Supporting Information Available:

Appendix SI1: Explanation and calculation of COSMO polarisation charge densities σ

As they play a key role for the presented paper, we here give a short summary of how polarisation charge densities are defined and calculated within the COSMO and COSMO-RS methods:

1) For a given geometry of the solute a COSMO cavity is generated around the solute X which is considered to be the interface between the interior of the solute having a dielectric constant of ε = 1 and the solvent continuum with a dielectric constant ε. For the purpose of COSMO-RS calculations and hence in this paper the conductor limit with infinte dielctric constant is employed. The construction of the cavity is based on using the exterior of intersecting atom centered spheres with element specific radii. The following default COSMO radii have been used in this paper (in Å): H: 1.30, C: 2.00, N: 1.83, O: 1.72, F: 1.72, Si: 2.20, P: 2.11, S: 2.16, Cl: 2.05, Br: 2.16, I: 2.32. Some smoothing is used in the intersection regions in order to avoid sharp crevices and tips which would cause electrostatic discontinuities. Basically the smoothing in COSMO is based on the contact surface of a probe sphere of radius 1.3 Å rolling over the ensemble of intersecting spheres.

2) As a result of the cavity construction algorithm the cavity surface is represented by a set m segments with positions $\underline{t}_\mu$ and areas s_μ. The electrostatic interaction matrix **A** of these segments is constructed, taking into account their nature as homogeneously charged surface segments.

3) For a start wave function or electron density of the solute X the m-dimensional vector of the electrostatic potentials $\underline{\phi}^X$ at the centers of the m surface segments is calculated.

4) The conductor screening charges $\underline{q}$ on the m segments are calculated from the equation $\mathbf{A}\underline{q} = -\underline{\phi}^X$.

5) In the next step of the self-consistent quantum chemistry iteration (either DFT of HF) the screening charges are taken into account as point charges and a new wavefunction or electron density is generated. This is continued until self-consistency is achieved.

6) At the end the screening charges are corrected for the outlying charge effect.

7) The screening charge densities $\sigma(\underline{r})$ at any position $\underline{r}$ on the COSMO cavity can now by calculated by a local averaging with a Gaussian weight function of width 0.5 Å according to eq.11 of ref. 21..

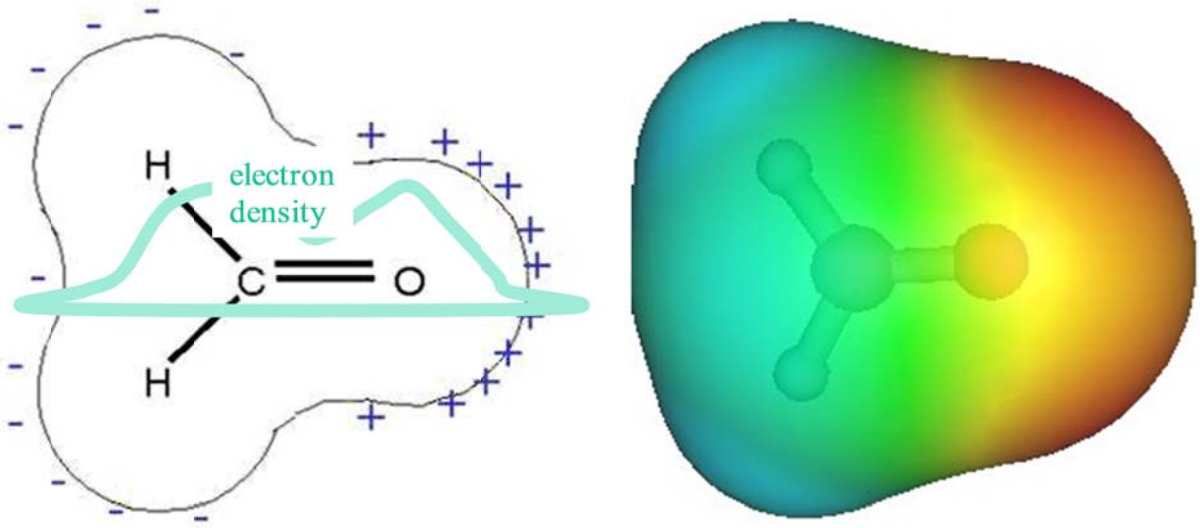

Figure SI1: Schematic illustration (left) and color coding (right) of the polarisation charge density σ on the surface of formaldehyde.

Table SI1: Experimental HB enthalpies and free energies[2] and COSMO-RS derived descriptors for the 307 compounds taken into account in the study. The last 18 compounds are the conformationally ambiguous compounds excluded in the first part of the analysis. All energies are in kJ/mol, and polarisation charge densities σ in e/nm². The acceptor atomic site is assigned from the maximum of σ on the COSMO surface. The original multiplicity is the acceptor multiplicity taken into account in the original free energy values reported in Ref. 10.

acceptor	element of acceptor	original multiplicity	$\Delta H°_{HB}$	$\Delta G°_{HB}$	σ_{acc}	$<\sigma>$	$\ln(\Omega_{HB})$	$<\sigma>_{conf}$	$\ln(\Omega_{HB,conf})$	raw $\Delta G°_{HB}$	raw$\Delta G°_{HB}$ +RTln(Ω_{HB})	raw$\Delta G°_{HB}$ +RTln($\Omega_{HB,conf}$)	log($f_{HB,conf}$)
Triphenylamine	C	3	-7.7	-3.3	0.64	0.52	3.65	0.52	3.65	-6.0	1.5	1.5	0.00
Benzene	C	1	-7.3	-3.3	0.62	0.53	2.81	0.53	2.81	-3.3	2.1	2.1	0.00
Methylbenzene	C	1	-7.9	-3.8	0.67	0.56	2.76	0.56	2.76	-3.8	1.5	1.5	0.00
1,4-Dimethylbenzene	C	1	-8.1	-4.1	0.72	0.59	2.69	0.59	2.69	-4.1	1.0	1.0	0.00
1,3,5-Trimethylbenzene	C	1	-8.8	-4.5	0.80	0.64	2.58	0.64	2.58	-4.5	0.4	0.4	0.00
Pentamethylbenzene	C	1	-10.3	-5.3	0.88	0.71	2.39	0.71	2.39	-5.3	-0.9	-0.9	0.00
1,2,3,4-Tetramethylbenzene	C	1	-9.1	-5.1	0.83	0.68	2.49	0.68	2.49	-5.1	-0.5	-0.5	0.00
Hexamethylbenzene	C	1	-10.8	-5.8	0.94	0.77	2.19	0.77	2.19	-5.8	-1.9	-1.9	0.00
1-Hexyne	C	1	-11.7	-5.0	0.95	0.84	2.13	0.84	2.13	-5.0	-1.3	-1.3	0.00
2-Hexyne	C	1	-11.7	-5.3	0.97	0.89	2.01	0.89	2.01	-5.3	-1.9	-1.9	0.00
1-Methylpyrrole	C	1	-12.2	-7.1	1.04	0.91	2.13	0.91	2.13	-7.1	-3.4	-3.4	0.00
Thiophene	C	1	-6.0	-2.9	0.71	0.55	2.69	0.55	2.69	-2.9	2.2	2.2	0.00
3-Hexyne	C	1	-11.1	-5.6	1.00	0.90	1.99	0.90	1.99	-5.6	-2.2	-2.2	0.00
Cyclohexene	C	1	-9.5	-1.5	1.01	0.85	1.36	0.85	1.36	-1.5	0.3	0.3	0.00
1,4-Cyclohexadiene	C	2	-6.2	-1.6	0.94	0.79	1.96	0.79	1.96	-3.3	0.0	0.0	0.00
1-Heptene	C	1	-6.8	-1.3	1.00	0.78	1.76	0.78	1.74	-1.3	1.5	1.5	0.00
N,N-Dicyclohexylethylamine	N	1	-33.6	-12.3	2.02	1.93	-1.04	1.98	-0.52	-12.3	-16.4	-15.1	0.00
Triethylamine	N	1	-39.4	-16.6	2.39	2.30	-1.16	2.29	-1.12	-16.6	-21.0	-20.9	-0.05
Tri-n-butylamine	N	1	-38.4	-14.4	2.40	2.29	-1.14	2.28	-1.09	-14.4	-18.8	-18.6	-0.06
Quinuclidine	N	1	-37.7	-21.0	2.37	2.26	-0.39	2.26	-0.39	-21.0	-23.5	-23.5	0.00

1,5-Diazabicyclo[4.3.0]non-5-ene(DBN)	N	1	-40.8	-28.2	2.55	2.41	0.28	2.40	0.28	-28.2	-29.0	-29.0	-0.02
4-Pyrrolidinopyridine	N	1	-36.3	-23.6	2.30	2.17	0.20	2.17	0.20	-23.6	-24.6	-24.6	0.00
3-Chloroquinuclidine	N	1	-34.1	-16.9	2.19	2.07	-0.37	2.07	-0.37	-16.9	-19.4	-19.4	0.00
2,2,6,6-Tetramethylpiperidine	N	1	-37.2	-16.3	2.36	2.28	-0.73	2.28	-0.73	-16.3	-19.6	-19.6	0.00
N-Benzilidene-tert-butylamine	N	1	-31.1	-13.2	2.02	1.91	-0.77	1.89	-0.68	-13.2	-16.6	-16.4	0.00
1-Methylimidazole	N	1	-34.0	-21.2	2.20	2.08	0.38	2.08	0.38	-21.2	-21.8	-21.8	0.00
2-Ethylpyridine	N	1	-34.0	-16.6	2.19	2.07	-0.22	2.07	-0.22	-16.6	-18.7	-18.7	0.00
2-tert-Butylpyridine+C247	N	1	-31.7	-13.8	2.06	1.97	-0.64	1.94	-0.50	-13.8	-16.9	-16.6	0.01
N,N,N',N'-Tetramethylethylenediamine	N	2	-35.5	-17.4	2.28	2.15	0.06	2.16	-0.03	-19.1	-20.5	-20.7	0.03
Triallylamine	N	1	-32.6	-13.2	2.13	2.02	-0.97	1.96	-0.65	-13.2	-17.1	-16.3	0.00
2-Phenylpyrrolidine	N	1	-33.3	-16.8	2.16	2.03	-0.68	2.05	-0.62	-16.8	-20.0	-19.9	-0.06
N,N-Diisopropylethylamine	N	1	-33.9	-11.8	2.21	2.13	-1.12	1.98	-0.41	-11.8	-16.1	-14.4	0.01
2-(3-Trifluoromethylphenyl)pyrrolidine	N	1	-30.5	-13.7	2.02	1.92	-0.66	1.91	-0.65	-13.7	-16.9	-16.9	0.05
2,4,6-Trimethylpyridine	N	1	-35.4	-18.8	2.31	2.18	-0.21	2.18	-0.21	-18.8	-20.8	-20.8	0.00
1,2,2,6,6-Pentamethylpiperidine	N	1	-34.0	-12.9	2.22	2.16	-0.99	2.16	-0.99	-12.9	-16.9	-16.9	0.00
2-(3-Fluorophenyl)pyrrolidine	N	1	-31.1	-15.3	2.06	1.95	-0.67	1.95	-0.64	-15.3	-18.5	-18.4	-0.01
N-Methylpyrrolidine	N	1	-34.8	-18.5	2.28	2.17	-0.53	2.17	-0.53	-18.5	-21.4	-21.4	0.00
5-Bromo-1-methylimidazole	N	1	-30.5	-18.3	2.05	1.93	0.41	1.93	0.41	-18.3	-18.8	-18.8	0.00
Tetramethylguanidine	N	1	-37.5	-24.0	2.44	2.29	0.19	2.29	0.19	-24.0	-25.1	-25.1	0.00
N,N,N',N'-Tetramethylhexane-1,6-diamine	N	2	-35.2	-17.6	2.31	2.16	-0.08	2.15	0.06	-19.3	-21.0	-20.7	-0.09
N,N-Dimethyl-N'-cyanoformamidine	N	1	-24.5	-17.4	1.72	1.57	1.73	1.57	1.73	-17.4	-14.6	-14.6	0.00
2-Phenyl-1-pyrroline	N	1	-31.0	-17.0	2.08	1.95	-0.07	1.95	-0.07	-17.0	-18.7	-18.7	0.00
Benzophenoneimine	N	1	-30.1	-16.1	2.12	1.99	-0.02	1.99	-0.02	-16.1	-17.7	-17.7	0.41
3,5-Dimethylpyridine	N	1	-31.9	-18.2	2.14	2.01	0.12	2.01	0.12	-18.2	-19.4	-19.4	0.00
N,N-Dimethylisopropylamine	N	1	-34.7	-18.0	2.30	2.18	-0.67	2.19	-0.62	-18.0	-21.2	-21.1	-0.11
Trans-3-dimethylaminoacrylonitrile	N	1	-23.5	-15.5	1.67	1.52	1.56	1.52	1.56	-15.5	-13.2	-13.2	0.00
Dimethylcyanamide	N	1	-22.4	-14.4	1.62	1.48	1.63	1.48	1.63	-14.4	-11.9	-11.9	0.00

N-Butylpyrrolidine	N	1	-34.5	-17.4	2.31	2.22	-0.62	2.22	-0.62	-17.4	-20.5	-20.5	0.00
2-Methoxypyridine	N	1	-25.8	-11.3	1.82	1.66	0.07	1.66	0.10	-11.3	-12.7	-12.6	-0.13
4-N,N-Dimethylaminopyridine	N	1	-34.1	-21.5	2.28	2.15	0.21	2.15	0.21	-21.5	-22.5	-22.5	0.00
N,N-Dimethylcyclohexylamine	N	1	-34.8	-18.0	2.32	2.20	-0.70	2.19	-0.67	-18.0	-21.3	-21.2	0.02
Pyrrolidine	N	1	-36.1	-20.3	2.41	2.31	-0.21	2.31	-0.21	-20.3	-22.4	-22.4	0.00
N,N-Dimethylethylamine	N	1	-34.5	-18.2	2.32	2.20	-0.62	2.20	-0.61	-18.2	-21.3	-21.2	0.00
2-(3-Fluorophenyl)-1-pyrroline	N	1	-29.0	-15.2	2.01	1.89	-0.10	1.90	-0.09	-15.2	-17.0	-17.0	0.01
Pyridazine	N	2	-27.9	-15.2	1.95	1.82	0.88	1.82	0.88	-16.9	-16.3	-16.3	0.00
N,N-Dimethylallylamine	N	1	-32.8	-16.8	2.23	2.12	-0.63	2.09	-0.53	-16.8	-19.9	-19.7	0.01
Trimethylamine	N	1	-33.5	-17.9	2.27	2.15	-0.48	2.15	-0.48	-17.9	-20.6	-20.6	0.00
2-Methyl-1-pyrroline	N	1	-34.2	-20.4	2.31	2.19	0.09	2.19	0.09	-20.4	-21.7	-21.7	0.00
2,6-Dimethylpyridine	N	1	-33.3	-17.7	2.26	2.12	-0.17	2.12	-0.17	-17.7	-19.6	-19.6	0.00
4-Dimethylaminobenzonitrile	N	1	-20.5	-13.0	1.55	1.39	1.48	1.39	1.48	-13.0	-10.9	-10.9	0.00
N-Methyl-1,2,3,6-tetrahydropyridine	N	1	-32.5	-17.1	2.21	2.10	-0.57	2.10	-0.58	-17.1	-20.1	-20.1	0.01
Diazabicyclooctane(DABCO)	N	2	-33.2	-18.9	2.27	2.17	0.32	2.17	0.32	-20.6	-21.4	-21.4	0.00
1-Piperidinecarbonitrile	N	1	-21.7	-14.8	1.62	1.48	1.65	1.49	1.65	-14.8	-12.3	-12.2	-0.03
Azetidine	N	1	-35.7	-20.5	2.41	2.29	-0.21	2.29	-0.21	-20.5	-22.5	-22.5	0.00
Diethylcyanamide	N	1	-21.9	-14.9	1.63	1.50	1.65	1.50	1.65	-14.9	-12.4	-12.4	0.00
3-Chloropyridine	N	1	-27.2	-13.2	1.94	1.80	0.12	1.80	0.12	-13.2	-14.4	-14.4	0.00
N,N-Dimethylpropargylamine	N	1	-29.3	-14.8	2.05	1.93	-0.44	1.97	-0.42	-14.8	-17.4	-17.4	-0.09
2-Fluoropyridine	N	1	-24.5	-11.1	1.79	1.65	0.24	1.65	0.24	-11.1	-12.0	-12.0	0.00
4-Methylaminopyridine	N	1	-33.5	-21.0	2.30	2.16	0.16	2.16	0.16	-21.0	-22.1	-22.1	0.00
4-Methylpyridine	N	1	-30.8	-17.7	2.15	2.01	0.11	2.01	0.11	-17.7	-19.0	-19.0	0.00
4-Chloro-N-methylpiperidine	N	1	-32.2	-15.5	2.21	2.09	-0.68	2.10	-0.66	-15.5	-18.7	-18.7	0.00
3-Chloromethyl-N-methylpiperidine	N	1	-32.9	-15.8	2.26	2.16	-0.71	2.12	-0.54	-15.8	-19.1	-18.7	-0.02
2-(3-Trifluoromethylphenyl)-1-pyrroline	N	1	-28.0	-14.4	1.99	1.87	-0.09	1.87	-0.09	-14.4	-16.2	-16.2	0.00
N-Methylpiperidine	N	1	-34.0	-17.8	2.33	2.22	-0.62	2.22	-0.62	-17.8	-20.9	-20.9	0.00