Electronic Supplementary Material (ESI) for Green Chemistry.

Supporting Information

S1: Silicate number and its implication on Sodium Silicate Mass Balances

Sodium silicate refers to a range of metasilicate compounds which satisfy the stoichiometry: $(Na_2O)_x{\cdot}(SiO_2)_y$. Consequently, the silicate number, *n (-)*, is often used to reflect the mass ratio of silica to sodium oxide present within a sodium silicate product - i.e:

$$n = {m_{SiO_2}}/{m_{Na_2O}} \quad (1)$$

Where: m_{SiO_2} is the mass of silica (kg),

m_{Na_2O} is the mass of sodium oxide (kg)

Using Equation 1, the overall mass of sodium silicate, $m_{silicate,n}$ (kg), can be calculated from a known silicate number and known mass of silica by:

$$m_{silicate,n} = m_{SiO_2} \times (1 + {1}/{n}) \quad (2)$$

Within the life cycle inventory source used in this work, the average amount of sodium silicate precursor used by industry (per kg of SAS produced) is described as being part of a 3.9 kg solution[1] . Of this amount, 27 wt% is SiO_2, and the silicate number is between 2 and 4 (EU Commission, 2007) - i.e.

$$m_{silica} = 0.27 \times 3.9 = 1.053\ kg \quad (3)$$

Consequently, the actual mass of sodium silicate used on a dry mass basis can be calculated as:

$$1.33\ kg \leq m_{silicate,n} \leq 1.58\ kg \quad (4)$$

A dry basis is what is required for the typical LCA models of sodium silicate[2]. This appears to have been overlooked previously by Roes *et al*.[3], who report the mass sodium silicate as 3.9kg in their inventory – a value more than 2 times greater than suggested by this work.

As values are reported based on a 1kg functional unit of SAS in this work, values in Equation 4 therefore also represent uncertainty in the demand for sodium silicate per 1 kg of SAS produced.

S2: Data Quality Scores of Life Cycle Inventory Flows

Data quality scores are given from 1 (low uncertainty) to 5 (high uncertainty) for all flows modelled using the data quality pedigree matrix method[4]. Scoring definitions were based on the ecoInvent data quality system, using the score values provided by Jungbluth and Frischknecht et al.[4].

Dry Mineral-derived Synthetic Amorphous Silica

Data quality scores for the dry mineral-derived synthetic amorphous silica are shown in Tables 1 to 11.

Table 1: Data quality score card for Silicon Tetrachloride. Model: Silicon Tetrachloride - GLO

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	2	Data is correct for the processes considered, but may not

		reflect all enterprises

Table 2: Data quality score card for hydrogen. Model: market for hydrogen, liquid - RER

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	3	Data lacking on the source (i.e. production method) of hydrogen production used.

Table 3: Data quality score card for electricity. Model: market group for heat, district or industrial, natural gas - RER

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	3	Lack of information on energy carrier used in process means that energy use could be from a different technology.

Table 4: Data quality score card for hazardous waste. Model: market for hazardous waste, for incineration - Europe without Switzerland.

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	4	Model selected based on those used to model equivalent titanium dioxide processes[a] within the ecoInvent database.

[a] Model: Titanium Dioxide model: titanium dioxide production, chloride process | titanium dioxide | APOS, U

Table 5: Data quality score card for landfill. Model: process-specific burdens, sanitary landfill, (product flow).

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	4	Model selection based on description of burden as “landfill” within the source text.

Table 6: Data quality score card for carbon dioxide. Model: carbon dioxide, fossil..

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	1	Technological criteria not considered relevant to emissions.

Table 7: Data quality score card for chlorine. Model: emission to air

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	1	Technological criteria not considered relevant to emissions.

Table 8: Data quality score card for hydrogen chloride. Model: emission to air

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	1	Technological criteria not considered relevant to emissions.

Table 9: Data quality score card for nitrogen oxides. Model: emission to air

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	1	Technological criteria not considered relevant to emissions.

Table 10: Data quality score card for particulates. Model: emission to air

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	1	Technological criteria not considered relevant to emissions.

Table 11: Data quality score card for Volatile organic carbons. Model: emission to air

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	1	Technological criteria not considered relevant to emissions.

Wet Mineral-derived Synthetic Amorphous Silica

Data quality scores for the wet mineral-derived synthetic amorphous silica are shown in Tables 12 to 23.

Table 12: Data quality score card for Sodium Silicate. Model: market for sodium silicate, without water, in 37% solution state - RER

Data Quality Indicator for	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	2	True solution state (i.e. wt%) may vary slightly different to that present in the model.

Table 13: Data quality score card for electricity. Model: market group for heat, district or industrial, natural gas - RER

Data Quality Indicator for	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	3	Lack of information on energy carrier used in process means that energy use could be from a different technology.

Table 14: Data quality score card for Sulfuric Acid. Model: market for sulfuric - RER

Data Quality Indicator for	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	1	Model provides estimates based on a blend of sources in the region.

Table 15: Data quality score card for Deionised Water. Model: market for water, deionised - Europe without Switzerland

Data Quality Indicator for	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	1	Model reflects reasonably expected technology, impact from deionised water already known to be negligible from prior investigation so no further thought required.

Table 16: Data quality score card for non-hazardous waste. Model: process-specific burdens, sanitary landfill, (product flow).

Data Quality Indicator for	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	4	Model selection based on description of burden as “landfill” within the source text.

Table 17: Data quality score card for wastewater. Model: wastewater, average.

Data Quality Indicator for	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	1	Based on reasonable fitting of model description with reported waste type.

Table 18: Data quality score card for carbon monoxide. Model: emission to air

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	1	Technological criteria not considered relevant to emissions

Table 19: Data quality score card for chemical oxygen demand (COD). Model: emission to water

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	1	Technological criteria not considered relevant to emissions

Table 20: Data quality score card for dissolved solids. Model: emission to water

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	1	Technological criteria not considered relevant to emissions

Table 21: Data quality score card for nitrogen oxides. Model: emission to air

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	1	Technological criteria not considered relevant to emissions

Table 22: Data quality score card for particulates. Model: emission to air

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	1	Technological criteria not considered relevant to emissions

Table 23: Data quality score card for sulfate. Model: emission to water

Data Quality Indicator	Score	Justification
Reliability	1	Reliable data source.
Completeness	3	Data not based on observation of all sites in the EU-15 region.
Temporal Correlation	5	Data reported in 2007, therefore minimum age at time of assessment is 14. Score of 5 chosen instead of 4 on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	1	Technological criteria not considered relevant to emissions

Dry Rice Husk-derived Synthetic Amorphous Silica

Data quality scores for the dry rice husk-derived synthetic amorphous silica are shown in Tables 24 to 26.

Table 24: Data quality score card for combustion of biomass to recover energy. Model: electricity production, wood, future - GLO.

Data Quality Indicator	Score	Justification
Reliability	2	Data based on combination of estimates and verified data from state-of-the-art plant.
Completeness	4	Data based on single state-of-the-art plant.
Temporal Correlation	3	Data based on state-of-the-art plant as of 2014. Therefore more than 6 years (score 2) but less than 10 years (score 4) since reporting.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	4	Data is for wood-based biomass combustion. Based on related process (direct combustion) and materials (rice husk vs. wood). However, differences in proximate properties between wood and rice-husk create uncertainty.

Table 25: Data quality score card for silicon tetrachloride. Model: sodium silicate production, hydrothermal liquor, product in 48% solution state - RER; references to quartz sand removed from reference.

Data Quality Indicator	Score	Justification
Reliability	2	Data based on a combination of stoichiometry-based estimates and supporting information from literature.
Completeness	5	Based on theoretical process therefore representativeness of real plant model used is unknown.
Temporal Correlation	5	No knowledge of time period. Reference from 2001.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	4	Data on related processes and materials. Materials only related as cannot be certain of quality relative to mineral-derived process.

Table 26: Data quality score card for synthetic amorphous silica (dry method). Model: *this work;* references to silicon feedstock removed from model.

Data Quality Indicator	Score	Justification
Reliability	1	Based on values reported for real plants.
Completeness	5	Based on theoretical process therefore representativeness of real plant model used is unknown.
Temporal Correlation	5	Based on 2007 data, therefore minimum age at time of assessment is 14. Score of 5 chosen instead on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	4	Data on related processes and materials. Materials only related as cannot be certain of quality relative to mineral-derived process.

Wet Rice Husk-derived Synthetic Amorphous Silica

Data quality scores for the wet rice husk-derived synthetic amorphous silica are shown in Tables 27 to 29.

Table 27: Data quality score card for combustion of biomass to recover energy. Model: electricity production, wood, future - GLO.

Data Quality Indicator	Score	Justification
Reliability	2	Data based on combination of estimates and verified data from state-of-the-art plant. Originating model suggests reliability score to be 1.
Completeness	4	Data based on single state-of-the-art plant.
Temporal Correlation	3	Data based on state-of-the-art plant as of 2014. Therefore more than 6 years (score 2) but less than 10 years (score 4) since reporting.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	4	Data is for wood-based biomass combustion. Based on related process (direct combustion) and materials (rice husk vs. wood). However, differences in proximate properties between wood and rice-husk create uncertainty.

Table 28: Data quality score card for sodium silicate (hydrothermal method). Model: sodium silicate production, hydrothermal liquor, product in 48% solution state - RER; references to quartz sand removed from reference.

Data Quality Indicator	Score	Justification
Reliability	1	Based on values reported for real plants.
Completeness	5	Based on theoretical process therefore representativeness of real plant model used is unknown.
Temporal Correlation	1	Underlying data references from 2019, therefore within 3 years of this work.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	4	Data on related processes and materials. Materials only related as cannot be certain of quality relative to mineral-derived process.

Table 29: Data quality score card for synthetic amorphous silica (wet method). Model: *this work;* references to silicon feedstock removed from model.

Data Quality Indicator	Score	Justification
Reliability	1	Based on values reported for real plants.
Completeness	5	Based on theoretical process therefore representativeness of real plant model used is unknown.
Temporal Correlation	5	Based on 2007 data, therefore minimum age at time of assessment is 14. Score of 5 chosen instead on this basis.
Geographical Correlation	5	Data intended to represent global geography.
Technological Correlation	4	Data on related processes and materials. Materials only related as cannot be certain of quality relative to mineral-derived process.

Regional Electricity Models

Data quality scores for each model was consistent with that shown in Table 30. This is because all models used were based on 2014 data.

Table 30: Data quality score card for all models of regional medium voltage electricity

Data Quality Indicator	Score	Justification
Reliability	N/a	Uncertainty in reliability not relevant at this stage.
Completeness	N/a	Uncertainty in reliability not relevant at this stage.
Temporal Correlation	3	Based on 2014 data.
Geographical Correlation	N/a	Uncertainty in reliability not relevant at this stage.
Technological Correlation	N/a	Uncertainty in reliability not relevant at this stage.

S3: Mass Conversion Efficiency of the Dry Process of Silica Synthesis

Conversion efficiency of Silica Synthesis stage of the dry method, η^{SS}(%), were calculated based on the average consumption of silane reagent per amount of silica produced reported for the EU-15 average[1]. This was related to the mass conversion efficiency based on the assumption that the silane used was tetrachlorosilane ($SiCl_4$) and using Equations 5 and 6.

$$\eta^{SS} = 100 \times {m_{SiO_2}}/{m_{SiO_2,theoretical}} \quad (5)$$

$$m_{SiO_2,theoretical} = m_{silane} \times \frac{M_{r,\,SiO2}}{M_{r,\,silane}} \quad (6)$$

Where: m_{SiO_2} is the mass of silica (kg),
m_{silane} is the mass of silicon tetrachloride (kg),
$M_{r,\,SiO2}$ is the molar mass of silica (g/mol),
$M_{r,\,silane}$ is the molar mass of silicon tetrachloride (g/mol),

Taking values for each variable as:

$m_{SiO_2} = 1\ kg$; $M_{r,\,SiO2} = 60\ g/mol$; $M_{r,\,silane} = 170\ g/mol$; $2.5\ kg \le m_{silane} \le 2.9\ kg$

Uncertainty in η^{RHAC} can be calculated as $98\% \le \eta^{RHAC} \le 114\%$. Estimates above 100% were ignored and uncertainty was considered to be within the range of $98\% \le \eta^{RHAC} \le 100\%$.

S4: Convergence of Percentile Estimates Derived from Monte Carlo Simulation

Checks for the reliance of a percentile, θ, calculated from Monte-Carlo simulations were made by visually assessing the convergence of θ as sample size, i, increased. This was done based on the relative difference, $\Delta\theta_i$, between the percentile calculated for a sample size, i, and the percentile calculated for the complete dataset of sample size, $i = n$. Where the relative difference is defined as:

$$\Delta\theta_i = 100 \times \left(\frac{\theta_i - \theta_{i=n}}{\theta_{i=n}}\right) \quad (8)$$

And in all cases in this work, $n = 200{,}000$.

Convergence results for all relevant distributions are shown in the following subsections. For ease of reading, convergence is shown for the 0.5th and 99.5th percentiles only. This is justified as these percentiles are the highest order statistics considered within the work, making them the most sensitive to the extreme values the may be randomly sampled during Monte-Carlo simulation, which may delay the convergence of $\Delta\theta_i$.

Convergence plots for all datasets/variables considered are shown in Figures 1 to 6. To minimise the number of visualisation required, the value of $\Delta\theta_i$ shown is always the maximum value of $\Delta\theta_i$ across the five environmental impact categories considered (GWP, LUP, MEP, MRS, ODP, TAP, TEP, WCP). Trends in Figures 1 to 6 can therefore be considered to show the most conservative consideration for $\Delta\theta_i$ as a function of dataset size that is possible when considering $\Delta\theta_i$. Importantly, Figures 1 to 6 demonstrate that in all cases the 99.5th and 0.5th percentiles of uncertainty distributions converge to within reasonable tolerance of ±5% relative error apart from in Figures 5 and 6, where convergence is comfortably to within ±10%.

Mineral Derived Processes

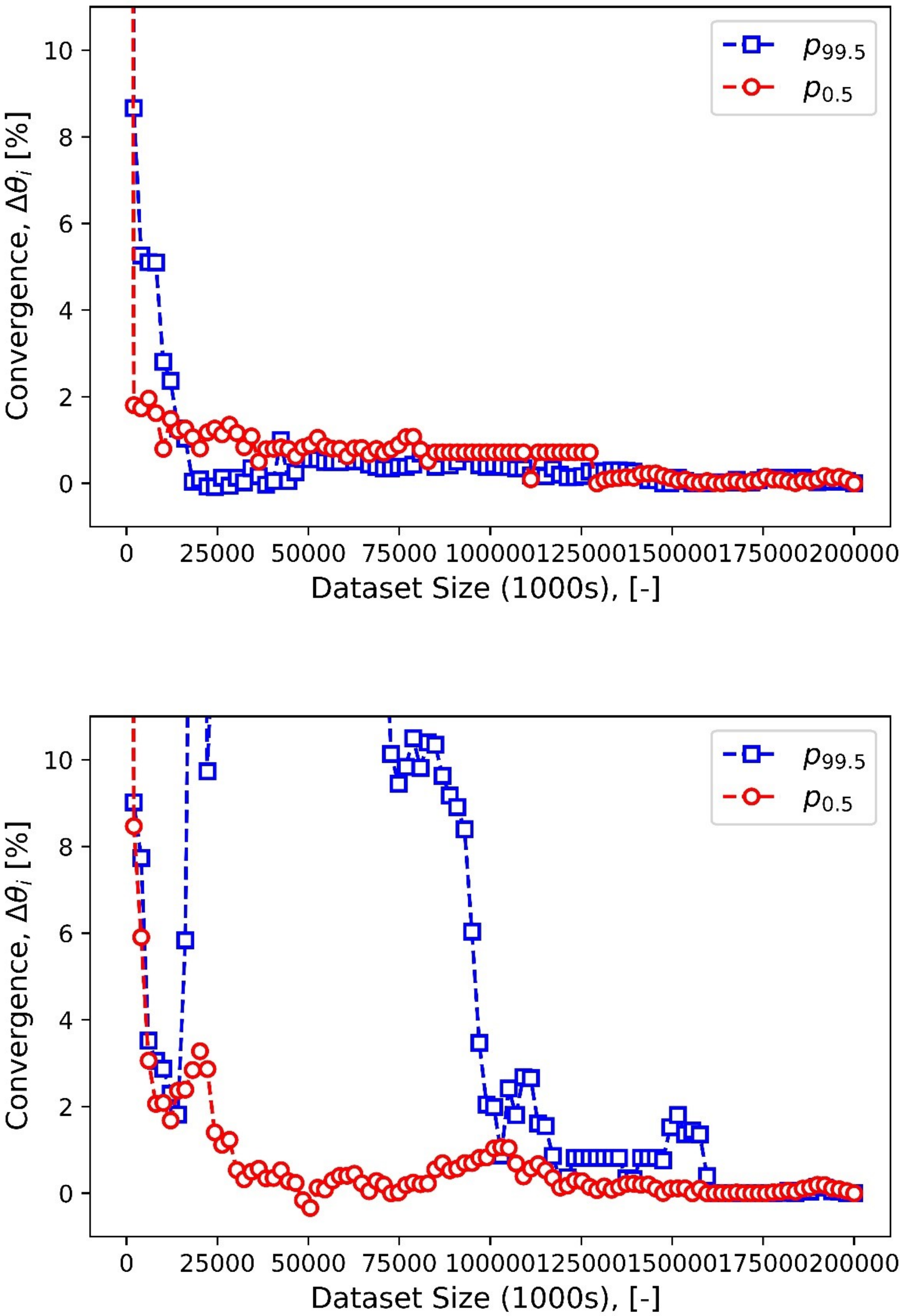


Figure 1: Convergence of the maximum relative difference in the estimates for the 0.5th and 99.5th percentiles for the wet (top) and dry (bottom) mineral processes.

Rice Husk Derived Processes

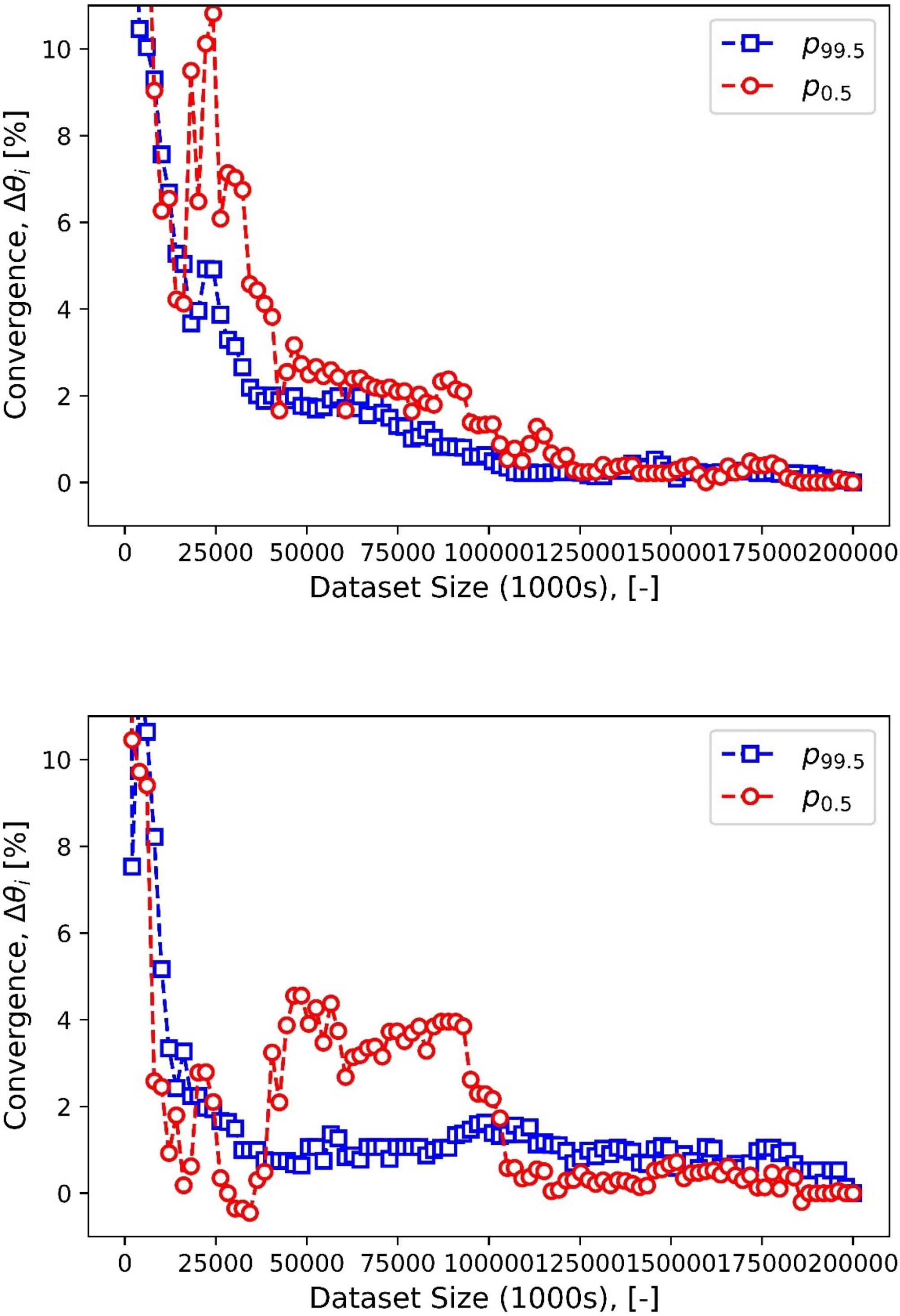


Figure 2: Convergence of the maximum relative difference in the estimates for the 0.5th and 99.5th percentiles for the silica produced according the wet (top) and dry (bottom) rice husk-derived methods.

Process Comparisons

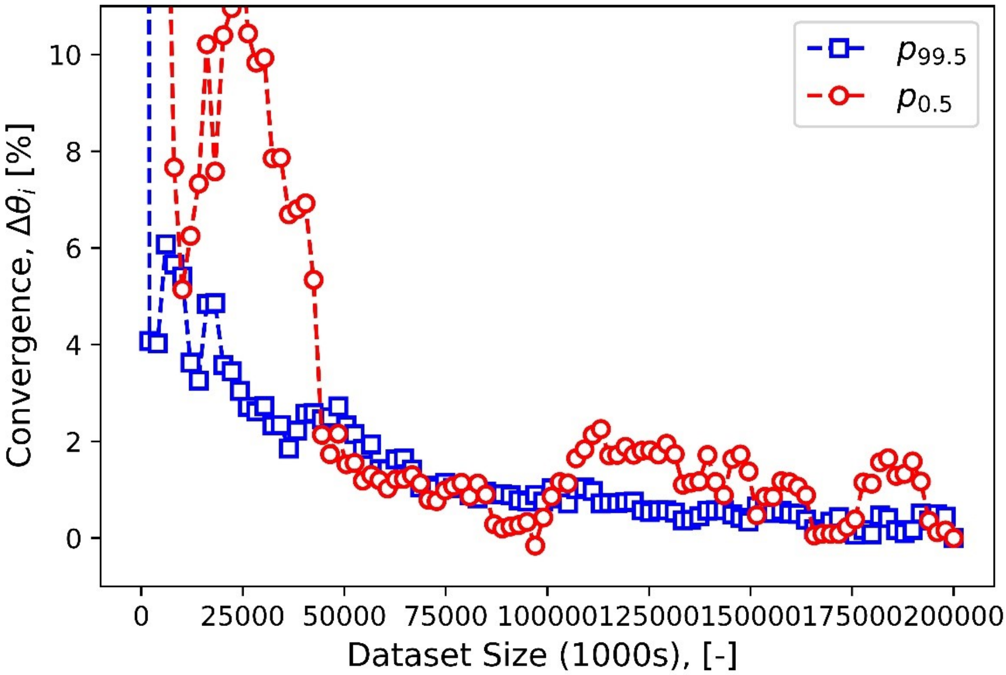
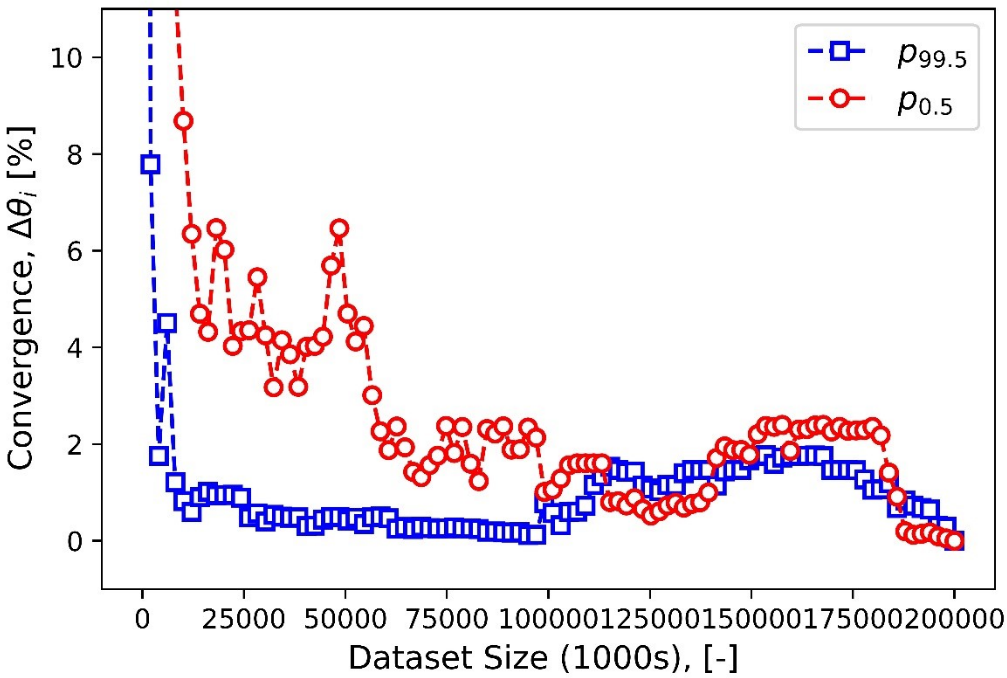


Figure 3: Convergence of the maximum relative difference in the estimates for the 0.5th and 99.5th percentiles for the comparisons of wet and dry mineral processes, $\Delta^{wet:dry}$



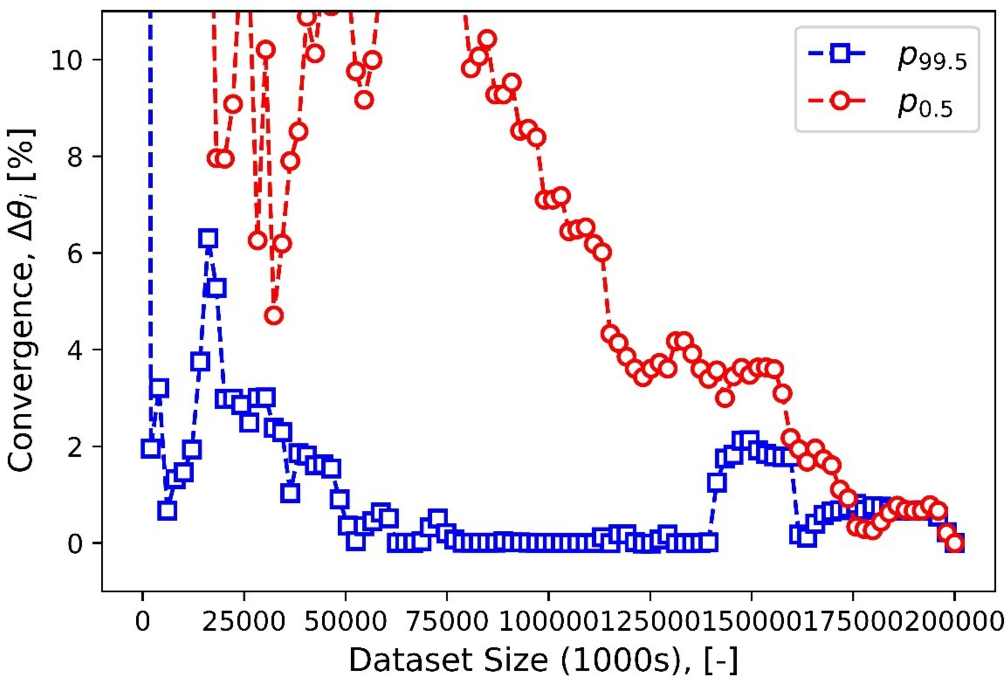
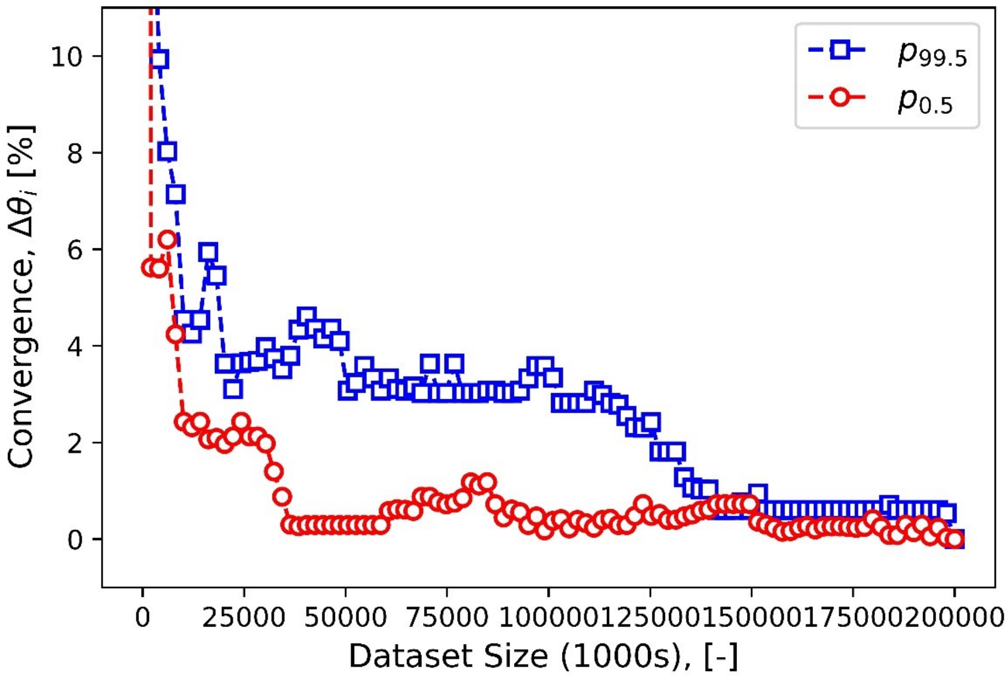


Figure 4: Convergence of the maximum relative difference in the estimates for the 0.5th and 99.5th percentiles for the comparisons of wet biomass and wet mineral processes, $\Delta^{biomass:mineral}$ *(top); and dry biomass and dry mineral processes,* $\Delta^{biomass:mineral}$ *(bottom).*

Benefits of Bio-energy Co-recovery



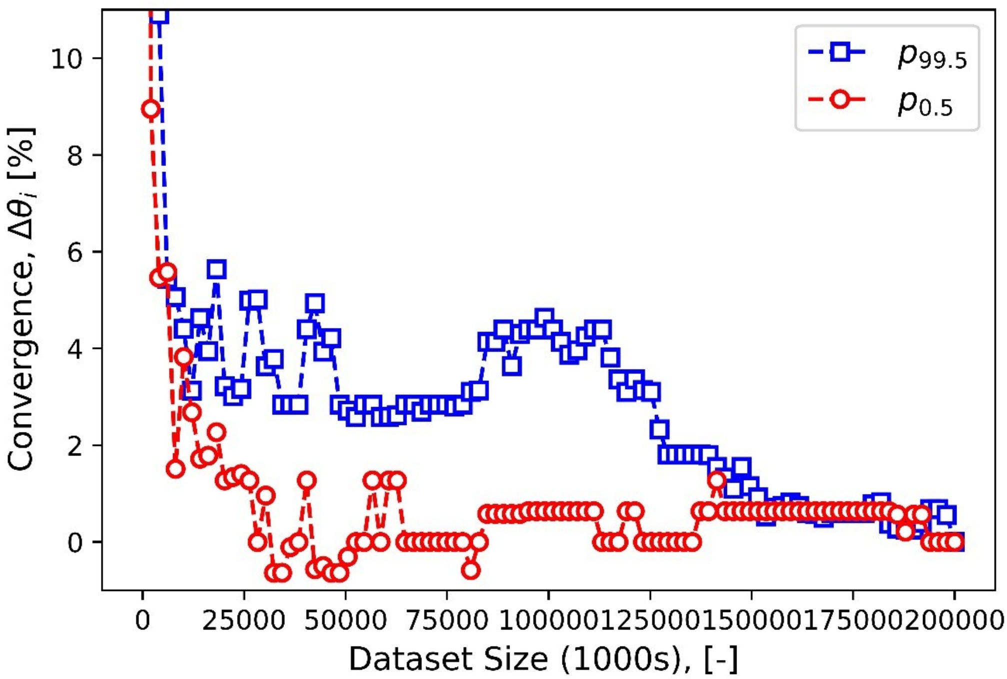


Figure 5: Convergence of the maximum relative difference in the estimates for the 0.5th and 99.5th percentiles for the benefit of rice husk-derived synthetic amorphous silica when coupled with bioenergy co-recovery to address new market demand, B_{GWP}^{new}. Results for wet method are shown on the top, results for dry method are shown on the bottom.

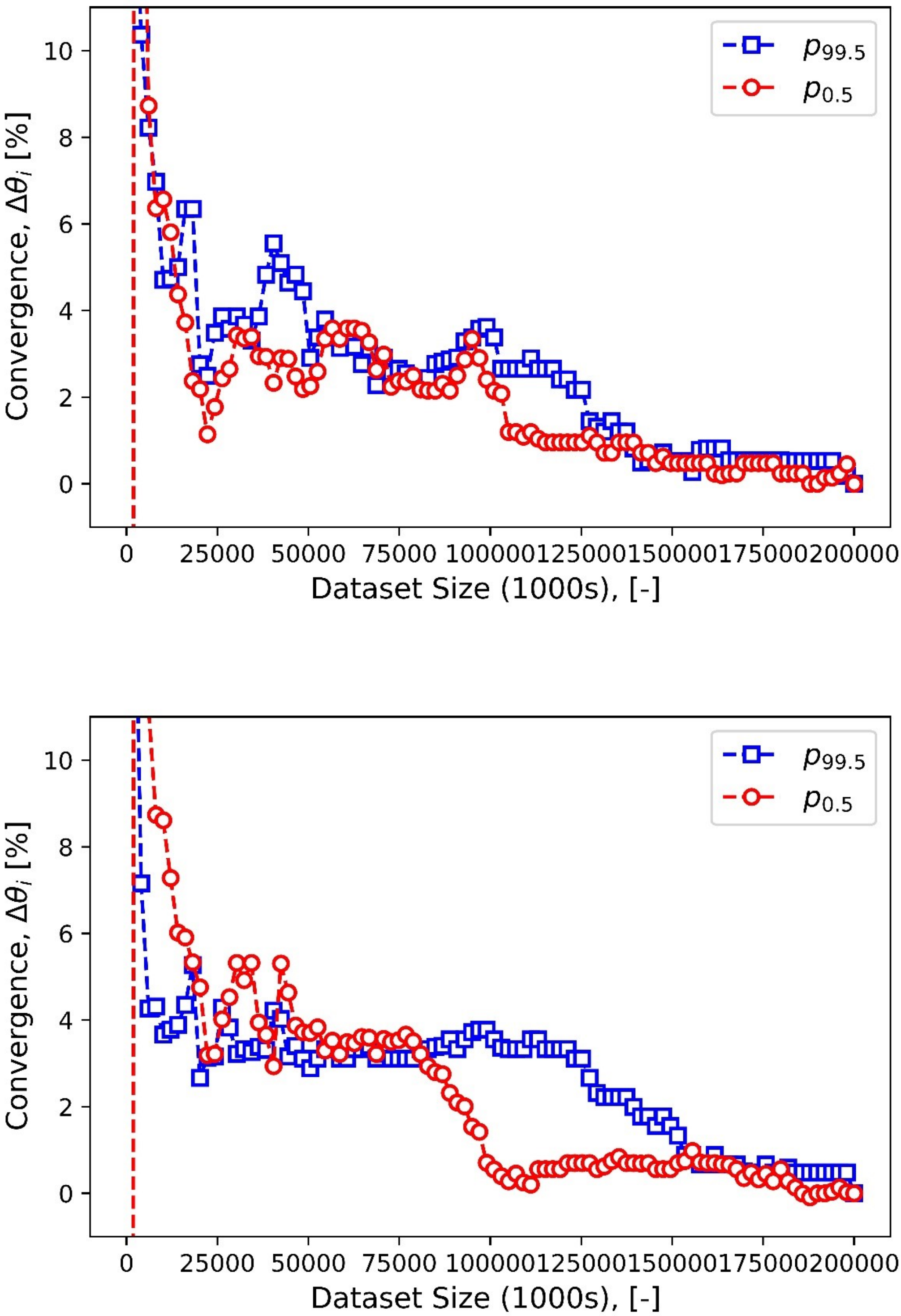
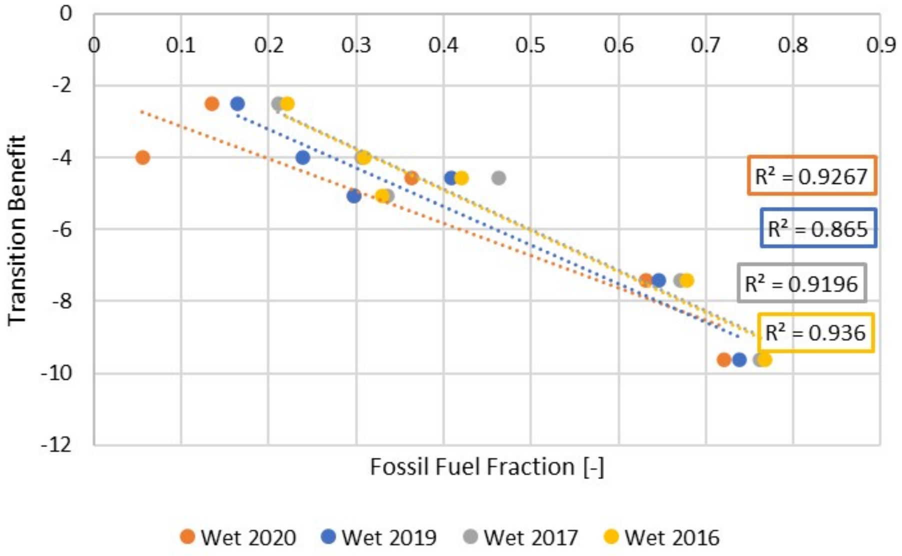


Figure 6: Convergence of the maximum relative difference in the estimates for the 0.5th and 99.5th percentiles for the benefit of rice husk-derived synthetic amorphous silica when coupled with bioenergy co-recovery to address existing market demand, $B^{existing}_{GWP}$. Results for wet method are shown on the top, results for dry method are shown on the bottom.

S5: Correlation of with Regional Dependence on Coal-derived Electricity

Regional electricity production statistics for the years 2016, 2017, 2019 and 2020 reported by British Petroleum (BP)[5–8] were used to understand the correlation of the benefit of producing rice husk-derived synthetic amorphous silica while considering bio-energy co-recovery and offsetting with regional energy blends. Results in Figure 7 show that benefits estimated for each region are strongly correlated ($R^2 > 0.8$) with the fraction of energy produced by coal for the years considered.



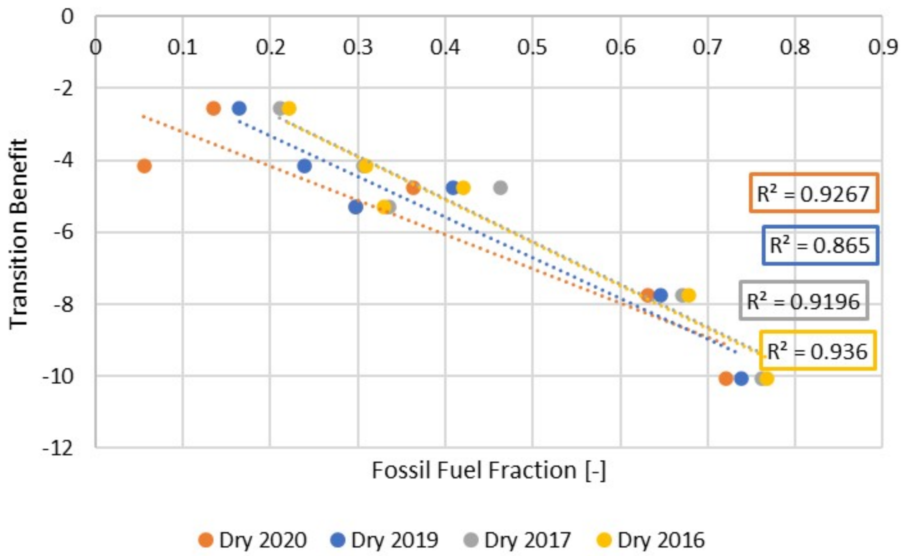


Figure 7: Relationship between benefit prediction of SAS produced by a wet (left) and dry (right) biomass-derived method and the fraction of coal contributing to regional electricity outputs annually

Finally, it can be seen in Figure 8 that the fraction of regional electricity produced by region from 2016 to 2020 did not vary significantly. Therefore it may be reasonable to suggest any difference between coal use in energy statistics used (2016-2020)[5–8] and the time frame of regional LCA models used (2014) is likely to be low – suggesting reliability of Figures 7 and 8 for the comparison being made.

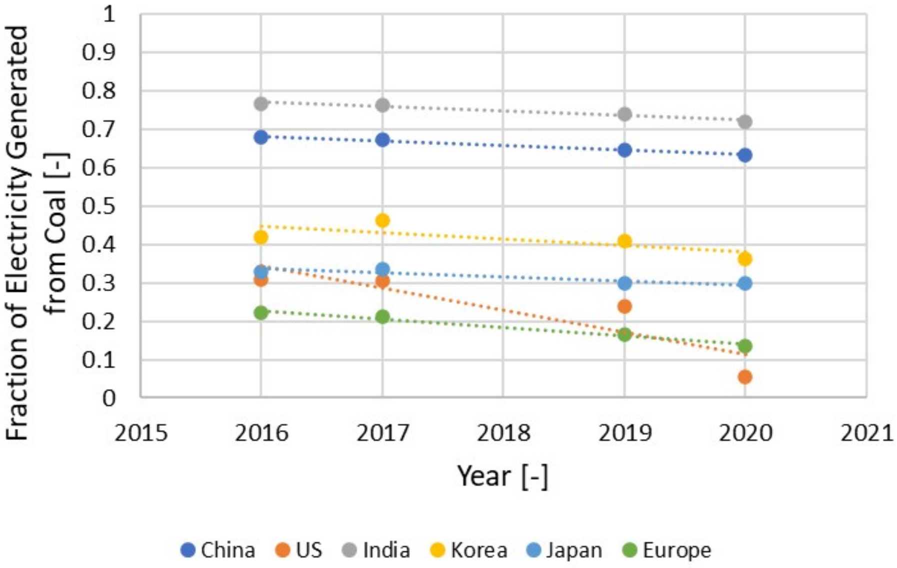


Figure 8: Change in the fraction of coal contributing to regional electricity outputs annually considered.

S5: Tabulated Deterministic Impact Estimates for all Processes

A summary of deterministic impact estimates for all impact categories evaluated by the ReCiPe 2016 Heirarchical method are provided in Table 31. Results for the benefit of scenarios in which bio-energy is co-recovered during rice husk combustion are summarised in Table 32.

Table 31: Impact predictions for M-SAS and RH-SAS processes made by the ReCiPe 2016 Hierarchical method.

Impact Factor	Wet M-SAS	Dry M-SAS	Wet RH-SAS	Dry RH-SAS	Impact Units (per kg_{SAS})
Fine particulate matter formation	0.00289	0.00605	0.0045955	0.0068498	kg PM2.5 eq
Fossil resource scarcity	0.58614	1.51133	0.475268	1.347728	kg oil eq
Freshwater ecotoxicity	0.00848	0.02301	0.0087194	0.0174927	kg 1,4-DCB
Freshwater eutrophication	0.00016	0.00084	0.00022889	0.00068	kg P eq
Global warming	2.08633	4.37691	1.81856642	4.1686779	kg CO2 eq
Human carcinogenic toxicity	0.01095	0.05272	0.01381976	0.0382463	kg 1,4-DCB
Human non-carcinogenic toxicity	0.43738	1.03933	0.66513012	1.0071263	kg 1,4-DCB
Ionizing radiation	0.00034	0.00719	0.00197226	0.006769	kBq Co-60 eq
Land use	0.02077	0.00728	-0.000868	-0.002941	m2a crop eq
Marine ecotoxicity	0.013	0.03239	0.01661581	0.0280808	kg 1,4-DCB
Marine eutrophication	0.00023	9.01E-05	0.00022602	7.771E-05	kg N eq
Mineral resource scarcity	0.00304	9.44E-06	1.0897E-07	9.121E-06	kg Cu eq
Ozone formation, Human health	0.00368	0.00704	0.01015934	0.0124983	kg NOx eq
Ozone formation, Terrestrial ecosystems	0.00373	0.00712	0.01018934	0.0125653	kg NOx eq
Stratospheric ozone depletion	5.10E-07	2.99E-06	3.1706E-06	4.814E-06	kg CFC11 eq
Terrestrial acidification	0.00984	0.01077	0.01341744	0.0145103	kg SO2 eq
Terrestrial ecotoxicity	2.05092	1.20396	7.27437446	6.4109036	kg 1,4-DCB
Water consumption	0.03345	0.08612	0.042596	0.083228	m3

Table 32: Scenario-dependent benefit predictions RH-SAS processes made by the ReCiPe 2016 Hierarchical method.

Benefit	India	China	Japan	South Korea	United States	Europe
Regional Grid Impact ($kgCO_2$-eq/MJ)	0.36	0.27	0.18	0.17	0.14	0.09
Wet New ($kgCO_2$-eq/kg_{SAS})	-7.53	-5.34	-2.99	-2.49	-1.92	-0.42
Wet Existing ($kgCO_2$-eq/kg_{SAS})	-9.62	-7.43	-5.08	-4.58	-4.00	-2.50
Dry New ($kgCO_2$-eq/kg_{SAS})	-5.68	-3.37	-0.90	-0.37	0.23	1.81
Dry Existing ($kgCO_2$-eq/kg_{SAS})	-10.06	-7.75	-5.28	-4.75	-4.14	-2.56

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