

Supplemental Information of: Argumentation Corrected Context Weighting-LCA: a Practical Method of Including Stakeholder Perspectives in Multi-Criteria Decision Support for Life Cycle Assessment

Joshua Sohn¹, Pierre Bisquert², Patrice Buche³, Abdelraouf Hecham⁴, Pradip P. Kalbar⁵, Ben Goldstein⁶, Morten Birkved⁷, Stig Irving Olsen^{8,*}

¹ DTU Management, Sustainability Division, Technical University of Denmark, 2800 kgs. Lyngby, Denmark; jsoh@dtu.dk

² University of Montpellier, INRAE, IATE, INRIA GraphIK, F-34060, Montpellier, France; pierre.bisquert@inra.fr

³ University of Montpellier, INRAE, IATE, INRIA GraphIK, F-34060, Montpellier, France; patrice.buche@inrae.fr

⁴ University of Montpellier, INRAE, IATE, INRIA GraphIK, F-34060, Montpellier, France; hecham@lirmm.fr

⁵ Centre for Urban Science and Engineering (CUSE) and Associate Faculty, Interdisciplinary Programme in Climate Studies, Indian Institute of Technology Bombay, Powai, Mumbai 400 076; kalbar@iitb.ac.in

⁶ School for Environment and Sustainability, University of Michigan, Ann Arbor, MI, 48109-1041, USA; benjgo@umich.edu

⁷ University of Southern Denmark, SDU Life Cycle Engineering, Dep. of Chemical Eng., Biotechnology and Environmental Tech., DK-5230 Odense M, Denmark; morb@kbm.sdu.dk

⁸ DTU Management, Sustainability Division, Technical University of Denmark, 2800 kgs. Lyngby, Denmark; siol@dtu.dk

* Correspondence: siol@dtu.dk; Tel.: +45- 45254668

Table 1: Stakeholder preference questionnaire

Respondent group:	Name of Respondent:	
Criteria/Indicator	ORDER OF IMPORTANCE (1 (most) to 18 (least), do not know)	Justification
Fine particulate matter formation		
Fossil resource scarcity		
Freshwater ecotoxicity		
Freshwater eutrophication		
Global warming		
Human carcinogenic toxicity		
Human non-carcinogenic toxicity		
Ionizing radiation		
Land use		
Marine ecotoxicity		
Marine eutrophication		
Mineral resource scarcity		
Ozone formation, Human health		
Ozone formation, Terrestrial ecosystems		
Stratospheric ozone depletion		
Terrestrial acidification		
Terrestrial ecotoxicity		
Water consumption		

Table 2: Decision maker weighting profiles from Agrocycle, C_a...C_r represent the 18 criteria in the ReCiPe2016 Life cycle impact assessment method: a. Fine particulate matter formation, b. Fossil resource scarcity, c. Freshwater ecotoxicity, d. Freshwater eutrophication, e. Global warming, f. Human carcinogenic toxicity, g. Human non-carcinogenic toxicity, h. Ionizing radiation, i. Land use, j. Marine ecotoxicity, k. Marine eutrophication, l. Mineral resource scarcity, m. Ozone formation, Human health, n. Ozone formation, Terrestrial ecosystems, o. Stratospheric ozone depletion, p. Terrestrial acidification, q. Terrestrial ecotoxicity, r. Water consumption

resp_id	C _a	C _b	C _c	C _d	C _e	C _f	C _g	C _h	C _i	C _j	C _k	C _l	C _m	C _n	C _o	C _p	C _q	C _r
1	0.078	0.006	0.194	0.026	0.067	0.022	0.003	0.017	0.139	0.031	0.010	0.014	0.043	0.037	0.050	0.058	0.092	0.111
2	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056
3	0.194	0.003	0.037	0.031	0.092	0.139	0.026	0.010	0.111	0.022	0.017	0.006	0.067	0.058	0.050	0.043	0.014	0.078
4	0.010	0.003	0.111	0.194	0.139	0.050	0.043	0.037	0.058	0.014	0.017	0.006	0.022	0.026	0.031	0.078	0.067	0.092
5	0.139	0.003	0.037	0.031	0.111	0.092	0.078	0.010	0.067	0.026	0.022	0.006	0.043	0.017	0.014	0.058	0.050	0.194
6	0.022	0.006	0.079	0.111	0.050	0.018	0.014	0.195	0.032	0.093	0.058	0.022	0.037	0.043	0.003	0.068	0.139	0.010
7			0.052	0.115	0.143	0.095	0.033		0.201	0.038	0.045		0.060	0.027	0.070	0.023	0.018	0.081
8	0.139	0.022	0.017	0.026	0.092	0.194	0.111	0.050	0.003	0.031	0.014	0.006	0.067	0.078	0.058	0.043	0.010	0.037
9	0.089	0.051	0.089	0.051	0.064	0.089	0.064	0.064	0.042	0.036	0.036	0.036	0.051	0.042	0.051	0.051	0.051	0.042
10	0.043	0.026	0.058	0.050	0.111	0.139	0.194	0.006	0.010	0.037	0.031	0.003	0.092	0.078	0.067	0.014	0.017	0.022

Table 3: Decision maker weighting profiles from NoAW, C_a...C_r represent the 18 criteria in the ReCiPe2016 Life cycle impact assessment method: a. Fine particulate matter formation, b. Fossil resource scarcity, c. Freshwater ecotoxicity, d. Freshwater eutrophication, e. Global warming, f. Human carcinogenic toxicity, g. Human non-carcinogenic toxicity, h. Ionizing radiation, i. Land use, j. Marine ecotoxicity, k. Marine eutrophication, l. Mineral resource scarcity, m. Ozone formation, Human health, n. Ozone formation, Terrestrial ecosystems, o. Stratospheric ozone depletion, p. Terrestrial acidification, q. Terrestrial ecotoxicity, r. Water consumption

Resp_id	C _a	C _b	C _c	C _d	C _e	C _f	C _g	C _h	C _i	C _j	C _k	C _l	C _m	C _n	C _o	C _p	C _q	C _r
1	0.033	0.021	0.079	0.063	0.111	0.111	0.079	0.079	0.018	0.063	0.053	0.025	0.038	0.029	0.038	0.053	0.063	0.045
2		0.010	0.079	0.056	0.139	0.139	0.056	0.041	0.026	0.056	0.056	0.026	0.048	0.056	0.041	0.056	0.048	0.066
3	0.042	0.050	0.075	0.027	0.104	0.060	0.020	0.023	0.104	0.075	0.031	0.023	0.060	0.104	0.017	0.075	0.075	0.036
4	0.056	0.035	0.067	0.047	0.056	0.117	0.083	0.067	0.041	0.047	0.041	0.047	0.056	0.047	0.067	0.041	0.047	0.041
5	0.031	0.006	0.092	0.078	0.111	0.194	0.139	0.014	0.010	0.067	0.058	0.003	0.050	0.043	0.037	0.022	0.017	0.026
6	0.041	0.003	0.089	0.075	0.107	0.187	0.133	0.021	0.065	0.036	0.030	0.048	0.025	0.025	0.025	0.017	0.017	0.056
7		0.035	0.067	0.056	0.117	0.067	0.067		0.083	0.067	0.056	0.040	0.047	0.047	0.047	0.056	0.067	0.083
8	0.079	0.018	0.068	0.058	0.195	0.111	0.111		0.050	0.043	0.043	0.022				0.032	0.032	0.139
9	0.045	0.038	0.111	0.111		0.111	0.063	0.008	0.111	0.063	0.063	0.063				0.038	0.063	0.111
10	0.060	0.040	0.060	0.048	0.085	0.060	0.048	0.048	0.060	0.060	0.048	0.040	0.048	0.048	0.048	0.048	0.060	0.085
11	0.039	0.175	0.061	0.016	0.175	0.071	0.045	0.009	0.100	0.052	0.033	0.012	0.009	0.006	0.003	0.045	0.024	0.125
12	0.127	0.024	0.127	0.051	0.127	0.073	0.073	0.024	0.051	0.073	0.009	0.017	0.033	0.028	0.033	0.033	0.024	0.073
13	0.058	0.002	0.068	0.050	0.082	0.143	0.102	0.043	0.043	0.068	0.050	0.037	0.032	0.032	0.032	0.050	0.068	0.043
14	0.021	0.021	0.015	0.015	0.057	0.057	0.041	0.021	0.171	0.057	0.057	0.057	0.041	0.041	0.041	0.057	0.057	0.171
15	0.016	0.004	0.228		0.228	0.228			0.016		0.044	0.004					0.228	0.004
16	0.053	0.029	0.061	0.024	0.177	0.084	0.101	0.003	0.127	0.020	0.009	0.053	0.053	0.053	0.053	0.016	0.072	0.012
17	0.045	0.045	0.052	0.038	0.129	0.045	0.045	0.061	0.061	0.052	0.038	0.045	0.045	0.045	0.073	0.038	0.052	0.092
18	0.033	0.070	0.106	0.051	0.024	0.085	0.070	0.044	0.148	0.002	0.002	0.106			0.038	0.028	0.085	0.106
19	0.006	0.003	0.026	0.043	0.139	0.014	0.010	0.078	0.194	0.058	0.031	0.050	0.017	0.022	0.092	0.037	0.067	0.111
20	0.068	0.003	0.037	0.037	0.168	0.096	0.037	0.068	0.068	0.068	0.068	0.003	0.068	0.068	0.068	0.037	0.037	0.003
21		0.003	0.118	0.098	0.033	0.053	0.046	0.010	0.147	0.023	0.028	0.007	0.039	0.014	0.019	0.083	0.071	0.206

Table 4: calculation of weighting profile for environmental impacts including comparison relating Arg-LCA weighting to equal weights given to environmental impacts a.) Agrocycle – polyphenol extraction case, b.) Agrocycle – Electricity production case, c.) NoAW – polyphenol extraction case. C_a...C_r represent the 18 criteria in the ReCiPe2016 Life cycle impact assessment method: a. Fine particulate matter formation, b. Fossil resource scarcity, c. Freshwater ecotoxicity, d. Freshwater eutrophication, e. Global warming, f. Human carcinogenic toxicity, g. Human non-carcinogenic toxicity, h. Ionizing radiation, i. Land use, j. Marine ecotoxicity, k. Marine eutrophication, l. Mineral resource scarcity, m. Ozone formation, Human health, n. Ozone formation, Terrestrial ecosystems, o. Stratospheric ozone depletion, p. Terrestrial acidification, q. Terrestrial ecotoxicity, r. Water consumption

	C _a	C _b	C _c	C _d	C _e	C _f	C _g	C _h	C _i	C _j	C _k	C _l	C _m	C _n	C _o	C _p	C _q	C _r
--	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------	----------------

normalized avg weight (stakeholder)	75.77	28.06	95.74	65.02	75.97	89.20	56.14	49.19	69.35	37.94	32.68	25.16	49.49	43.89	43.49	46.35	53.09	63.48
RIF	0%	4%	3%	1%	1%	1%	0%	0%	0%	3%	0%	0%	0%	0%	0%	0%	1%	0%
RVF	0%	8%	8%	4%	2%	2%	0%	1%	0%	7%	0%	0%	1%	1%	0%	1%	1%	0%
CWM	0%	6%	5%	2%	1%	2%	0%	1%	0%	5%	0%	0%	1%	1%	0%	0%	1%	0%
ARG-LCA weight	15.09	116.48	348.51	106.62	67.43	94.71	4.34	28.34	0.74	118.06	0.57	0.00	17.81	18.99	1.58	14.80	35.79	10.14
comparison to equal weights	27%	210%	627%	192%	121%	170%	8%	51%	1%	213%	1%	0%	32%	34%	3%	27%	64%	18%

a.

	C_a	C_b	C_c	C_d	C_e	C_f	C_g	C_h	C_i	C_j	C_k	C_l	C_m	C_n	C_o	C_p	C_q	C_r
normalized avg weight (stakeholder)	75.7 7	28.06	95.74	65.02	75.9 7	89.20	56.1 4	49.19	69.3 5	37.94	32.6 8	25.1 6	49.4 9	43.8 9	43.4 9	46.3 5	53.0 9	63.4 8
RIF	3%	20%	30%	16%	5%	9%	1%	18%	1%	25%	0%	0%	5%	6%	1%	6%	7%	2%
RVF	16%	109%	93%	93%	24%	43%	2%	166%	11%	71%	2%	0%	31%	36%	2%	32%	46%	11%
CWM	9%	64%	62%	55%	14%	26%	1%	92%	6%	48%	1%	0%	18%	21%	1%	19%	26%	6%
ARG-LCA weight	26.5 8	219.9 67.07	132.0 0	40.8 0	87.81 0	2.64	167.9 3	15.7 5	67.39 1.32	0.00	33.6 8	34.9 7	2.40	32.5 7	52.1 6	15.0 3		
comparison to equal weights	48%	121 %	396%	238%	73%	158 %	5%	302%	28%	121 %	2%	0%	61%	63%	4%	59%	94%	27%

b.

	C_a	C_b	C_c	C_d	C_e	C_f	C_g	C_h	C_i	C_j	C_k	C_l	C_m	C_n	C_o	C_p	C_q	C_r
normalized avg weight (stakeholder)	47.5	30.75	83.06	46.20	112.05	90.00	65.03	37.97	71.30	53.07	39.16	34.33	42.00	43.13	42.03	42.98	54.34	65.10
RIF	0%	4%	3%	1%	1%	1%	0%	0%	0%	3%	0%	0%	0%	0%	0%	0%	1%	0%
RVF	0%	8%	8%	4%	2%	2%	0%	1%	0%	7%	0%	0%	1%	1%	0%	1%	1%	0%
CWM	0%	6%	5%	2%	1%	2%	0%	1%	0%	5%	0%	0%	1%	1%	0%	0%	1%	0%
ARG-LCA weight	9.46	127.68	302.42	75.77	99.48	95.57	5.03	21.88	0.76	165.19	0.68	0.00	15.12	18.67	1.52	13.73	36.64	10.40
comparison to equal weights	17%	230%	544%	136%	179%	172%	9%	39%	1%	297%	1%	0%	27%	34%	3%	25%	66%	19%

c.

Table 5: Electricity production impacts, shown for 1 MWh of production

	Fine particulate matter formation	Fossil resource scarcity	Freshwater ecotoxicity	Freshwater eutrophication	Global warming	Human carcinogenic toxicity	Human non-carcinogenic toxicity	Ionizing radiation	Land use	Marine ecotoxicity	Marine eutrophication	Mineral resource scarcity	Ozone formation, Human health	Ozone formation, Terrestrial ecosystems	Stratospheric ozone depletion	Terrestrial acidification	Terrestrial ecotoxicity	Water consumption	Cost
biogas	0.868737	28.4214	23.6821	0.245357	195.559	16.7938	516.48	22.8204	46.7586	30.9557	0.080233	0.558138	0.504625	0.512911	0.001406	5.54614	340.848	4.56359	106.29
biomass	0.349467	11.3829	2.60628	0.008946	47.9536	2.66344	340.897	0.83793	678.229	4.39887	0.001011	0.222068	1.45726	1.47441	0.00043	1.15349	1302.1	0.182446	108.25
coal	0.68429	268.702	20.372	0.609223	1011.93	45.5165	598.972	4.02984	10.8193	28.4049	0.040463	0.349344	2.02178	2.03466	0.000318	2.06631	249.803	1.17089	106.13
geothermal																			
al	0.163598	18.1656	2.25855	0.037239	84.13	7.70314	62.2873	9.61043	1.10961	3.12178	0.002408	0.589444	0.169901	0.172671	2.44E-05	0.285598	113.672	0.686097	106.5
hydro	0.011027	1.14042	0.182737	0.001683	7.12937	0.76455	5.05502	0.27677	0.107861	0.264109	9.91E-05	0.094143	0.018602	0.018955	3.94E-06	0.018091	23.388	29.2987	108.36
natural gas	0.137296	152.106	0.845524	0.006541	427.832	1.47829	14.4632	1.11306	0.187115	1.09678	0.00146	0.120577	0.305112	0.321799	0.000141	0.397015	35.8121	0.770516	105.17
nuclear	0.043334	3.15418	0.926647	0.008834	13.0709	1.78071	25.0074	794.778	0.319501	1.37478	0.013283	0.734055	0.04099	0.041735	3.88E-05	0.048428	222.689	3.0262	108.11
oil	4.17151	620.912	3.78292	0.036009	1933.54	10.3215	140.013	19.9476	3.13793	10.4788	0.054111	0.553653	6.42764	6.49345	0.001378	13.1847	6949.05	5.92798	106.67
solar	0.142701	14.7629	15.8367	0.051637	60.5168	5.69392	223.514	5.58199	1.67701	21.0627	0.005604	0.757561	0.143079	0.150154	2.82E-05	0.302632	1611.39	1.8934	117.27
wind	0.029843	3.43062	5.23515	0.009131	13.5688	4.48956	42.3749	0.61758	0.921008	6.58757	0.000751	0.374196	0.038079	0.03964	5.34E-06	0.05669	138.944	0.152321	108.28

Table 6: Polyphenol extraction impacts

	Fine particulate matter formation	Fossil resource scarcity	Freshwater ecotoxicity	Freshwater eutrophication	Global warming	Human carcinogenic toxicity	Human non-carcinogenic toxicity	Ionizing radiation	Land use	Marine ecotoxicity	Marine eutrophication	Mineral resource scarcity	Ozone formation, Human health	Ozone formation, Terrestrial ecosystems	Stratospheric ozone depletion	Terrestrial acidification	Terrestrial ecotoxicity	Water consumption	Cost
S-Acn-10	4.18E-02	2.12E+01	5.99E-01	6.50E-03	6.00E+01	8.05E-01	1.56E+01	1.30E+00	3.41E-01	9.06E-01	4.30E-04	5.52E-02	6.50E-02	6.76E-02	1.41E-05	1.11E-01	7.51E+01	2.92E-01	1.24E+01
S-Acn-5	2.26E-02	1.13E+01	3.09E-01	3.47E-03	3.23E+01	4.24E-01	8.07E+00	7.36E-01	1.97E-01	4.70E-01	2.30E-04	2.82E-02	3.50E-02	3.64E-02	7.62E-06	6.05E-02	4.05E+01	1.53E-01	8.60E+00
PLE-EthOH-25	6.27E-02	2.89E+01	1.08E+00	1.28E-02	8.72E+01	1.31E+00	2.85E+01	3.38E+00	8.11E-01	1.60E+00	9.70E-04	9.95E-02	9.12E-02	9.45E-02	2.65E-05	1.63E-01	1.26E+02	5.02E-01	1.51E+01
PLE-EthOH-10	2.62E-02	1.20E+01	4.38E-01	5.26E-03	3.64E+01	5.37E-01	1.16E+01	1.41E+00	3.42E-01	6.51E-01	4.00E-04	4.02E-02	3.82E-02	3.95E-02	1.10E-05	6.84E-02	5.24E+01	2.05E-01	8.30E+00