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Spplementary Information

Method S1 Inventory analysis for poplar plantation

To reflect variation in the country-specific agro-ecosystems and plantation management characteristics, literature data representing current country-level average fertilizer inputs and composition, fertilizer-induced field emissions, poplar plantation management practices and average poplar biomass yields in different EU regions were used to develop the LCA inventory.

The fertilizer application rate and compositions modelled (see Table S.2) varied by country and were estimated based on poplar trial data in France and the country-level average fertilizer inputs (IFA, 2011; EuropeanCommission, 2012b) which reflect country-specific soil conditions and farming practices. In the modelled EU countries, 65-90% of N fertilizer applied is in the form of straight nitrogen, whereas between 50-100% of P and K fertilizers are applied as multi-nutrient (compound fertilizer) forms (except for Italy). In Italy, a higher percentage of straight P and K fertilizers are applied to agricultural lands (about 70% of P fertilizer and 55% of K fertilizer as straight fertilizer) than the other countries modelled. Ammonium nitrate together with calcium ammonium nitrate dominate the straight N fertilizer application in France, Slovakia and Sweden, accounting for 45%, 42%, 62% of total N, respectively, whereas urea and urea ammonium nitrate solution is the dominant N fertilizer applied in Italy (approx..70% of total N fertilizer). Urea together with urea ammonium nitrate solution also plays an important role in N inputs in France and Spain (42% and 39% of total N fertilizer respectively). No urea type fertilizer is applied in Sweden.

The emission factors (EFs) for N fertilizer-induced field emissions were calculated based on the EU country-level N budget balances (Velthof *et al.*, 2009; De Vries *et al.*, 2011), which take into account the country-specific climatic and soil conditions. The N_2O EF modelled here accounted for direct N_2O emissions from poplar plantations, but also for two indirect N_2O emissions pathways i.e. N_2O emission due to N leaching and re-deposition of NH_3 and NO_x evolved from agricultural soil (De Vries *et al.*, 2011). N_2 emissions produced via the denitrification process was modelled as the major N loss pathway accounting for 50-70% of total N lost (De Vries *et al.*, 2011). The highest EF for nitrate-N leaching to the hydrosphere was modelled for Spain, followed by Italy and France. This pattern reflected the regional soil profiles, particularly the organic matter contents – low organic carbon contents in Spain, Italy and France (see Fig S.1) limit the denitrification process, which acts as the main mechanism of nitrate removal in deep soil.

The carbon sequestration into above-ground biomass was calculated by assuming that the carbon contained in oven dry poplar woody biomass is 50% (Hansen, 1993; Gielen *et al.*, 2005; Rytter, 2012). According to the estimations in the European soils database nearly 40% of European soils have low to very low organic matter contents and this proportion reaches more than 70% in southern Europe (Arrouays *et al.*, 2004). A promising measure to enhance soil carbon stock is to introduce perennial bioenergy crops on set-aside land (Arrouays *et al.*, 2004; Freibauer *et al.*, 2004) and further benefit could be achieved by growing bioenergy crops on marginal, degraded and abandoned lands (Blanco-Canqui, 2010). The potential for enhanced soil carbon sequestration beneath managed poplar plantation have stimulated considerable research interest (Hansen, 1993; Freibauer *et al.*, 2004; Gupta *et al.*, 2009; Garten *et al.*, 2011; Rytter, 2012). In the present study, accumulation of soil organic carbon due to fine root turnover and leaf litter fall has been taken into account. Based on the annual soil carbon sequestration rate reported in previous studies (Hansen, 1993; Freibauer *et al.*, 2004; Gupta *et al.*, 2009; Garten *et al.*, 2011; Rytter, 2012), it was estimated that the soil organic carbon accumulation (over the levels before poplar plantation establishment) achieved 6% - 24% of the total above-ground woody biomass. In the current study, a 'defalt' soil carbon sequestration rate of 0.12 kg C/kg OD above-ground biomass was modelled for the current and prospective 2020/2030 scenarios, and the effects of including soil carbon accumulations representing the upper and lower range of values reported in literature on the environmental profiles of poplar-based bioethanol was investigated via sensitivity analysis. In reality, soil carbon accummulation could be manipulated via selection of hybrid poplar with genetic traits favouring the enhanced capacity to store carbon in long-lived soil pools (e.g. the hydrid poplar clones with roots more resistant to attack by soil microorganisms which could prolong dead root decomposition and turnover times of soil carbon pool consequently increase long-term soil carbon sequestration potential (Garten *et al.*, 2011)). Such impacts of variation in genetic traits of hybrid poplar on soil carbon accumulation is out of the current study scope but would be interesting to investigate in future research.

Method S2 Sensitivity analysis

Sensitivity analsysis of the characterization model

As an alternative to the mid-point method CML 2 Baseline 2000, the damage-oriented method Eco-Indicator 99 H (hierarchist version 2.08, land use excluded) was also applied to the LCA model.

The comparison in Table S.1 indicates that although the impact categories evaluated in the two methods are not identical, most of them overlapped. The CML 2 baseline 2000 method represents eco-toxicity in three sub-categories whilst Eco-indicators 99 uses only one aggregated eco-toxic indicator result. Equivalent to photochemical potential in CML 2 baseline (summer smog), Eco-indicators 99 includes a respiratory organics impact category where respiratory effects resulting from exposure to organic compounds in summer-smog are evaluated (Goedkoop & Spriensma, 2001; PRéConsultants, 2004). Eco-indictors 99 also accounts for winter smog (respiratory inorganic), damages induced by radioactive radiation and conversion and occupation of land (PRéConsultants, 2004) all of which are not in the scope of CML baseline method.

Unlike the CML method, EI 99 aggregates acidification and eutrophication potential of all substances into a single indicator result. As given in Figs S.6 a and b most of the E100 current scenarios appear to have a lower impact than petrol over the life cycle in the aggregated acidification/eutrophication EI 99 category; this is somewhat different from the CML findings in Figs S.3 a and b, where E100 incurred higher acidification and eutrophication scores to petrol. In addition, the lower EI 99 aggregated acidification/eutrophication impacts for prospective E100 scenarios in Figs S.7 a and b differ from the CML outcomes (see Fig S.3 c and d) where E100 under 2020 and 2030 scenarios gave similar (higher) acidification/eutrophication impacts than petrol. In the EI 99 prospective E100 scenarios higher impacts occurred in mineral resources depletion but much lower burdens on fossil fuel in comparison with petrol (Figs S7 a and b). This finding differs to an extent from the results derived from CML method (abiotic depletion in Fig S.3 c and d) due to the dominant contribution (over 90% impacts) in abiotic depletion in CML being from fossil fuel rather than minerals.

Sensitivity analysis of the allocation approach

The influence of choice of allocation approach on the LCA results varies between the countries, scenarios modelled and the impact categories investigated (Fig S.8 - S.9 and Tables S.23 - S.32). The change in allocation approach produced significant effects on the GWP_{100} profiles of poplar-derived E100 bioethanol across all EU countries especially in Italy, where a dramatic increase in GWP_{100} occurred when shifting from system expansion to energy allocation approach. Similar trends were also observed in the E100 bioethanol modelled for Spain and Slovakia – GWP_{100} impacts of E100 bioethanol under current and future scenarios increased by 5% - 80% and 60% - 115% respectively as a consequence of switching to an energy allocation approach. Conversely, the GWP_{100} scores of E100 bioethanol in France and Sweden declined with the change to energy allocation (decrease by 20% - 50% for current scenarios and 9% - 18% for future scenarios).

Generally, in France and Sweden, E100 bioethanol under current scenarios appeared more sensitive to the allocation approach than the future scenarios – the shifts in the characterized LCIA profiles of current E100 bioethanol were found to be above the sensitivity threshold (10%) in almost all impact categories whereas for future bioethanol only GWP_{100} was sensitive to the allocation approach. In the other three EU countries, there was no significant difference in the the sensitivity response to allocation approach between the current and future scnearios but the sensivitity of LCIA results varied with impact categories. In the case of Italy, Slovakia, and Spain, the environmental performances of E100 bioethanol were sensitive to allocation approach in abiotic depletion, eutrophication, GWP_{100} and toxicity impact categories.

Overall, the allocation approach was not a sensitivity issue for the LCIA comparisons between E100 bioethanol and petrol – regardless of the allocation approach, current E100 bioethanol was environmentally superior to petrol in GWP_{100}, ODP and POCP and under prospective scenarios E100 bioethanol delivered even greater environmental advantages over petrol in abiotic depletion, GWP_{100}, ODP and POCP.

Table S1 Comparison of CML 2 baseline and Eco-indicators 99

	CML 2 baseline 2000 [a]	**Eco-indictors 99** [b]
LCIA element	Characterization Normalization	Characterization Normalization Weighting
LCIA approach	Midpoint /Problem-oriented	Endpoint/Damage-oriented
Impact categories concerned	Abiotic depletion	Minerals (resource depletion)
		Fossil Fuels (resource depletion)
	Global warming potential	Climate change (human health)
	Ozone layer depletion	Ozone layer (human health)
	Acidification	Acidification/eutrophication (eco-system quality)
	Eutrophication	
	Human toxicity	Carcinogens (human health)
	Aquatic eco-toxicity (fresh water and marine)	Eco-toxicity (eco-system quality)
	Terrestrial eco-toxicity	
	Photochemical potential	Respiratory organic (human health)
	--	Respiratory inorganic (human health)
	--	Radiation (human health) [c]
	--	Land use (eco-system quality) [c]

a. (Guinée et al., 2001; PRéConsultants, 2004)
b. (Goedkoop & Spriensma, 2001)
c. brackets in Ecoindicators 99 indicate the category end-point concerned in damage assessment

Table S2 Country-specific fertilizer compositions [a]

	France	Italy	Slovakia	Spain	Sweden
N fertilizer inputs (% N fertilizer applied)					
Ammonium nitrate as N	32.53%	0.00%	3.61%	4.56%	5.68%
Ammonium phosphate as N	2.00%	9.14%	1.20%	7.17%	0.00%
Ammonium sulphate as N	0.82%	4.57%	7.23%	7.34%	0.06%
Calcium ammonium nitrate as N	12.81%	14.63%	38.55%	18.45%	56.22%
NK compound fertilizer as N [b]	0.00%	0.00%	0.00%	1.72%	0.00%
NPK compound fertilizer as N [b]	5.54%	6.40%	20.48%	12.76%	35.21%
Nitrogen solutions as N [c]	28.43%	0.18%	3.61%	7.75%	0.00%
Other N straight fertilizer as N [d]	2.37%	0.18%	0.00%	9.25%	0.00%
Other NP compound fertilizer as N [b]	2.02%	2.19%	0.00%	0.25%	2.84%
Urea as N	13.49%	62.71%	25.30%	30.75%	0.00%
P_2O_5 fertilizer inputs (%P_2O_5 applied)					
Ammonium phosphate as P_2O_5	26.20%	61.54%	0.00%	48.55%	0.00%
Ground rock direct application as P_2O_5	1.21%	0.00%	0.00%	0.00%	0.00%
NPK compound fertilizer as P_2O_5 [e]	20.63%	27.13%	100.00%	43.20%	80.00%
NP compound fertilizer as P_2O_5 [f]	9.54%	1.03%	0.00%	0.00%	5.00%
Other P straight as P_2O_5 [g]	1.06%	0.00%	0.00%	6.71%	0.00%
P K compound fertilizer as P_2O_5 [h]	17.43%	0.51%	0.00%	0.00%	15.00%
Single superphosphate as P_2O_5	4.66%	5.13%	0.00%	0.31%	0.00%
Triple superphosphate as P_2O_5	19.28%	4.67%	0.00%	1.24%	0.00%
K_2O fertilizer inputs(%K_2O applied)					
NK compound fertilizer K_2O [i]	0.00%	1.82%	0.00%	0.00%	0.00%
NPK compound fertilizer as K_2O [i]	29.99%	35.45%	84.62%	68.00%	76.00%
Other K straight as K_2O [j]	5.55%	7.27%	0.00%	0.00%	0.00%
P K compound fertilizer as K_2O [i]	20.59%	0.91%	0.00%	0.00%	8.00%
Potassium chloride as K_2O	41.71%	36.36%	7.69%	27.47%	12.00%
Potassium sulphate as K_2O	2.16%	18.18%	7.69%	4.52%	4.00%

a. *Data derived from EU statistics (IFA, 2011; EuropeanCommission, 2012a)*
b. *Assumed as ammonium nitrate*
c. *Assumed as urea ammonium nitrate*
d. *Assumed as calcium nitrate*
e. *Assumed as diammonium phosphate*
f. *Assumed as monoammonim phosphate*
g. *Assumed as calcium phosphate*
h. *Assumed as phosphate rock*
i. *Assumed as potassium chloride*
j. *Assumed as potassium nitrate*

Table S3 Country-specific energy sources for electricity generation (Ecoinvent database (v2.2))

	France	**Italy**	**Spain**	**Slovakia**	**Sweden**
Hard coal	4.47%	15.14%	24.37%	10.82%	0.67%
Peat	0.00%	0.00%	0.00%	0.00%	0.46%
Lignite	0.00%	0.00%	3.72%	7.57%	0.00%
Oil	1.01%	16.10%	8.45%	2.39%	1.30%
Natural gas	3.18%	45.75%	19.60%	7.84%	0.50%
Industrial gas	0.48%	1.89%	0.40%	1.36%	0.54%
Hydropower	11.88%	19.90%	12.70%	14.73%	40.50%
Photovoltaic	0.00%	0.00%	0.04%	0.00%	0.00%
Wind power	0.15%	0.67%	5.82%	0.00%	0.61%
Nuclear	78.50%	0.00%	22.83%	55.27%	50.97%
Biomass	0.24%	0.10%	1.51%	0.01%	4.39%
Biogas	0.08%	0.44%	0.56%	0.01%	0.06%

Table S4 Characterized LCIA profiles of poplar biomass at farm-gate under current scenarios (unit: 1 kg OD poplar biomass; method: CML 2 baseline 2000).

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC
Abiotic depletion (kg Sb eq)	2.14E-04	2.57E-04	3.97E-04	4.09E-04	1.81E-04	1.64E-04	1.88E-04	1.78E-04	4.54E-04	4.74E-04
Acidification(kg SO_2 eq)	3.65E-04	6.92E-04	3.02E-04	3.68E-04	1.96E-04	2.43E-04	2.05E-04	2.62E-04	3.86E-04	5.56E-04
Eutrophication(kg PO_4^{3-} eq)	1.28E-04	2.64E-04	1.54E-04	2.54E-04	7.97E-05	1.36E-04	1.10E-04	2.13E-04	1.90E-04	3.31E-04
GWP100 (kg CO_2 eq) -excluding C sequestration	8.43E-02	1.77E-01	5.66E-02	6.71E-02	3.00E-02	3.46E-02	4.59E-02	7.53E-02	7.81E-02	1.16E-01
GWP100 (kg CO_2 eq) -including C sequestration[a]	-2.19	-2.10	-2.22	-2.21	-2.24	-2.24	-2.23	-2.20	-2.20	-2.16
ODP (kg CFC-11 eq)	1.33E-08	2.92E-08	1.19E-08	2.38E-08	1.12E-08	2.35E-08	1.00E-08	2.04E-08	1.23E-08	2.39E-08
Human toxicity(kg 1,4-DB eq)	2.52E-02	3.85E-02	5.24E-02	6.04E-02	2.05E-02	2.53E-02	2.09E-02	2.56E-02	6.12E-02	7.07E-02
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	4.72E-03	7.46E-03	1.65E-02	1.89E-02	3.69E-03	4.60E-03	3.88E-03	5.00E-03	1.99E-02	2.29E-02
Marine aquatic eco-toxicity (kg 1,4-DB eq)	9.51E+00	1.78E+01	3.21E+01	3.88E+01	6.86E+00	1.05E+01	7.45E+00	1.18E+01	3.89E+01	4.67E+01
Terrestrial eco-toxicity (kg 1,4-DB eq)	1.13E-04	2.15E-04	8.24E-04	9.49E-04	7.54E-05	1.15E-04	8.51E-05	1.39E-04	1.02E-03	1.17E-03
POCP (kg C_2H_4)	2.92E-05	9.22E-06	3.55E-05	1.50E-05	2.83E-05	6.56E-06	2.83E-05	6.59E-06	3.74E-05	1.72E-05

a.The carbon sequestered into above ground biomass (assumed as 0.5kg C/Oven Dry (OD) kg above-ground woody biomass yield (Hansen, 1993; Gielen et al., 2005; Rytter, 2012; Guo et al., 2013)) and the carbon accumulated in soil organic matter due to leaf litter and fine root turnover (assumed as 0.12 kg C/OD kg above-ground woody biomass yield(Hansen, 1993; Freibauer et al., 2004; Garten et al., 2011; Rytter, 2012)) are included here.

Table S5 Characterized LCIA profiles of poplar biomass at farm-gate under 2020 scenarios (unit: 1 kg OD poplar biomass; method: CML 2 baseline 2000).

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC
Abiotic depletion (kg Sb eq)	1.84E-04	1.64E-04	3.18E-04	2.87E-04	1.63E-04	1.06E-04	1.69E-04	1.19E-04	3.53E-04	3.24E-04
Acidification(kg SO_2 eq)	2.75E-04	4.41E-04	2.47E-04	2.58E-04	1.68E-04	1.57E-04	1.76E-04	1.75E-04	3.02E-04	3.80E-04
Eutrophication(kg PO_4^{3-} eq)	9.28E-05	1.68E-04	1.17E-04	1.78E-04	6.23E-05	8.79E-05	8.36E-05	1.42E-04	1.40E-04	2.26E-04
GWP100 (kg CO_2 eq) -excluding C sequestration	6.04E-02	1.13E-01	4.53E-02	4.71E-02	2.59E-02	2.24E-02	3.68E-02	5.03E-02	5.94E-02	7.92E-02
GWP100 (kg CO_2 eq) -including C sequestration[a]	-2.21	-2.16	-2.23	-2.23	-2.25	-2.25	-2.24	-2.22	-2.21	-2.19
ODP (kg CFC-11 eq)	9.34E-09	1.86E-08	9.05E-09	1.66E-08	8.03E-09	1.51E-08	7.47E-09	1.36E-08	9.16E-09	1.63E-08
Human toxicity(kg 1,4-DB eq)	2.07E-02	2.46E-02	4.05E-02	4.25E-02	1.77E-02	1.65E-02	1.82E-02	1.72E-02	4.60E-02	4.85E-02
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	3.81E-03	4.78E-03	1.22E-02	1.33E-02	3.16E-03	2.99E-03	3.33E-03	3.36E-03	1.43E-02	1.56E-02
Marine aquatic eco-toxicity (kg 1,4-DB eq)	7.32E+00	1.13E+01	2.35E+01	2.72E+01	5.65E+00	6.81E+00	6.13E+00	7.92E+00	2.78E+01	3.20E+01
Terrestrial eco-toxicity (kg 1,4-DB eq)	8.49E-05	1.37E-04	5.87E-04	6.65E-04	6.12E-05	7.45E-05	6.86E-05	9.29E-05	7.11E-04	8.03E-04
POCP (kg C_2H_4)	2.81E-05	5.89E-06	3.27E-05	1.05E-05	2.75E-05	4.25E-06	2.76E-05	4.42E-06	3.38E-05	1.18E-05

a.The carbon sequestered into above ground biomass (assumed as 0.5kg C/Oven Dry (OD) kg above-ground woody biomass yield (Hansen, 1993; Gielen et al., 2005; Rytter, 2012; Guo et al., 2013)) and the carbon accumulated in soil organic matter due to leaf litter and fine root turnover (assumed as 0.12 kg C/OD kg above-ground woody biomass yield(Hansen, 1993; Freibauer et al., 2004; Garten et al., 2011; Rytter, 2012)) are included here.

Table S6 Characterized LCIA profiles of poplar biomass at farm-gate under 2030 scenarios (unit: 1 kg OD poplar biomass; method: CML 2 baseline 2000).

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC
Abiotic depletion (kg Sb eq)	1.72E-04	1.29E-04	2.80E-04	2.30E-04	1.54E-04	7.73E-05	1.60E-04	9.01E-05	2.98E-04	2.44E-04
Acidification(kg SO_2 eq)	2.42E-04	3.47E-04	2.21E-04	2.07E-04	1.54E-04	1.14E-04	1.62E-04	1.32E-04	2.56E-04	2.86E-04
Eutrophication(kg PO_4^{3-} eq)	7.97E-05	1.32E-04	1.00E-04	1.43E-04	5.38E-05	6.38E-05	7.06E-05	1.07E-04	1.13E-04	1.70E-04
GWP100 (kg CO_2 eq) -excluding C sequestration	5.15E-02	8.85E-02	3.99E-02	3.78E-02	2.39E-02	1.63E-02	3.23E-02	3.78E-02	4.93E-02	5.95E-02
GWP100 (kg CO_2 eq) -including C sequestration[a]	-2.22	-2.18	-2.23	-2.24	-2.25	-2.26	-2.24	-2.24	-2.22	-2.21
ODP (kg CFC-11 eq)	7.85E-09	1.46E-08	7.72E-09	1.33E-08	6.47E-09	1.10E-08	6.20E-09	1.02E-08	7.46E-09	1.23E-08
Human toxicity(kg 1,4-DB eq)	1.90E-02	1.94E-02	3.50E-02	3.41E-02	1.64E-02	1.20E-02	1.68E-02	1.30E-02	3.77E-02	3.65E-02
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	3.47E-03	3.77E-03	1.02E-02	1.06E-02	2.90E-03	2.19E-03	3.05E-03	2.54E-03	1.13E-02	1.18E-02
Marine aquatic eco-toxicity (kg 1,4-DB eq)	6.50E+00	8.94E+00	1.95E+01	2.18E+01	5.06E+00	4.96E+00	5.47E+00	5.97E+00	2.17E+01	2.40E+01
Terrestrial eco-toxicity (kg 1,4-DB eq)	7.44E-05	1.08E-04	4.77E-04	5.33E-04	5.42E-05	5.43E-05	6.04E-05	7.00E-05	5.42E-04	6.03E-04
POCP (kg C_2H_4)	2.77E-05	4.64E-06	3.14E-05	8.44E-06	2.71E-05	3.09E-06	2.73E-05	3.33E-06	3.19E-05	8.85E-06

a.The carbon sequestered into above ground biomass (assumed as 0.5kg C/Oven Dry (OD) kg above-ground woody biomass yield (Hansen, 1993; Gielen et al., 2005; Rytter, 2012; Guo et al., 2013)) and the carbon accumulated in soil organic matter due to leaf litter and fine root turnover (assumed as 0.12 kg C/OD kg above-ground woody biomass yield(Hansen, 1993; Freibauer et al., 2004; Garten et al., 2011; Rytter, 2012)) are included here.

Table S7 Characterized LCIA profiles of E100 (DA pretreatment, current scenarios) vs. petrol at use phase (unit:driving FFV for 100km; method: CML 2 baseline 2000)

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC	Petrol
Abiotic depletion (kg Sb eq)	2.15E-01	2.17E-01	1.71E-01	1.72E-01	1.87E-01	1.86E-01	2.09E-01	2.09E-01	1.83E-01	1.84E-01	1.65E-01
Acidification(kg SO_2 eq)	2.50E-01	2.63E-01	2.15E-01	2.17E-01	2.10E-01	2.12E-01	2.40E-01	2.42E-01	1.96E-01	2.03E-01	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	4.27E-02	4.80E-02	3.77E-02	4.15E-02	2.86E-02	3.08E-02	4.07E-02	4.46E-02	3.50E-02	4.04E-02	1.92E-02
GWP100 (kg CO_2 eq)	1.32E+01	1.68E+01	6.06E+00	6.47E+00	8.21E+00	8.39E+00	1.21E+01	1.32E+01	8.04E+00	9.49E+00	2.64E+01
ODP (kg CFC-11 eq)	1.95E-06	2.57E-06	1.43E-06	1.89E-06	1.67E-06	2.14E-06	1.90E-06	2.30E-06	1.71E-06	2.16E-06	3.12E-06
Human toxicity(kg 1,4-DB eq)	1.72E+01	1.77E+01	1.76E+01	1.79E+01	1.49E+01	1.51E+01	1.65E+01	1.67E+01	1.74E+01	1.78E+01	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	5.18E+00	5.28E+00	4.98E+00	5.07E+00	3.09E+00	3.12E+00	4.87E+00	4.91E+00	4.26E+00	4.38E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	1.05E+04	1.09E+04	9.70E+03	9.95E+03	5.86E+03	6.00E+03	9.87E+03	1.00E+04	8.25E+03	8.56E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	9.07E-02	9.46E-02	1.04E-01	1.09E-01	6.12E-02	6.27E-02	8.72E-02	8.93E-02	1.16E-01	1.22E-01	1.75E-02
POCP (kg C_2H_4)	1.21E-02	1.13E-02	1.10E-02	1.02E-02	1.07E-02	9.87E-03	1.19E-02	1.11E-02	1.04E-02	9.61E-03	2.99E-02

Table S8 Characterized LCIA profiles of E100 (LHW pretreatment, current scenarios) vs. petrol at use phase (unit:driving FFV for 100km; method: CML 2 baseline 2000)

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC	Petrol
Abiotic depletion (kg Sb eq)	2.49E-01	2.51E-01	1.69E-01	1.70E-01	2.00E-01	1.99E-01	2.39E-01	2.39E-01	1.88E-01	1.89E-01	1.65E-01
Acidification(kg SO_2 eq)	2.38E-01	2.55E-01	1.78E-01	1.81E-01	1.72E-01	1.74E-01	2.23E-01	2.26E-01	1.44E-01	1.52E-01	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	3.93E-02	4.60E-02	3.00E-02	3.49E-02	1.54E-02	1.82E-02	3.60E-02	4.11E-02	2.47E-02	3.16E-02	1.92E-02
GWP100 (kg CO_2 eq)	1.26E+01	1.72E+01	5.19E-01	1.04E+00	4.78E+00	5.01E+00	1.13E+01	1.27E+01	3.59E+00	5.45E+00	2.64E+01
ODP (kg CFC-11 eq)	2.13E-06	2.92E-06	1.24E-06	1.82E-06	1.67E-06	2.27E-06	2.10E-06	2.61E-06	1.73E-06	2.30E-06	3.12E-06
Human toxicity(kg 1,4-DB eq)	1.75E+01	1.81E+01	1.77E+01	1.81E+01	1.36E+01	1.39E+01	1.64E+01	1.66E+01	1.72E+01	1.77E+01	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	4.07E+00	4.21E+00	3.51E+00	3.63E+00	4.21E-01	4.66E-01	3.55E+00	3.60E+00	2.19E+00	2.33E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	8.36E+03	8.77E+03	6.45E+03	6.78E+03	1.87E+02	3.66E+02	7.21E+03	7.43E+03	3.79E+03	4.18E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	3.15E-02	3.65E-02	4.27E-02	4.89E-02	-1.96E-02	-1.76E-02	2.59E-02	2.85E-02	5.88E-02	6.64E-02	1.75E-02
POCP (kg C_2H_4)	1.21E-02	1.12E-02	1.01E-02	9.10E-03	9.76E-03	8.68E-03	1.18E-02	1.08E-02	9.03E-03	8.03E-03	2.99E-02

Table S9 Characterized LCIA profiles of E100 (2020 scenarios) vs. petrol at use phase (unit:driving FFV for 100km; method: CML 2 baseline 2000)

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC	Petrol
Abiotic depletion (kg Sb eq)	1.14E-01	1.13E-01	1.03E-01	1.02E-01	1.05E-01	1.04E-01	1.12E-01	1.10E-01	1.07E-01	1.06E-01	1.65E-01
Acidification(kg SO_2 eq)	1.09E-01	1.14E-01	9.81E-02	9.85E-02	9.55E-02	9.52E-02	1.04E-01	1.04E-01	9.33E-02	9.57E-02	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	2.05E-02	2.28E-02	1.95E-02	2.13E-02	1.60E-02	1.68E-02	1.99E-02	2.16E-02	1.90E-02	2.16E-02	1.92E-02
GWP100 (kg CO_2 eq)	2.81E+00	4.39E+00	5.58E-01	6.15E-01	9.06E-01	7.99E-01	2.19E+00	2.60E+00	1.33E+00	1.92E+00	2.64E+01
ODP (kg CFC-11 eq)	1.04E-06	1.32E-06	8.94E-07	1.12E-06	9.41E-07	1.16E-06	1.01E-06	1.19E-06	9.76E-07	1.19E-06	3.12E-06
Human toxicity (kg 1,4-DB eq)	9.61E+00	9.73E+00	1.00E+01	1.01E+01	8.92E+00	8.88E+00	9.39E+00	9.36E+00	1.00E+01	1.01E+01	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	2.29E+00	2.32E+00	2.36E+00	2.39E+00	1.67E+00	1.67E+00	2.20E+00	2.20E+00	2.17E+00	2.21E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	4.26E+03	4.38E+03	4.24E+03	4.35E+03	2.86E+03	2.89E+03	4.04E+03	4.10E+03	3.87E+03	3.99E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	1.73E-02	1.89E-02	2.86E-02	3.10E-02	8.38E-03	8.78E-03	1.61E-02	1.69E-02	3.34E-02	3.62E-02	1.75E-02
POCP (kg C_2H_4)	6.07E-03	5.40E-03	5.82E-03	5.15E-03	5.66E-03	4.96E-03	6.01E-03	5.31E-03	5.66E-03	4.99E-03	2.99E-02

Table S10 Characterized LCIA profiles of E100 (2030 scenarios) vs. petrol at use phase (unit:driving FFV for 100km; method: CML 2 baseline 2000)

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC	Petrol
Abiotic depletion (kg Sb eq)	1.13E-01	1.12E-01	1.02E-01	1.00E-01	1.05E-01	1.03E-01	1.12E-01	1.10E-01	1.05E-01	1.03E-01	1.65E-01
Acidification(kg SO_2 eq)	1.08E-01	1.11E-01	9.73E-02	9.69E-02	9.51E-02	9.39E-02	1.04E-01	1.03E-01	9.19E-02	9.28E-02	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	2.01E-02	2.17E-02	1.90E-02	2.03E-02	1.57E-02	1.60E-02	1.95E-02	2.06E-02	1.82E-02	1.99E-02	1.92E-02
GWP100 (kg CO_2 eq)	2.54E+00	3.66E+00	3.97E-01	3.32E-01	8.46E-01	6.14E-01	2.05E+00	2.22E+00	1.02E+00	1.33E+00	2.64E+01
ODP (kg CFC-11 eq)	9.95E-07	1.20E-06	8.53E-07	1.02E-06	8.93E-07	1.03E-06	9.68E-07	1.09E-06	9.25E-07	1.07E-06	3.12E-06
Human toxicity(kg 1,4-DB eq)	9.56E+00	9.58E+00	9.87E+00	9.84E+00	8.88E+00	8.75E+00	9.35E+00	9.23E+00	9.79E+00	9.75E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	2.28E+00	2.29E+00	2.30E+00	2.31E+00	1.66E+00	1.64E+00	2.19E+00	2.18E+00	2.08E+00	2.09E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	4.23E+03	4.31E+03	4.12E+03	4.19E+03	2.84E+03	2.84E+03	4.02E+03	4.04E+03	3.68E+03	3.75E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	1.70E-02	1.80E-02	2.52E-02	2.69E-02	8.16E-03	8.17E-03	1.59E-02	1.62E-02	2.83E-02	3.01E-02	1.75E-02
POCP (kg C_2H_4)	6.06E-03	5.36E-03	5.78E-03	5.08E-03	5.65E-03	4.92E-03	6.00E-03	5.28E-03	5.60E-03	4.90E-03	2.99E-02

Table S11 Characterized LCIA profiles of E10 (DA pretreatment, current scenarios) vs. petrol at use phase (unit:driving FFV for 100km; method: CML 2 baseline 2000)

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC	Petrol
Abiotic depletion (kg Sb eq)	1.70E-01	1.70E-01	1.67E-01	1.67E-01	1.68E-01	1.68E-01	1.70E-01	1.70E-01	1.68E-01	1.68E-01	1.65E-01
Acidification(kg SO_2 eq)	1.14E-01	1.15E-01	1.12E-01	1.12E-01	1.11E-01	1.12E-01	1.14E-01	1.14E-01	1.10E-01	1.11E-01	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	2.11E-02	2.15E-02	2.07E-02	2.10E-02	2.00E-02	2.02E-02	2.09E-02	2.12E-02	2.05E-02	2.09E-02	1.92E-02
GWP100 (kg CO_2 eq)	2.57E+01	2.59E+01	2.51E+01	2.52E+01	2.53E+01	2.53E+01	2.56E+01	2.57E+01	2.53E+01	2.54E+01	2.64E+01
ODP (kg CFC-11 eq)	3.06E-06	3.11E-06	3.02E-06	3.06E-06	3.04E-06	3.07E-06	3.06E-06	3.09E-06	3.04E-06	3.08E-06	3.12E-06
Human toxicity(kg 1,4-DB eq)	3.98E+00	4.02E+00	4.01E+00	4.03E+00	3.82E+00	3.83E+00	3.93E+00	3.94E+00	4.00E+00	4.02E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	9.61E-01	9.69E-01	9.46E-01	9.53E-01	8.06E-01	8.09E-01	9.38E-01	9.41E-01	8.93E-01	9.02E-01	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	3.22E+03	3.25E+03	3.16E+03	3.18E+03	2.88E+03	2.89E+03	3.17E+03	3.18E+03	3.05E+03	3.08E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	2.30E-02	2.33E-02	2.40E-02	2.44E-02	2.09E-02	2.10E-02	2.28E-02	2.29E-02	2.49E-02	2.53E-02	1.75E-02
POCP (kg C_2H_4)	2.89E-02	2.88E-02	2.88E-02	2.87E-02	2.88E-02	2.87E-02	2.88E-02	2.88E-02	2.87E-02	2.87E-02	2.99E-02

Table S12 Characterized LCIA profiles of E10 (LHW pretreatment, current scenarios) vs. petrol at use phase (unit:driving FFV for 100km; method: CML 2 baseline 2000)

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC	Petrol
Abiotic depletion (kg Sb eq)	1.73E-01	1.73E-01	1.67E-01	1.67E-01	1.69E-01	1.69E-01	1.72E-01	1.72E-01	1.68E-01	1.68E-01	1.65E-01
Acidification(kg SO_2 eq)	1.14E-01	1.15E-01	1.09E-01	1.09E-01	1.09E-01	1.09E-01	1.12E-01	1.13E-01	1.07E-01	1.07E-01	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	2.08E-02	2.13E-02	2.01E-02	2.05E-02	1.91E-02	1.93E-02	2.06E-02	2.10E-02	1.97E-02	2.03E-02	1.92E-02
GWP100 (kg CO_2 eq)	2.56E+01	2.60E+01	2.47E+01	2.48E+01	2.50E+01	2.51E+01	2.55E+01	2.56E+01	2.50E+01	2.51E+01	2.64E+01
ODP (kg CFC-11 eq)	3.07E-06	3.13E-06	3.01E-06	3.05E-06	3.04E-06	3.08E-06	3.07E-06	3.11E-06	3.04E-06	3.09E-06	3.12E-06
Human toxicity(kg 1,4-DB eq)	4.00E+00	4.05E+00	4.02E+00	4.05E+00	3.72E+00	3.74E+00	3.92E+00	3.94E+00	3.98E+00	4.02E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	8.79E-01	8.89E-01	8.38E-01	8.46E-01	6.10E-01	6.13E-01	8.40E-01	8.44E-01	7.40E-01	7.51E-01	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	3.06E+03	3.09E+03	2.92E+03	2.94E+03	2.46E+03	2.47E+03	2.98E+03	2.99E+03	2.72E+03	2.75E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	1.87E-02	1.90E-02	1.95E-02	1.99E-02	1.49E-02	1.50E-02	1.82E-02	1.84E-02	2.07E-02	2.12E-02	1.75E-02
POCP (kg C_2H_4)	2.89E-02	2.88E-02	2.87E-02	2.86E-02	2.87E-02	2.86E-02	2.88E-02	2.88E-02	2.86E-02	2.86E-02	2.99E-02

Table S13 Characterized LCIA profiles of E85 (DA pretreatment, current scenarios) vs. petrol at use phase (unit:driving FFV for 100km; method: CML 2 baseline 2000)

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC	Petrol
Abiotic depletion (kg Sb eq)	2.04E-01	2.06E-01	1.69E-01	1.70E-01	1.82E-01	1.81E-01	2.00E-01	1.99E-01	1.79E-01	1.79E-01	1.65E-01
Acidification(kg SO_2 eq)	2.20E-01	2.30E-01	1.92E-01	1.94E-01	1.88E-01	1.89E-01	2.12E-01	2.13E-01	1.77E-01	1.82E-01	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	3.78E-02	4.20E-02	3.38E-02	3.69E-02	2.66E-02	2.83E-02	3.62E-02	3.94E-02	3.17E-02	3.61E-02	1.92E-02
GWP100 (kg CO_2 eq)	1.58E+01	1.86E+01	1.01E+01	1.04E+01	1.18E+01	1.19E+01	1.49E+01	1.58E+01	1.16E+01	1.28E+01	2.64E+01
ODP (kg CFC-11 eq)	2.18E-06	2.66E-06	1.76E-06	2.12E-06	1.95E-06	2.32E-06	2.13E-06	2.45E-06	1.98E-06	2.34E-06	3.12E-06
Human toxicity(kg 1,4-DB eq)	1.43E+01	1.47E+01	1.46E+01	1.49E+01	1.25E+01	1.26E+01	1.37E+01	1.39E+01	1.44E+01	1.47E+01	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	4.25E+00	4.34E+00	4.10E+00	4.17E+00	2.59E+00	2.61E+00	4.01E+00	4.04E+00	3.52E+00	3.61E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	8.93E+03	9.18E+03	8.25E+03	8.46E+03	5.20E+03	5.31E+03	8.39E+03	8.53E+03	7.10E+03	7.34E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	7.58E-02	7.89E-02	8.68E-02	9.07E-02	5.23E-02	5.35E-02	7.30E-02	7.47E-02	9.57E-02	1.00E-01	1.75E-02
POCP (kg C_2H_4)	1.56E-02	1.49E-02	1.47E-02	1.41E-02	1.45E-02	1.38E-02	1.54E-02	1.48E-02	1.42E-02	1.36E-02	2.99E-02

Table S14 Characterized LCIA profiles of E85 (LHW pretreatment, current scenarios) vs. petrol at use phase (unit:driving FFV for 100km; method: CML 2 baseline 2000)

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC	Petrol
Abiotic depletion (kg Sb eq)	2.31E-01	2.33E-01	1.68E-01	1.68E-01	1.92E-01	1.92E-01	2.24E-01	2.23E-01	1.83E-01	1.84E-01	1.65E-01
Acidification(kg SO_2 eq)	2.10E-01	2.23E-01	1.62E-01	1.65E-01	1.57E-01	1.59E-01	1.99E-01	2.01E-01	1.35E-01	1.42E-01	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	3.51E-02	4.05E-02	2.77E-02	3.17E-02	1.61E-02	1.83E-02	3.25E-02	3.66E-02	2.35E-02	2.90E-02	1.92E-02
GWP100 (kg CO_2 eq)	1.53E+01	1.89E+01	5.65E+00	6.06E+00	9.04E+00	9.23E+00	1.42E+01	1.54E+01	8.10E+00	9.58E+00	2.64E+01
ODP (kg CFC-11 eq)	2.32E-06	2.94E-06	1.60E-06	2.07E-06	1.95E-06	2.43E-06	2.29E-06	2.70E-06	1.99E-06	2.45E-06	3.12E-06
Human toxicity(kg 1,4-DB eq)	1.45E+01	1.50E+01	1.47E+01	1.50E+01	1.15E+01	1.16E+01	1.36E+01	1.38E+01	1.43E+01	1.47E+01	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	3.37E+00	3.48E+00	2.92E+00	3.02E+00	4.58E-01	4.94E-01	2.95E+00	3.00E+00	1.87E+00	1.98E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	7.19E+03	7.51E+03	5.66E+03	5.93E+03	6.67E+02	8.10E+02	6.27E+03	6.44E+03	3.54E+03	3.85E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	2.85E-02	3.26E-02	3.76E-02	4.25E-02	-1.22E-02	-1.06E-02	2.41E-02	2.62E-02	5.03E-02	5.64E-02	1.75E-02
POCP (kg C_2H_4)	1.56E-02	1.48E-02	1.40E-02	1.32E-02	1.37E-02	1.29E-02	1.54E-02	1.45E-02	1.31E-02	1.23E-02	2.99E-02

Table S15 Characterized LCIA profiles of E10 (2020 scenarios) vs. petrol at use phase (unit:driving FFV for 100km; method: CML 2 baseline 2000)

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC	Petrol
Abiotic depletion (kg Sb eq)	1.63E-01	1.63E-01	1.62E-01	1.62E-01	1.62E-01	1.62E-01	1.63E-01	1.62E-01	1.62E-01	1.62E-01	1.65E-01
Acidification(kg SO_2 eq)	1.04E-01	1.04E-01	1.03E-01	1.03E-01	1.03E-01	1.03E-01	1.04E-01	1.04E-01	1.03E-01	1.03E-01	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	1.94E-02	1.96E-02	1.94E-02	1.95E-02	1.91E-02	1.92E-02	1.94E-02	1.95E-02	1.93E-02	1.95E-02	1.92E-02
GWP100 (kg CO_2 eq)	2.49E+01	2.50E+01	2.47E+01	2.47E+01	2.48E+01	2.47E+01	2.49E+01	2.49E+01	2.48E+01	2.48E+01	2.64E+01
ODP (kg CFC-11 eq)	2.99E-06	3.01E-06	2.98E-06	3.00E-06	2.99E-06	3.00E-06	2.99E-06	3.00E-06	2.99E-06	3.00E-06	3.12E-06
Human toxicity(kg 1,4-DB eq)	3.42E+00	3.43E+00	3.45E+00	3.46E+00	3.37E+00	3.37E+00	3.41E+00	3.40E+00	3.45E+00	3.46E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	7.48E-01	7.50E-01	7.53E-01	7.55E-01	7.02E-01	7.02E-01	7.41E-01	7.41E-01	7.39E-01	7.42E-01	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	2.76E+03	2.77E+03	2.76E+03	2.76E+03	2.65E+03	2.66E+03	2.74E+03	2.75E+03	2.73E+03	2.74E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	1.76E-02	1.77E-02	1.84E-02	1.86E-02	1.70E-02	1.70E-02	1.75E-02	1.76E-02	1.88E-02	1.90E-02	1.75E-02
POCP (kg C_2H_4)	2.84E-02	2.84E-02	2.84E-02	2.84E-02	2.84E-02	2.83E-02	2.84E-02	2.84E-02	2.84E-02	2.83E-02	2.99E-02

Table S16 Characterized LCIA profiles of E10 (2030 scenarios) vs. petrol at use phase (unit:driving FFV for 100km; method: CML 2 baseline 2000)

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC	Petrol
Abiotic depletion (kg Sb eq)	1.63E-01	1.63E-01	1.62E-01	1.62E-01	1.62E-01	1.62E-01	1.63E-01	1.62E-01	1.62E-01	1.62E-01	1.65E-01
Acidification(kg SO_2 eq)	1.04E-01	1.04E-01	1.03E-01	1.03E-01	1.03E-01	1.03E-01	1.04E-01	1.04E-01	1.03E-01	1.03E-01	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	1.94E-02	1.95E-02	1.93E-02	1.94E-02	1.91E-02	1.91E-02	1.94E-02	1.94E-02	1.93E-02	1.94E-02	1.92E-02
GWP100 (kg CO_2 eq)	2.49E+01	2.50E+01	2.47E+01	2.47E+01	2.48E+01	2.47E+01	2.48E+01	2.49E+01	2.48E+01	2.48E+01	2.64E+01
ODP (kg CFC-11 eq)	2.99E-06	3.01E-06	2.98E-06	2.99E-06	2.98E-06	2.99E-06	2.99E-06	3.00E-06	2.98E-06	3.00E-06	3.12E-06
Human toxicity(kg 1,4-DB eq)	3.42E+00	3.42E+00	3.44E+00	3.44E+00	3.37E+00	3.36E+00	3.40E+00	3.39E+00	3.44E+00	3.43E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	7.47E-01	7.48E-01	7.48E-01	7.49E-01	7.01E-01	7.00E-01	7.40E-01	7.39E-01	7.32E-01	7.33E-01	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	2.76E+03	2.76E+03	2.75E+03	2.75E+03	2.65E+03	2.65E+03	2.74E+03	2.74E+03	2.72E+03	2.72E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	1.76E-02	1.77E-02	1.82E-02	1.83E-02	1.69E-02	1.69E-02	1.75E-02	1.75E-02	1.84E-02	1.86E-02	1.75E-02
POCP (kg C_2H_4)	2.84E-02	2.84E-02	2.84E-02	2.83E-02	2.84E-02	2.83E-02	2.84E-02	2.84E-02	2.84E-02	2.83E-02	2.99E-02

Table S17 Characterized LCIA profiles of E85 (2020 scenarios) vs. petrol at use phase (unit:driving FFV for 100km; method: CML 2 baseline 2000)

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC	Petrol
Abiotic depletion (kg Sb eq)	1.23E-01	1.23E-01	1.15E-01	1.14E-01	1.17E-01	1.15E-01	1.22E-01	1.21E-01	1.18E-01	1.17E-01	1.65E-01
Acidification(kg SO_2 eq)	1.07E-01	1.11E-01	9.86E-02	9.89E-02	9.65E-02	9.63E-02	1.04E-01	1.04E-01	9.48E-02	9.67E-02	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	2.02E-02	2.20E-02	1.93E-02	2.08E-02	1.66E-02	1.72E-02	1.96E-02	2.11E-02	1.90E-02	2.10E-02	1.92E-02
GWP100 (kg CO_2 eq)	7.48E+00	8.74E+00	5.68E+00	5.72E+00	5.96E+00	5.87E+00	6.98E+00	7.31E+00	6.29E+00	6.77E+00	2.64E+01
ODP (kg CFC-11 eq)	1.45E-06	1.67E-06	1.33E-06	1.51E-06	1.37E-06	1.54E-06	1.42E-06	1.57E-06	1.40E-06	1.57E-06	3.12E-06
Human toxicity(kg 1,4-DB eq)	8.24E+00	8.34E+00	8.58E+00	8.63E+00	7.69E+00	7.66E+00	8.06E+00	8.04E+00	8.58E+00	8.64E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	1.95E+00	1.98E+00	2.00E+00	2.03E+00	1.46E+00	1.45E+00	1.88E+00	1.88E+00	1.86E+00	1.89E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	3.91E+03	4.01E+03	3.90E+03	3.99E+03	2.80E+03	2.82E+03	3.74E+03	3.79E+03	3.60E+03	3.70E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	1.73E-02	1.86E-02	2.63E-02	2.81E-02	1.01E-02	1.05E-02	1.63E-02	1.69E-02	3.01E-02	3.23E-02	1.75E-02
POCP (kg C_2H_4)	1.08E-02	1.02E-02	1.06E-02	1.00E-02	1.04E-02	9.88E-03	1.07E-02	1.02E-02	1.04E-02	9.91E-03	2.99E-02

Table S18 Characterized LCIA profiles of E85 (2030 scenarios) vs. petrol at use phase (unit:driving FFV for 100km; method: CML 2 baseline 2000)

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC	Petrol
Abiotic depletion (kg Sb eq)	1.23E-01	1.22E-01	1.14E-01	1.13E-01	1.16E-01	1.15E-01	1.22E-01	1.20E-01	1.16E-01	1.15E-01	1.65E-01
Acidification(kg SO_2 eq)	1.06E-01	1.09E-01	9.80E-02	9.76E-02	9.62E-02	9.52E-02	1.03E-01	1.03E-01	9.37E-02	9.44E-02	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	1.99E-02	2.11E-02	1.89E-02	2.00E-02	1.64E-02	1.66E-02	1.93E-02	2.02E-02	1.83E-02	1.97E-02	1.92E-02
GWP100 (kg CO_2 eq)	7.26E+00	8.16E+00	5.55E+00	5.50E+00	5.91E+00	5.72E+00	6.87E+00	7.00E+00	6.04E+00	6.29E+00	2.64E+01
ODP (kg CFC-11 eq)	1.41E-06	1.58E-06	1.30E-06	1.43E-06	1.33E-06	1.44E-06	1.39E-06	1.49E-06	1.36E-06	1.47E-06	3.12E-06
Human toxicity(kg 1,4-DB eq)	8.20E+00	8.21E+00	8.44E+00	8.42E+00	7.66E+00	7.55E+00	8.03E+00	7.94E+00	8.38E+00	8.35E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	1.94E+00	1.95E+00	1.95E+00	1.96E+00	1.45E+00	1.43E+00	1.87E+00	1.86E+00	1.78E+00	1.79E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	3.89E+03	3.95E+03	3.80E+03	3.86E+03	2.78E+03	2.78E+03	3.73E+03	3.74E+03	3.46E+03	3.51E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	1.70E-02	1.79E-02	2.36E-02	2.49E-02	9.97E-03	9.98E-03	1.61E-02	1.64E-02	2.60E-02	2.75E-02	1.75E-02
POCP (kg C_2H_4)	1.08E-02	1.02E-02	1.05E-02	9.98E-03	1.04E-02	9.85E-03	1.07E-02	1.01E-02	1.04E-02	9.84E-03	2.99E-02

Table S19 Characterized LCIA profiles of E100 (DA pretreatment, current scenarios) vs. petrol at use phase (unit:driving FFV for 100km; method: Ecoindicator 99 H)

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC	Petrol
Carcinogens (DALY)	4.77E-06	5.06E-06	5.38E-06	5.68E-06	3.64E-06	3.79E-06	4.40E-06	4.58E-06	4.75E-06	5.09E-06	4.45E-07
Resp. organics (DALY)	3.59E-08	1.89E-08	3.45E-08	1.73E-08	3.48E-08	1.75E-08	3.58E-08	1.84E-08	3.67E-08	1.96E-08	1.36E-07
Resp. inorganics (DALY)	1.60E-05	1.69E-05	1.41E-05	1.41E-05	1.10E-05	1.09E-05	1.57E-05	1.57E-05	1.21E-05	1.23E-05	1.25E-05
Climate change (DALY)	2.81E-06	3.63E-06	1.26E-06	1.36E-06	1.71E-06	1.76E-06	2.53E-06	2.80E-06	1.69E-06	2.03E-06	5.54E-06
Radiation (DALY)	-8.96E-08	-8.78E-08	1.06E-07	1.12E-07	-1.05E-07	-1.04E-07	-2.12E-07	-2.11E-07	5.00E-08	5.82E-08	1.08E-08
Ozone layer (DALY)	2.06E-09	2.70E-09	1.51E-09	1.98E-09	1.75E-09	2.25E-09	2.00E-09	2.42E-09	1.80E-09	2.27E-09	3.28E-09
Ecotoxicity (PAF*m2yr)	4.11E+00	4.27E+00	4.37E+00	4.46E+00	2.69E+00	2.69E+00	3.95E+00	3.97E+00	4.51E+00	4.64E+00	1.03E+00
Acidification/ Eutrophication (PAF*m2yr)	5.82E-01	6.92E-01	4.35E-01	4.45E-01	4.59E-01	4.68E-01	5.16E-01	5.28E-01	4.16E-01	4.62E-01	6.83E-01
Minerals (MJ surplus)	3.20E-01	3.64E-01	4.71E-01	5.04E-01	3.04E-01	3.20E-01	3.03E-01	3.22E-01	5.05E-01	5.46E-01	3.82E-02
Fossil fuels (MJ surplus)	5.49E+01	5.52E+01	4.50E+01	4.49E+01	5.22E+01	5.19E+01	5.42E+01	5.40E+01	5.15E+01	5.14E+01	4.96E+01

Table S20 Characterized LCIA profiles of E100 (LHW pretreatment, current scenarios) vs. petrol at use phase (unit:driving FFV for 100km; method: Ecoindicator 99 H)

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC	Petrol
Carcinogens (DALY)	3.55E-06	3.92E-06	4.36E-06	4.74E-06	1.60E-06	1.80E-06	2.92E-06	3.16E-06	3.17E-06	3.60E-06	4.45E-07
Resp. organics (DALY)	4.43E-08	2.24E-08	4.10E-08	1.90E-08	4.24E-08	2.02E-08	4.41E-08	2.18E-08	4.48E-08	2.29E-08	1.36E-07
Resp. inorganics (DALY)	1.45E-05	1.57E-05	1.10E-05	1.10E-05	6.09E-06	5.93E-06	1.43E-05	1.42E-05	7.34E-06	7.64E-06	1.25E-05
Climate change (DALY)	2.69E-06	3.75E-06	1.02E-07	2.22E-07	9.97E-07	1.05E-06	2.37E-06	2.71E-06	7.65E-07	1.20E-06	5.54E-06
Radiation (DALY)	-2.43E-07	-2.41E-07	7.72E-08	8.56E-08	-2.71E-07	-2.69E-07	-4.58E-07	-4.57E-07	-2.61E-08	-1.57E-08	1.08E-08
Ozone layer (DALY)	2.24E-09	3.07E-09	1.30E-09	1.92E-09	1.75E-09	2.39E-09	2.21E-09	2.75E-09	1.82E-09	2.42E-09	3.28E-09
Ecotoxicity (PAF*m2yr)	2.93E+00	3.14E+00	3.04E+00	3.16E+00	4.87E-01	4.86E-01	2.68E+00	2.71E+00	3.17E+00	3.34E+00	1.03E+00
Acidification/ Eutrophication (PAF*m2yr)	5.77E-01	7.18E-01	3.42E-01	3.54E-01	3.90E-01	4.01E-01	4.88E-01	5.04E-01	2.96E-01	3.56E-01	6.83E-01
Minerals (MJ surplus)	1.40E-01	1.97E-01	3.37E-01	3.79E-01	1.19E-01	1.40E-01	1.17E-01	1.41E-01	3.76E-01	4.29E-01	3.82E-02
Fossil fuels (MJ surplus)	6.78E+01	6.81E+01	4.99E+01	4.98E+01	6.33E+01	6.29E+01	6.67E+01	6.64E+01	6.12E+01	6.10E+01	4.96E+01

Table S21 Characterized LCIA profiles of E100 (2020 scenario) vs. petrol at use phase (unit:driving FFV for 100km; method: Ecoindicator 99 H)

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC	Petrol
Carcinogens (DALY)	2.37E-06	2.50E-06	2.71E-06	2.86E-06	2.02E-06	2.08E-06	2.25E-06	2.34E-06	2.56E-06	2.72E-06	4.45E-07
Resp. organics (DALY)	2.49E-08	1.11E-08	2.49E-08	1.11E-08	2.46E-08	1.07E-08	2.48E-08	1.09E-08	2.56E-08	1.18E-08	1.36E-07
Resp. inorganics (DALY)	7.36E-06	7.53E-06	6.90E-06	6.64E-06	5.79E-06	5.43E-06	7.19E-06	6.88E-06	6.38E-06	6.24E-06	1.25E-05
Climate change (DALY)	6.06E-07	9.77E-07	1.11E-07	1.28E-07	1.84E-07	1.65E-07	4.60E-07	5.61E-07	2.79E-07	4.22E-07	5.54E-06
Radiation (DALY)	-3.38E-08	-3.30E-08	3.57E-08	3.92E-08	-3.85E-08	-3.81E-08	-6.99E-08	-6.94E-08	2.19E-08	2.60E-08	1.08E-08
Ozone layer (DALY)	1.10E-09	1.39E-09	9.41E-10	1.18E-09	9.90E-10	1.22E-09	1.06E-09	1.26E-09	1.03E-09	1.26E-09	3.28E-09
Ecotoxicity (PAF*m2yr)	1.85E+00	1.87E+00	2.12E+00	2.12E+00	1.41E+00	1.35E+00	1.79E+00	1.75E+00	2.21E+00	2.22E+00	1.03E+00
Acidification/ Eutrophication (PAF*m2yr)	2.71E-01	3.15E-01	2.19E-01	2.16E-01	2.22E-01	2.16E-01	2.40E-01	2.36E-01	2.19E-01	2.35E-01	6.83E-01
Minerals (MJ surplus)	8.31E-02	9.78E-02	1.66E-01	1.78E-01	7.51E-02	7.60E-02	7.60E-02	7.90E-02	1.85E-01	2.00E-01	3.82E-02
Fossil fuels (MJ surplus)	3.08E+01	3.06E+01	2.83E+01	2.79E+01	3.00E+01	2.94E+01	3.06E+01	3.01E+01	3.02E+01	2.98E+01	4.96E+01

Table S22 Characterized LCIA profiles of E100 (2030 scenario) vs. petrol at use phase (unit:driving FFV for 100km; method: Ecoindicator 99 H)

Impact category	Sweden SRC	Sweden VSRC	Italy SRC	Italy VSRC	Slovakia SRC	Slovakia VSRC	France SRC	France VSRC	Spain SRC	Spain VSRC	Petrol
Carcinogens (DALY)	2.35E-06	2.44E-06	2.63E-06	2.74E-06	2.01E-06	2.04E-06	2.24E-06	2.29E-06	2.43E-06	2.55E-06	4.45E-07
Resp. organics (DALY)	2.49E-08	1.10E-08	2.47E-08	1.08E-08	2.45E-08	1.05E-08	2.48E-08	1.08E-08	2.53E-08	1.14E-08	1.36E-07
Resp. inorganics (DALY)	7.26E-06	7.22E-06	6.77E-06	6.41E-06	5.74E-06	5.26E-06	7.14E-06	6.70E-06	6.18E-06	5.88E-06	1.25E-05
Climate change (DALY)	5.44E-07	8.10E-07	7.67E-08	6.70E-08	1.71E-07	1.25E-07	4.29E-07	4.75E-07	2.12E-07	2.90E-07	5.54E-06
Radiation (DALY)	-3.39E-08	-3.34E-08	3.04E-08	3.31E-08	-3.86E-08	-3.84E-08	-7.00E-08	-6.98E-08	1.37E-08	1.67E-08	1.08E-08
Ozone layer (DALY)	1.05E-09	1.26E-09	8.99E-10	1.08E-09	9.41E-10	1.08E-09	1.02E-09	1.15E-09	9.74E-10	1.13E-09	3.28E-09
Ecotoxicity (PAF*m2yr)	1.83E+00	1.81E+00	2.02E+00	1.99E+00	1.40E+00	1.31E+00	1.77E+00	1.70E+00	2.05E+00	2.02E+00	1.03E+00
Acidification/ Eutrophication (PAF*m2yr)	2.62E-01	2.91E-01	2.16E-01	2.07E-01	2.19E-01	2.07E-01	2.37E-01	2.27E-01	2.11E-01	2.16E-01	6.83E-01
Minerals (MJ surplus)	7.94E-02	8.65E-02	1.47E-01	1.52E-01	7.25E-02	6.74E-02	7.32E-02	7.02E-02	1.55E-01	1.61E-01	3.82E-02
Fossil fuels (MJ surplus)	3.08E+01	3.03E+01	2.81E+01	2.75E+01	2.99E+01	2.92E+01	3.05E+01	2.99E+01	2.99E+01	2.94E+01	4.96E+01

Table S23 Sensitivity analysis on allocation approach - characterized LCIA profiles of SRC poplar-derived E100 bioethanol in France over whole life cycle vs. petrol (unit: driving FFV for 100km; method: CML 2 baseline 2000 V2.05)

Impact category	Energy current DA	Expansion current DA	Energy current LHW	Expansion current LHW	Energy 2020	Expansion 2020	Energy 2030	Expansion 2030	Petrol
Abiotic depletion (kg Sb eq)	1.87E-01	2.09E-01	1.97E-01	2.39E-01	1.09E-01	1.12E-01	1.09E-01	1.12E-01	1.65E-01
Acidification(kg SO_2 eq)	2.12E-01	2.40E-01	1.83E-01	2.23E-01	1.01E-01	1.04E-01	1.01E-01	1.04E-01	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	3.67E-02	4.07E-02	3.08E-02	3.60E-02	1.95E-02	1.99E-02	1.91E-02	1.95E-02	1.92E-02
GWP100 (kg CO_2 eq)	9.06E+00	1.21E+01	5.62E+00	1.13E+01	1.82E+00	2.19E+00	1.69E+00	2.05E+00	2.64E+01
ODP (kg CFC-11 eq)	1.69E-06	1.90E-06	1.72E-06	2.10E-06	9.77E-07	1.01E-06	9.40E-07	9.68E-07	3.12E-06
Human toxicity(kg 1,4-DB eq)	1.54E+01	1.65E+01	1.47E+01	1.64E+01	9.36E+00	9.39E+00	9.32E+00	9.35E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	4.59E+00	4.87E+00	3.39E+00	3.55E+00	2.23E+00	2.20E+00	2.22E+00	2.19E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	9.32E+03	9.87E+03	6.92E+03	7.21E+03	4.13E+03	4.04E+03	4.11E+03	4.02E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	8.04E-02	8.72E-02	2.86E-02	2.59E-02	1.71E-02	1.61E-02	1.69E-02	1.59E-02	1.75E-02
POCP (kg C_2H_4)	1.05E-02	1.19E-02	9.57E-03	1.18E-02	5.81E-03	6.01E-03	5.80E-03	6.00E-03	2.99E-02

Notes: Energy=energy allocation; Expansion= system expansion allocation approach

Table S24 Sensitivity analysis on allocation approach - characterized LCIA profiles of VSRC poplar-derived E100 bioethanol in France over whole life cycle vs. petrol (unit: driving FFV for 100km; method: CML 2 baseline 2000 V2.05)

Impact category	Energy current DA	Expansion current DA	Energy current LHW	Expansion current LHW	Energy 2020	Expansion 2020	Energy 2030	Expansion 2030	Petrol
Abiotic depletion (kg Sb eq)	1.86E-01	2.09E-01	1.97E-01	2.39E-01	1.08E-01	1.10E-01	1.07E-01	1.10E-01	1.65E-01
Acidification(kg SO_2 eq)	2.14E-01	2.42E-01	1.85E-01	2.26E-01	1.01E-01	1.04E-01	1.00E-01	1.03E-01	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	4.02E-02	4.46E-02	3.48E-02	4.11E-02	2.12E-02	2.16E-02	2.02E-02	2.06E-02	1.92E-02
GWP100 (kg CO_2 eq)	1.00E+01	1.32E+01	6.75E+00	1.27E+01	2.21E+00	2.60E+00	1.85E+00	2.22E+00	2.64E+01
ODP (kg CFC-11 eq)	2.03E-06	2.30E-06	2.12E-06	2.61E-06	1.16E-06	1.19E-06	1.06E-06	1.09E-06	3.12E-06
Human toxicity(kg 1,4-DB eq)	1.56E+01	1.67E+01	1.49E+01	1.66E+01	9.33E+00	9.36E+00	9.21E+00	9.23E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	4.63E+00	4.91E+00	3.43E+00	3.60E+00	2.23E+00	2.20E+00	2.21E+00	2.18E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	9.47E+03	1.00E+04	7.09E+03	7.43E+03	4.18E+03	4.10E+03	4.12E+03	4.04E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	8.22E-02	8.93E-02	3.06E-02	2.85E-02	1.78E-02	1.69E-02	1.72E-02	1.62E-02	1.75E-02
POCP (kg C_2H_4)	9.74E-03	1.11E-02	8.73E-03	1.08E-02	5.14E-03	5.31E-03	5.11E-03	5.28E-03	2.99E-02

Notes: Energy=energy allocation; Expansion= system expansion allocation approach

Table S25 Sensitivity analysis on allocation approach - characterized LCIA profiles of SRC poplar-derived E100 bioethanol in Italy over whole life cycle vs. petrol (unit: driving FFV for 100km; method: CML 2 baseline 2000 V2.05)

Impact category	Energy current DA	Expansion current DA	Energy current LHW	Expansion current LHW	Energy 2020	Expansion 2020	Energy 2030	Expansion 2030	Petrol
Abiotic depletion (kg Sb eq)	1.94E-01	1.71E-01	2.05E-01	1.69E-01	1.13E-01	1.03E-01	1.12E-01	1.02E-01	1.65E-01
Acidification(kg SO_2 eq)	2.15E-01	2.15E-01	1.87E-01	1.78E-01	1.04E-01	9.81E-02	1.03E-01	9.73E-02	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	3.82E-02	3.77E-02	3.25E-02	3.00E-02	2.05E-02	1.95E-02	2.00E-02	1.90E-02	1.92E-02
GWP100 (kg CO_2 eq)	9.42E+00	6.06E+00	6.03E+00	5.19E-01	2.07E+00	5.58E-01	1.91E+00	3.97E-01	2.64E+01
ODP (kg CFC-11 eq)	1.75E-06	1.43E-06	1.79E-06	1.24E-06	1.02E-06	8.94E-07	9.84E-07	8.53E-07	3.12E-06
Human toxicity(kg 1,4-DB eq)	1.65E+01	1.76E+01	1.59E+01	1.77E+01	1.00E+01	1.00E+01	9.85E+00	9.87E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	5.01E+00	4.98E+00	3.87E+00	3.51E+00	2.49E+00	2.36E+00	2.43E+00	2.30E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	1.01E+04	9.70E+03	7.87E+03	6.45E+03	4.63E+03	4.24E+03	4.52E+03	4.12E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	1.05E-01	1.04E-01	5.70E-02	4.27E-02	3.22E-02	2.86E-02	2.90E-02	2.52E-02	1.75E-02
POCP (kg C_2H_4)	1.07E-02	1.10E-02	9.85E-03	1.01E-02	5.96E-03	5.82E-03	5.92E-03	5.78E-03	2.99E-02

Notes: Energy=energy allocation; Expansion= system expansion allocation approach

Table S26 Sensitivity analysis on allocation approach - characterized LCIA profiles of VSRC poplar-derived E100 bioethanol in Italy over whole life cycle vs. petrol (unit: driving FFV for 100km; method: CML 2 baseline 2000 V2.05)

Impact category	Energy current DA	Expansion current DA	Energy current LHW	Expansion current LHW	Energy 2020	Expansion 2020	Energy 2030	Expansion 2030	Petrol
Abiotic depletion (kg Sb eq)	1.94E-01	1.72E-01	2.06E-01	1.70E-01	1.12E-01	1.02E-01	1.11E-01	1.00E-01	1.65E-01
Acidification(kg SO_2 eq)	2.17E-01	2.17E-01	1.89E-01	1.81E-01	1.04E-01	9.85E-02	1.02E-01	9.69E-02	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	4.15E-02	4.15E-02	3.64E-02	3.49E-02	2.22E-02	2.13E-02	2.12E-02	2.03E-02	1.92E-02
GWP100 (kg CO_2 eq)	9.77E+00	6.47E+00	6.44E+00	1.04E+00	2.12E+00	6.15E-01	1.85E+00	3.32E-01	2.64E+01
ODP (kg CFC-11 eq)	2.14E-06	1.89E-06	2.25E-06	1.82E-06	1.24E-06	1.12E-06	1.15E-06	1.02E-06	3.12E-06
Human toxicity(kg 1,4-DB eq)	1.67E+01	1.79E+01	1.62E+01	1.81E+01	1.01E+01	1.01E+01	9.82E+00	9.84E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	5.09E+00	5.07E+00	3.97E+00	3.63E+00	2.52E+00	2.39E+00	2.44E+00	2.31E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	1.04E+04	9.95E+03	8.13E+03	6.78E+03	4.74E+03	4.35E+03	4.58E+03	4.19E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	1.09E-01	1.09E-01	6.19E-02	4.89E-02	3.44E-02	3.10E-02	3.06E-02	2.69E-02	1.75E-02
POCP (kg C_2H_4)	1.00E-02	1.02E-02	9.06E-03	9.10E-03	5.32E-03	5.15E-03	5.26E-03	5.08E-03	2.99E-02

Notes: Energy=energy allocation; Expansion= system expansion allocation approach

Table S27 Sensitivity analysis on allocation approach - characterized LCIA profiles of SRC poplar-derived E100 bioethanol in Spain over whole life cycle vs. petrol (unit: driving FFV for 100km; method: CML 2 baseline 2000 V2.05)

Impact category	Energy current DA	Expansion current DA	Energy current LHW	Expansion current LHW	Energy 2020	Expansion 2020	Energy 2030	Expansion 2030	Petrol
Abiotic depletion (kg Sb eq)	1.96E-01	1.83E-01	2.07E-01	1.88E-01	1.14E-01	1.07E-01	1.13E-01	1.05E-01	1.65E-01
Acidification(kg SO_2 eq)	2.18E-01	1.96E-01	1.90E-01	1.44E-01	1.05E-01	9.33E-02	1.04E-01	9.19E-02	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	3.94E-02	3.50E-02	3.39E-02	2.47E-02	2.12E-02	1.90E-02	2.04E-02	1.82E-02	1.92E-02
GWP100 (kg CO_2 eq)	1.01E+01	8.04E+00	6.86E+00	3.59E+00	2.48E+00	1.33E+00	2.18E+00	1.02E+00	2.64E+01
ODP (kg CFC-11 eq)	1.76E-06	1.71E-06	1.80E-06	1.73E-06	1.03E-06	9.76E-07	9.77E-07	9.25E-07	3.12E-06
Human toxicity(kg 1,4-DB eq)	1.68E+01	1.74E+01	1.62E+01	1.72E+01	1.02E+01	1.00E+01	9.93E+00	9.79E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	5.12E+00	4.26E+00	4.01E+00	2.19E+00	2.55E+00	2.17E+00	2.46E+00	2.08E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	1.04E+04	8.25E+03	8.13E+03	3.79E+03	4.76E+03	3.87E+03	4.58E+03	3.68E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	1.11E-01	1.16E-01	6.46E-02	5.88E-02	3.58E-02	3.34E-02	3.09E-02	2.83E-02	1.75E-02
POCP (kg C_2H_4)	1.08E-02	1.04E-02	9.92E-03	9.03E-03	5.99E-03	5.66E-03	5.94E-03	5.60E-03	2.99E-02

Notes: Energy=energy allocation; Expansion= system expansion allocation approach

Table S28 Sensitivity analysis on allocation approach - characterized LCIA profiles of VSRC poplar-derived E100 bioethanol in Spain over whole life cycle vs. petrol (unit: driving FFV for 100km; method: CML 2 baseline 2000 V2.05)

Impact category	Energy current DA	Expansion current DA	Energy current LHW	Expansion current LHW	Energy 2020	Expansion 2020	Energy 2030	Expansion 2030	Petrol
Abiotic depletion (kg Sb eq)	1.96E-01	1.84E-01	2.08E-01	1.89E-01	1.14E-01	1.06E-01	1.11E-01	1.03E-01	1.65E-01
Acidification(kg SO_2 eq)	2.24E-01	2.03E-01	1.96E-01	1.52E-01	1.07E-01	9.57E-02	1.05E-01	9.28E-02	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	4.41E-02	4.04E-02	3.93E-02	3.16E-02	2.37E-02	2.16E-02	2.20E-02	1.99E-02	1.92E-02
GWP100 (kg CO_2 eq)	1.14E+01	9.49E+00	8.31E+00	5.45E+00	3.05E+00	1.92E+00	2.48E+00	1.33E+00	2.64E+01
ODP (kg CFC-11 eq)	2.15E-06	2.16E-06	2.25E-06	2.30E-06	1.23E-06	1.19E-06	1.12E-06	1.07E-06	3.12E-06
Human toxicity(kg 1,4-DB eq)	1.71E+01	1.78E+01	1.66E+01	1.77E+01	1.02E+01	1.01E+01	9.89E+00	9.75E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	5.22E+00	4.38E+00	4.12E+00	2.33E+00	2.58E+00	2.21E+00	2.47E+00	2.09E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	1.06E+04	8.56E+03	8.44E+03	4.18E+03	4.88E+03	3.99E+03	4.65E+03	3.75E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	1.17E-01	1.22E-01	7.06E-02	6.64E-02	3.84E-02	3.62E-02	3.26E-02	3.01E-02	1.75E-02
POCP (kg C_2H_4)	1.01E-02	9.61E-03	9.14E-03	8.03E-03	5.35E-03	4.99E-03	5.27E-03	4.90E-03	2.99E-02

Notes: Energy=energy allocation; Expansion= system expansion allocation approach

Table S29 Sensitivity analysis on allocation approach - characterized LCIA profiles of SRC poplar-derived E100 bioethanol in Slovakia over whole life cycle vs. petrol (unit: driving FFV for 100km; method: CML 2 baseline 2000 V2.05)

Impact category	Energy current DA	Expansion current DA	Energy current LHW	Expansion current LHW	Energy 2020	Expansion 2020	Energy 2030	Expansion 2030	Petrol
Abiotic depletion (kg Sb eq)	1.86E-01	1.87E-01	1.97E-01	2.00E-01	1.09E-01	1.05E-01	1.09E-01	1.05E-01	1.65E-01
Acidification(kg SO_2 eq)	2.12E-01	2.10E-01	1.83E-01	1.72E-01	1.01E-01	9.55E-02	1.01E-01	9.51E-02	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	3.57E-02	2.86E-02	2.96E-02	1.54E-02	1.89E-02	1.60E-02	1.87E-02	1.57E-02	1.92E-02
GWP100 (kg CO_2 eq)	8.53E+00	8.21E+00	5.00E+00	4.78E+00	1.51E+00	9.06E-01	1.45E+00	8.46E-01	2.64E+01
ODP (kg CFC-11 eq)	1.73E-06	1.67E-06	1.76E-06	1.67E-06	9.93E-07	9.41E-07	9.48E-07	8.93E-07	3.12E-06
Human toxicity(kg 1,4-DB eq)	1.54E+01	1.49E+01	1.47E+01	1.36E+01	9.35E+00	8.92E+00	9.31E+00	8.88E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	4.58E+00	3.09E+00	3.38E+00	4.21E-01	2.22E+00	1.67E+00	2.22E+00	1.66E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	9.30E+03	5.86E+03	6.90E+03	1.87E+02	4.12E+03	2.86E+03	4.10E+03	2.84E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	8.01E-02	6.12E-02	2.82E-02	-1.96E-02	1.69E-02	8.38E-03	1.67E-02	8.16E-03	1.75E-02
POCP (kg C_2H_4)	1.05E-02	1.07E-02	9.57E-03	9.76E-03	5.81E-03	5.66E-03	5.80E-03	5.65E-03	2.99E-02

Notes: Energy=energy allocation; Expansion= system expansion allocation approach

Table S30 Sensitivity analysis on allocation approach - characterized LCIA profiles of VSRC poplar-derived E100 bioethanol in Slovakia over whole life cycle vs. petrol (unit: driving FFV for 100km; method: CML 2 baseline 2000 V2.05)

Impact category	Energy current DA	Expansion current DA	Energy current LHW	Expansion current LHW	Energy 2020	Expansion 2020	Energy 2030	Expansion 2030	Petrol
Abiotic depletion (kg Sb eq)	1.86E-01	1.86E-01	1.96E-01	1.99E-01	1.07E-01	1.04E-01	1.06E-01	1.03E-01	1.65E-01
Acidification(kg SO_2 eq)	2.13E-01	2.12E-01	1.84E-01	1.74E-01	1.01E-01	9.52E-02	9.97E-02	9.39E-02	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	3.76E-02	3.08E-02	3.18E-02	1.82E-02	1.96E-02	1.68E-02	1.89E-02	1.60E-02	1.92E-02
GWP100 (kg CO_2 eq)	8.68E+00	8.39E+00	5.18E+00	5.01E+00	1.41E+00	7.99E-01	1.23E+00	6.14E-01	2.64E+01
ODP (kg CFC-11 eq)	2.13E-06	2.14E-06	2.24E-06	2.27E-06	1.20E-06	1.16E-06	1.08E-06	1.03E-06	3.12E-06
Human toxicity(kg 1,4-DB eq)	1.56E+01	1.51E+01	1.49E+01	1.39E+01	9.31E+00	8.88E+00	9.18E+00	8.75E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	4.61E+00	3.12E+00	3.42E+00	4.66E-01	2.22E+00	1.67E+00	2.19E+00	1.64E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	9.42E+03	6.00E+03	7.04E+03	3.66E+02	4.15E+03	2.89E+03	4.10E+03	2.84E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	8.14E-02	6.27E-02	2.97E-02	-1.76E-02	1.73E-02	8.78E-03	1.67E-02	8.17E-03	1.75E-02
POCP (kg C_2H_4)	9.74E-03	9.87E-03	8.73E-03	8.68E-03	5.14E-03	4.96E-03	5.10E-03	4.92E-03	2.99E-02

Notes: Energy=energy allocation; Expansion= system expansion allocation approach

Table S31 Sensitivity analysis on allocation approach - characterized LCIA profiles of SRC poplar-derived E100 bioethanol in Sweden over whole life cycle vs. petrol (unit: driving FFV for 100km; method: CML 2 baseline 2000 V2.05)

Impact category	Energy current DA	Expansion current DA	Energy current LHW	Expansion current LHW	Energy 2020	Expansion 2020	Energy 2030	Expansion 2030	Petrol
Abiotic depletion (kg Sb eq)	1.88E-01	2.15E-01	1.98E-01	2.49E-01	1.09E-01	1.14E-01	1.09E-01	1.13E-01	1.65E-01
Acidification(kg SO_2 eq)	2.17E-01	2.50E-01	1.89E-01	2.38E-01	1.04E-01	1.09E-01	1.03E-01	1.08E-01	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	3.73E-02	4.27E-02	3.15E-02	3.93E-02	1.98E-02	2.05E-02	1.94E-02	2.01E-02	1.92E-02
GWP100 (kg CO_2 eq)	1.03E+01	1.32E+01	7.10E+00	1.26E+01	2.51E+00	2.81E+00	2.25E+00	2.54E+00	2.64E+01
ODP (kg CFC-11 eq)	1.80E-06	1.95E-06	1.84E-06	2.13E-06	1.03E-06	1.04E-06	9.88E-07	9.95E-07	3.12E-06
Human toxicity(kg 1,4-DB eq)	1.56E+01	1.72E+01	1.49E+01	1.75E+01	9.43E+00	9.61E+00	9.39E+00	9.56E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	4.62E+00	5.18E+00	3.42E+00	4.07E+00	2.24E+00	2.29E+00	2.23E+00	2.28E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	9.39E+03	1.05E+04	7.00E+03	8.36E+03	4.16E+03	4.26E+03	4.14E+03	4.23E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	8.14E-02	9.07E-02	2.96E-02	3.15E-02	1.76E-02	1.73E-02	1.73E-02	1.70E-02	1.75E-02
POCP (kg C_2H_4)	1.05E-02	1.21E-02	9.61E-03	1.21E-02	5.83E-03	6.07E-03	5.81E-03	6.06E-03	2.99E-02

Notes: Energy=energy allocation; Expansion= system expansion allocation approach

Table S32 Sensitivity analysis on allocation approach - characterized LCIA profiles of VSRC poplar-derived E100 bioethanol in Sweden over whole life cycle vs. petrol (unit: driving FFV for 100km; method: CML 2 baseline 2000 V2.05)

Impact category	Energy current DA	Expansion current DA	Energy current LHW	Expansion current LHW	Energy 2020	Expansion 2020	Energy 2030	Expansion 2030	Petrol
Abiotic depletion (kg Sb eq)	1.89E-01	2.17E-01	2.00E-01	2.51E-01	1.09E-01	1.13E-01	1.08E-01	1.12E-01	1.65E-01
Acidification(kg SO_2 eq)	2.28E-01	2.63E-01	2.02E-01	2.55E-01	1.09E-01	1.14E-01	1.06E-01	1.11E-01	1.03E-01
Eutrophication(kg PO_4^{3-} eq)	4.19E-02	4.80E-02	3.68E-02	4.60E-02	2.20E-02	2.28E-02	2.09E-02	2.17E-02	1.92E-02
GWP100 (kg CO_2 eq)	1.34E+01	1.68E+01	1.07E+01	1.72E+01	4.02E+00	4.39E+00	3.32E+00	3.66E+00	2.64E+01
ODP (kg CFC-11 eq)	2.33E-06	2.57E-06	2.46E-06	2.92E-06	1.30E-06	1.32E-06	1.18E-06	1.20E-06	3.12E-06
Human toxicity(kg 1,4-DB eq)	1.60E+01	1.77E+01	1.54E+01	1.81E+01	9.55E+00	9.73E+00	9.40E+00	9.58E+00	2.90E+00
Fresh water aquatic eco-toxicity (kg 1,4-DB eq)	4.71E+00	5.28E+00	3.53E+00	4.21E+00	2.27E+00	2.32E+00	2.24E+00	2.29E+00	6.19E-01
Marine aquatic eco-toxicity (kg 1,4-DB eq)	9.66E+03	1.09E+04	7.32E+03	8.77E+03	4.28E+03	4.38E+03	4.21E+03	4.31E+03	2.62E+03
Terrestrial eco-toxicity (kg 1,4-DB eq)	8.47E-02	9.46E-02	3.36E-02	3.65E-02	1.91E-02	1.89E-02	1.83E-02	1.80E-02	1.75E-02
POCP (kg C_2H_4)	9.83E-03	1.13E-02	8.84E-03	1.12E-02	5.18E-03	5.40E-03	5.15E-03	5.36E-03	2.99E-02

Notes: Energy=energy allocation; Expansion= system expansion allocation approach

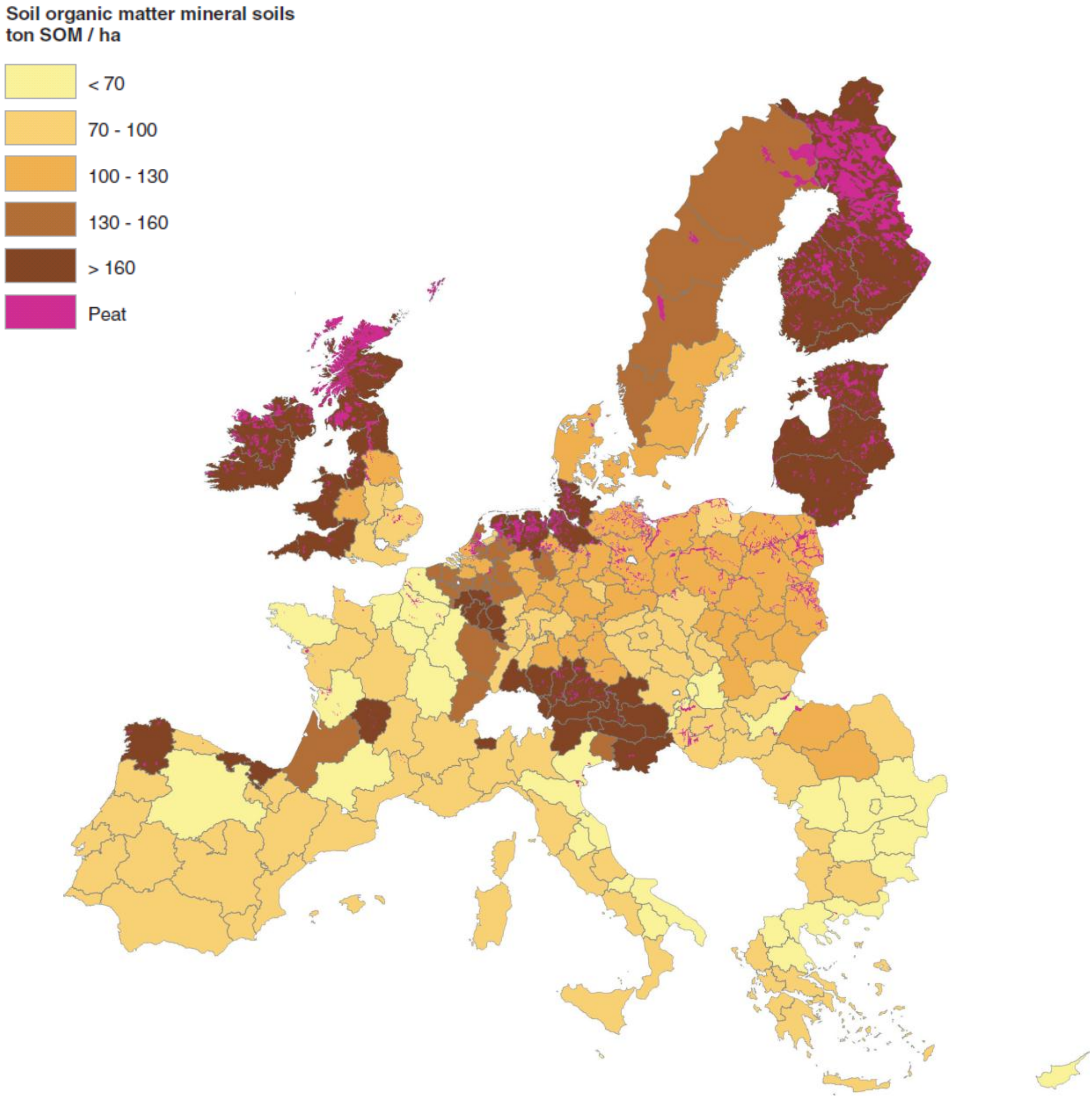

Figure S1 Organic C stocks in mineral soils in EU (Velthof *et al.*, 2011)

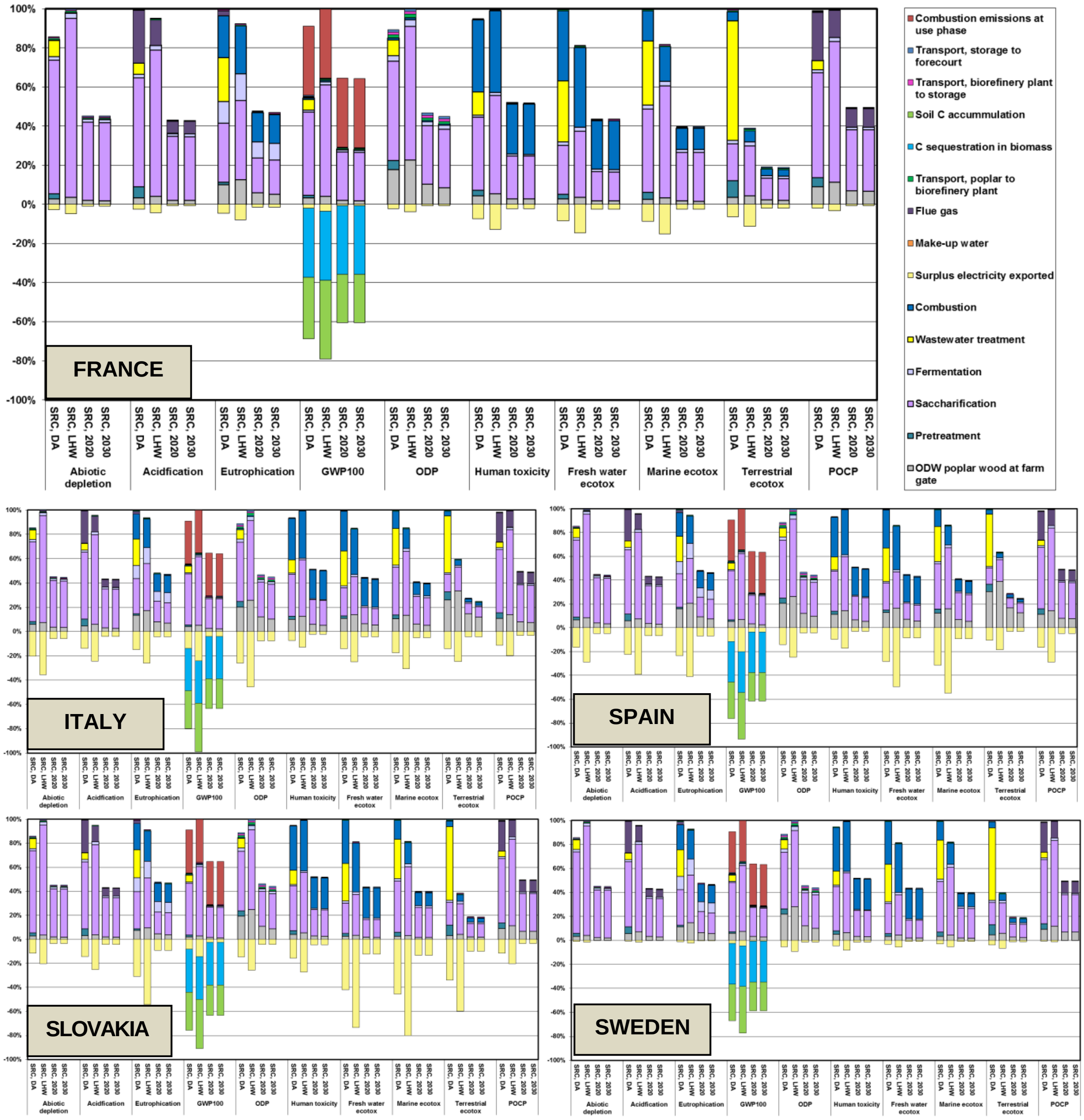

Figure S2 Characterized LCIA profiles of SRC poplar-derived E100 bioethanol over the whole life cycle in current vs. future scenarios (unit: driving FFV for 100km; method: CML 2 baseline 2000)

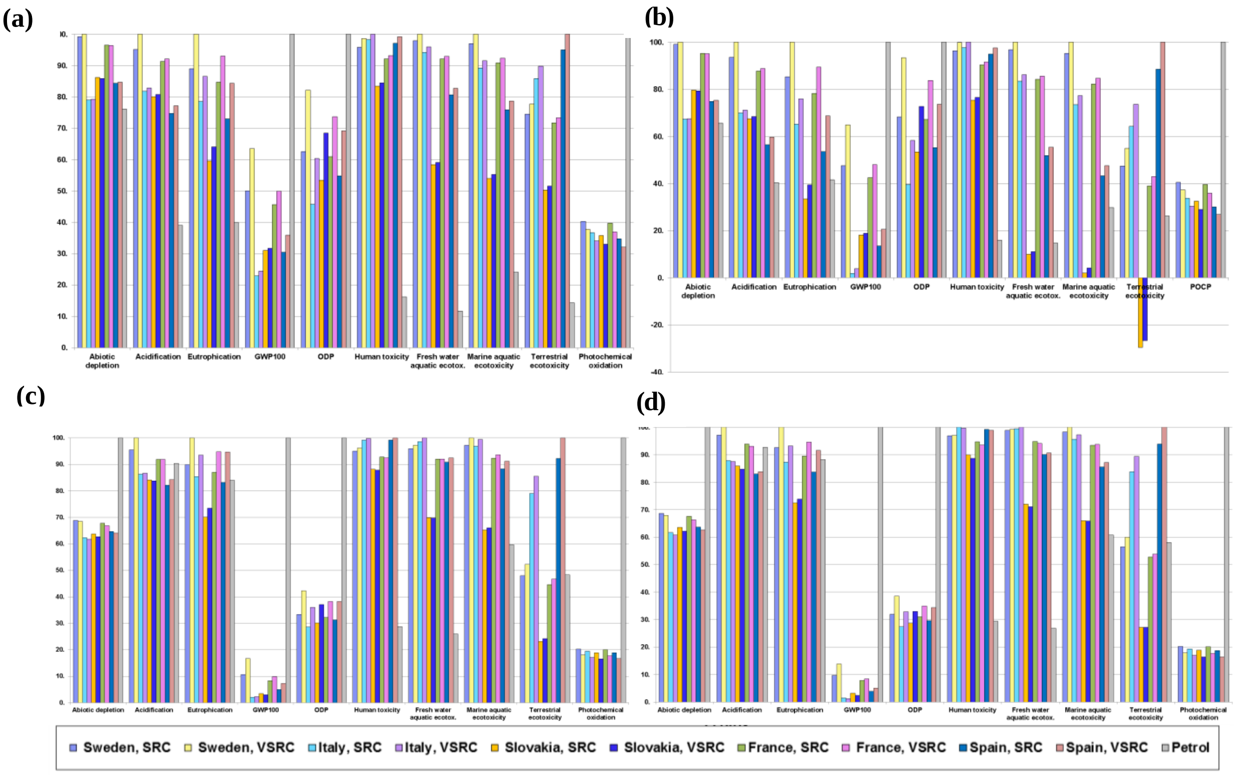

Figure S3 Characterized LCIA profiles of E100 bioethanol over life cycle vs. petrol (a) current DA pretreatment; (b) current LHW pretreatment; (c) 2020 scenario (d) 2030 scenario (unit: driving FFV for 100km; method: CML 2 baseline 2000)

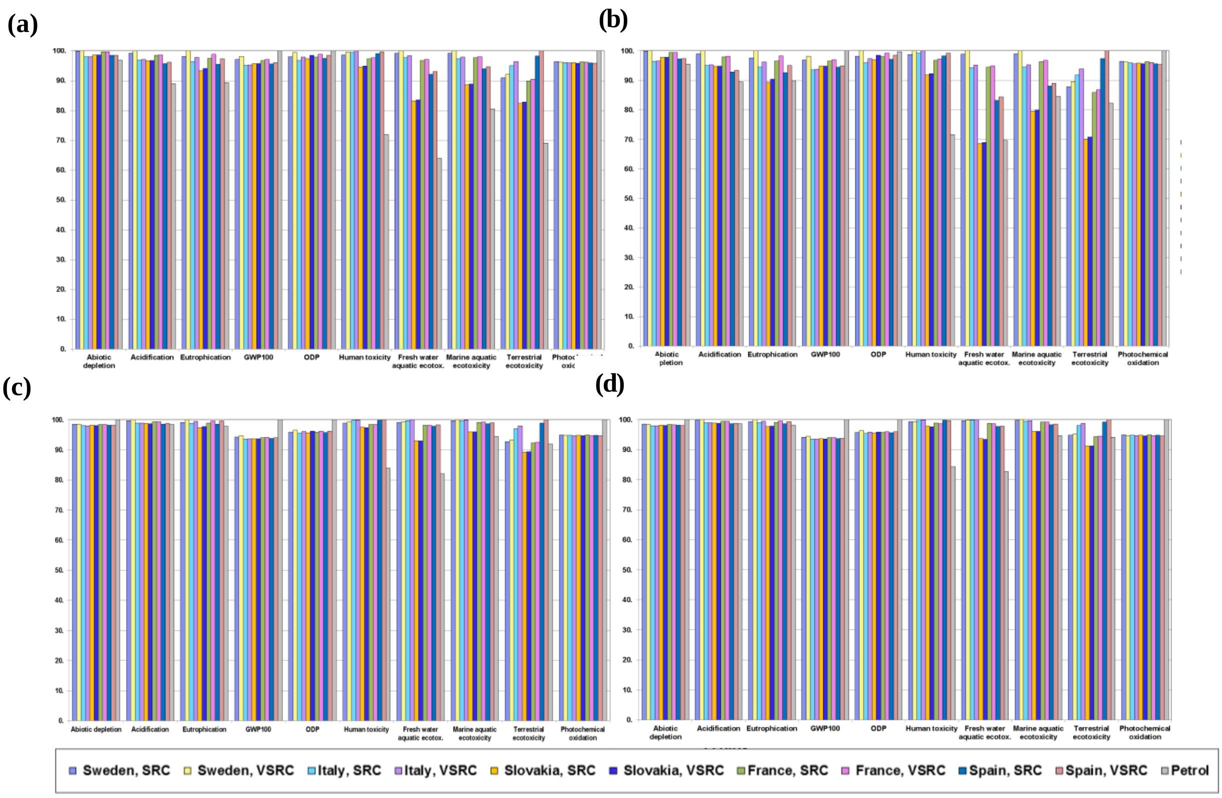

Figure S4 Characterized LCIA profiles of E10 over life cycle vs. petrol (a) current DA pretreatment; (b) current LHW pretreatment; (c) 2020 scenario (d) 2030 scenario (unit: driving FFV for 100km; method: CML 2 baseline 2000)

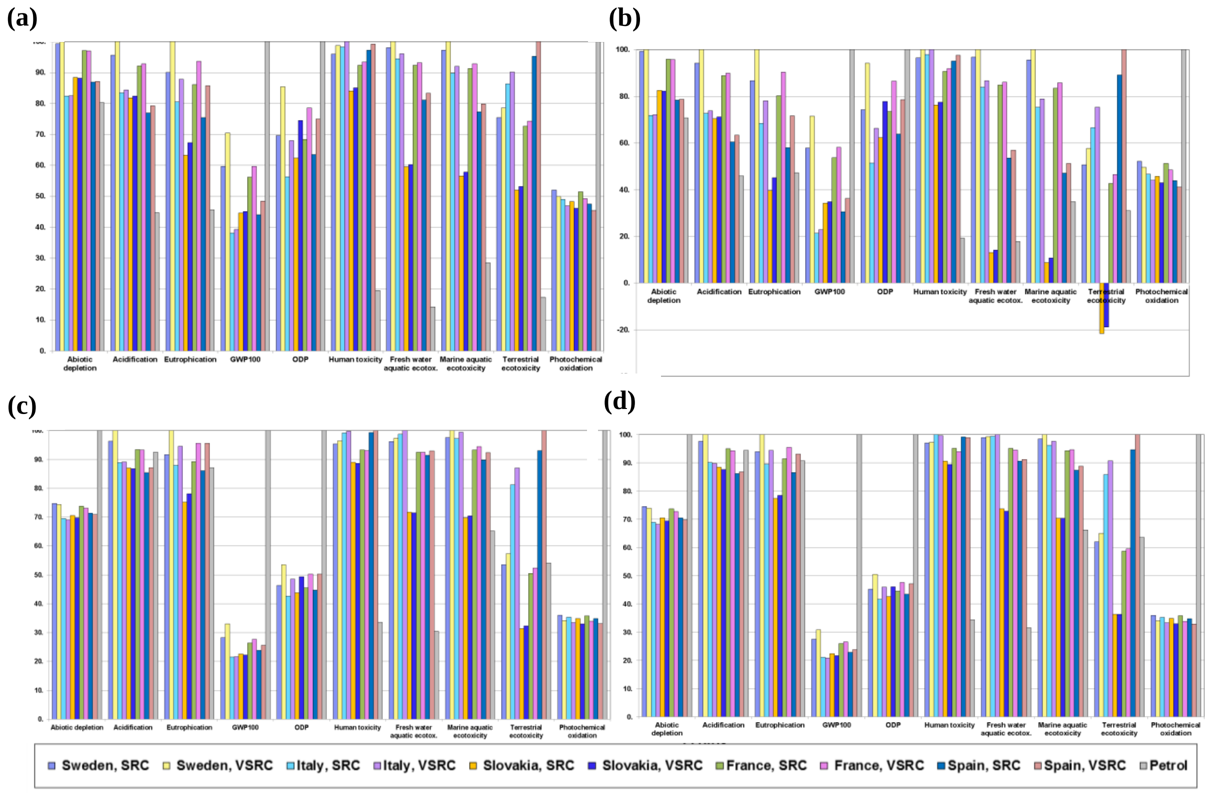

Figure S5 Characterized LCIA profiles of E85 over life cycle vs. petrol (a) current DA pretreatment; (b) current LHW pretreatment; (c) 2020 scenario (d) 2030 scenario (unit: driving FFV for 100km; method: CML 2 baseline 2000)

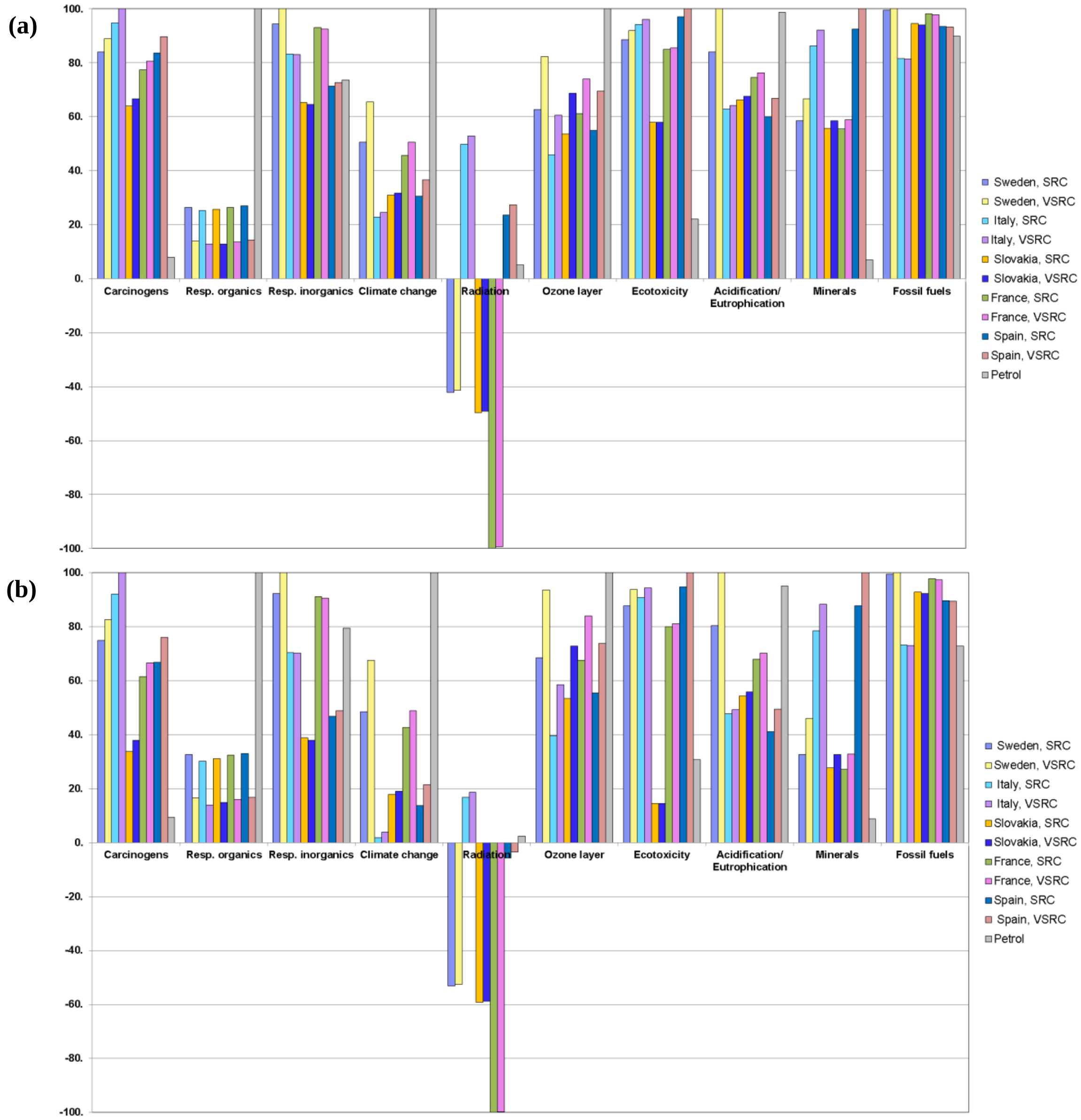

Figure S6 Sensitivity analysis of the characterization model - characterized LCIA profiles of poplar-derived bioethanol (E100) over life cycle vs. petrol (a) DA pretreatment; (b) LHW pretreatment (unit: driving FFV for 100km; method: Eco-indicator 99 H)

(a)

(b)

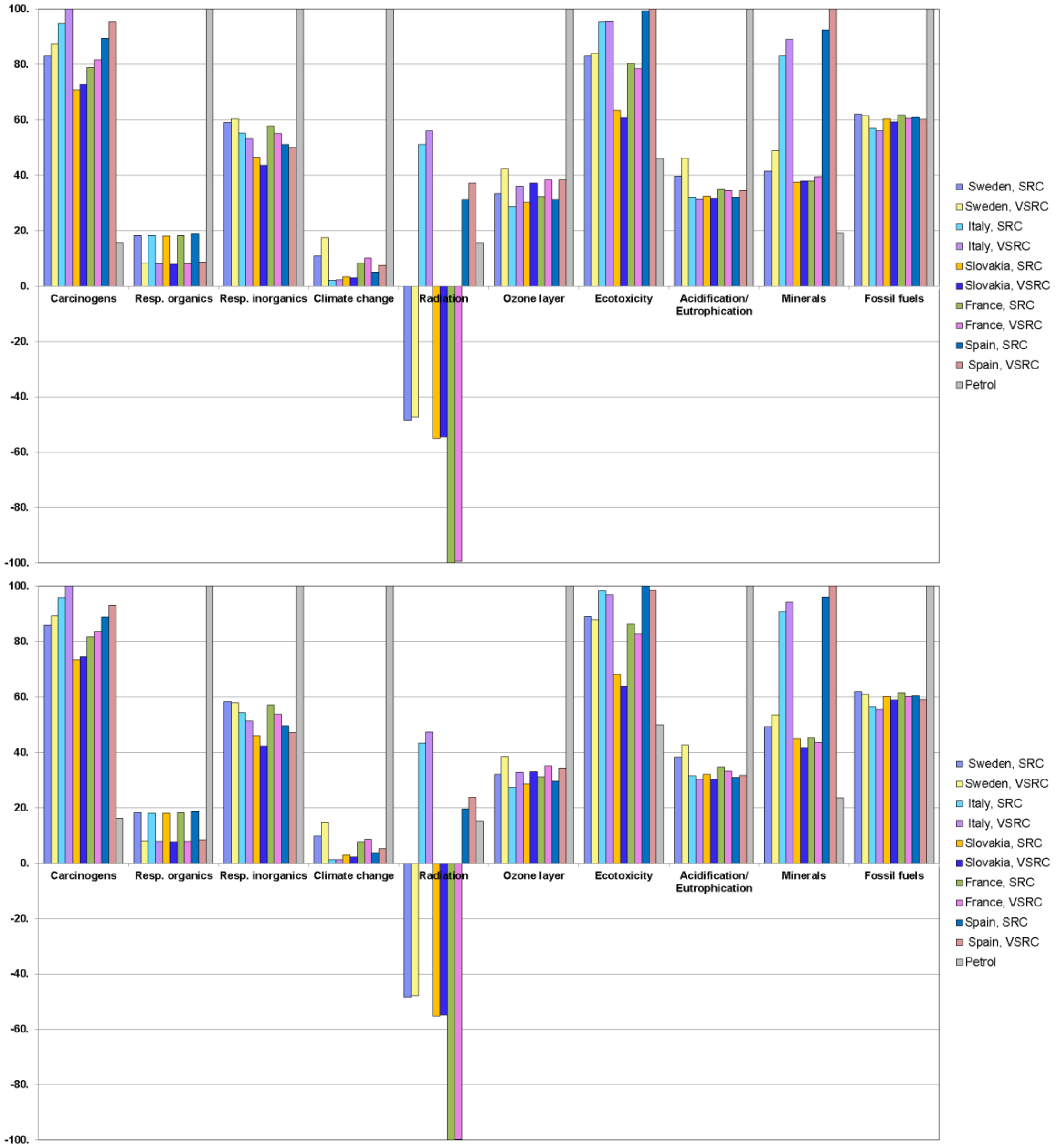

Figure S7 Sensitivity analysis of the characterization model - characterized LCIA profiles of poplar-derived bioethanol (E100) over life cycle vs. petrol (a) 2020 scenario; (b) 2030 scenario (unit: driving FFV for 100km; method: Eco-indicator 99 H)

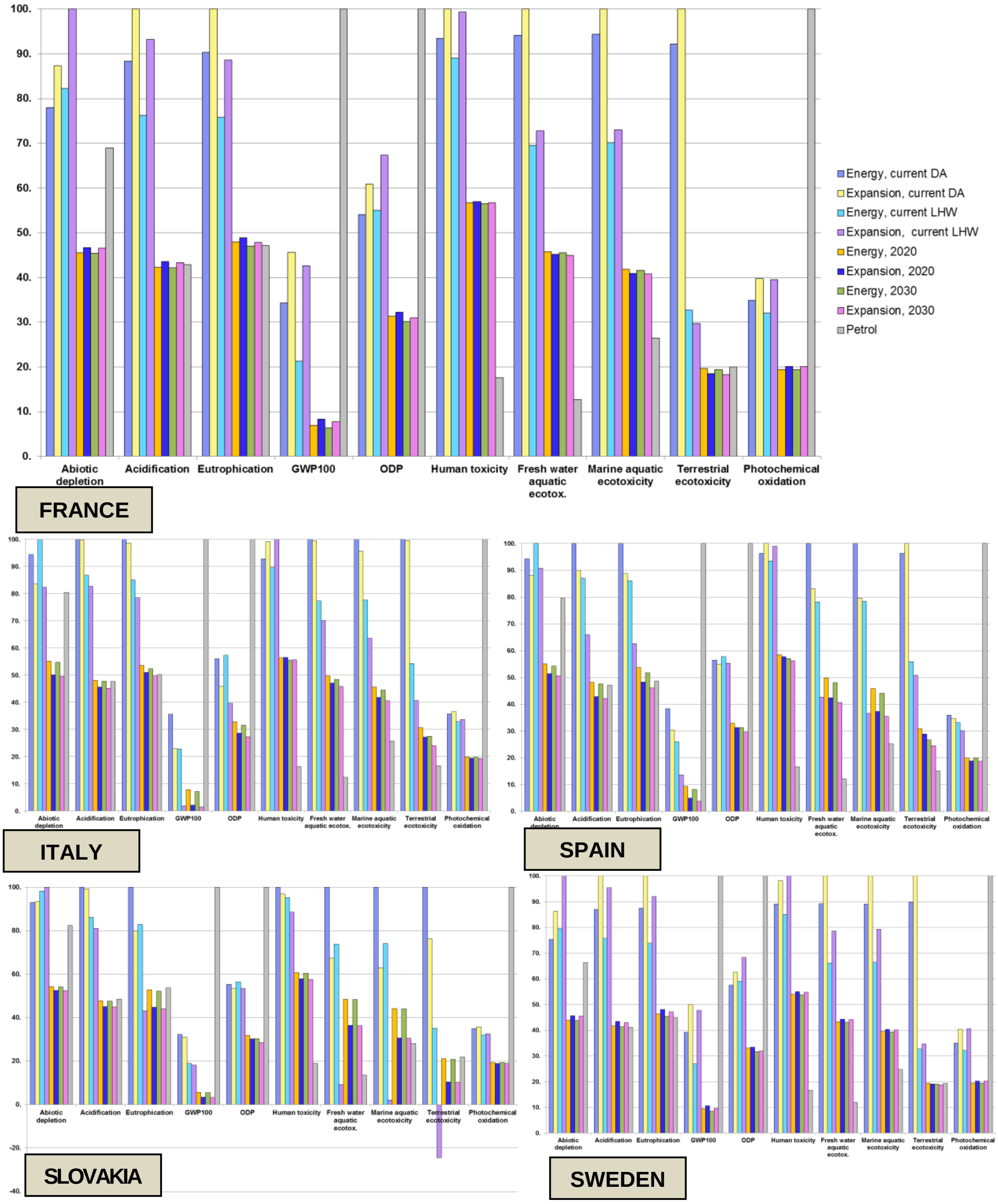

Figure S8 Sensitivity analysis of the allocation approach - characterized LCIA profiles of SRC poplar-derived E100 bioethanol over whole life cycle vs. petrol (unit: driving FFV for 100km; method: CML 2 baseline 2000 V2.05)

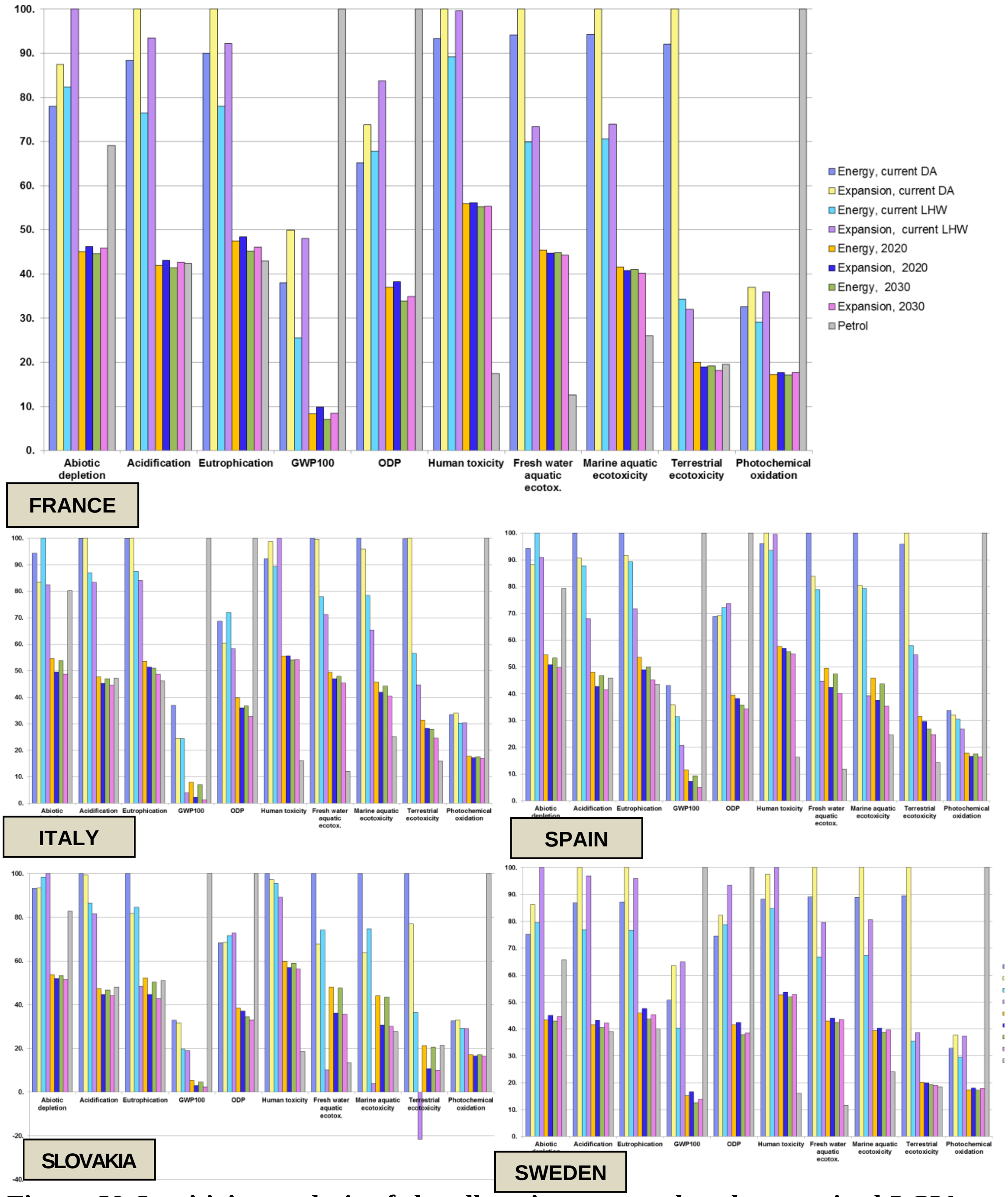

Figure S9 Sensitivity analysis of the allocation approach - characterized LCIA profiles of VSRC poplar-derived E100 bioethanol over whole life cycle vs. petrol (unit: driving FFV for 100km; method: CML 2 baseline 2000 V2.05)

References

Arrouays D, Freibauer A, Rounsevell MDA, Smith P, Verhagen J 2004. *Carbon sequestration in soils: estimates for Europe and France, uncertainties and research and references needs* Brussels, Belgium: European Commission Joint Research Center.

Blanco-Canqui H. 2010. Energy Crops and Their Implications on Soil and Environment. *Agronomy Journal* **102**(2): 403-419.

De Vries W, Leip A, Reinds GJ, Kros J, Lesschen JP, Bouwman AF, Grizzetti B, Bouraoui F, Butterbach-Bahl K, Bergamaschi P, Winiwarter W. 2011. *Geographical variation in terrestrial nitrogen budgets across Europe- The European Nitrogen Assessment*. Cambridege: UK: Cambridge University Press.

EuropeanCommission 2012a. *Agri-environmental indicator - mineral fertiliser consumption*. European Commission Eurostat. URL http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Fertiliser_consumption_and_nutrient_balance_statistics [accessed Aug 2012].

EuropeanCommission 2012b. *Fertiliser consumption and nutrient balance statistic.* European Commission Eurostat. URL http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Fertiliser_consumption_and_nutrient_balance_statistics [accessed Aug 2012]

Freibauer A, Rounsevell MDA, Smith P, Verhagen J. 2004. Carbon sequestration in the agricultural soils of Europe. *Geoderma* **122**(1): 1-23.

Garten CT, Wullschleger SD, Classen AT. 2011. Review and model-based analysis of factors influencing soil carbon sequestration under hybrid poplar. *Biomass & Bioenergy* **35**(1): 214-226.

Gielen B, Calfapietra C, Lukac M, Wittig VE, De Angelis P, Janssens IA, Moscatelli MC, Grego S, Cotrufo MF, Godbold DL, Hoosbeek MR, Long SP, Miglietta F, Polle A, Bernacchi CJ, Davey PA, Ceulemans R, Scarascia-Mugnozza GE. 2005. Net carbon storage in a poplar plantation (POPFACE) after three years of free-air CO2 enrichment. *Tree Physiology* **25**(11): 1399-1408.

Goedkoop M, Spriensma R 2001. *The Eco-indicator 99 A damage oriented method for Life Cycle Impact Assessment Methodology Report*. Amersfoort, the Netherlands: PRé Consultants.

Guinée JB, Gorree M, Heijungs R, Huppes G, Kleijn R, Koning A, Oers LV, Sleeswijk AW, Suh S, Haes HAU, Bruijn H, Duin RV, Huijbregts MAJ 2001. *Life Cycle Assessment An Operational Guide to the ISO Standards Final report (part 1, 2, 3).* Maastricht, the Netherlands: Ministry of Housing, Spatial Planning and the Evironment & Center of Environmental Science -Leiden University.

Guo M, Facciotto G, Li C, Bergante S, Murphy R 2013. Environmental vability of bioethanol derived from the poplar clone Imola. *20th International Symposium on Alcohol Fuels*. Cape Town.

Gupta N, Kukal SS, Bawa SS, Dhaliwal GS. 2009. Soil organic carbon and aggregation under poplar based agroforestry system in relation to tree age and soil type. *Agroforestry Systems* **76**(1): 27-35.

Hansen EA. 1993. Soil carbon sequestration beneath hybrid poplar plantations in the North Central United States. *Biomass and Bioenergy* **5**(6): 431-436.

IFA 2011. *IFA statistics*. Paris, France: International Fertilizer Industry Association URL http://www.fertilizer.org/ifa/ifadata/search [Accessed Aug 2012]

PRéConsultants 2004. *Simapro 7.0 Database Manual Methods library*. Amersfoort, the Netherlands: PRé Consultants.

Rytter R-M. 2012. The potential of willow and poplar plantations as carbon sinks in Sweden. *Biomass and Bioenergy* **36**(0): 86-95.

Velthof G, Barot S, Bloem J, Butterbach-Bahl K, de Vries W, Kros J, Lavelle P, Olesen JE, Oenema O. 2011. Nitrogen as a threat to European soil quality. *The European Nitrogen Assessment*. Cambridge, UK: Cambridge University Press.

Velthof GL, Oudendag D, Witzke HP, Asman WAH, Klimont Z, Oenema O. 2009. Integrated Assessment Of Nitrogen Losses From Agriculture In Eu-27 Using Miterra-europe. *J. Environ. Qual.* **38**(2): 402-417.