.590488	30747.0198	3475.799947
TX	42180.61917	8178.44352	206019.5158	16192.76116
UT	5983.138069	1252.750315	129176.6583	2389.546548
VA	6365.148458	1293.197961	46281.83359	2502.576168
WA	135502.6851	28312.48021	432622.8312	54057.99038
Total	1442618.236	289771.9754	8531600.957	563869.4401

Table 12 Optimized short-range flight-level quantitative data for each destination state

State	CO2 Reduction (kg)	Fuel Cost Saving ($)	Total Flight Distance (km)	Total Cost Saving ($)
AL	180047.9655	37131.19161	161847.8395	71340.30505
AR	159368.4199	29179.13951	200636.9422	59459.13928
AZ	4898849.73	943551.0425	1668518.313	1874332.491
CA	11621242.57	2253436.597	5048532.445	4461472.686
CO	1281503.556	249474.0111	1915010.801	492959.6868
CT	16662.78057	3500.933894	54000.7069	6666.862202
FL	6247612.822	1298324.548	5292775.452	2485370.984
GA	3112066.2	641116.1841	2933792.069	1232408.762
IA	49197.38479	9805.849084	99137.58858	19153.35219
ID	279221.9846	56842.94874	303426.4099	109895.1258
IL	1330005.59	262319.5438	1883206.346	515020.6058
IN	477505.8115	95226.52201	688660.5646	185952.6262
KS	42734.40868	8684.863485	95193.52207	16804.40113
KY	770498.6969	152796.0039	801305.5974	299190.7563
LA	96027.59313	19365.14696	286551.8488	37610.38965
MA	217582.5464	45271.59877	484088.671	86612.28259
MD	569028.7324	117343.1915	721183.838	225458.6506
ME	10692.96287	2191.102139	45691.99426	4222.765085
MI	571477.592	117061.1039	565925.0395	225641.8463
MN	421584.0405	85869.26512	659259.2543	165970.2328
MO	584842.6534	115899.2641	926942.647	227019.3682
MS	29157.23702	5913.645764	58388.31092	11453.5208
MT	29838.78359	6074.015653	127654.384	11743.38453
NC	2726609.012	561826.577	2560587.131	1079882.289
ND	5719.116389	1195.941303	16564.75131	2282.573417
NE	28404.28844	5286.249952	93842.51731	10683.06475
NH	12556.22994	2583.018378	31786.80623	4968.702066
NJ	355819.7215	72775.86569	507351.6515	140381.6128
NM	90175.33867	16662.18063	205530.1782	33795.49498
NV	1648771.092	323331.5799	909163.0587	636598.0874
NY	1129334.219	230187.4612	1672868.464	444760.9628
OH	468251.0184	94364.6374	578241.4294	183332.3309
OK	104732.022	20256.8075	243643.9975	40155.89168
OR	322133.468	64706.6295	425512.9969	125911.9884

PA	1035260.16	212206.7613	1030366.278	408906.1917
RI	33159.12638	6782.46489	67376.04555	13082.6989
SC	1094993.895	224492.0282	757468.3798	432540.8682
SD	57664.62492	11694.93224	99278.86642	22651.21098
TN	887953.8447	173628.4682	1229749.784	342339.6987
TX	4946023.318	942098.9912	5188290.674	1881843.422
UT	928155.1031	182586.5638	772692.4878	358936.0334
VA	1710136.371	349705.1687	1733223.119	674631.0792
VT	5982.701822	1268.992887	17196.80401	2405.706233
WA	60578.44801	12071.48236	100768.6257	23581.38748
WI	231687.8318	46709.75139	370227.4643	90730.43943
WV	10888.18095	2277.587837	10500.41871	4346.342218
WY	17371.78772	3470.762221	9130.132271	6771.401888
Total	50909110.99	10118548.62	43653092.65	19791279.7

Table 13 Optimized medium-range flight-level quantitative data for each destination state

State	CO2 Reduction (kg)	Fuel Cost Saving ($)	Total Flight Distance (km)	Total Cost Saving ($)
AK	15192.92548	2815.651991	26445.59432	5702.307832
AL	13009.96898	2741.009642	59825.7942	5212.903747
AR	44262.44252	8893.142559	62411.66192	17303.00664
AZ	727445.7405	139860.8118	3201753.528	278075.5025
CA	5773702.105	1110436.223	11339823.98	2207439.623
CO	879959.3496	178638.5139	3430065.016	345830.7903
CT	78259.15424	16066.06732	209907.6008	30935.30663
FL	6577910.94	1348491.16	10638090.76	2598294.239
GA	358042.0687	70246.2051	1692708.331	138274.1982
IA	58808.91956	12029.13399	181006.1951	23202.82871
ID	7382.334236	1434.934609	40909.29876	2837.578114
IL	2040627.969	410482.9667	3976813.934	798202.2808
IN	225356.4011	45816.31991	436375.6233	88634.03612
KS	1005.1235	214.0589514	10617.98379	405.0324164
KY	84406.73374	17479.40474	307186.0756	33516.68415
LA	118412.224	22501.93193	421332.0559	45000.2545
MA	298254.9551	60493.83801	1229694.126	117162.2795
MD	381586.3927	74618.87567	1144396.931	147120.2903
ME	24686.04294	5158.447632	53290.94992	9848.795791
MI	866515.3049	177592.6949	1776114.788	342230.6029
MN	506073.6559	101397.5788	1570660.567	197551.5734
MO	407254.7797	82383.26791	782755.5676	159761.676
MT	17084.00439	3093.295913	79628.77544	6339.256747
NC	224288.0572	44127.12389	1672876.726	86741.85476
ND	43089.19406	8505.660726	57132.37281	16692.6076
NE	36647.18187	7153.887431	133155.1803	14116.85199
NH	42115.49471	8796.456418	78769.79208	16798.40041
NJ	943667.667	191229.4521	2620940.484	370526.3089
NM	19389.93263	3907.661169	97209.66689	7591.748369
NV	869552.4322	164790.5157	3215995.813	330005.4778
NY	1491868.643	302259.1105	4888325.646	585714.1527
OH	376834.1221	76446.92654	957862.0071	148045.4097
OK	51428.13343	10473.7274	125239.0456	20245.07275
OR	209738.3455	41521.94883	717246.0747	81372.23448

PA	727920.886	147625.3376	2108530.479	285930.3059
PR	79036.48762	15997.25728	366552.7214	31014.18993
RI	30124.0711	6288.010592	46286.30062	12011.5841
SC	33109.02498	6888.098216	145974.2084	13178.81296
SD	19806.18443	3999.012094	45737.13711	7762.187135
TN	114120.1641	23398.14061	705375.3883	45080.97179
TX	4886625.479	929641.425	8381545.984	1858100.266
UT	278024.7814	55072.36801	1262036.529	107897.0765
VA	569672.1204	109653.0617	2349039.988	217890.7646
VI	5172.395896	1043.366504	47062.68486	2026.121724
VT	5531.610707	1147.359475	9832.244605	2198.365509
WA	904492.1398	179563.8033	2651497.893	351417.3098
WI	235024.5952	46466.92401	376554.3182	91121.5971
WY	3605.118718	665.3257847	11791.04258	1350.298341
Total	31706123.8	6279547.496	75744384.87	12303711.02

Table 14 Optimized long-range flight-level quantitative data for each destination state

State	CO2 Reduction (kg)	Fuel Cost Saving ($)	Total Flight Distance (km)	Total Cost Saving ($)
AK	2906.056516	525.3343092	34915.18983	1077.485047
AZ	81366.82075	15928.68745	271068.8726	31388.38339
CA	325412.9052	65115.63007	2037595.184	126944.0821
CO	22306.06988	4634.216659	224616.1459	8872.369936
FL	170558.9504	35267.85948	662165.4219	67674.06006
GA	4963.295445	1005.660571	50570.95872	1948.686705
HI	249476.9946	49013.58846	1597755.322	96414.21744
IL	3738.542858	786.909139	101319.5417	1497.232282
MA	129123.9067	25179.86972	965075.4017	49713.412
MI	9578.238901	1984.483857	50209.4714	3804.349249
MN	4259.423837	857.9520805	44620.21629	1667.242609
NJ	49671.45682	10246.43414	428709.1339	19684.01093
NV	51384.70482	9514.924902	313835.6348	19278.01882
NY	72134.23612	14891.63935	640693.4477	28597.14422
OR	21518.89579	4467.793881	126087.481	8556.384081
PA	22158.76197	4564.07929	132803.275	8774.244065
PR	7419.32617	1536.421511	30747.0198	2946.093484
TX	37862.80074	7342.545798	206019.5158	14536.47794
UT	5628.368206	1178.520619	133889.0584	2247.910578
VA	5741.882847	1166.662459	46281.83359	2257.6202
WA	165406.5969	34562.76165	432622.8312	65990.01506
Total	1442618.236	289771.9754	8531600.957	563869.4401

Supplementary materials for farm-and-flight selection optimization

Table 15 Detailed quantitative data for each solar farm and flight market penetration rate

Solar Farm	Flight	Energy (MWh)	Duration (hours)	CO2 Reduction (kg)	Fuel Cost Saving ($)	Total Cost Saving ($)
0.1	0.1	10365.88354	1845.899778	12335132.85	2241464.412	4585139.653
0.1	0.2	12541.91504	2057.328611	13700536.58	2440854.989	5043956.939
0.1	0.3	13131.91743	2153.874667	14343404.65	2555315.776	5280562.658
0.1	0.4	13131.91743	2153.874667	14343404.65	2555315.776	5280562.658
0.1	0.5	13131.91743	2153.874667	14343404.65	2555315.776	5280562.658
0.1	0.6	13131.91743	2153.874667	14343404.65	2555315.776	5280562.658
0.1	0.7	13131.91743	2153.874667	14343404.65	2555315.776	5280562.658
0.1	0.8	13131.91743	2153.874667	14343404.65	2555315.776	5280562.658
0.1	0.9	13131.91743	2153.874667	14343404.65	2555315.776	5280562.658
0.1	1	13131.91743	2153.874667	14343404.65	2555315.776	5280562.658
0.2	0.1	12711.65708	2447.938889	16407911.62	3032549.778	6150052.985
0.2	0.2	16252.89902	3135.986167	21021236.68	3886750.554	7880785.523
0.2	0.3	17995.19352	3529.8285	23675598.44	4392214.666	8890578.37
0.2	0.4	18906.22723	3688.292667	24733511.71	4583409.527	9282776.752
0.2	0.5	19174.03279	3797.810333	25482023.86	4736534.012	9578118.546
0.2	0.6	19174.67494	3798.051722	25483671.18	4736868.506	9578766.029
0.2	0.7	19174.67494	3798.051722	25483671.18	4736868.506	9578766.029
0.2	0.8	19174.67494	3798.051722	25483671.18	4736868.506	9578766.029
0.2	0.9	19174.67494	3798.051722	25483671.18	4736868.506	9578766.029
0.2	1	19174.67494	3798.051722	25483671.18	4736868.506	9578766.029
0.3	0.1	13857.92588	2915.963667	19606598.97	3686824.346	7412078.15
0.3	0.2	18560.97558	3874.130167	26042026.09	4889623.873	9837608.83
0.3	0.3	20924.20607	4474.097167	30099561.61	5676505.684	11395422.39
0.3	0.4	22376.7307	4695.306444	31567687.33	5932921.544	11930782.14
0.3	0.5	23091.82147	4882.093778	32831908.51	6179098.773	12417161.39
0.3	0.6	23349.54272	5153.262889	34704705.55	6581751.371	13175645.43
0.3	0.7	23398.68913	5229.2425	35230556.78	6695909.481	13389715.27
0.3	0.8	23398.68913	5229.2425	35230556.78	6695909.481	13389715.27
0.3	0.9	23398.68913	5229.2425	35230556.78	6695909.481	13389715.27
0.3	1	23398.68913	5229.2425	35230556.78	6695909.481	13389715.27
0.4	0.1	14725.46034	3175.158611	21366880.57	4035667.562	8095374.869

0.4	0.2	19845.04629	4338.091111	29205847.18	5529647.626	11078758.59
0.4	0.3	22843.23004	5166.332889	34819871.2	6631245.307	13247020.83
0.4	0.4	24677.85914	5575.9025	37579136.94	7155574.02	14295610.04
0.4	0.5	25715.50944	5894.453222	39743894.35	7585958.415	15137298.34
0.4	0.6	26244.36822	6122.944	41306977.01	7907160.403	15755486.04
0.4	0.7	26520.7485	6387.024	43129594.92	8297813.547	16492436.58
0.4	0.8	26581.50409	6536.392944	44165091.55	8524317.897	16915685.29
0.4	0.9	26581.50409	6536.392944	44165091.55	8524317.897	16915685.29
0.4	1	26581.50409	6536.392944	44165091.55	8524317.897	16915685.29
0.5	0.1	14973.38262	3269.266944	22009221.43	4166214.902	8347966.975
0.5	0.2	20645.26885	4673.769722	31501074.2	6000179.779	11985383.88
0.5	0.3	24155.85606	5710.721444	38541454.39	7393471.373	14716347.71
0.5	0.4	26237.71109	6329.165389	42740947.65	8225127.455	16345907.51
0.5	0.5	27549.33279	6828.976056	46152673.56	8918761.824	17687769.8
0.5	0.6	28368.02263	7179.088889	48547360.87	9410451.576	18634450.14
0.5	0.7	28960.68219	7459.378222	50467484.66	9807722.895	19396544.98
0.5	0.8	29218.16122	7673.645778	51944713.71	10122761.15	19992256.75
0.5	0.9	29266.16304	7701.390611	52135291.7	10162704.09	20068409.51
0.5	1	29266.16304	7701.390611	52135291.7	10162704.09	20068409.51
0.6	0.1	15049.33125	3318.629222	22348742.45	4237827.79	8484088.856
0.6	0.2	21146.96888	4923.303056	33211748.34	6355362.51	12665594.69
0.6	0.3	25035.40519	6214.780222	42003452.66	8118708.041	16099364.05
0.6	0.4	27434.79419	7004.393444	47377673.1	9195547.841	18197305.73
0.6	0.5	29067.85089	7666.274444	51900683.09	10120127.29	19981257.08
0.6	0.6	30103.93359	8016.050167	54282591.95	10598689.11	20912381.58
0.6	0.7	30864.37324	8372.351889	56723100.42	11103288.26	21880677.34
0.6	0.8	31256.07241	8603.456944	58310941.2	11436471.49	22515550.32
0.6	0.9	31434.77145	8765.130778	59426320.14	11675084.65	22966085.48
0.6	1	31434.77145	8765.130778	59426320.14	11675084.65	22966085.48
0.7	0.1	15101.56948	3352.753333	22583465.84	4287349.104	8578207.613
0.7	0.2	21432.10835	5088.725278	34348076.93	6593574.644	13119709.26
0.7	0.3	25580.14335	6491.636889	43902012.77	8513472.495	16854854.92
0.7	0.4	28219.23225	7416.526111	50205166.38	9784734.74	19323716.35
0.7	0.5	30137.84627	8188.523333	55479997.59	10862330.85	21403530.39
0.7	0.6	31384.57577	8712.108667	59060119.81	11596341.95	22817764.72
0.7	0.7	32275.34882	9091.571389	61655387.55	12129049.71	23843573.34
0.7	0.8	32796.9801	9383.781222	63661792.01	12548798.24	24644538.72
0.7	0.9	33097.87475	9589.882611	65080165.92	12848742.49	25213974.01
0.7	1	33126.18755	9607.318611	65200021.98	12873951.78	25261955.96

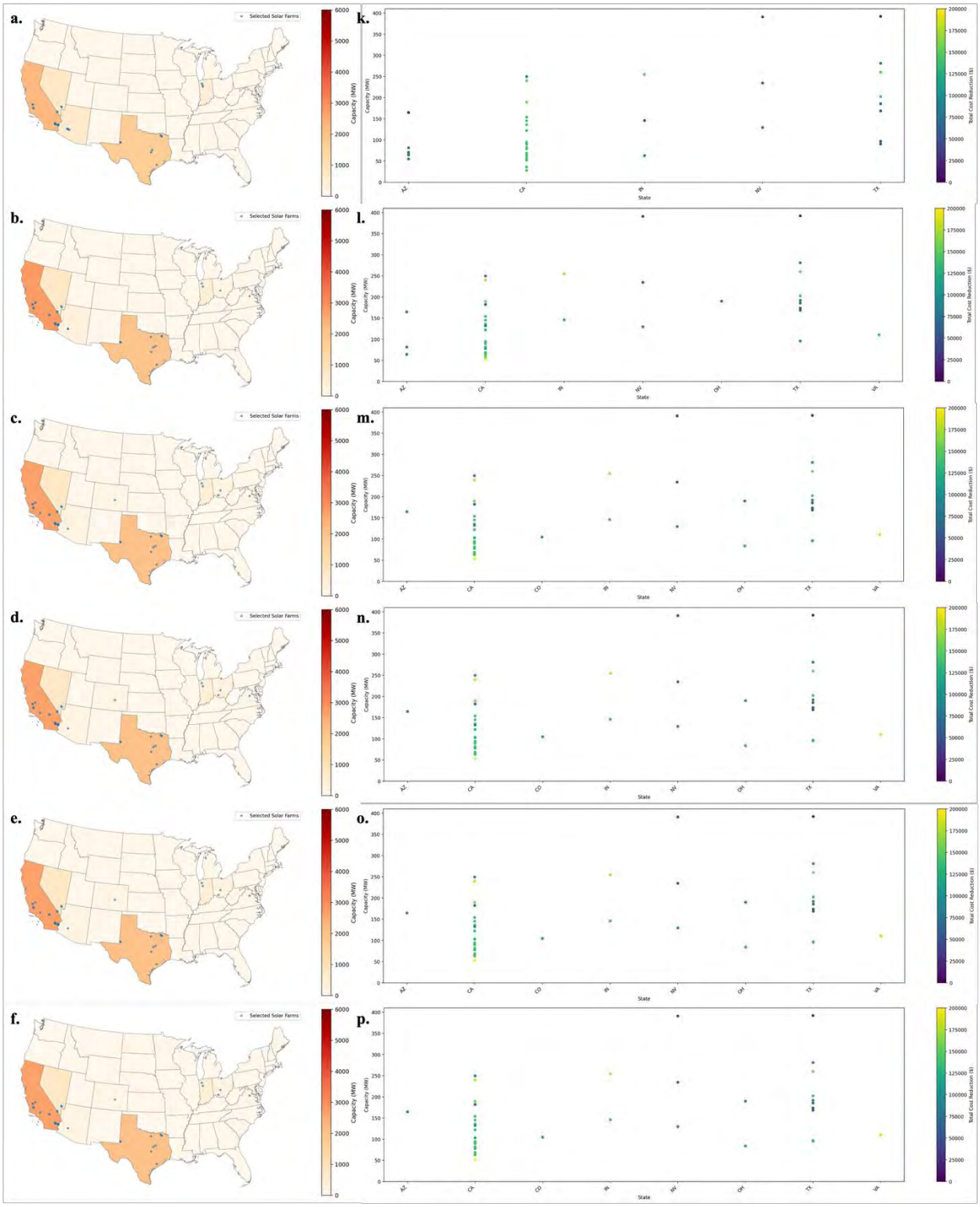
0.8	0.1	15116.25114	3368.463333	22691977.04	4310690.967	8622166.605
0.8	0.2	21625.97418	5172.053722	34918070.72	6710656.23	13345089.67
0.8	0.3	25872.14236	6666.608667	45104400.62	8765993.09	17335829.21
0.8	0.4	28744.16239	7680.164222	52012781.88	10160291.48	20042720.04
0.8	0.5	30851.65864	8558.474	58017631.63	11390653.76	22414003.77
0.8	0.6	32305.08299	9151.327111	62069382.09	12219348.94	24012531.54
0.8	0.7	33311.75673	9581.964278	65014851.34	12824143.1	25176964.85
0.8	0.8	33938.82534	9893.022111	67147226.1	13266802.18	26024775.14
0.8	0.9	34344.72289	10132.99561	68796038.79	13612819.31	26684066.68
0.8	1	34434.52086	10212.9475	69347554.02	13730736.94	26906772.2
0.9	0.1	15117.36034	3370.585444	22706676.71	4313894.685	8628163.26
0.9	0.2	21657.08529	5193.2885	35064201.56	6741553.343	13403751.64
0.9	0.3	26002.85518	6738.333111	45596754.74	8868867.391	17532250.79
0.9	0.4	29029.12654	7833.969389	53068357.12	10380623.52	20463611.37
0.9	0.5	31240.68486	8734.027111	59219403.6	11638442.03	22890128.71
0.9	0.6	32851.23198	9407.702611	63825489.42	12582490.57	24709333.56
0.9	0.7	33966.64628	9913.475167	67288080.34	13296686.27	26081421.54
0.9	0.8	34669.81146	10251.27583	69602718.64	13776115.72	27000632.26
0.9	0.9	35141.47469	10529.03756	71511078.3	14176512.3	27763617.18
0.9	1	35332.09788	10654.52761	72374335.25	14358710.84	28109834.54
1	0.1	15116.08497	3370.193667	22704014.29	4313365.319	8627128.034
1	0.2	21663.45592	5194.703944	35073735.94	6743363.631	13407373.46
1	0.3	26019.71403	6749.786167	45675567.16	8885527.283	17563885.04
1	0.4	29104.6033	7878.661167	53375431.47	10445071.21	20586403.18
1	0.5	31369.00575	8799.760333	59670221.56	11732228.58	23069570.68
1	0.6	33077.46684	9539.466778	64730654.63	12772285.76	25071110.14
1	0.7	34248.06961	10049.78928	68222227.72	13490287.45	26452510.72
1	0.8	35017.885	10429.33528	70823880.37	14030139	27486676.27
1	0.9	35546.12597	10722.27706	72835056.04	14450631.36	28289292.01
1	1	35794.19273	10880.48194	73922989.23	14679879.02	28725246.97

Table 16 System parameters

Symbol	Description	Value	Unit
$\dot{m}_{fuel}$	Fuel burn rate	2,200	kg/h
C_{fuel}	Fuel price	0.7	$/kg
e_{fuel}	CO2 per fuel	3.16	kg CO2/kg
P_{cruise}	Cruise power demand	10.3	MW
v_{cruise}	Cruise speed	235	m/s
h_{cruise}	Cruise altitude	12,100	m
A_r	Receiving aperture	261.6	m²
ε	Powered threshold	1	MW
λ	Operating wavelength	0.05	m
τ_{max}	Max time shift	1,800	s
S_{ab}	Safety ground-level power density	20	W/m²
C_{elec}	Solar electricity cost	58	$/MWh
e_{solar}	Solar CO_2 intensity	48	kg CO2/MWh
C_{CO2}	Social cost of carbon	0.19	$/kg CO2
P_f	Effective capacity of each solar farm f	/	MW
$\eta_{dc\text{-}rf}$	DC to RF conversion	68.87%	/
η_{free}	Free-space propagation	95%	/
$\eta_{rf\text{-}dc}$	RF to DC conversion	78.67%	/
η_{spot}	Beam spot efficiency	87%	/
η_{sys}	End-to-end efficiency	44.78%	/

Table 17 Notation for optimization

Symbol	Description
Sets	
I	Set of flights, $\|I\| = 143{,}152$
F	Set of qualified solar farms, $\|F\| = 437$
T	Set of discrete time steps over the analysis horizon
S_i	Set of admissible time-shift options for flight i; $S_i = \{-\tau_{max}, ..., \tau_{max}\}$
Parameters	
$z_{f,i,t}$	Slant-range distance between farm f and flight i at time t
$a_{f,i,t}$	Binary coverage parameter: 1 if flight i within energy boundary of farm f at time t
$c_{i,t,s}$	Binary in-flight indicator: 1 if flight i airborne at time t under shift s
Decision Variables	
$p_{f,i,t}$	Power transmitted from farm f to flight i at time t (continuous, ≥ 0)
$r_{i,t}$	Total received power at flight i at time t (continuous, ≥ 0)
$b_{i,t}$	Binary: 1 if flight i receives beamed power at time t
$d_{i,s}$	Binary: 1 if flight i is shifted by s (flight schedule optimization only)
x_f	Binary: 1 if farm f is equipped with SoPhAr (farm-and-flight choice optimization only)
x_i	Binary: 1 if flight i is equipped with receiver (farm-and-flight choice optimization only)


a.
b.
c.
d.
e.
f.
Selected Solar Farms
Capacity (MW)
k.
l.
m.
n.
o.
p.
State
Total Cost Reduction ($)
AZ
CA
CO
IN
NV
OH
TX
VA

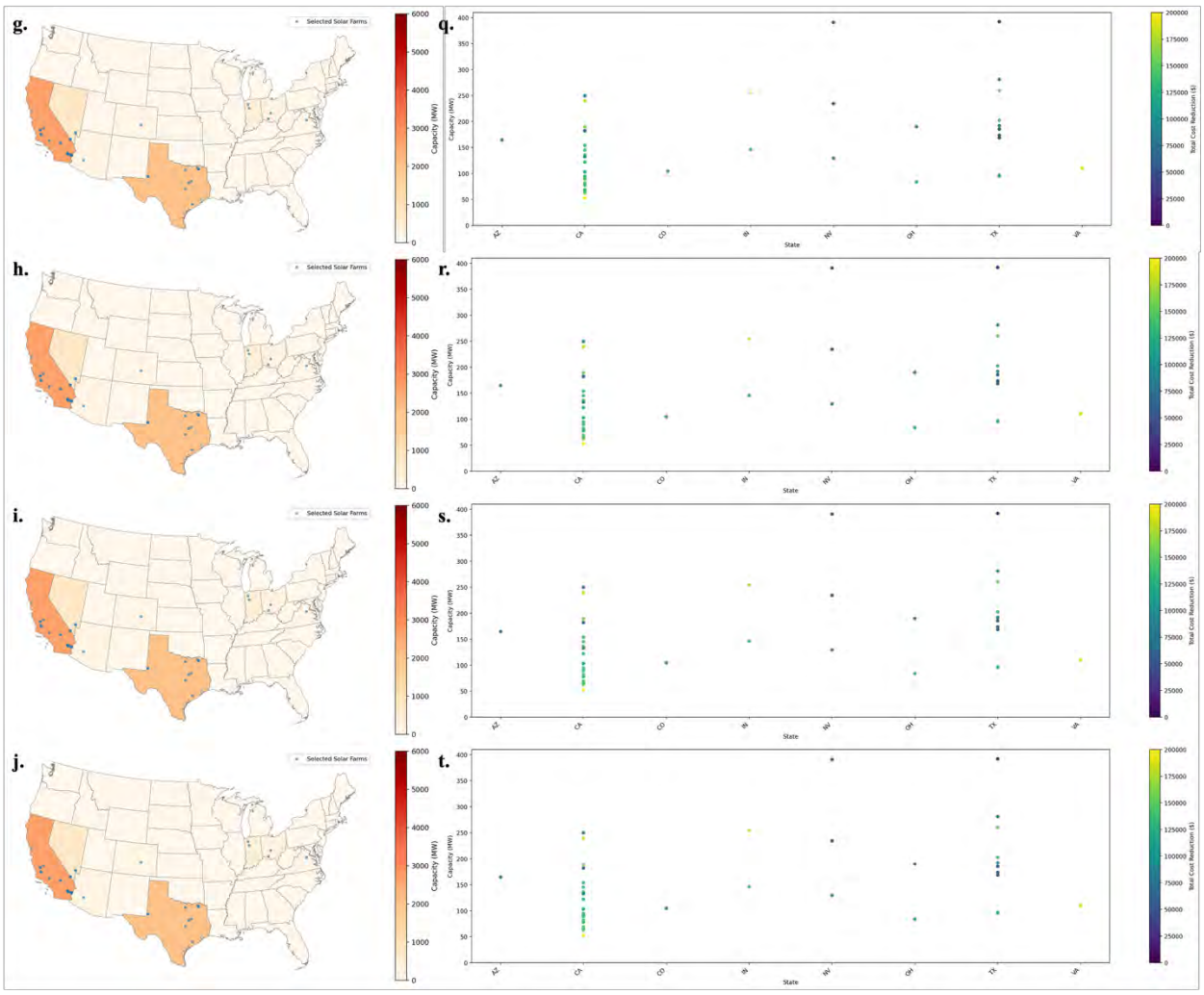


Figure 1 10% Solar farm selection across different flight market penetration rates

a-j, Spatial distribution of selected solar farms (blue dots); and the color of the states represents the total optimized solar capacity (MW). k-t, Scatter plot aggregates the relationship between individual solar farm capacity (MW) and total cost reduction ($), colored by cost reduction magnitude; and each dot represents one farm, clustered by state.

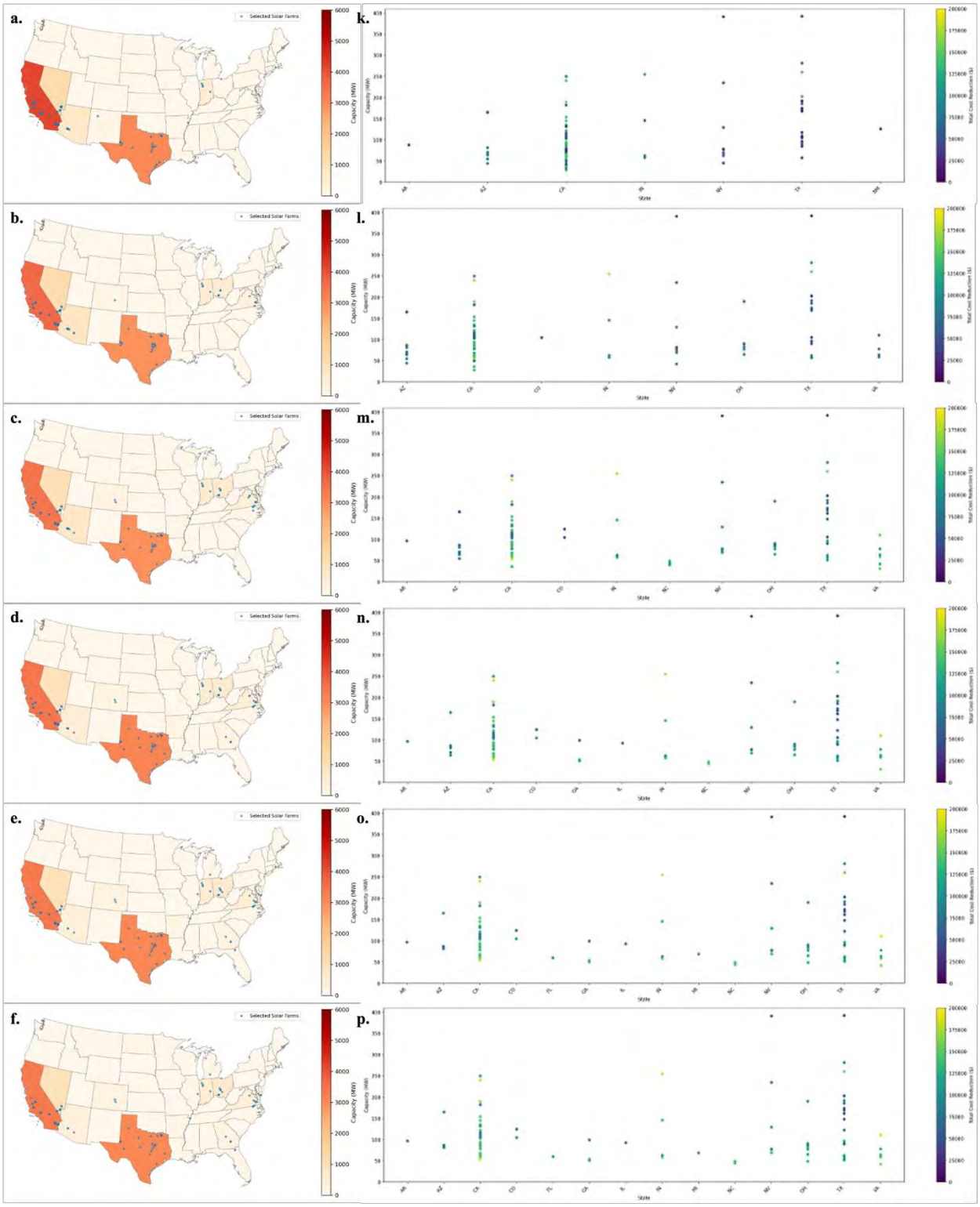

a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Selected Solar Farms
Capacity (MW)
Total Cost Reduction ($)
State

Figure 2 20% Solar farm selection across different flight market penetration rates

a-j, Spatial distribution of selected solar farms (blue dots); and the color of the states represents the total optimized solar capacity (MW). k-t, Scatter plot aggregates the relationship between individual solar farm capacity (MW) and total cost reduction ($), colored by cost reduction magnitude; and each dot represents one farm, clustered by state.

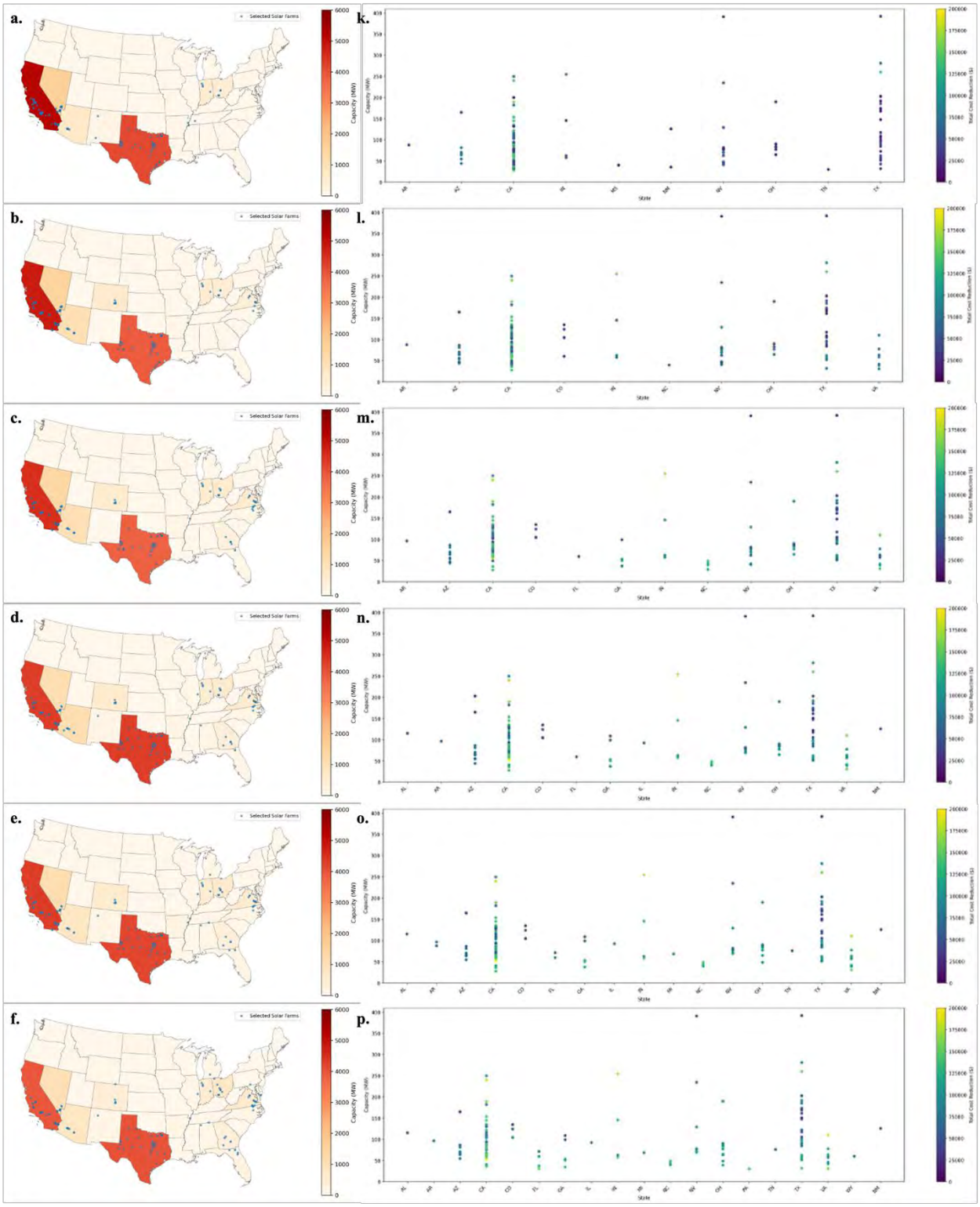
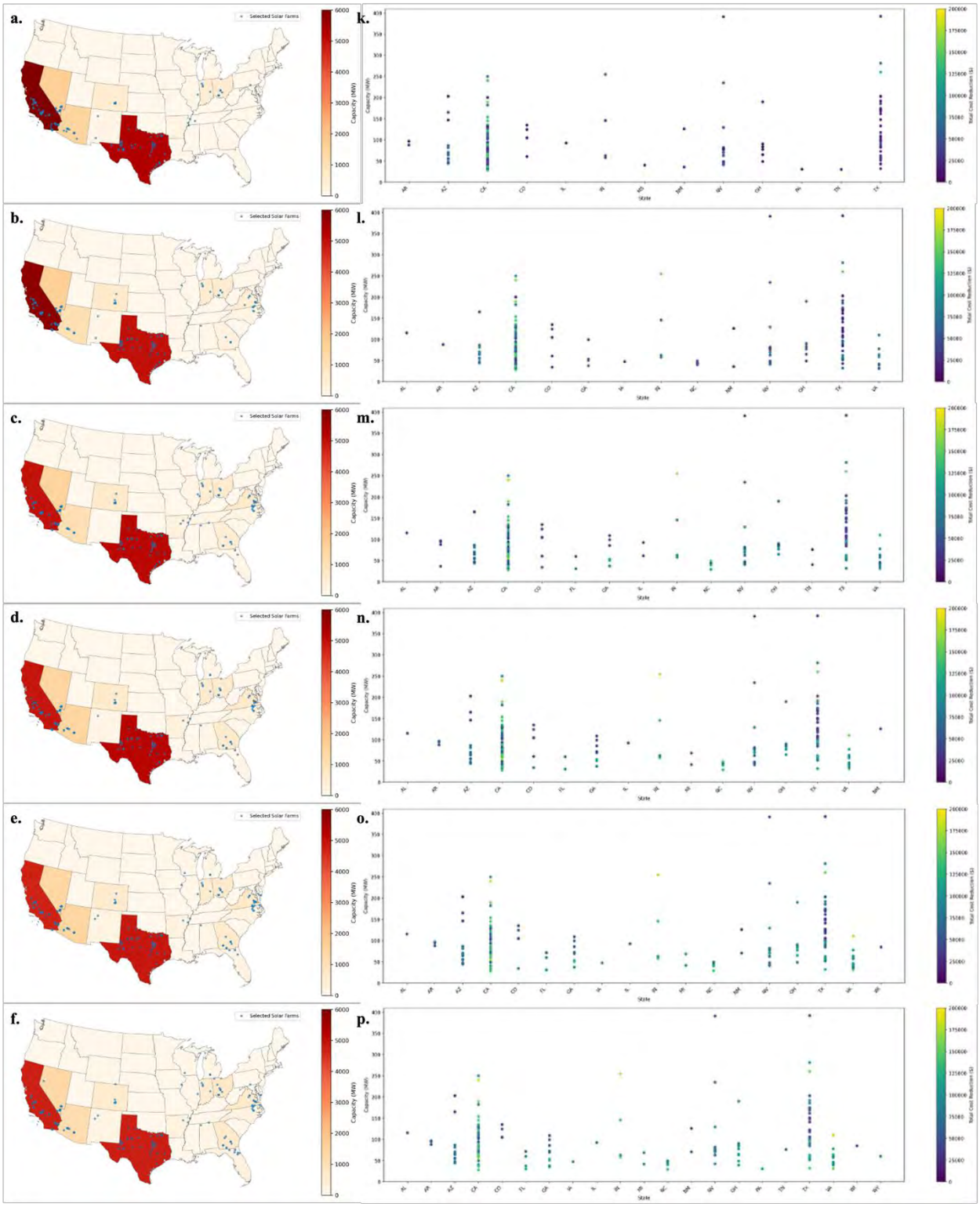

a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Selected Solar Farms
Capacity (MW)
Total Cost Reduction ($)
State

Figure 3 30% Solar farm selection across different flight market penetration rates

a-j, Spatial distribution of selected solar farms (blue dots); and the color of the states represents the total optimized solar capacity (MW). k-t, Scatter plot aggregates the relationship between individual solar farm capacity (MW) and total cost reduction ($), colored by cost reduction magnitude; and each dot represents one farm, clustered by state.


a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Selected Solar Farms
Capacity (MW)
Total Cost Reduction ($)
State

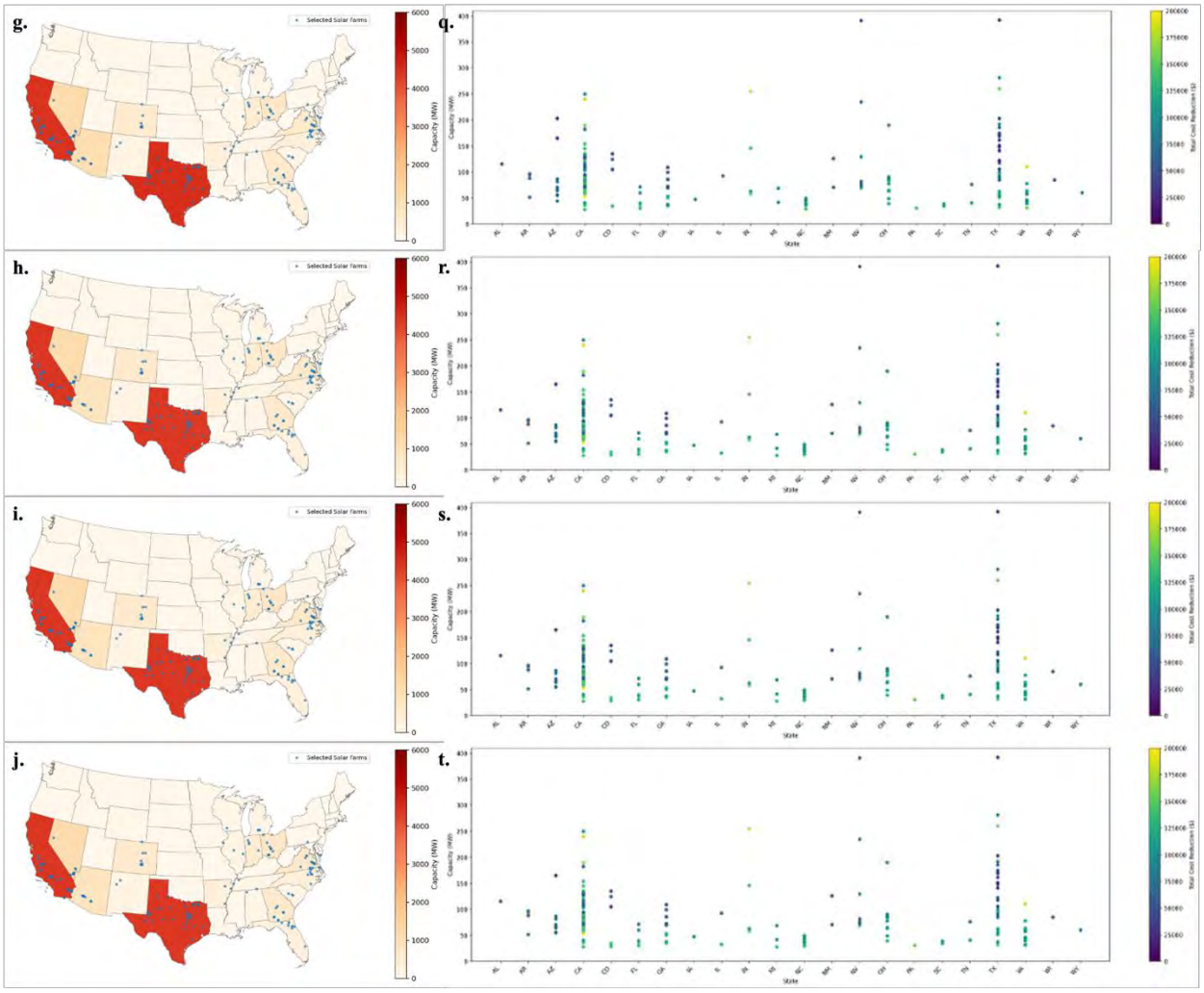
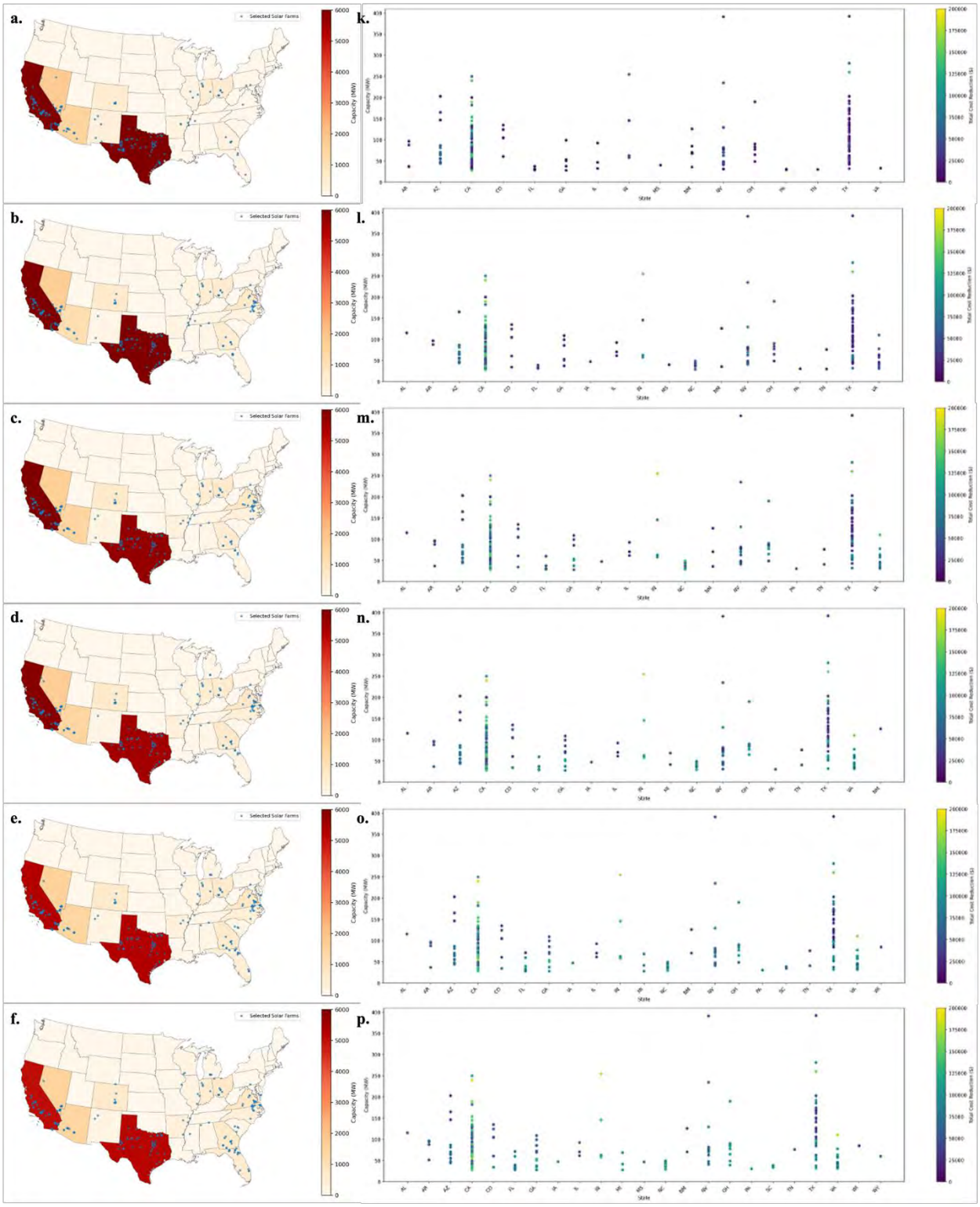


Figure 4 40% Solar farm selection across different flight market penetration rates

a-j, Spatial distribution of selected solar farms (blue dots); and the color of the states represents the total optimized solar capacity (MW). k-t, Scatter plot aggregates the relationship between individual solar farm capacity (MW) and total cost reduction ($), colored by cost reduction magnitude; and each dot represents one farm, clustered by state.


a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Selected Solar Farms
Capacity (MW)
Total Cost Reduction ($)
State

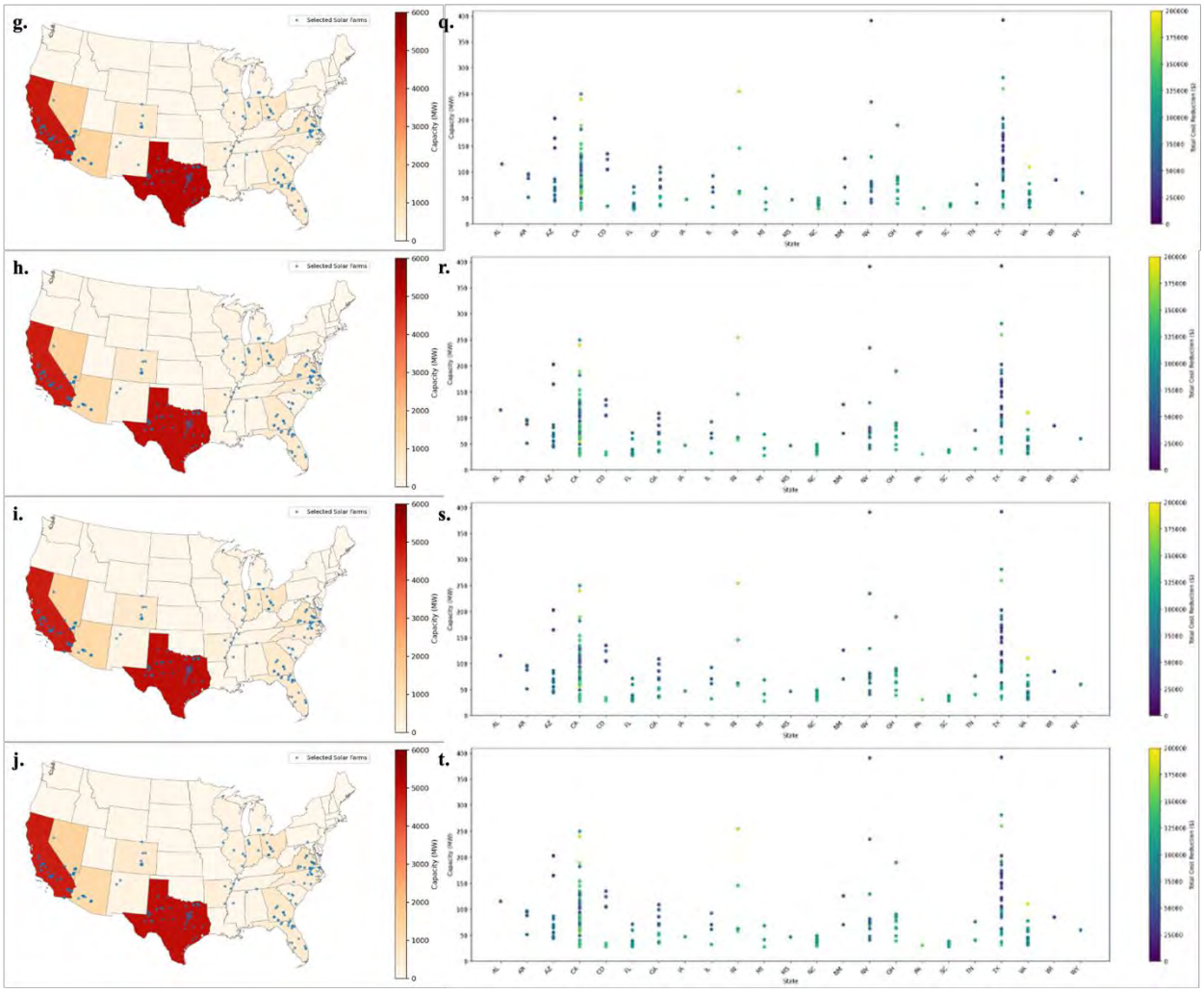
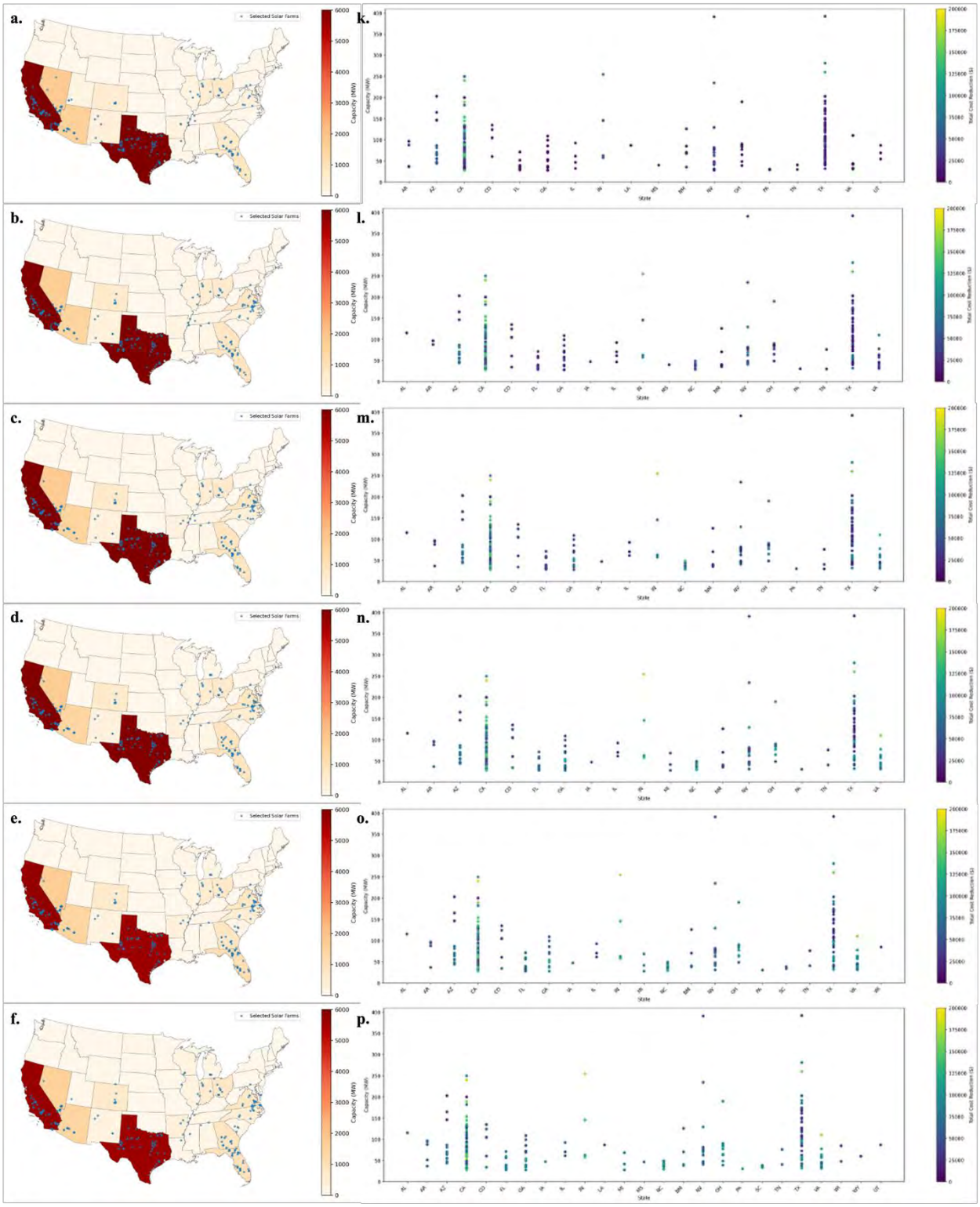


Figure 5 50% Solar farm selection across different flight market penetration rates

a-j, Spatial distribution of selected solar farms (blue dots); and the color of the states represents the total optimized solar capacity (MW). k-t, Scatter plot aggregates the relationship between individual solar farm capacity (MW) and total cost reduction ($), colored by cost reduction magnitude; and each dot represents one farm, clustered by state.


a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Selected Solar Farms
Capacity (MW)
Total Cost Reduction ($)
State

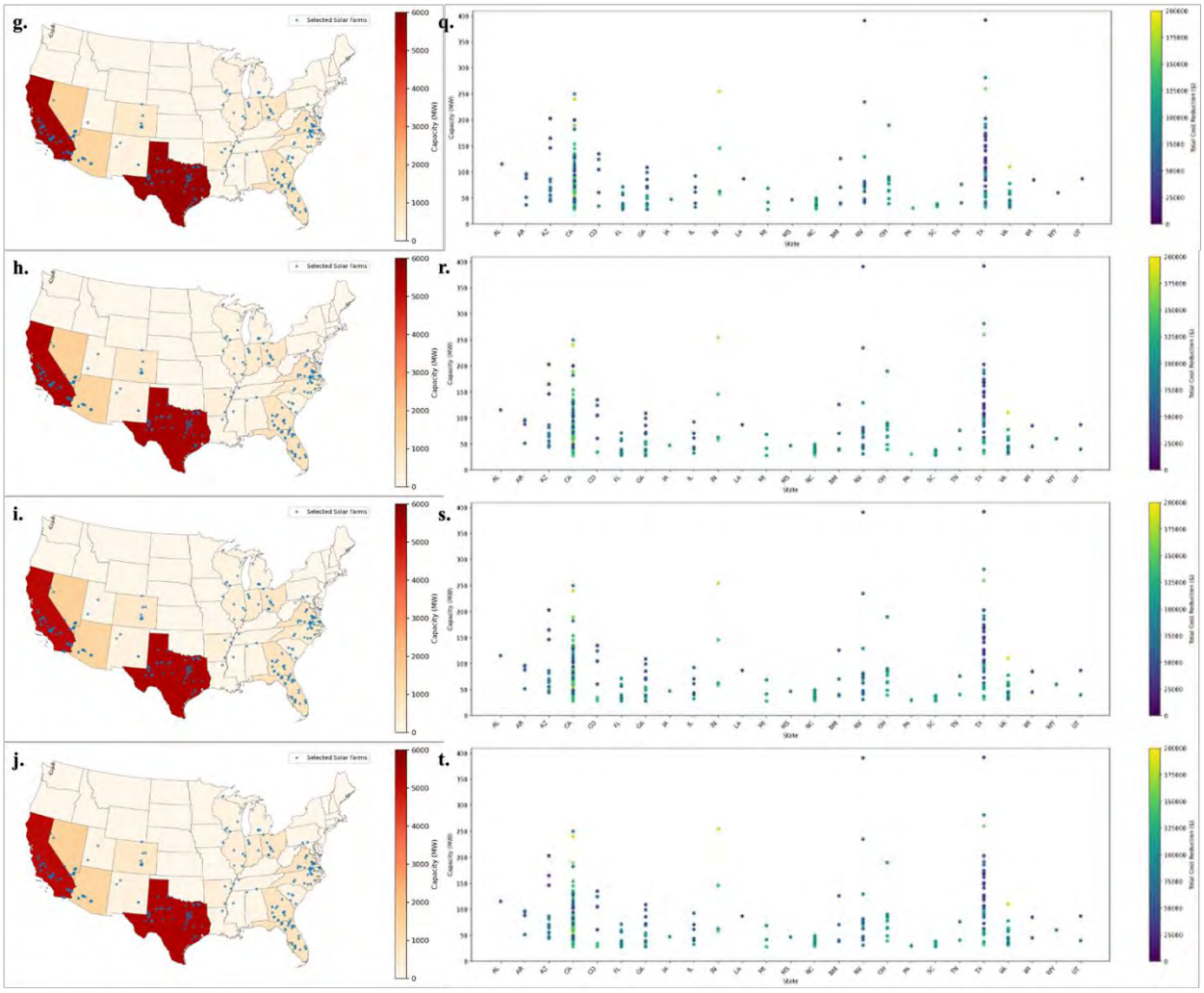
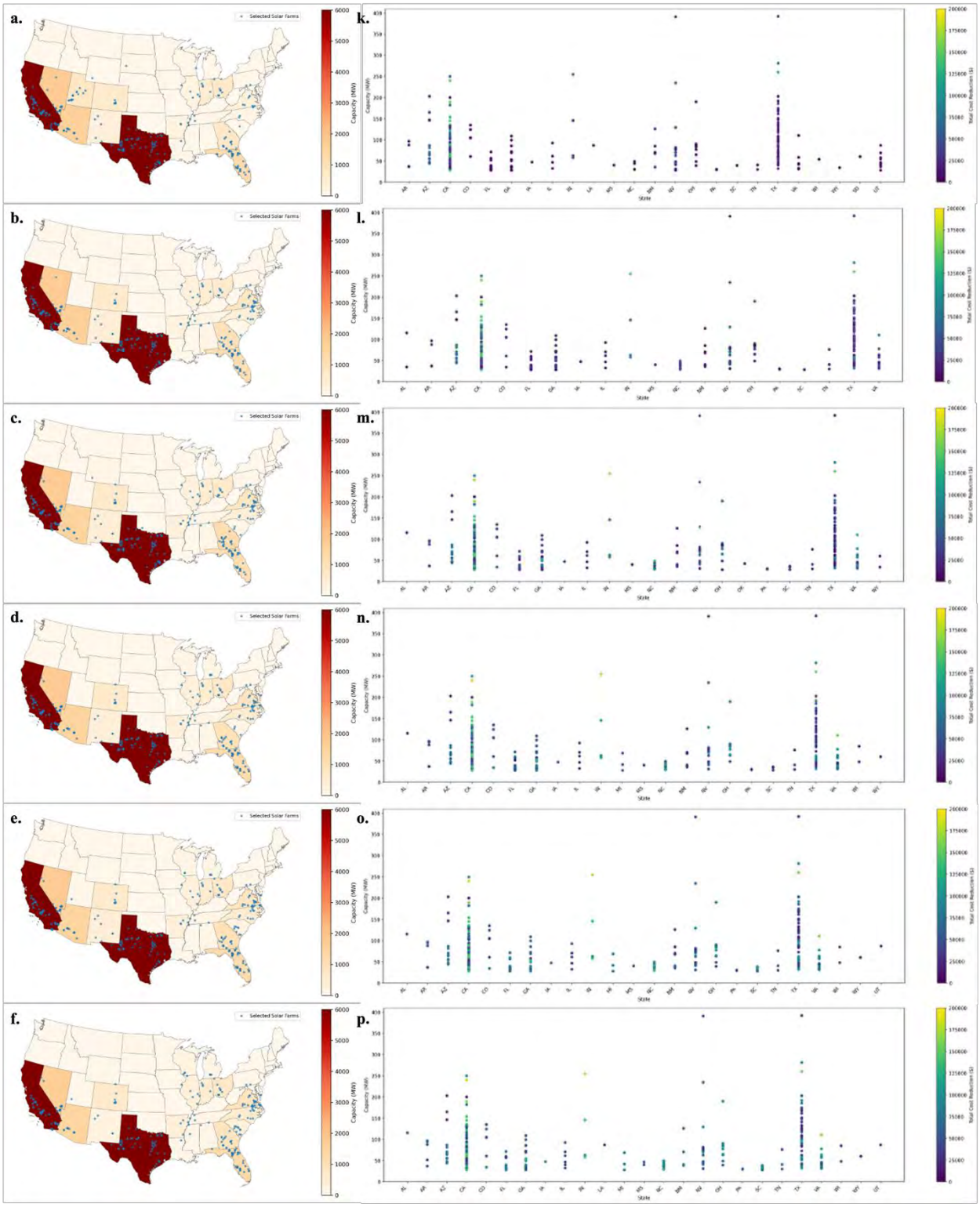


Figure 6 60% Solar farm selection across different flight market penetration rates

a-j, Spatial distribution of selected solar farms (blue dots); and the color of the states represents the total optimized solar capacity (MW). k-t, Scatter plot aggregates the relationship between individual solar farm capacity (MW) and total cost reduction ($), colored by cost reduction magnitude; and each dot represents one farm, clustered by state.


a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Selected Solar Farms
Capacity (MW)
Total Cost Reduction ($)
State

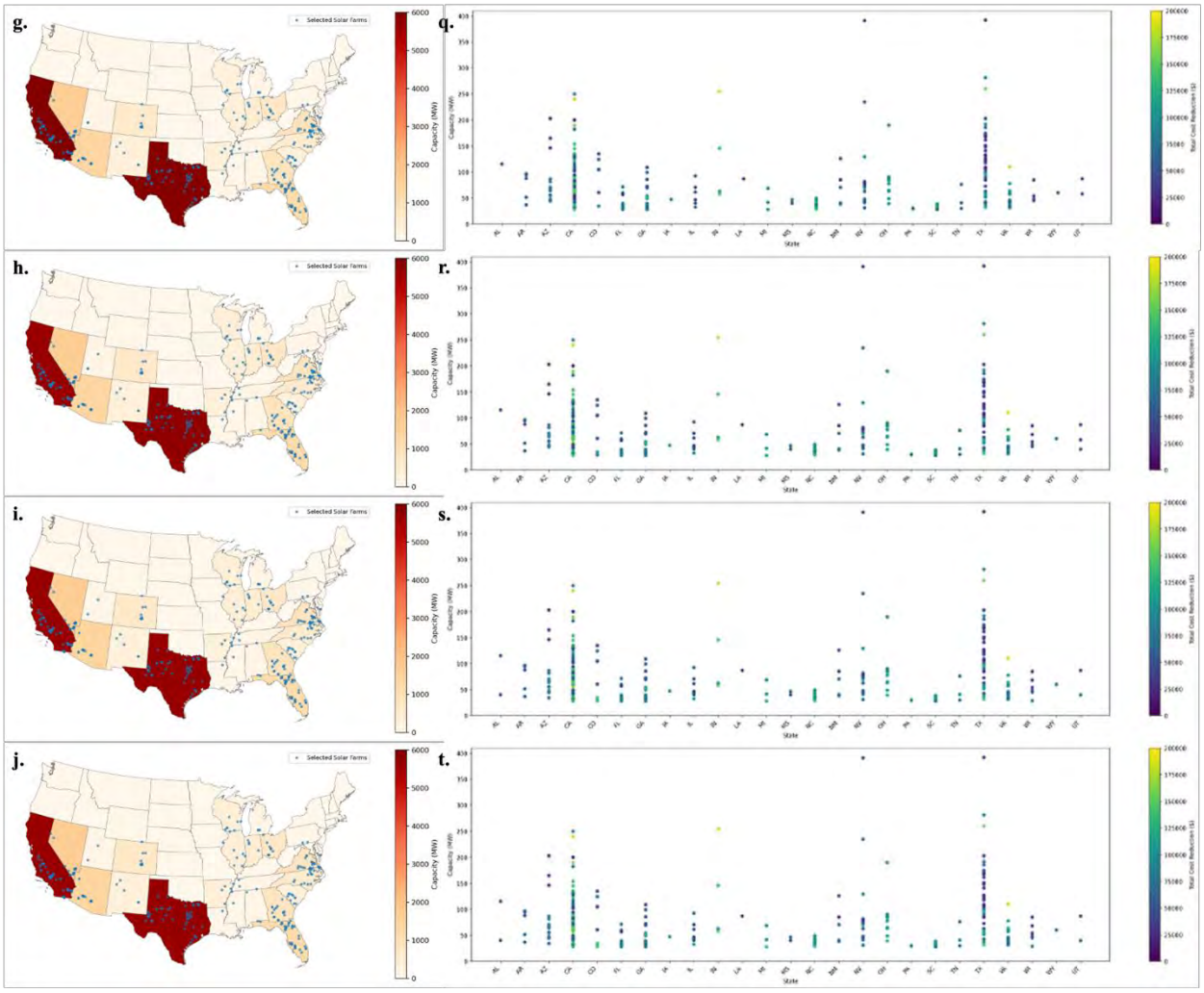
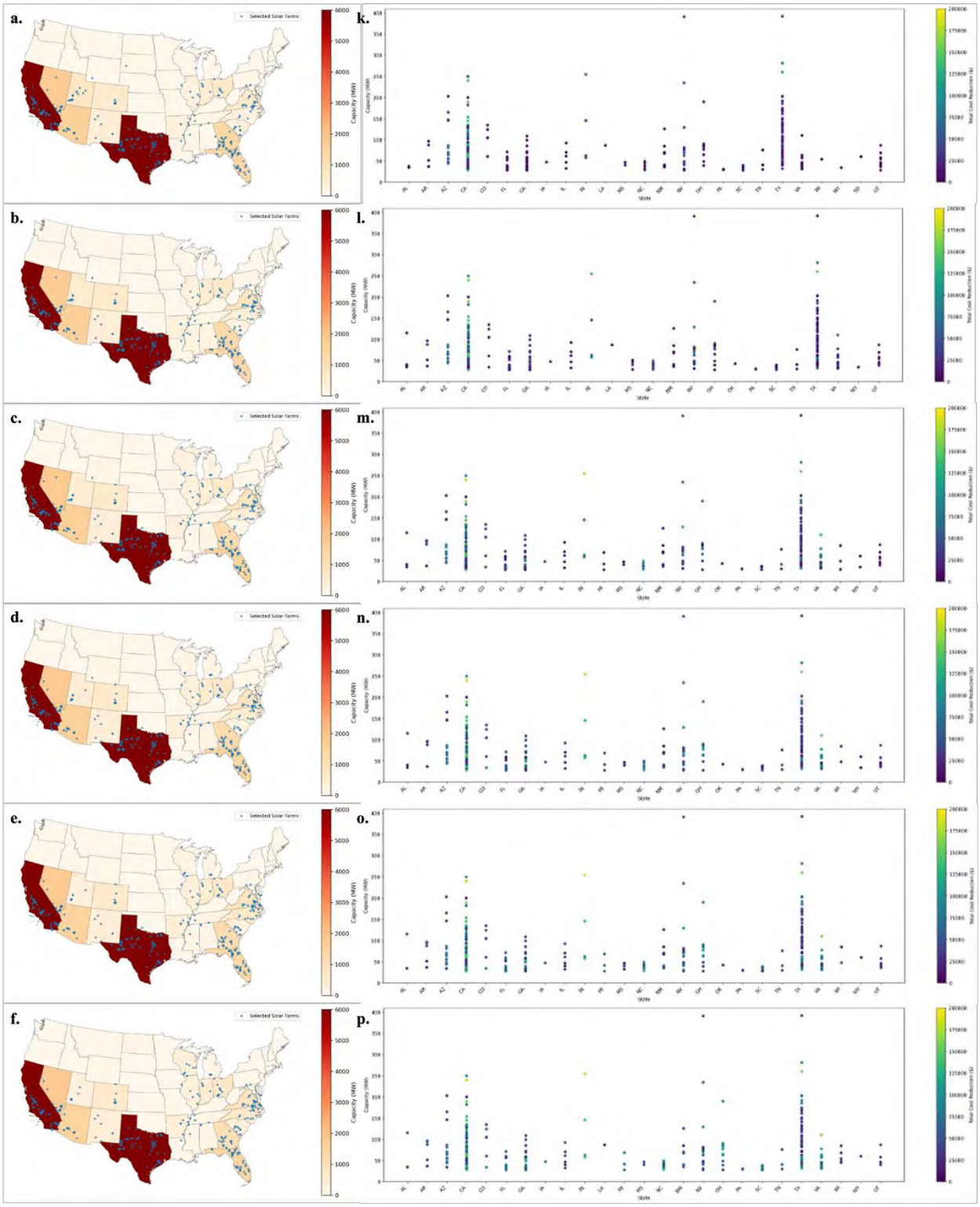


Figure 7 70% Solar farm selection across different flight market penetration rates

a-j, Spatial distribution of selected solar farms (blue dots); and the color of the states represents the total optimized solar capacity (MW). k-t, Scatter plot aggregates the relationship between individual solar farm capacity (MW) and total cost reduction ($), colored by cost reduction magnitude; and each dot represents one farm, clustered by state.


a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Selected Solar Farms
Capacity (MW)
State
Total Cost Reduction ($)

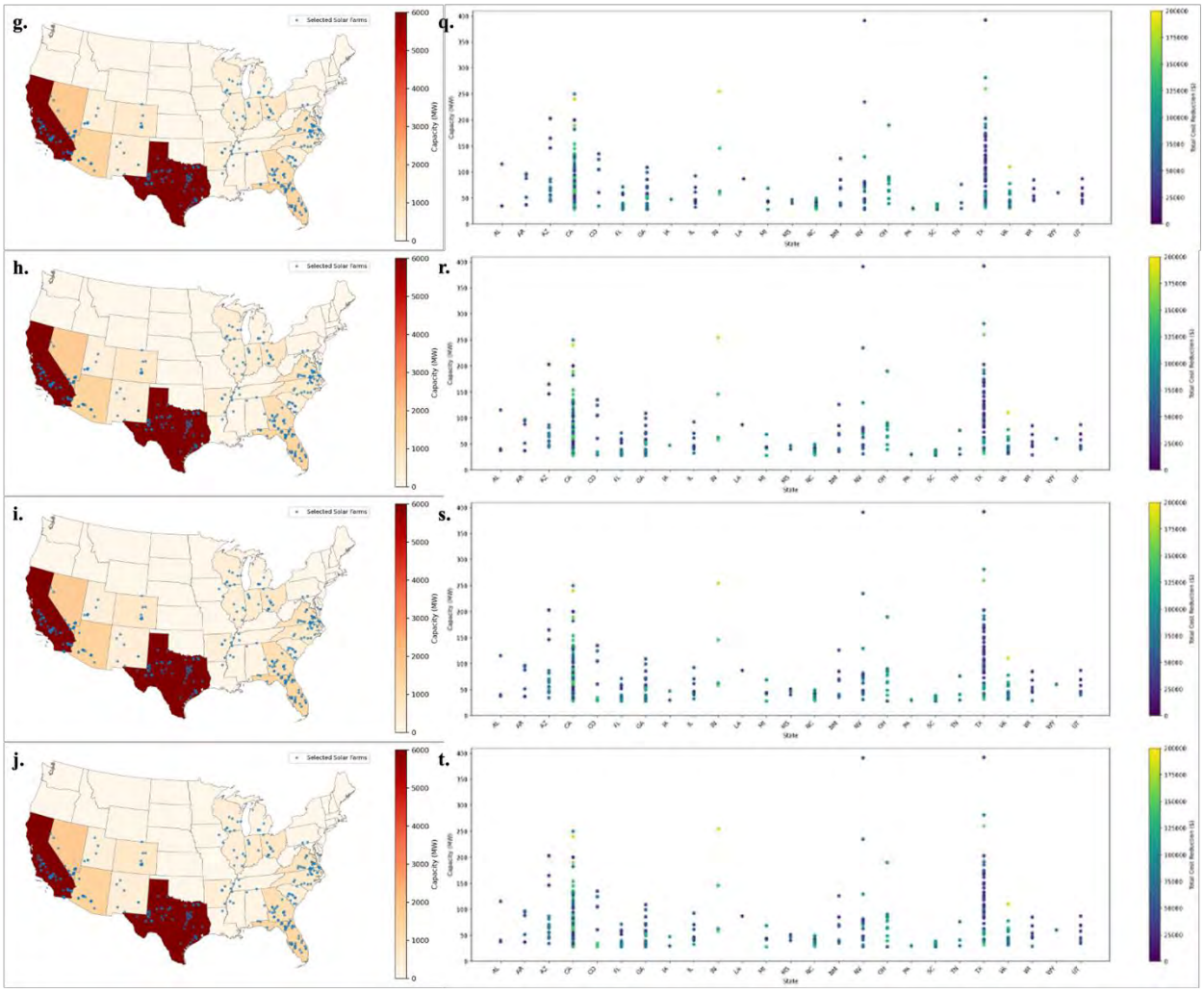
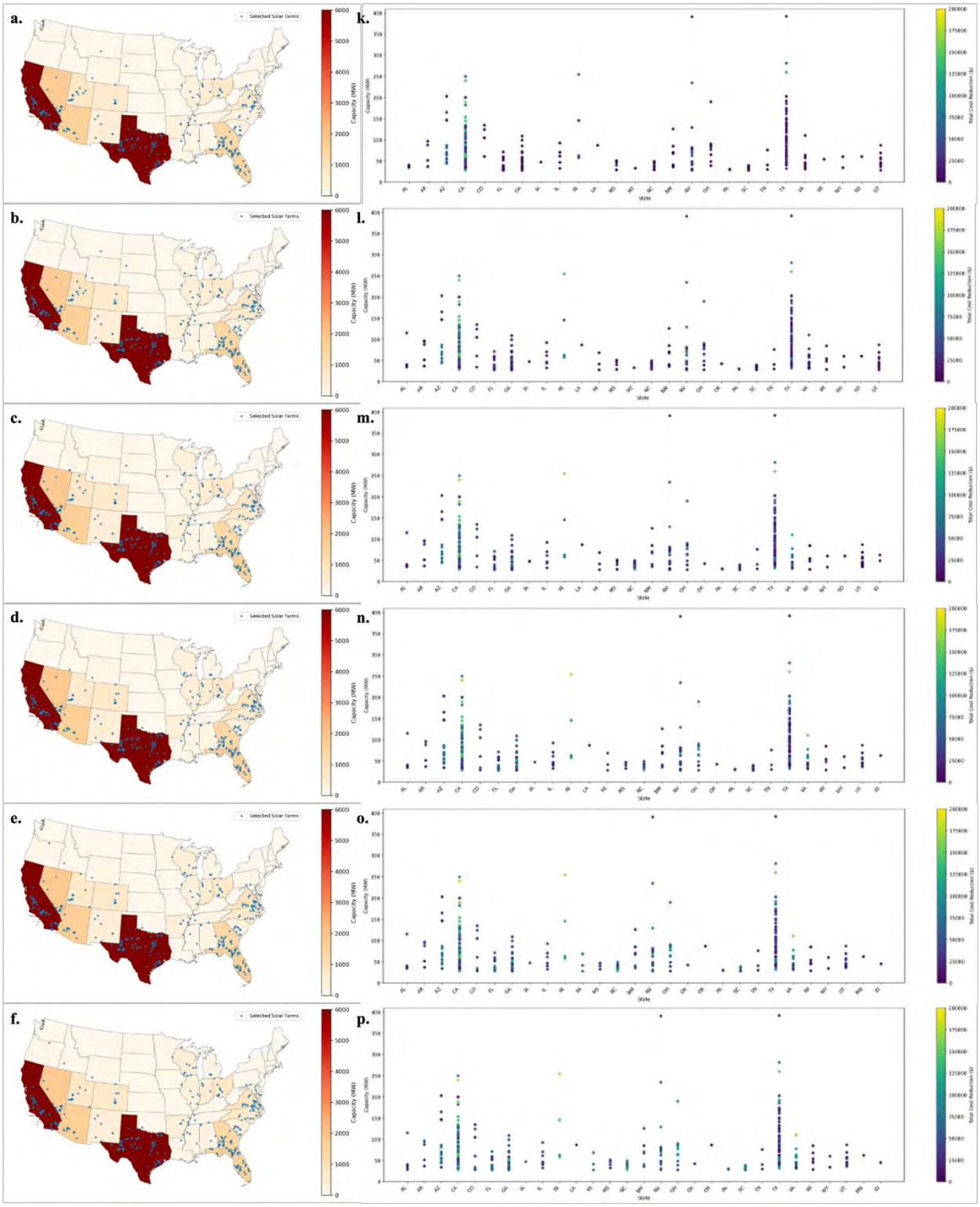


Figure 8 80% Solar farm selection across different flight market penetration rates

a-j, Spatial distribution of selected solar farms (blue dots); and the color of the states represents the total optimized solar capacity (MW). k-t, Scatter plot aggregates the relationship between individual solar farm capacity (MW) and total cost reduction ($), colored by cost reduction magnitude; and each dot represents one farm, clustered by state.


a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Selected Solar Farms
Capacity (MW)
Total Cost Reduction ($)
State

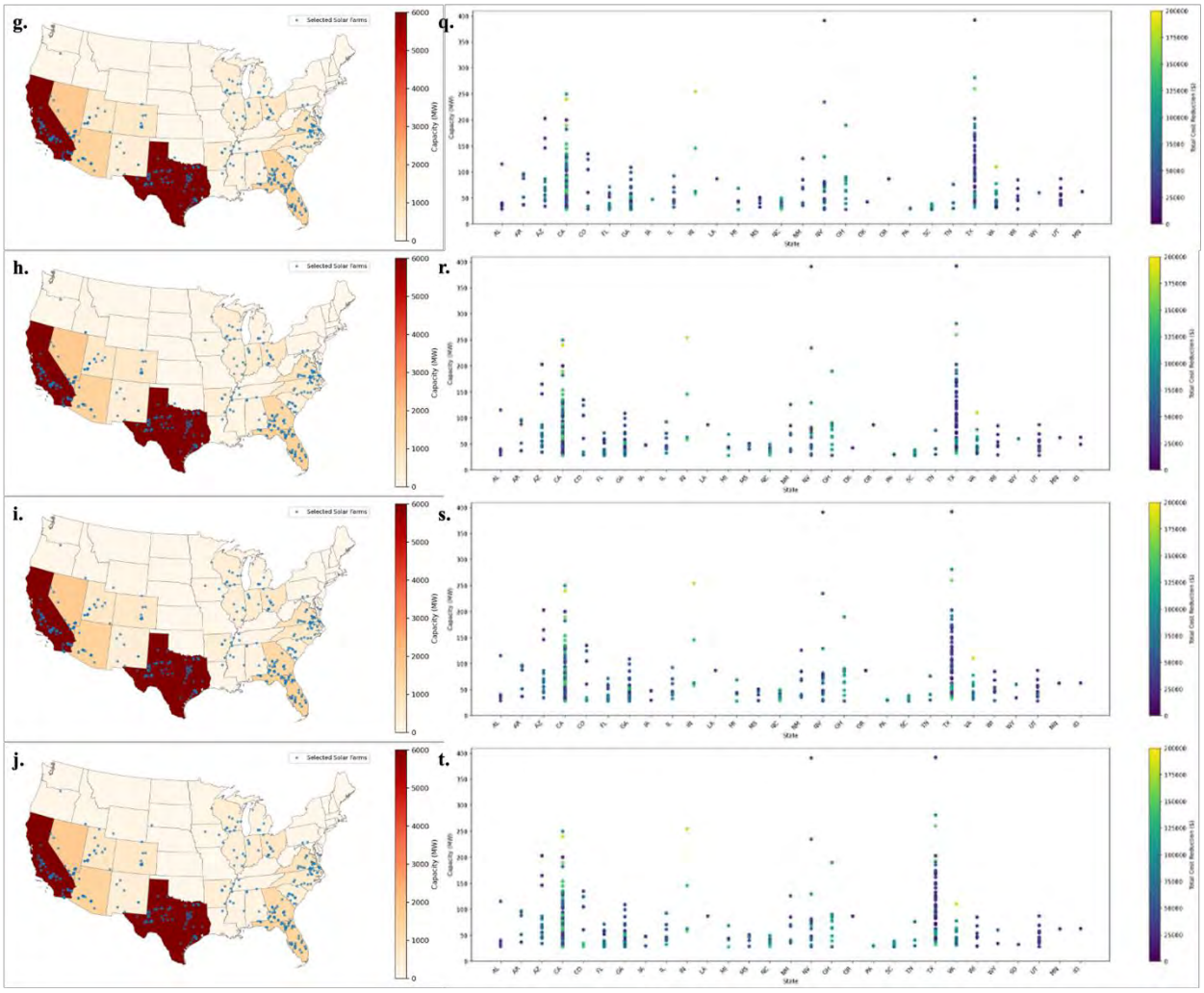


Figure 9 90% Solar farm selection across different flight market penetration rates

a-j, Spatial distribution of selected solar farms (blue dots); and the color of the states represents the total optimized solar capacity (MW). k-t, Scatter plot aggregates the relationship between individual solar farm capacity (MW) and total cost reduction ($), colored by cost reduction magnitude; and each dot represents one farm, clustered by state.

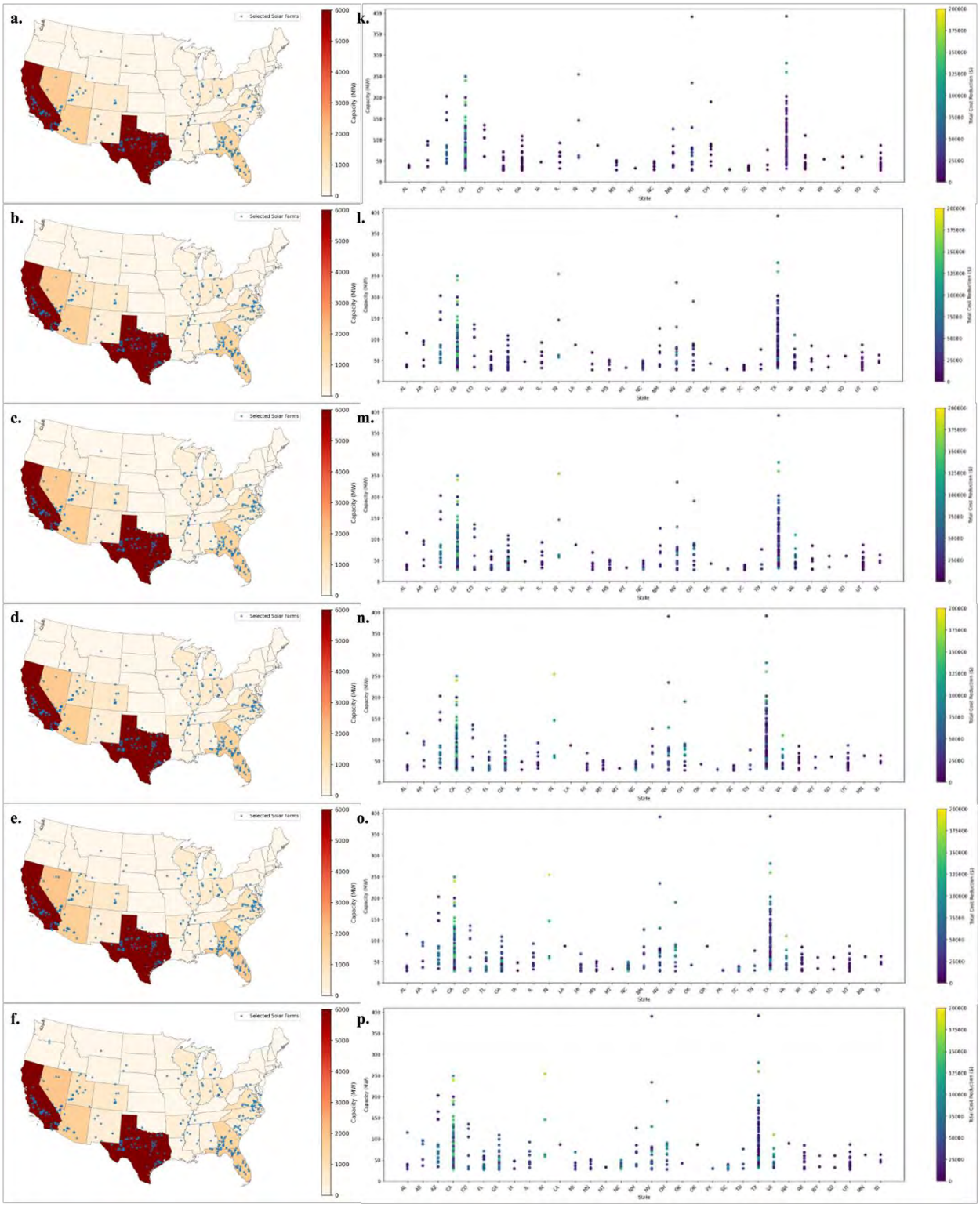
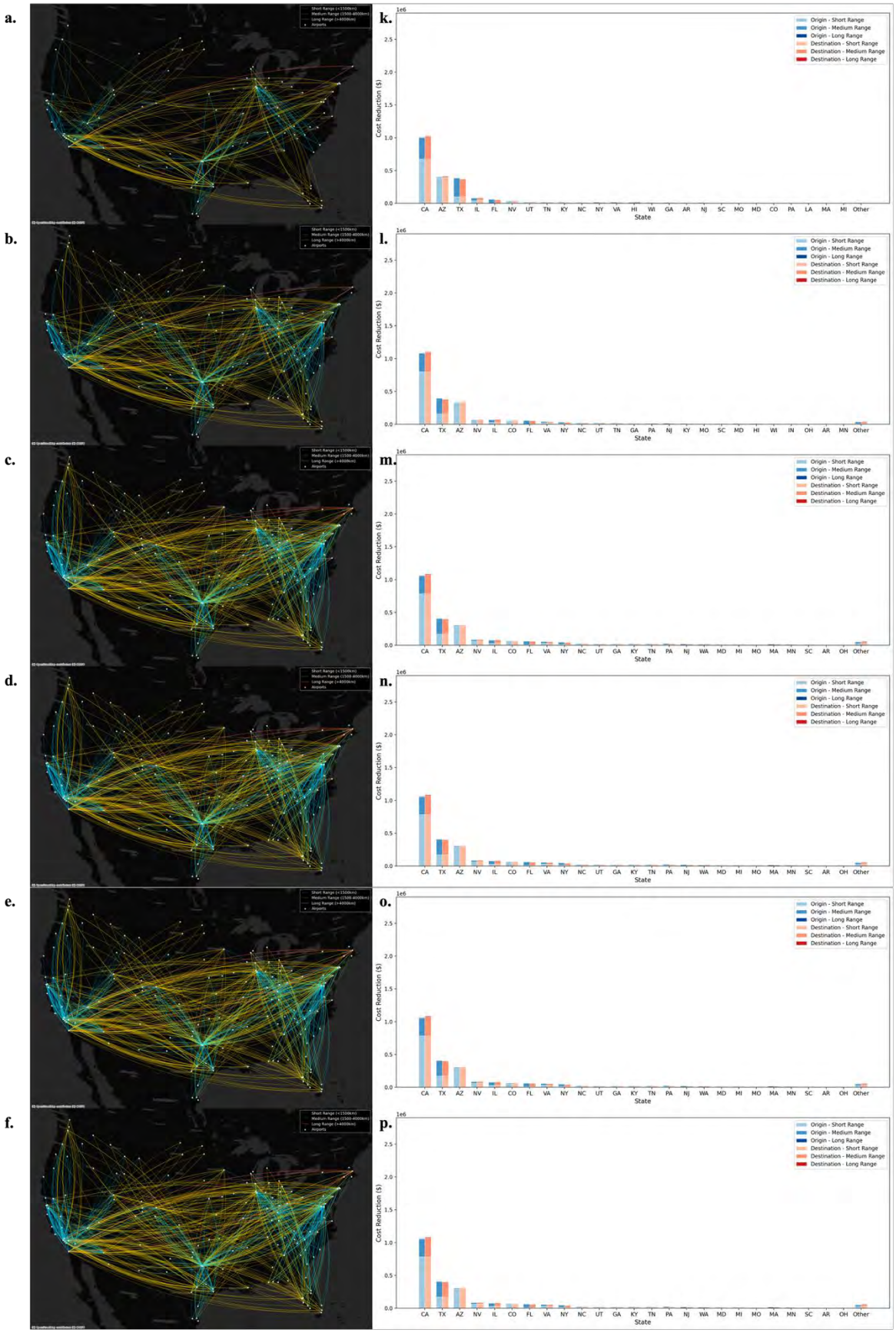

a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Selected Solar Farms
Capacity (MW)
State
Total Cost Reduction ($)

Figure 10 100% Solar farm selection across different flight market penetration rates

a-j, Spatial distribution of selected solar farms (blue dots); and the color of the states represents the total optimized solar capacity (MW). k-t, Scatter plot aggregates the relationship between individual solar farm capacity (MW) and total cost reduction ($), colored by cost reduction magnitude; and each dot represents one farm, clustered by state.


a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Origin - Short Range
Origin - Medium Range
Origin - Long Range
Destination - Short Range
Destination - Medium Range
Destination - Long Range
Cost Reduction ($)
State
1e6

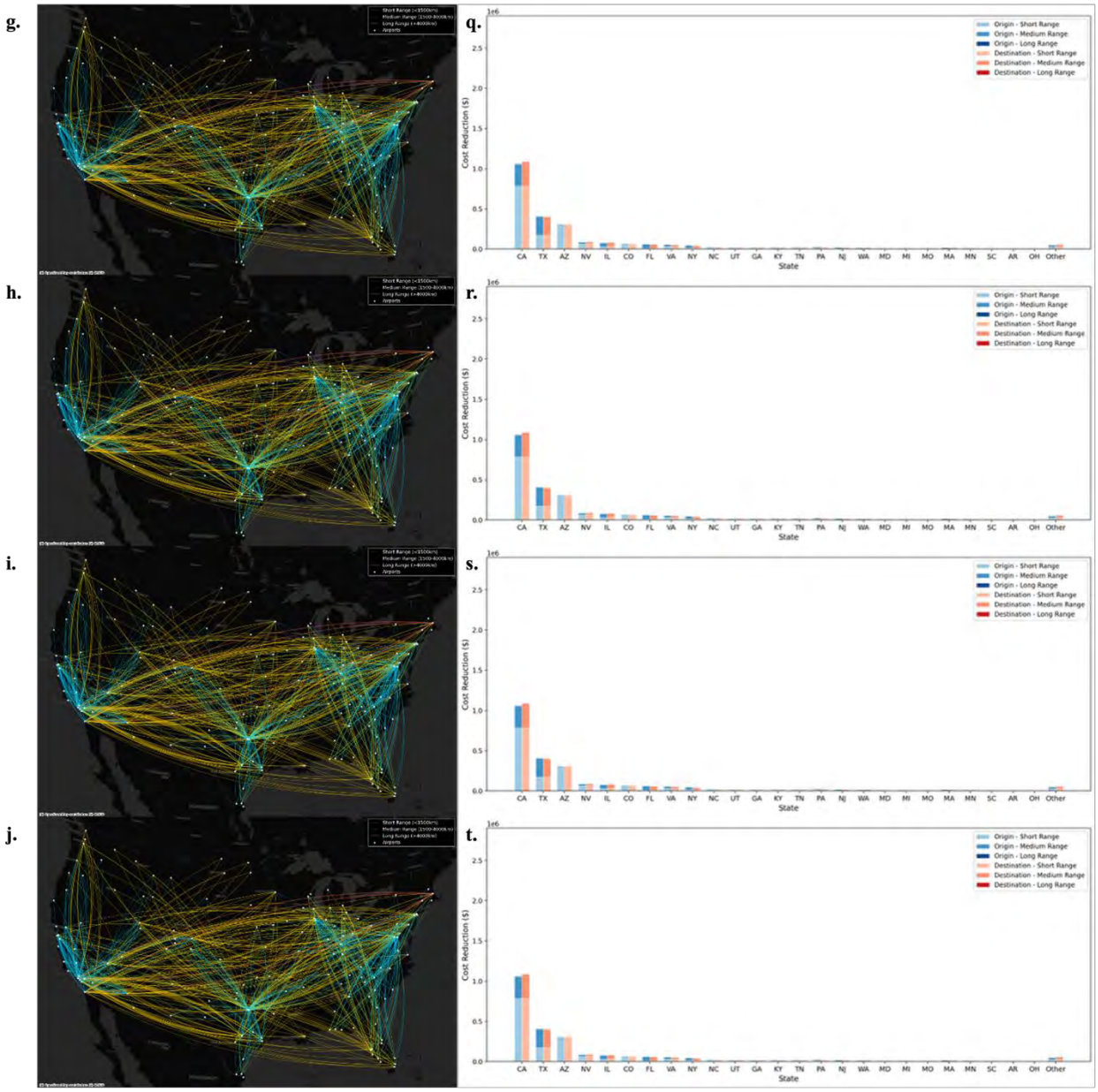
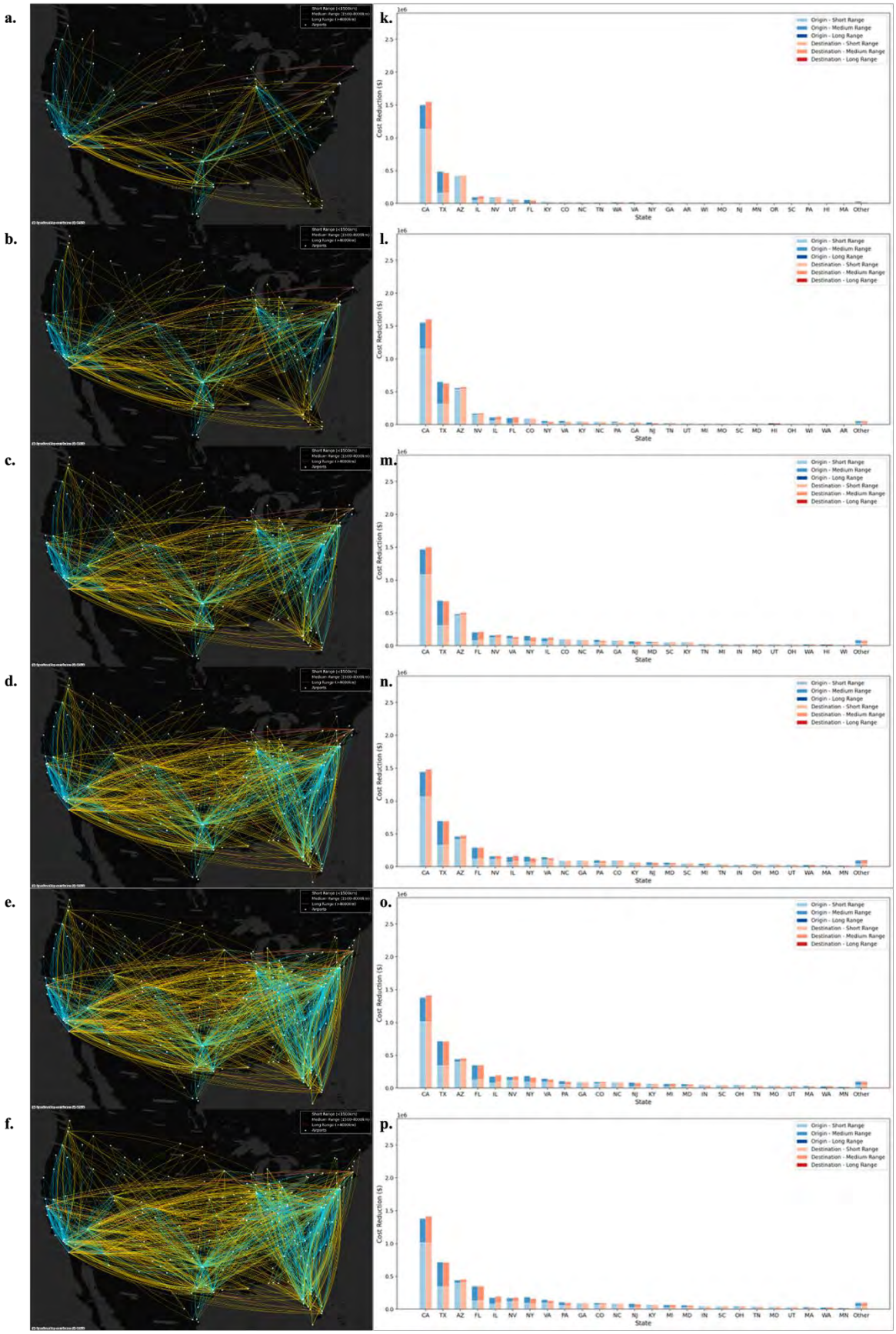


Figure 11 10% Flight selection across different solar farm market penetration rates

a-j, Spatial distribution of selected flights; each line represents a flight connection colored flight range categories: short-range (0-1,500 km, cyan), medium-range (1,500-4,000 km, yellow), and long-range (>4,000 km, magenta); and airports are shown as white points. k-t, State-level cost reductions aggregated by flight origin and destination states, with states ordered by total savings ($); for each state, the left bar (blue shades) represents cost savings associated with flight origins, and the right bar (orange shades) represents savings associated with destinations; and bar segments are stacked by flight range category.


a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Origin - Short Range
Origin - Medium Range
Origin - Long Range
Destination - Short Range
Destination - Medium Range
Destination - Long Range
Cost Reduction ($)
State
1e6

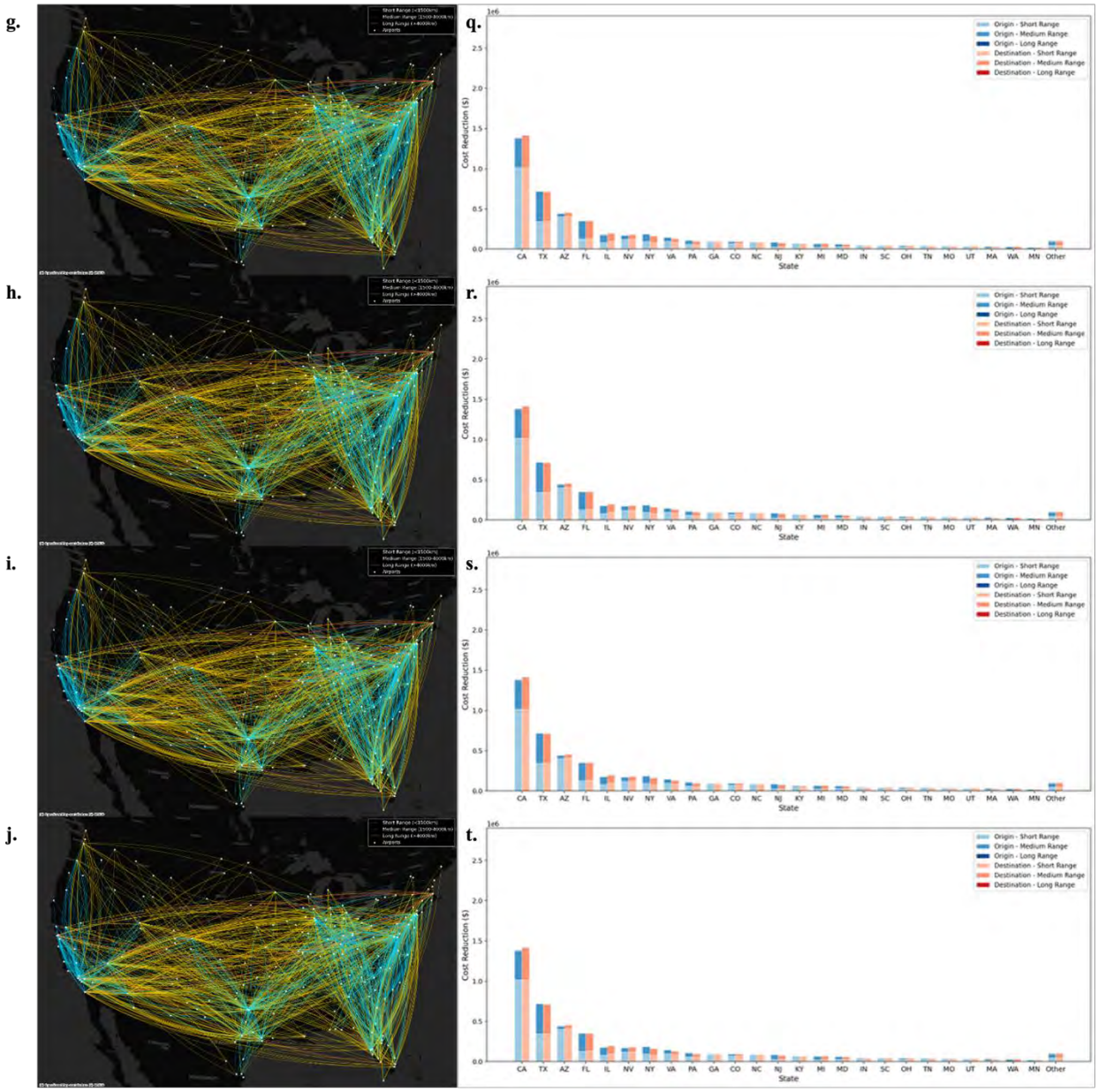
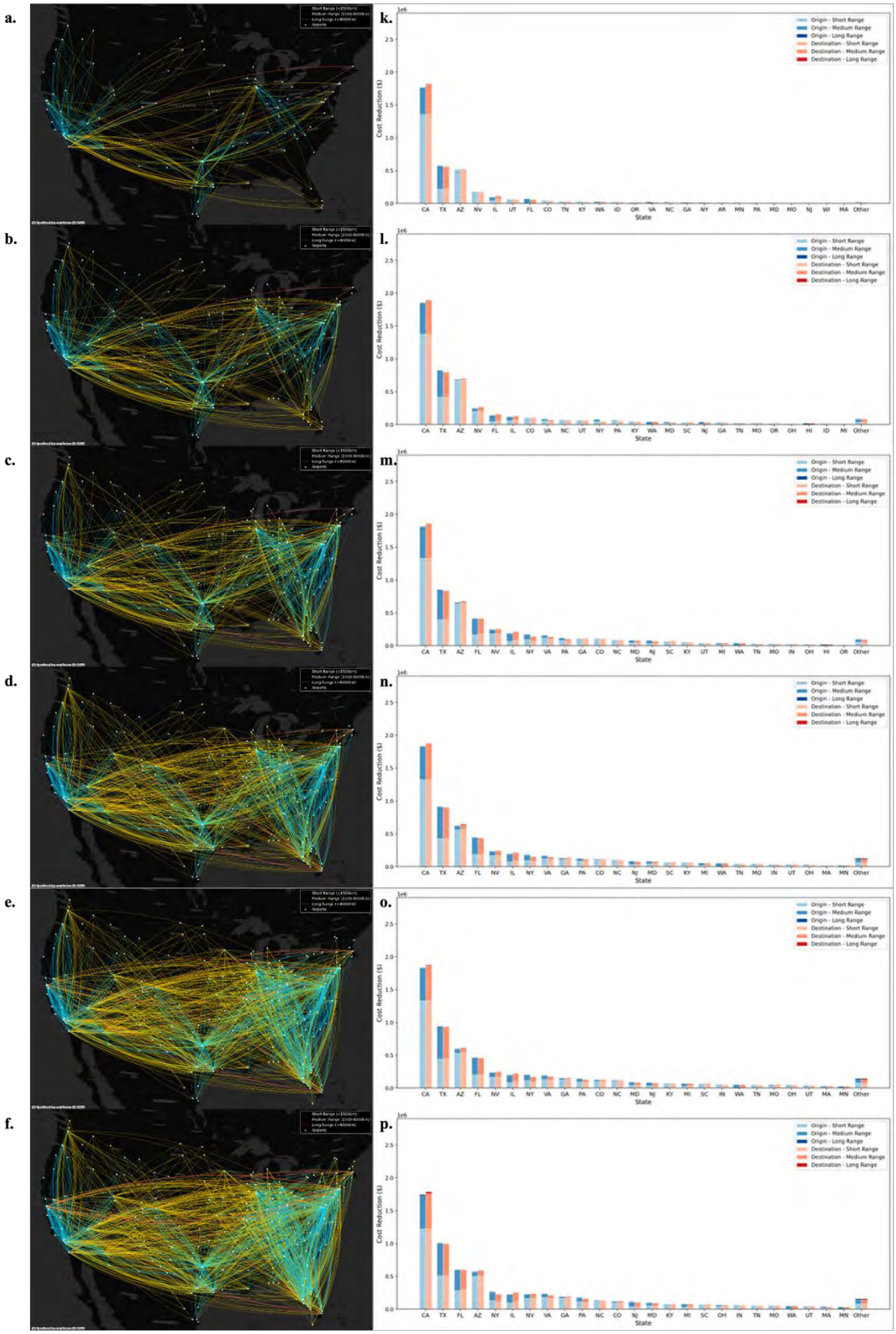


Figure 12 20% Flight selection across different solar farm market penetration rates

a-j, Spatial distribution of selected flights; each line represents a flight connection colored flight range categories: short-range (0-1,500 km, cyan), medium-range (1,500-4,000 km, yellow), and long-range (>4,000 km, magenta); and airports are shown as white points. k-t, State-level cost reductions aggregated by flight origin and destination states, with states ordered by total savings ($); for each state, the left bar (blue shades) represents cost savings associated with flight origins, and the right bar (orange shades) represents savings associated with destinations; and bar segments are stacked by flight range category.


a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Origin - Short Range
Origin - Medium Range
Origin - Long Range
Destination - Short Range
Destination - Medium Range
Destination - Long Range
Cost Reduction ($)
State

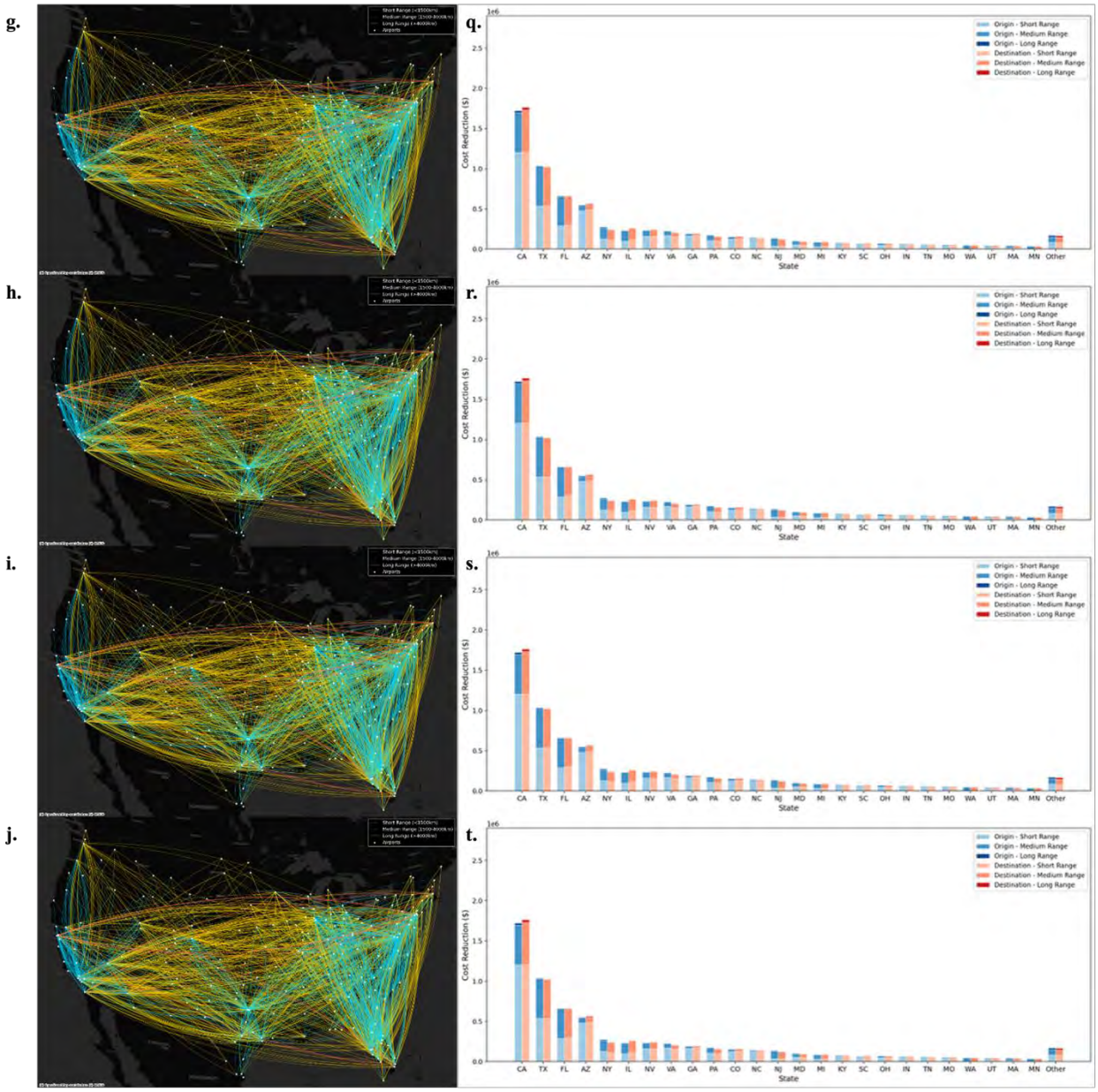
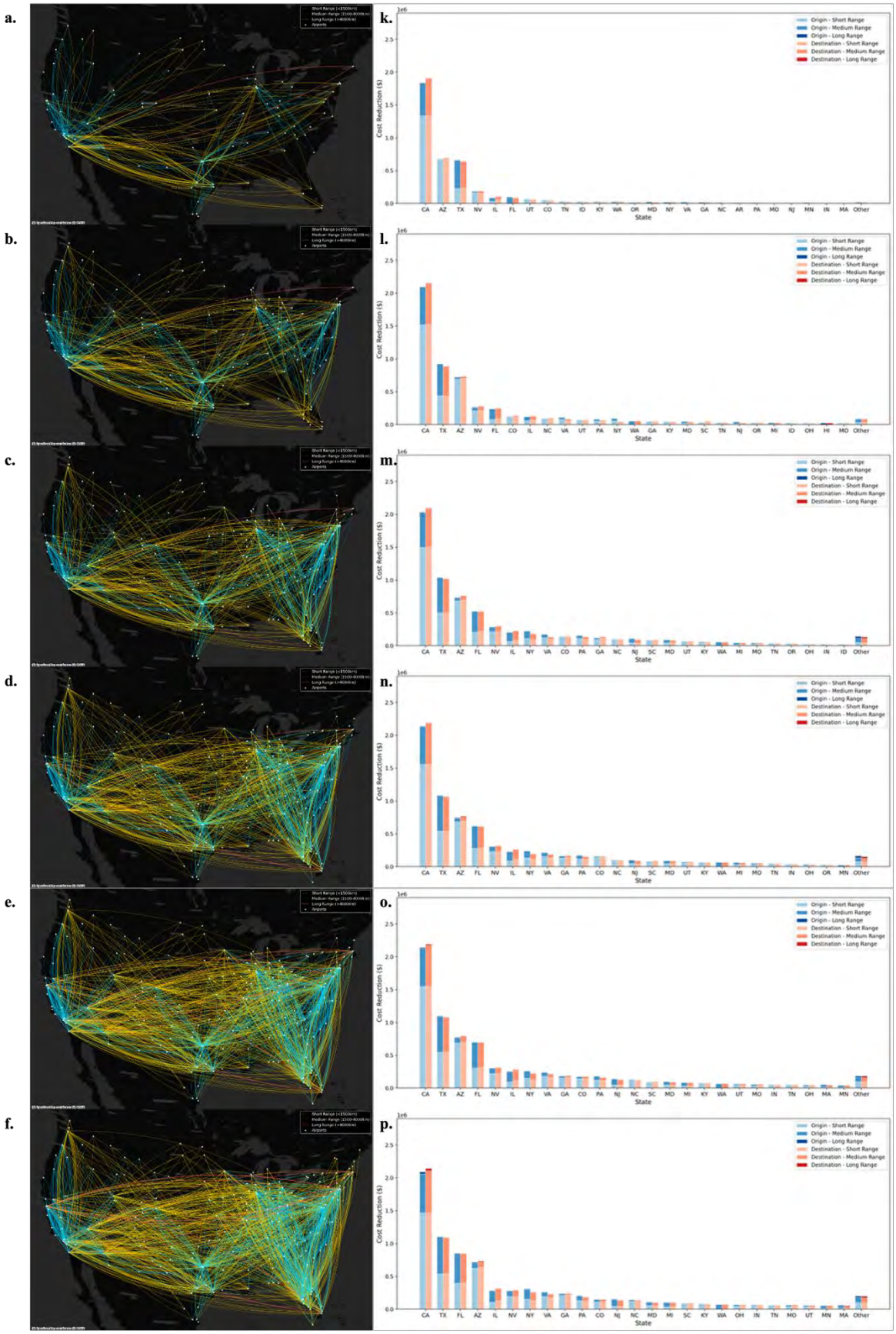


Figure 13 30% Flight selection across different solar farm market penetration rates

a-j, Spatial distribution of selected flights; each line represents a flight connection colored flight range categories: short-range (0-1,500 km, cyan), medium-range (1,500-4,000 km, yellow), and long-range (>4,000 km, magenta); and airports are shown as white points. k-t, State-level cost reductions aggregated by flight origin and destination states, with states ordered by total savings ($); for each state, the left bar (blue shades) represents cost savings associated with flight origins, and the right bar (orange shades) represents savings associated with destinations; and bar segments are stacked by flight range category.


a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Origin - Short Range
Origin - Medium Range
Origin - Long Range
Destination - Short Range
Destination - Medium Range
Destination - Long Range
Cost Reduction ($)
State

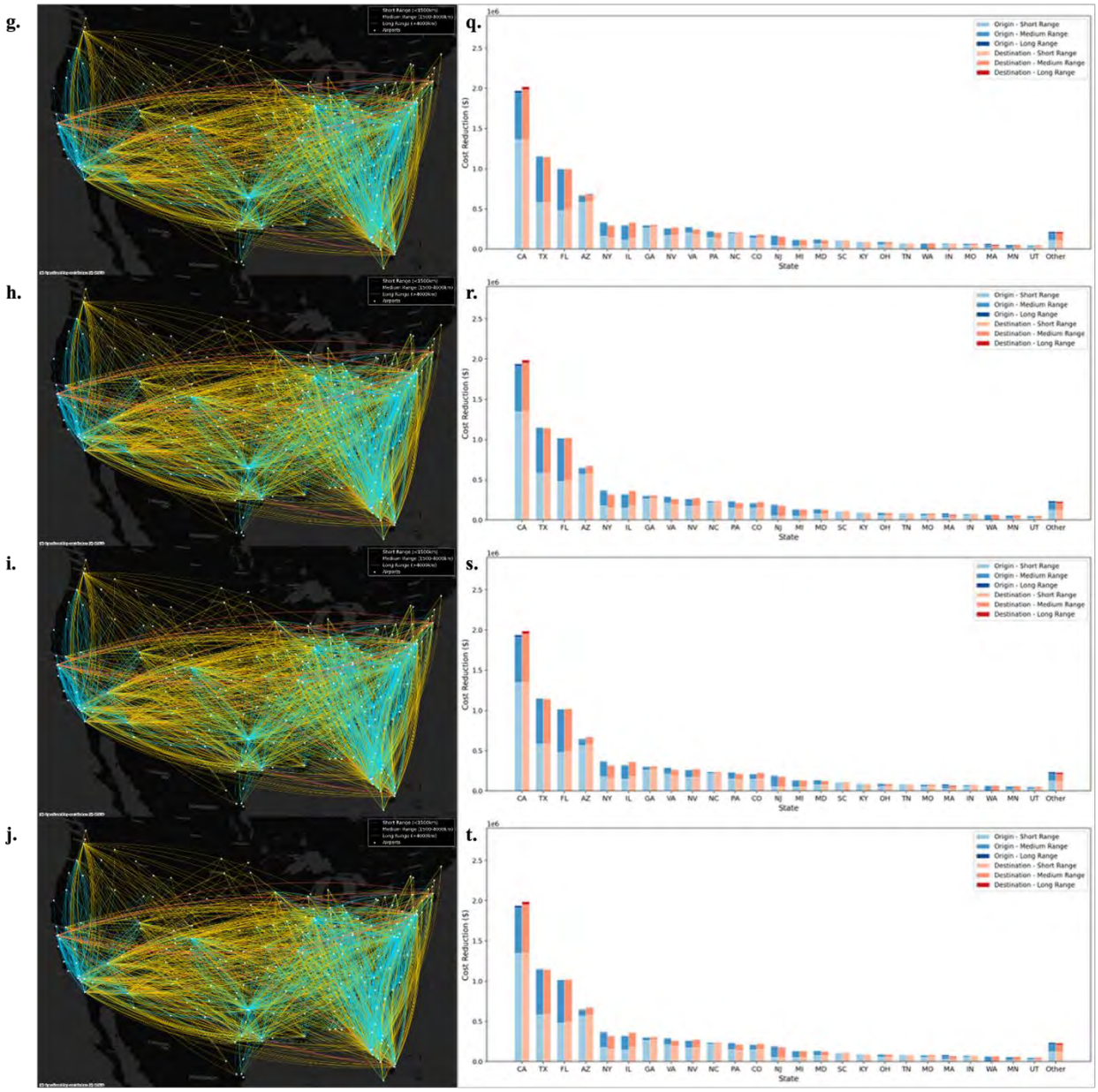
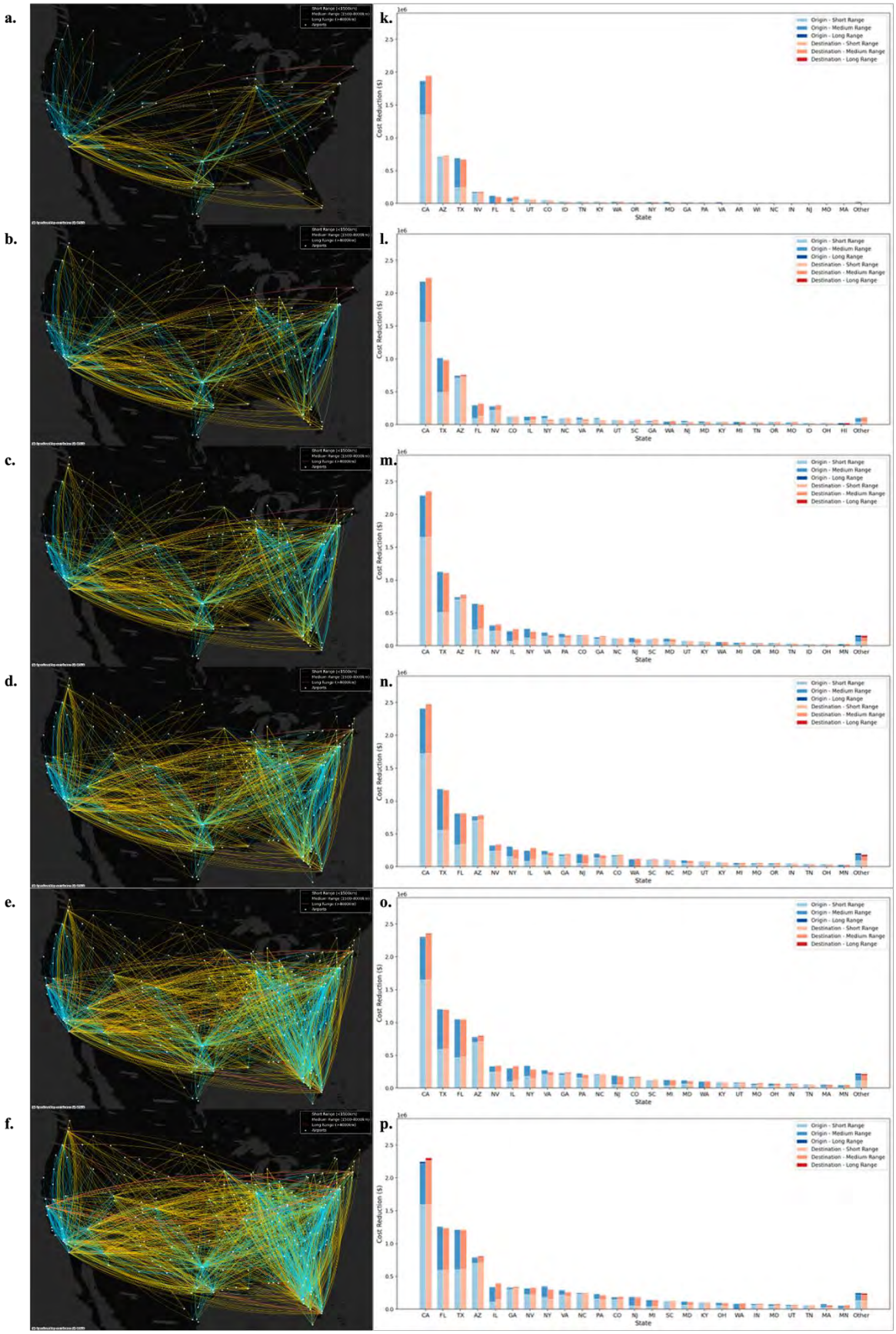


Figure 14 40% Flight selection across different solar farm market penetration rates

a-j, Spatial distribution of selected flights; each line represents a flight connection colored flight range categories: short-range (0-1,500 km, cyan), medium-range (1,500-4,000 km, yellow), and long-range (>4,000 km, magenta); and airports are shown as white points. k-t, State-level cost reductions aggregated by flight origin and destination states, with states ordered by total savings ($); for each state, the left bar (blue shades) represents cost savings associated with flight origins, and the right bar (orange shades) represents savings associated with destinations; and bar segments are stacked by flight range category.


a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Origin - Short Range
Origin - Medium Range
Origin - Long Range
Destination - Short Range
Destination - Medium Range
Destination - Long Range
Cost Reduction ($)
State

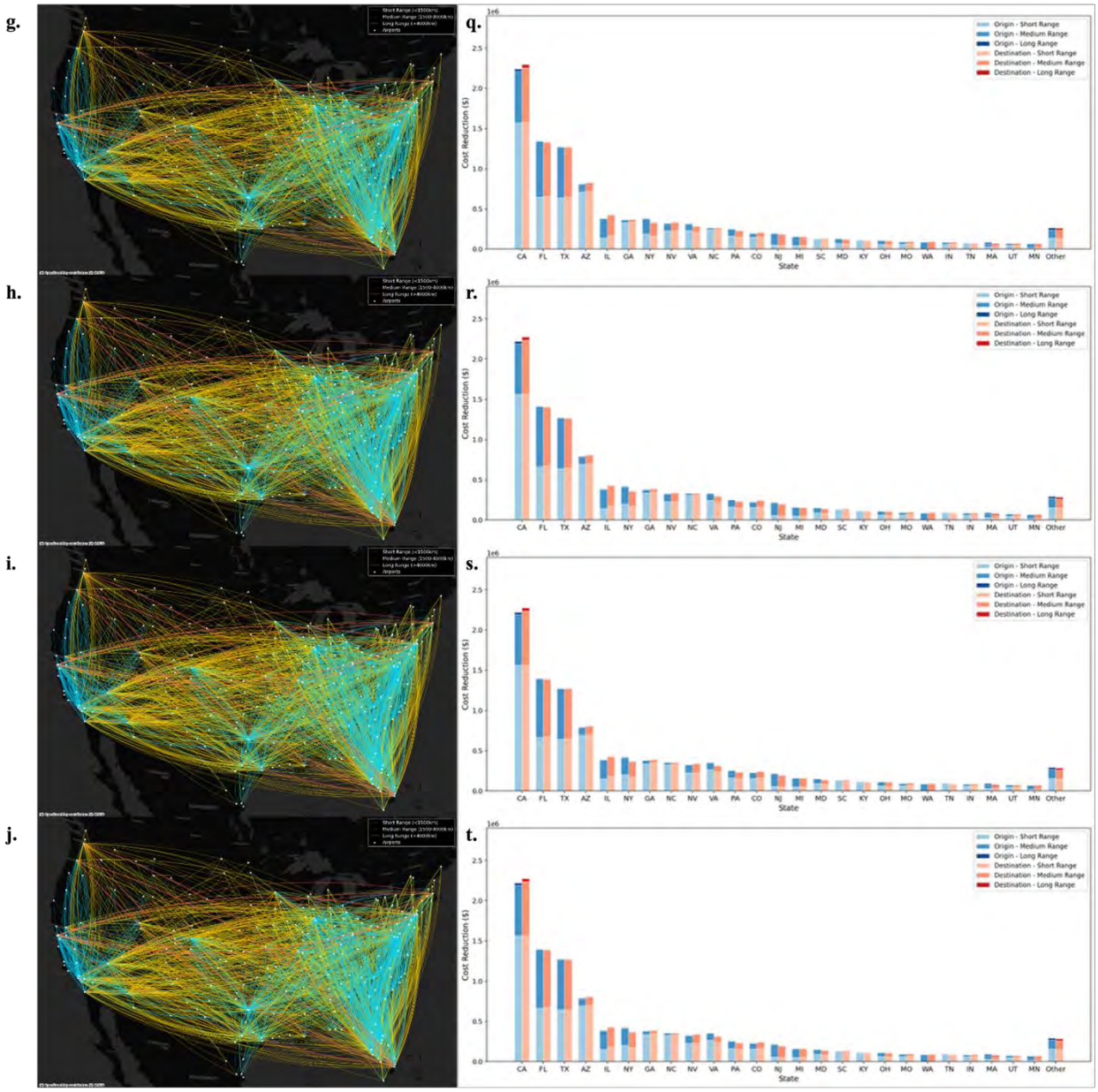
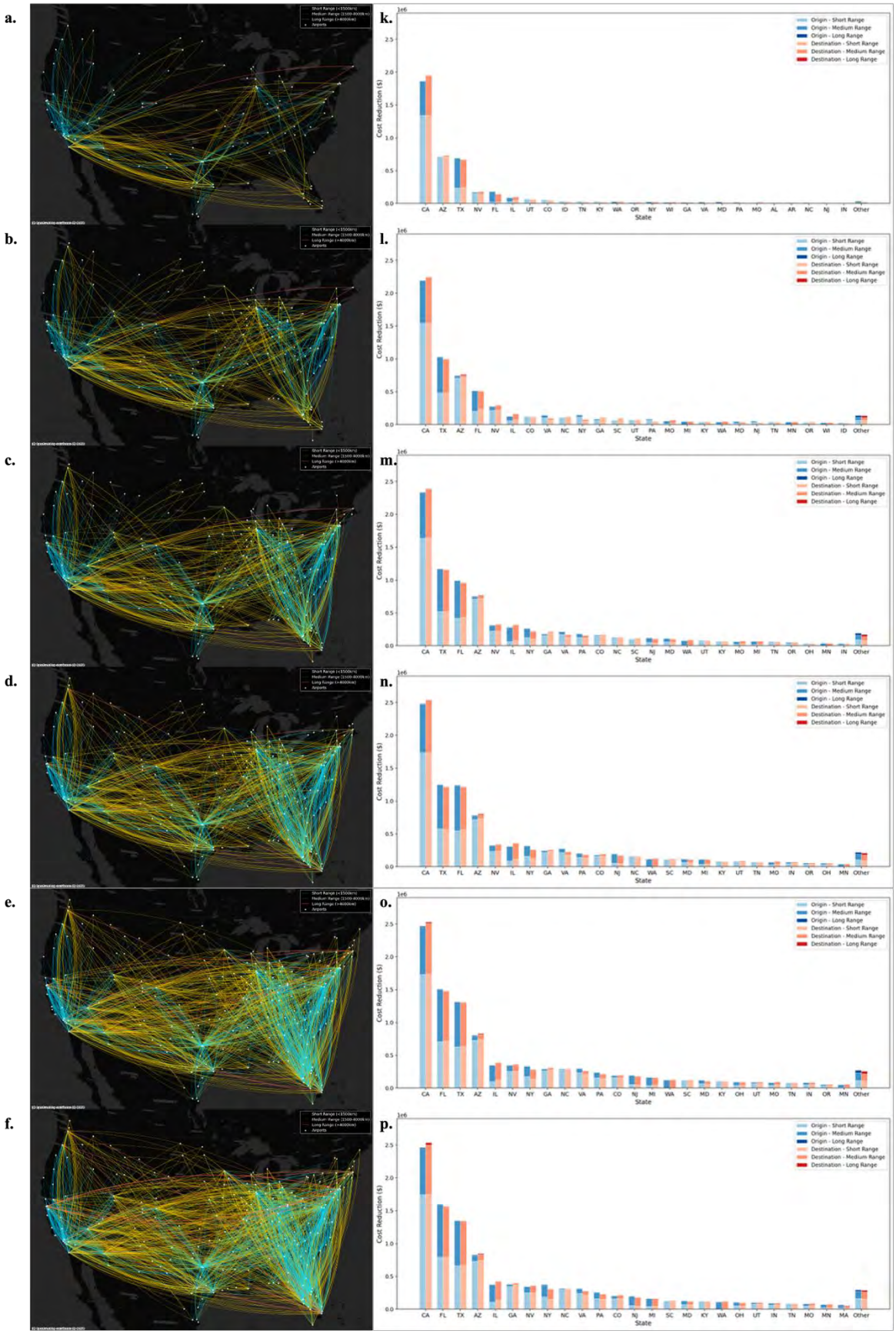


Figure 15 50% Flight selection across different solar farm market penetration rates

a-j, Spatial distribution of selected flights; each line represents a flight connection colored flight range categories: short-range (0-1,500 km, cyan), medium-range (1,500-4,000 km, yellow), and long-range (>4,000 km, magenta); and airports are shown as white points. k-t, State-level cost reductions aggregated by flight origin and destination states, with states ordered by total savings ($); for each state, the left bar (blue shades) represents cost savings associated with flight origins, and the right bar (orange shades) represents savings associated with destinations; and bar segments are stacked by flight range category.


a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Origin - Short Range
Origin - Medium Range
Origin - Long Range
Destination - Short Range
Destination - Medium Range
Destination - Long Range
Cost Reduction ($)
State

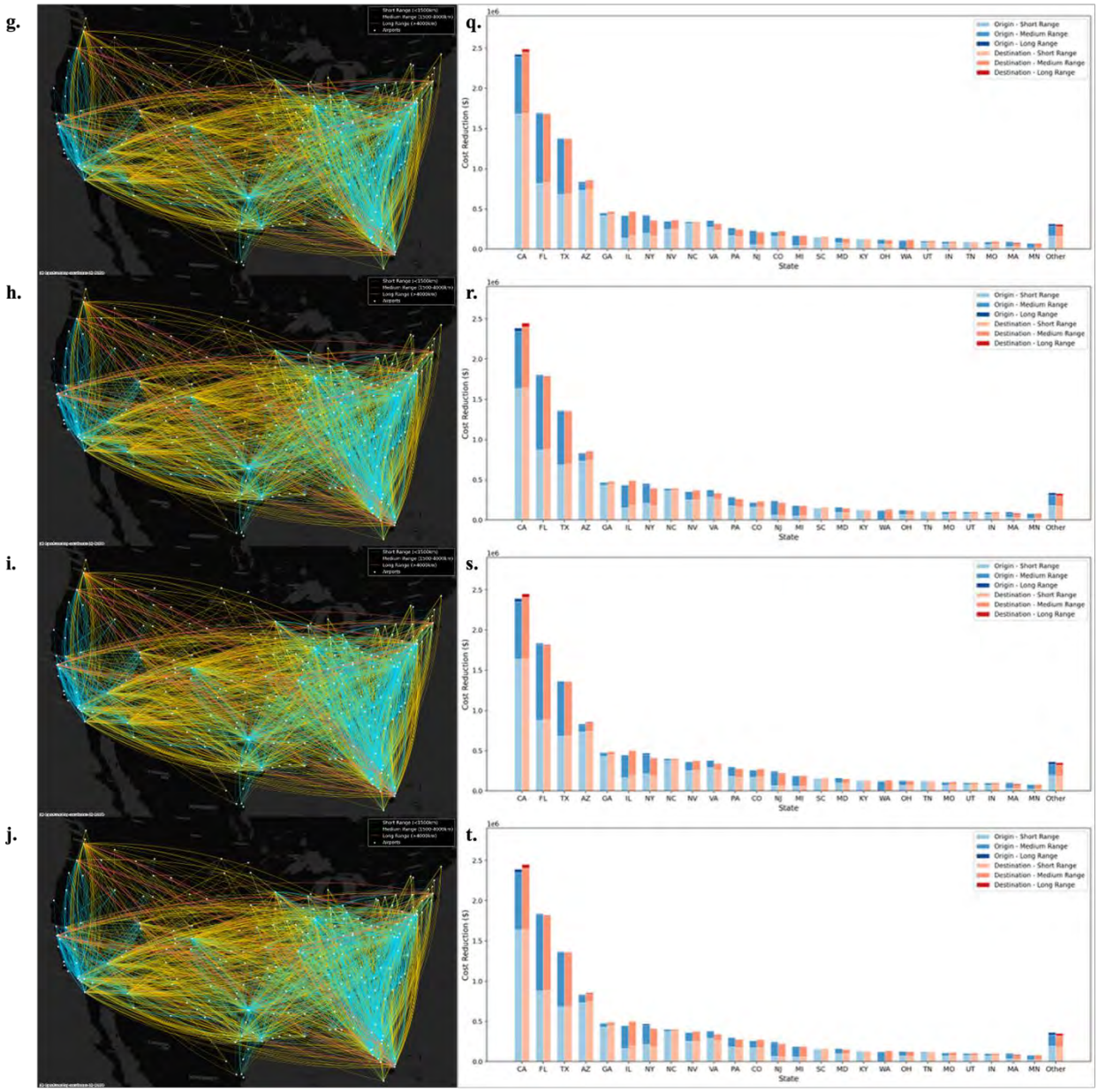
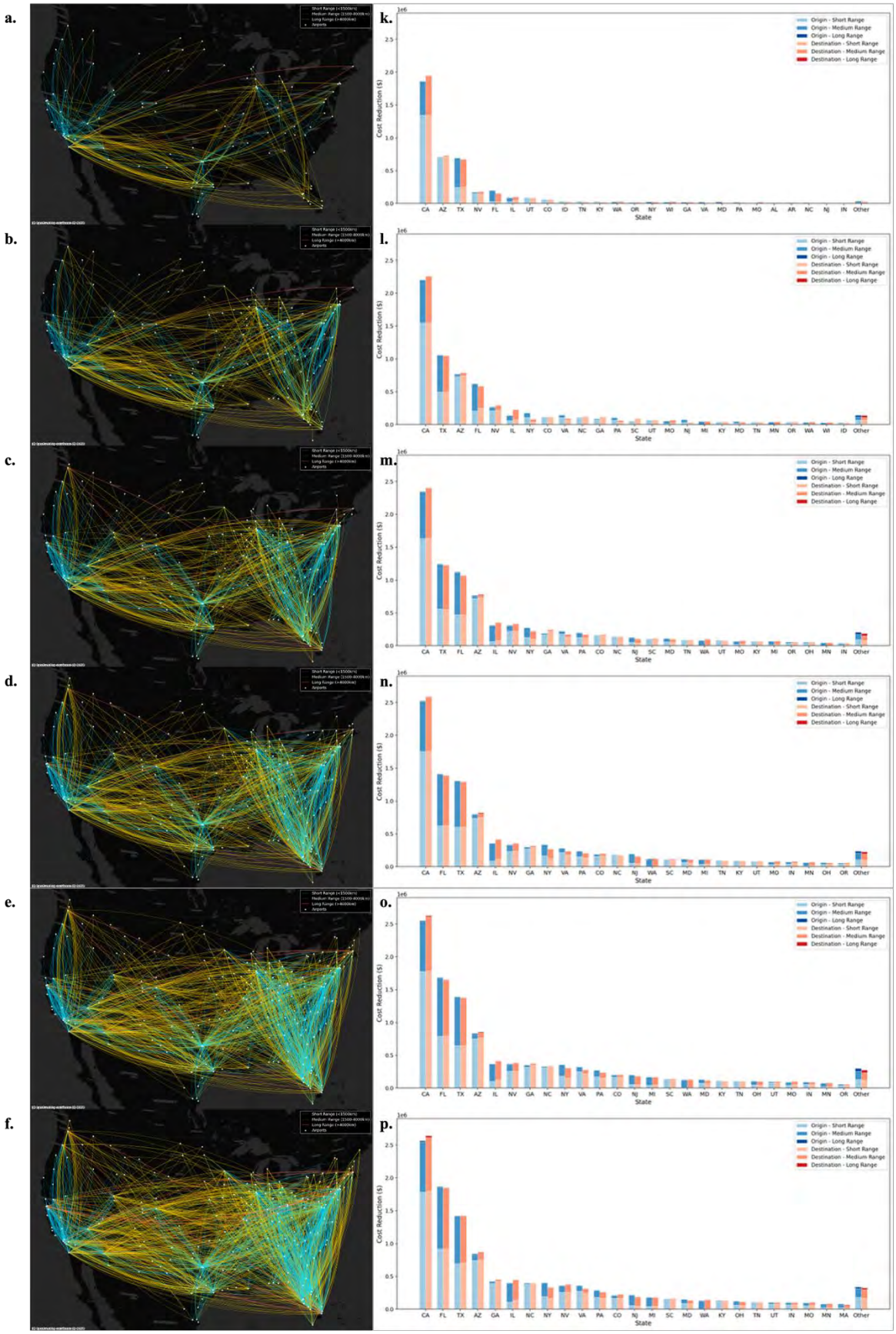


Figure 16 60% Flight selection across different solar farm market penetration rates

a-j, Spatial distribution of selected flights; each line represents a flight connection colored flight range categories: short-range (0-1,500 km, cyan), medium-range (1,500-4,000 km, yellow), and long-range (>4,000 km, magenta); and airports are shown as white points. k-t, State-level cost reductions aggregated by flight origin and destination states, with states ordered by total savings ($); for each state, the left bar (blue shades) represents cost savings associated with flight origins, and the right bar (orange shades) represents savings associated with destinations; and bar segments are stacked by flight range category.


a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Origin - Short Range
Origin - Medium Range
Origin - Long Range
Destination - Short Range
Destination - Medium Range
Destination - Long Range
Cost Reduction ($)
State

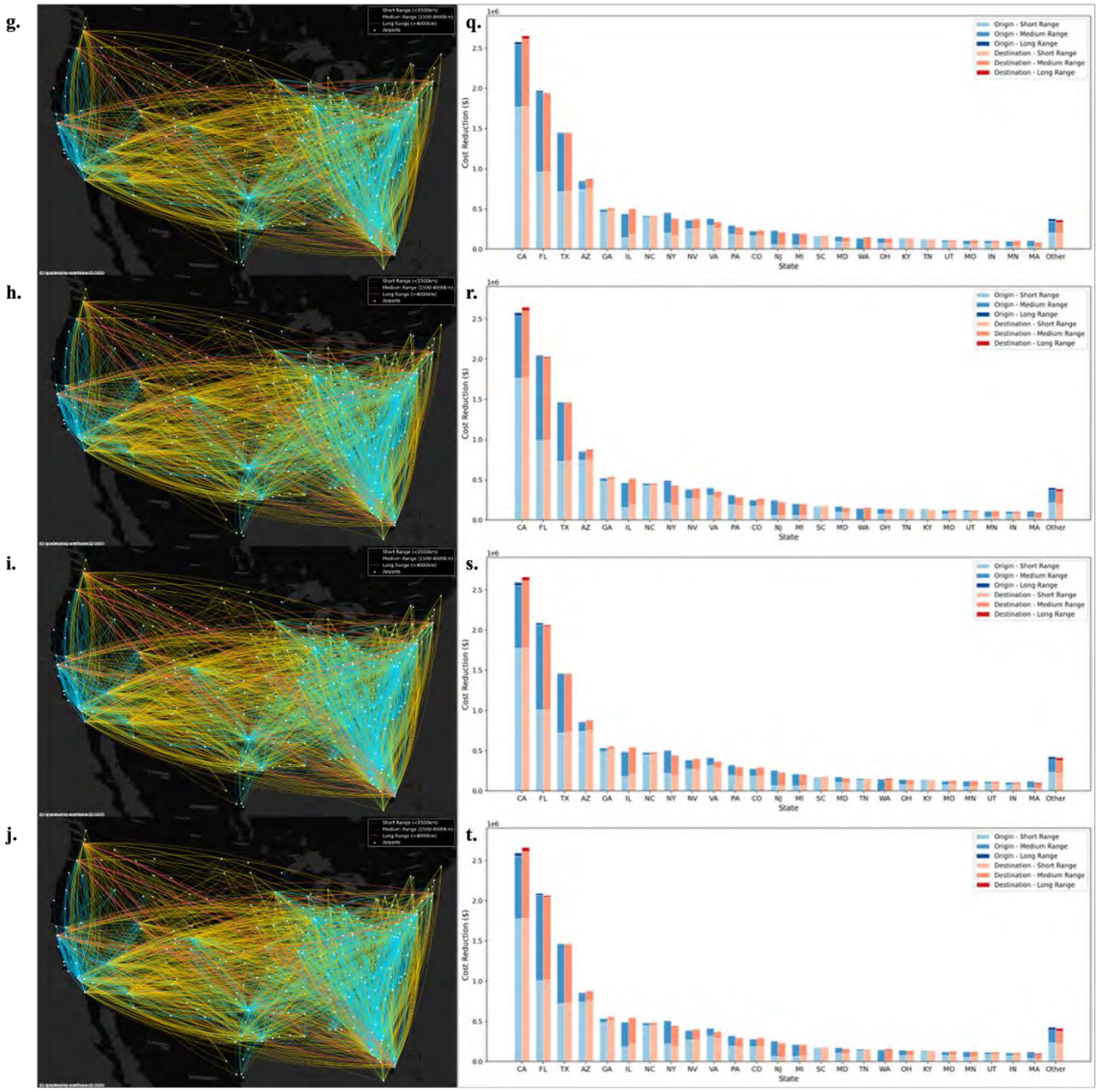
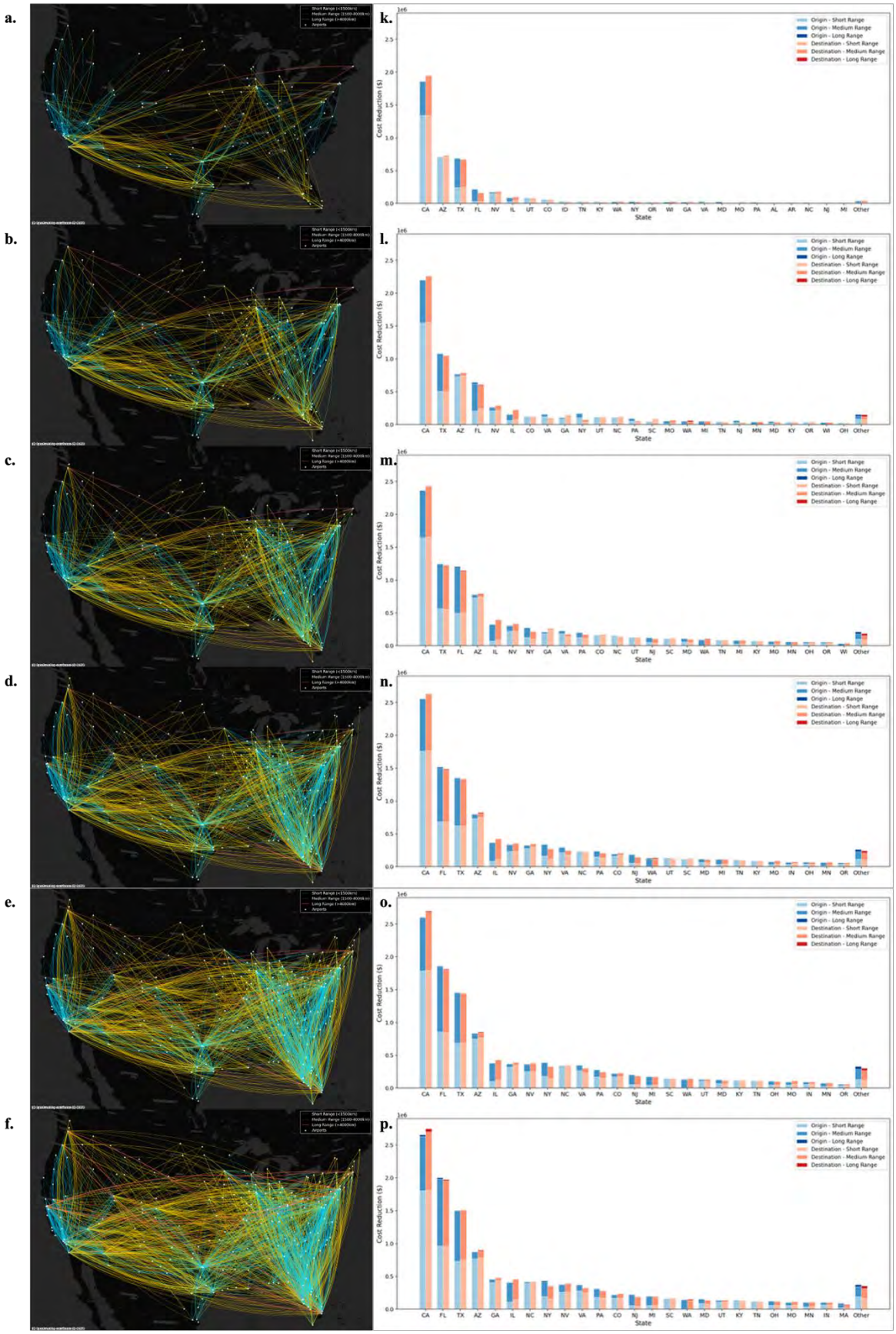


Figure 17 70% Flight selection across different solar farm market penetration rates

a-j, Spatial distribution of selected flights; each line represents a flight connection colored flight range categories: short-range (0-1,500 km, cyan), medium-range (1,500-4,000 km, yellow), and long-range (>4,000 km, magenta); and airports are shown as white points. k-t, State-level cost reductions aggregated by flight origin and destination states, with states ordered by total savings ($); for each state, the left bar (blue shades) represents cost savings associated with flight origins, and the right bar (orange shades) represents savings associated with destinations; and bar segments are stacked by flight range category.


a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Origin - Short Range
Origin - Medium Range
Origin - Long Range
Destination - Short Range
Destination - Medium Range
Destination - Long Range
Cost Reduction ($)
State

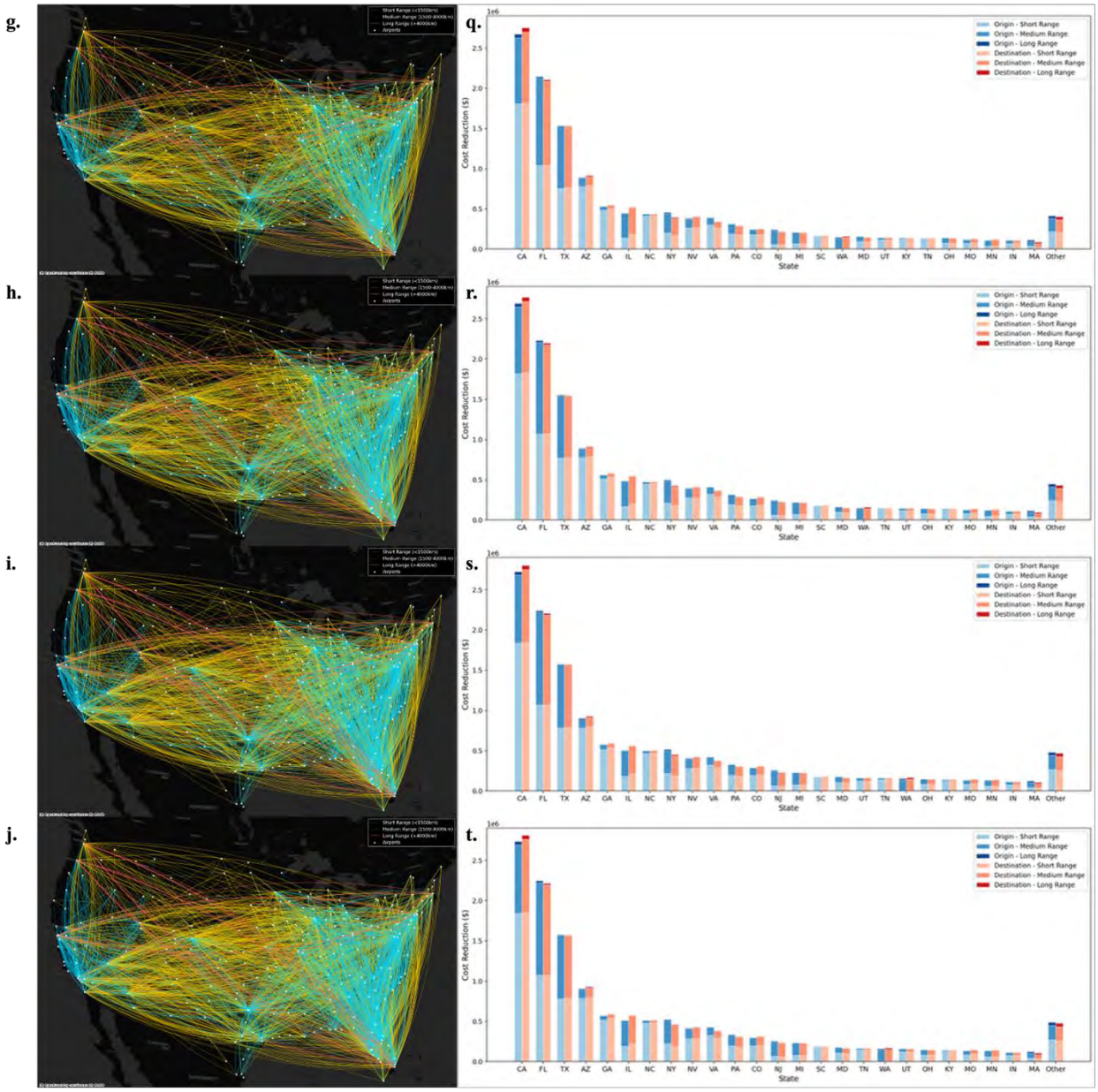
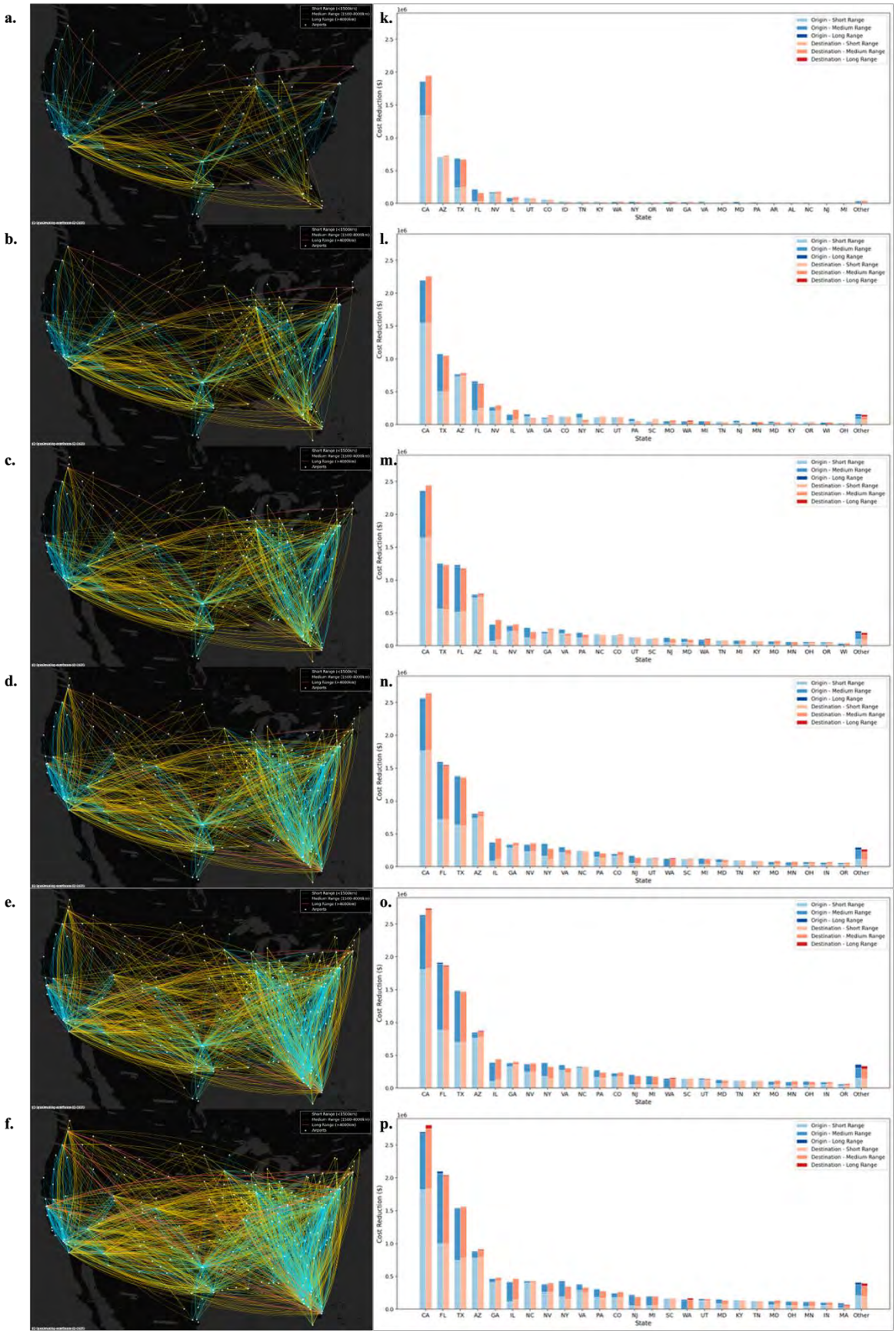


Figure 18 80% Flight selection across different solar farm market penetration rates

a-j, Spatial distribution of selected flights; each line represents a flight connection colored flight range categories: short-range (0-1,500 km, cyan), medium-range (1,500-4,000 km, yellow), and long-range (>4,000 km, magenta); and airports are shown as white points. k-t, State-level cost reductions aggregated by flight origin and destination states, with states ordered by total savings ($); for each state, the left bar (blue shades) represents cost savings associated with flight origins, and the right bar (orange shades) represents savings associated with destinations; and bar segments are stacked by flight range category.


a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Origin - Short Range
Origin - Medium Range
Origin - Long Range
Destination - Short Range
Destination - Medium Range
Destination - Long Range
Cost Reduction ($)
State

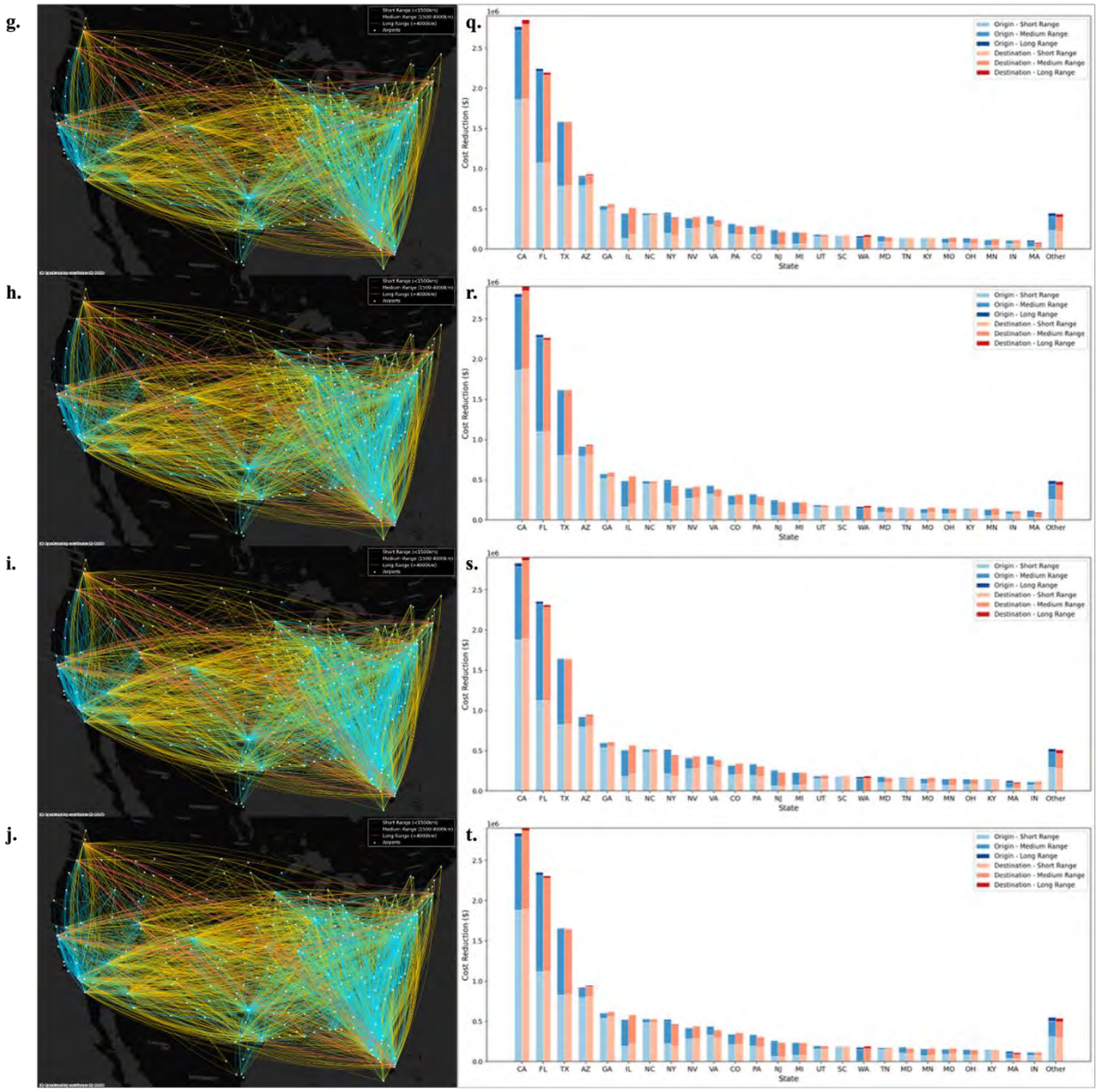
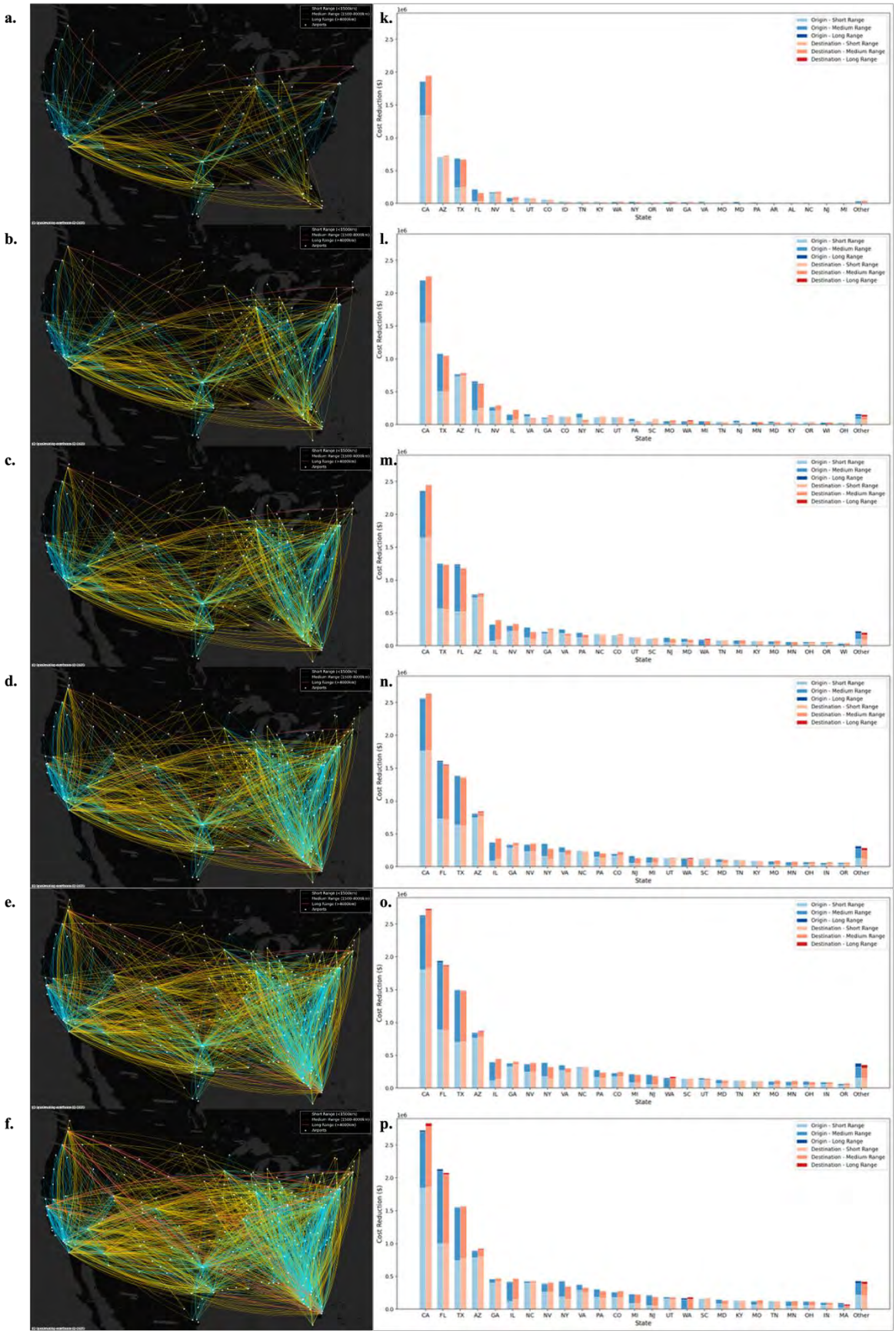


Figure 19 90% Flight selection across different solar farm market penetration rates

a-j, Spatial distribution of selected flights; each line represents a flight connection colored flight range categories: short-range (0-1,500 km, cyan), medium-range (1,500-4,000 km, yellow), and long-range (>4,000 km, magenta); and airports are shown as white points. k-t, State-level cost reductions aggregated by flight origin and destination states, with states ordered by total savings ($); for each state, the left bar (blue shades) represents cost savings associated with flight origins, and the right bar (orange shades) represents savings associated with destinations; and bar segments are stacked by flight range category.


a.
b.
c.
d.
e.
f.
k.
l.
m.
n.
o.
p.
Origin - Short Range
Origin - Medium Range
Origin - Long Range
Destination - Short Range
Destination - Medium Range
Destination - Long Range
Cost Reduction ($)
State

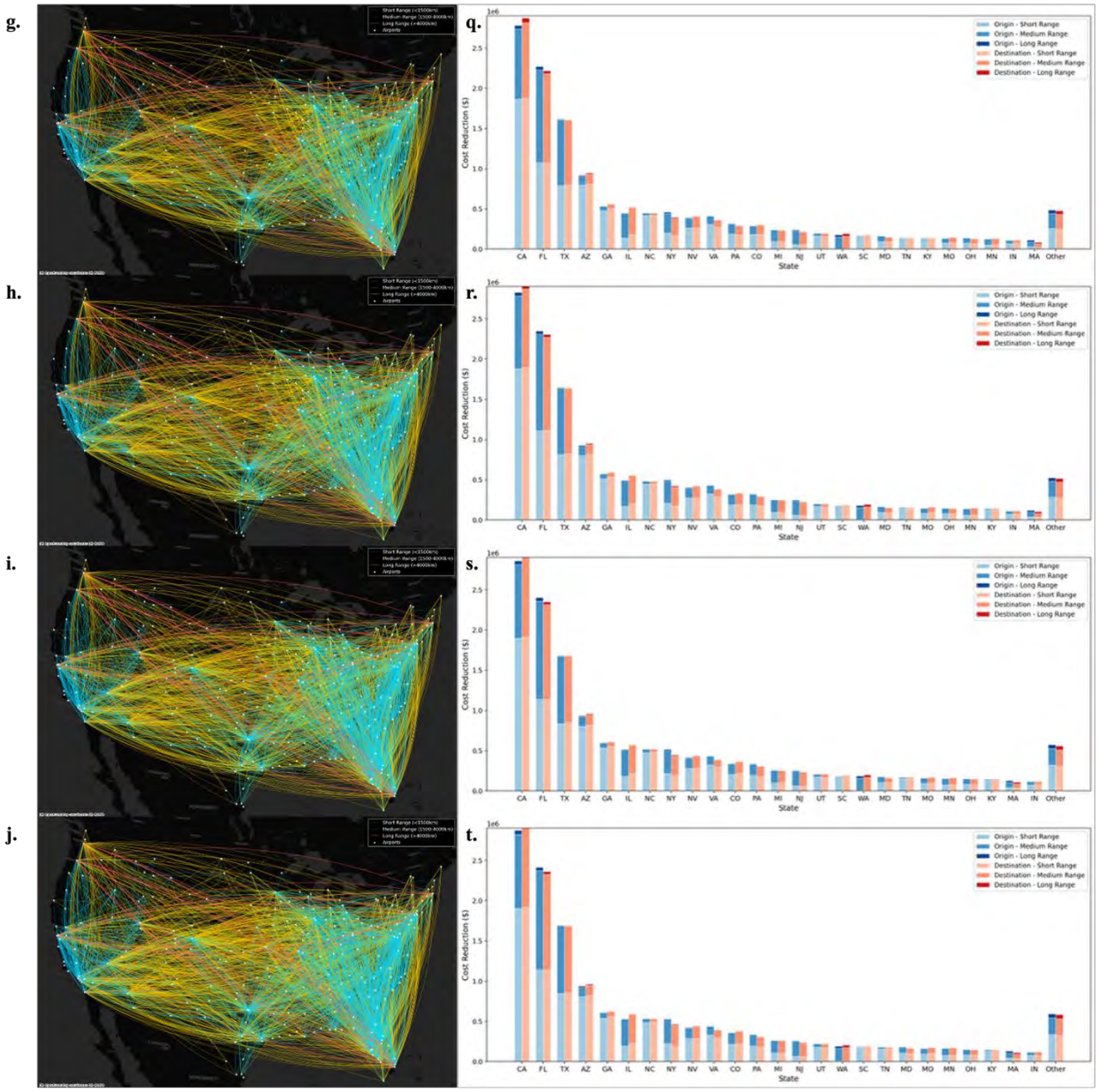


Figure 20 100% Flight selection across different solar farm market penetration rates

a-j, Spatial distribution of selected flights; each line represents a flight connection colored flight range categories: short-range (0-1,500 km, cyan), medium-range (1,500-4,000 km, yellow), and long-range (>4,000 km, magenta); and airports are shown as white points. k-t, State-level cost reductions aggregated by flight origin and destination states, with states ordered by total savings ($); for each state, the left bar (blue shades) represents cost savings associated with flight origins, and the right bar (orange shades) represents savings associated with destinations; and bar segments are stacked by flight range category.

Supplementary materials for case study

Note 1 Solar farm case study

We selected a solar farm with the highest energy supplied for case study. The chosen solar farm is Desert Sunlight 300, LLC (Solar Farm ID 230), located in Riverside County, California (33.818886° N, 115.389389° W). Commissioned in 2014, this facility is a utility-scale ground-mounted photovoltaic (PV) plant that uses thin-film technology with a fixed-tilt configuration (tilt: 22°, azimuth: 120°). The site has an installed capacity of 313.7 MW AC and 399.0 MW DC, with an energy beaming safety capacity of 239.92 MW. Based on our case study analysis, during the study period (7th -13th April, 2025), this site can supply 657.88 MWh of energy, support 78.71 flight-hours, reduce CO_2 emissions by 515,644 kg, and generate total cost reduction of $181,036. The location and power transfer range of this solar farm are presented in Fig. 21, and the flights it can support are presented in Fig. 22.

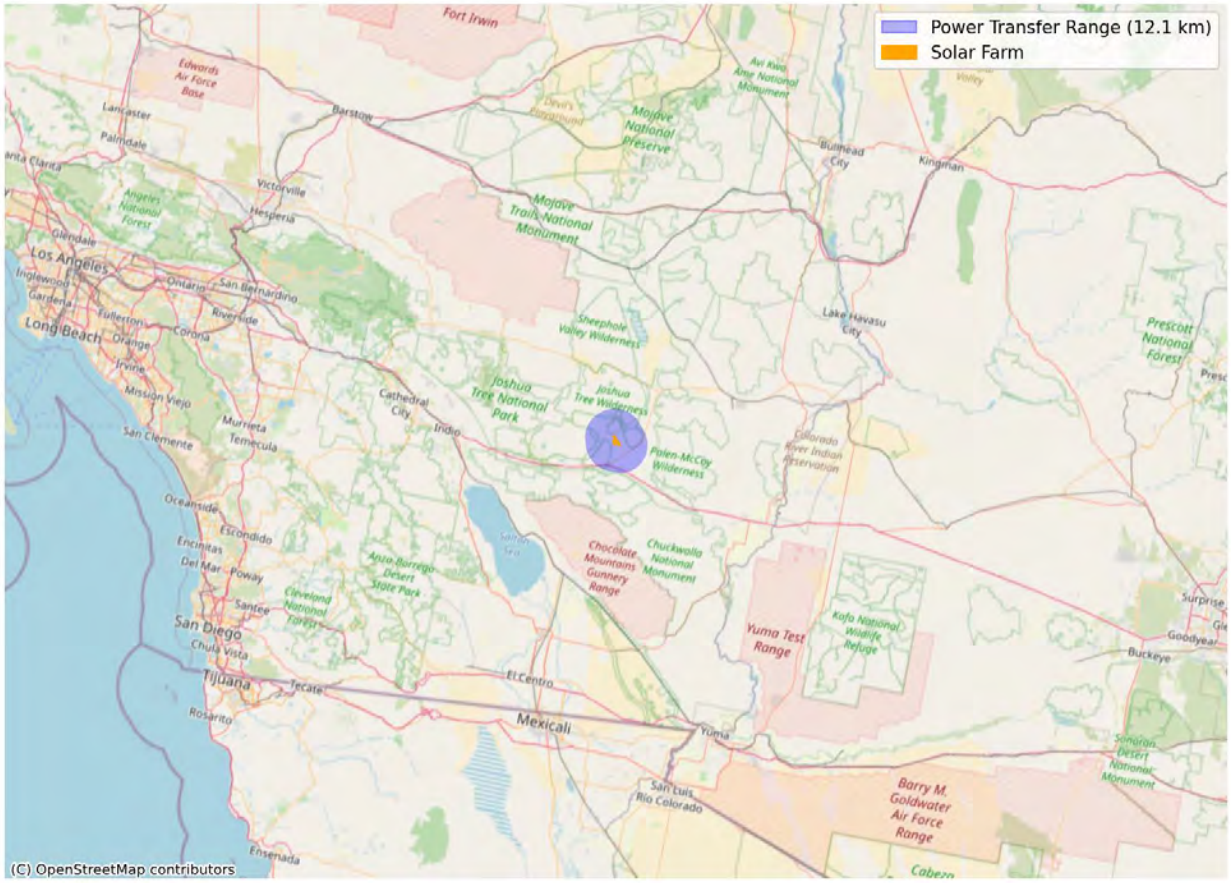


Figure 21 Location and power transfer range of the selected solar farm in the solar farm case study

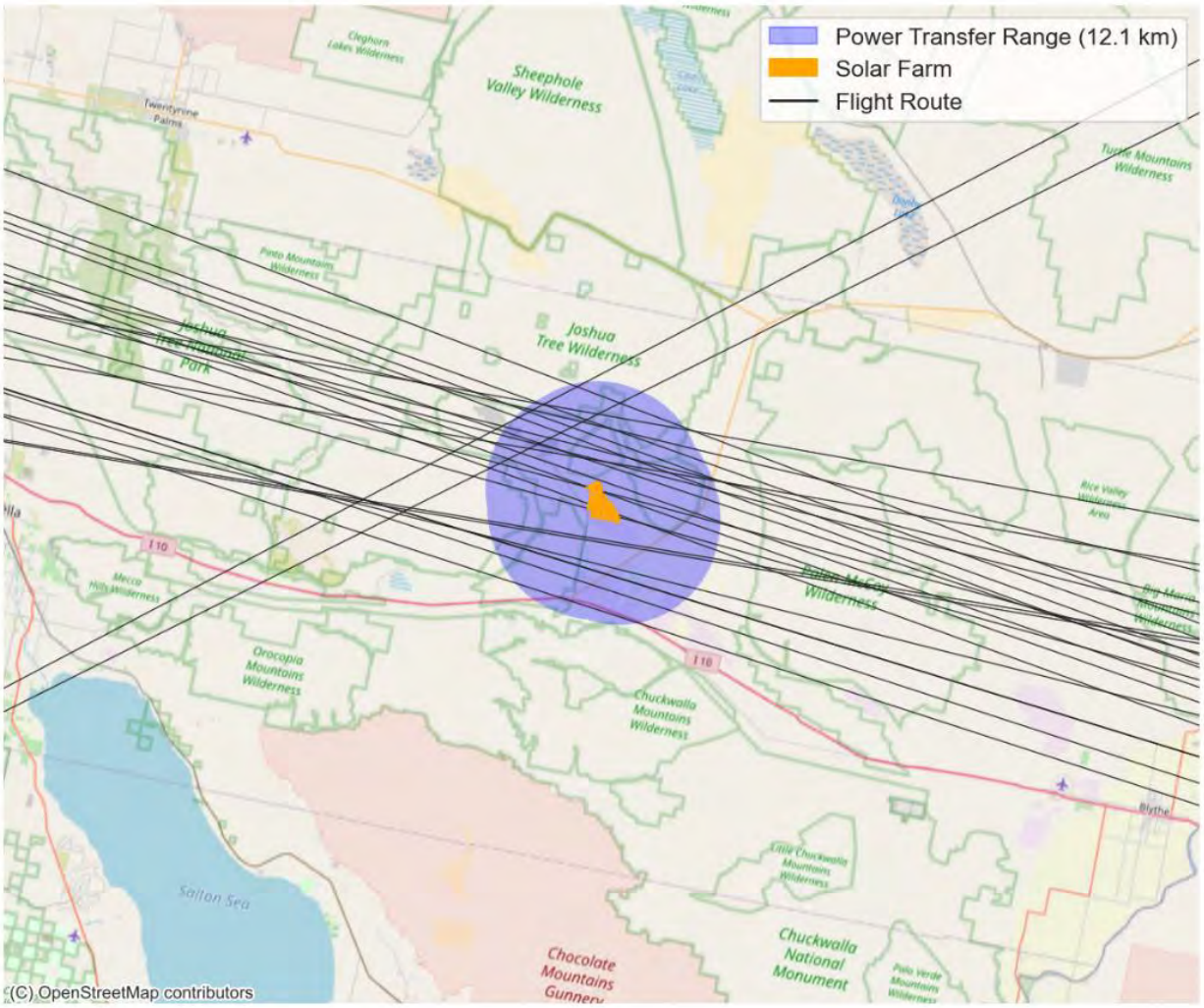


Figure 22 Flights supported by the selected solar farm in the solar farm case study

The energy supplied by the selected solar farm over the study period is shown in Fig. 23. Energy output remains very low during nighttime and early morning hours, then rises rapidly after sunrise, reaches daytime peaks of roughly 8 MWh, and declines again toward evening. This daily cycle is consistently observed throughout the week, reflecting the strong dependence of flight frequency. Although the overall temporal pattern is stable, the magnitude of daytime output varies, which is related to the flight schedule. In summary, the selected solar farm can provide substantial daytime energy supply, but its contribution is time dependent.

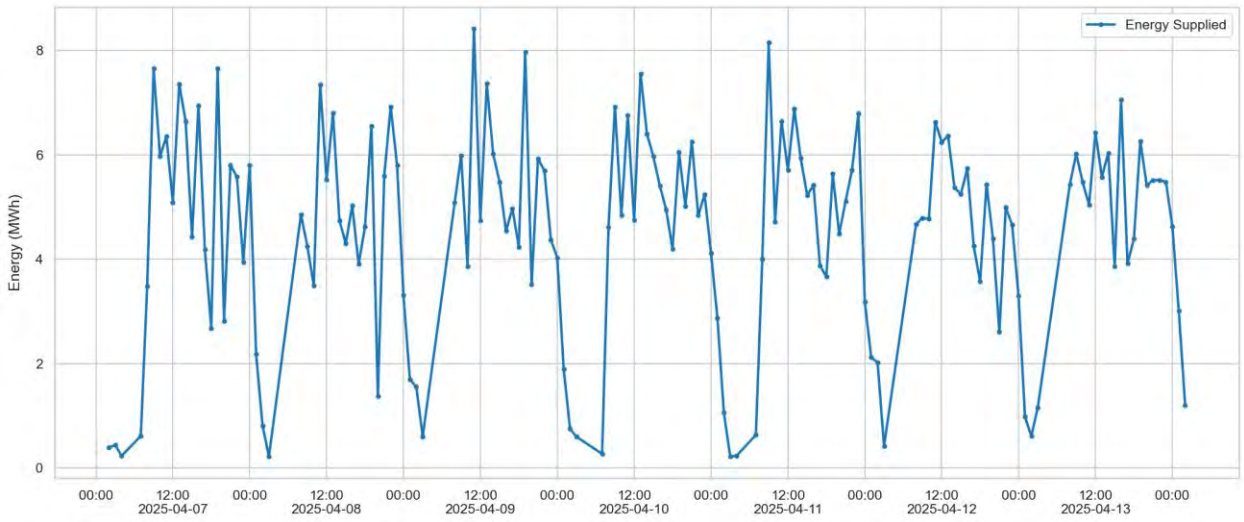


Figure 23 Energy supplied by the selected solar farm in the solar farm case study

Note 2 Flight case study

We selected a case study flight between Austin (AUS) and Los Angeles (LAX), representing a major intercity corridor linking Texas and California, which have the top two energy supported among the states. The selected flight departed from AUS at 7:37 PM CDT and landed in LAX at 9:10 PDT on 8th April, 2025, for a total duration of 213 minutes. The flight received 3.71 MWh of transmitted energy in approximately 50 minutes of operation. Notably, 22 solar farms jointly supplied energy to this flight. The power beaming support reduced CO2 emissions by 5,575 kg and generated total cost reduction of $2,119. The flight and associated solar farms are shown in Fig. 24.

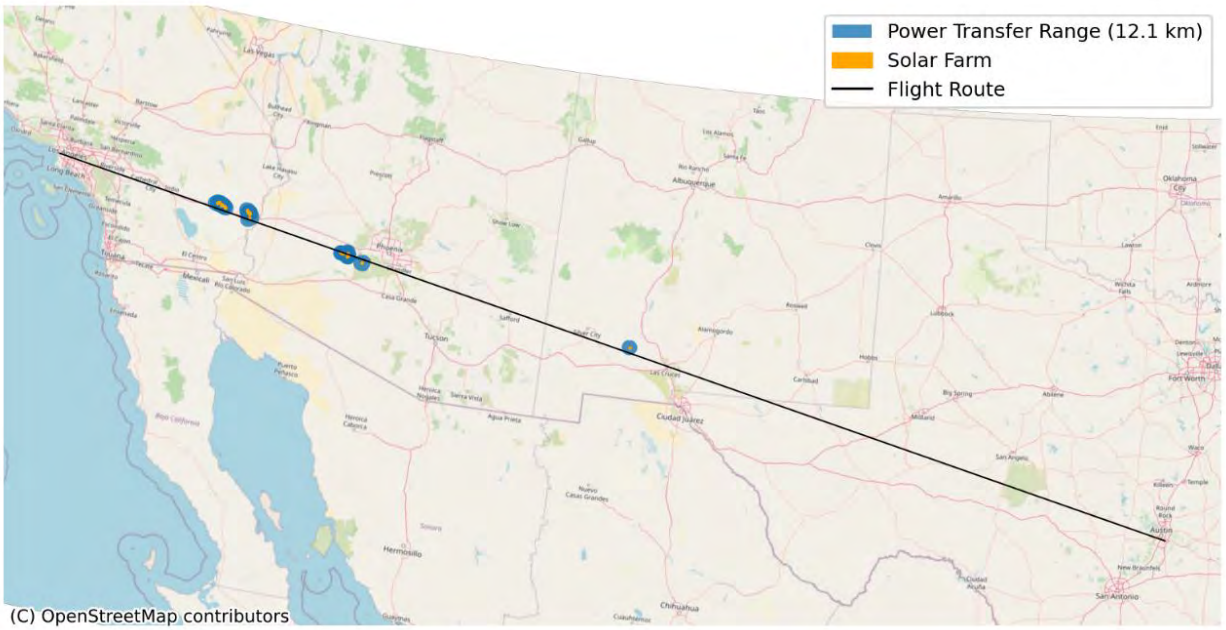


Figure 24 Selected flight and associated solar farms in the flight case study

The power received by the case study flight during operation is shown in Fig. 25. Power reception is highly intermittent, with long periods of zero supply interrupted by several short bursts of energy transfer. The most substantial energy transfer occurs later, where the flight passing the cluster of solar farms. The received power rises sharply and reaches maximum (10.3 MW). These high-power segments indicate that the flight receives energy only during specific time windows.

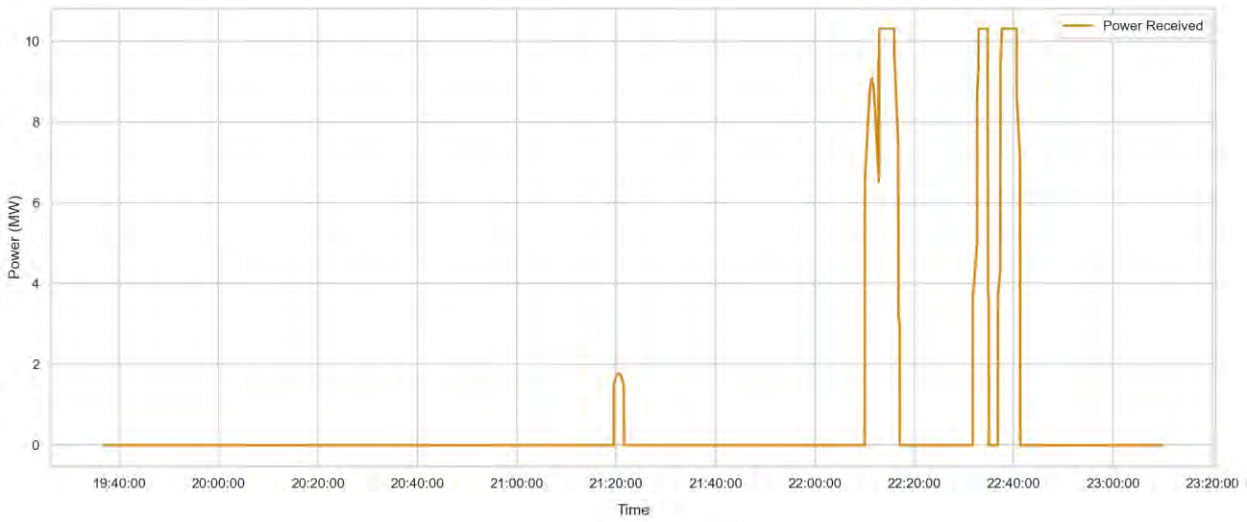


Figure 25 Power received by the selected flight in the flight case study