Supplementary Materials

The Role of Biorefinery Co-Products, Market Proximity and Feedstock Environmental Footprint in Meeting Biofuel Policy Goals for Winter Barley-to-Ethanol

Sabrina Spatari [1,2,*], Alexander Staedel [1], Paul R. Adler [3], Saurajyoti Kar [1], William J. Parton [4], Kevin B. Hicks [5], Andrew J. McAloon [5] and Patrick L. Gurian [1]

This supporting information file contains 5 tables and 3 figures.

Table S1. Fossil Energy Input in Cumulative Energy Demand (CED) for Winter barley-to-ethanol Scenarios (MJ/MJ).

Life cycle input	WBE1	WBE2	WBE3	WBE4
Feedstock Production:				
Fertilizer (N)	0.15	0.15	0.15	0.15
Traction	0.03	0.03	0.03	0.03
Fertilizer (P)	0.03	0.03	0.03	0.03
Transport	0.04	0.04	0.04	0.04
Fertilizer (K20)	0.01	0.01	0.01	0.01
Lime	0.00	0.00	0.00	0.00
Total (Feedstock)	*0.26*	*0.26*	*0.26*	*0.26*
Biorefinery:				
Natural Gas	0.65	0.65	0.65	0.65
Electricity	0.18	0.14	0.14	0.14
Process	0.00	0.00	0.00	0.00
Chemicals, nutrients, enzymes	0.08	0.08	0.08	0.08
Transport (co-products)	0.02	0.02	0.02	0.02
CO_2, Liquid, Avoided	−0.21			
Co-product credits:				
Soy Meal, Avoided	−0.09	−0.09	−0.09	
On Site Steam, Avoided	−0.09	−0.09		
Heat, Coal, Avoided	−0.24	−0.24		
Total (Biorefinery)	*0.29*	*0.45*	*0.79*	*0.88*
Fuel Transport and Distribution	0.002	0.002	0.002	0.002
CED (Fossil Energy)	**0.55**	**0.71**	**1.05**	**1.14**

Table S2. Projected Changes in Barley Production in the United States (Millions of Bushels)[1]

	Control Case	Barley Case	Difference	Increase in production (%) and portion used for biofuel (%)
All barley	17512	20594	3082	
Used in biofuel	0	3108	3108	
Winter	1236	1389	153	5 (production)
Used in biofuel	0	1328	1328	43 (biofuel use)
Spring	16277	19205	2928	95 (production)
Used in biofuel	0	1780	1780	57 (biofuel use)

[1] Data taken from U.S. EPA [1], Table II.B.1-4.

Table S3. Projected Changes in Barley Uses in the United States U.S. EPA's Barley Biofuel Scenario[1]

	Control Case	Barley Case	Difference
Production	17512	20594	3082
Used in biofuel	0	3108	3108
Used in feed	4151	4150	−1
Used in feed and malting	13796	13786	−10
Net exports	−435	−453	−18

[1] Data taken from U.S. EPA [1], Table II.B.1-4.

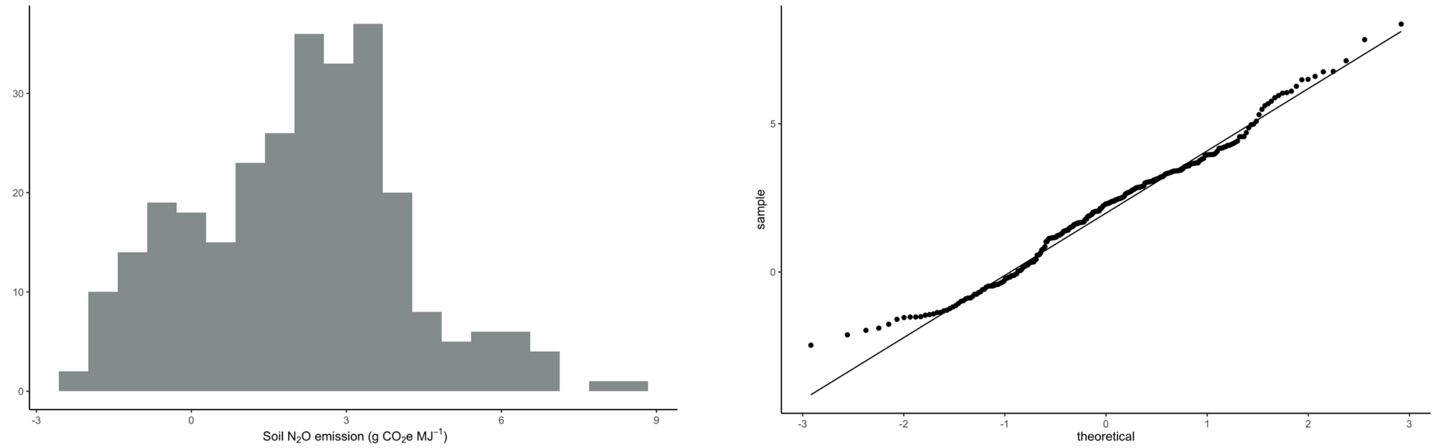
Table S4. Projected Change in Barley Production (million bushels) by State[1]

	Control Case	Barley Case	Difference
Oregon	30	59	29
Wyoming	12	24	12
Montana	78	89	11
Virginia	6	9	3
California	15	17	2
Rest of United States	177	178	0
Total	319	375	56

[1] Data taken from U.S. EPA [1], Table II.B.1-5. Data were converted from million lb to million bushels assuming 48 lb per bu to align with Tables S1 and S2.

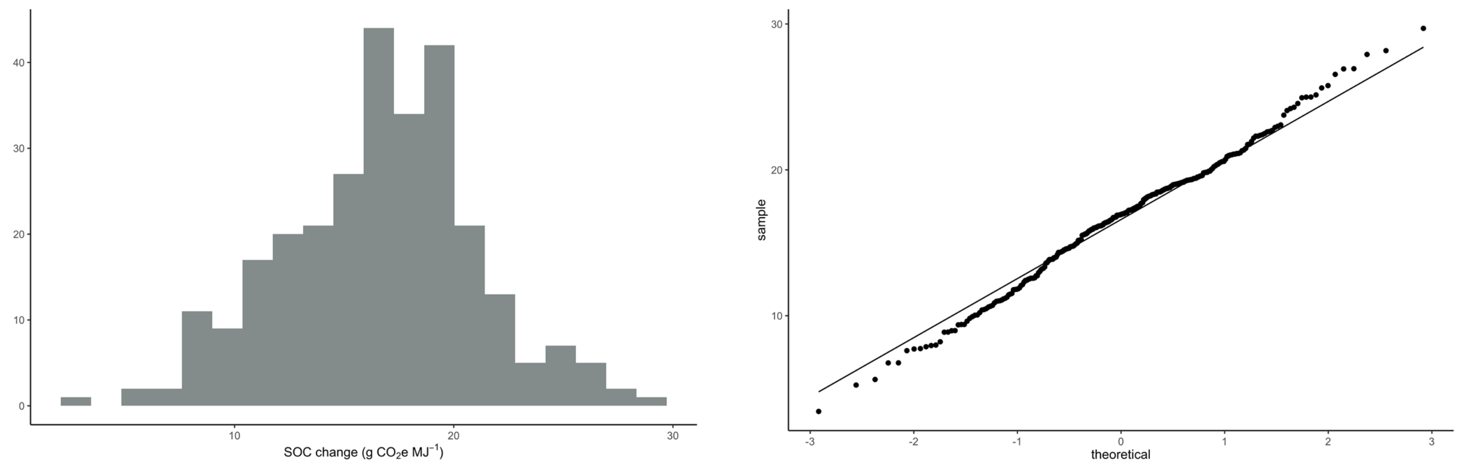
Table S5. Normal distribution parameters for N_2O emissions, SOC change and life cycle GHGs for WBE1, WBE2, WBE3 and WBE4.

Data and Scenarios	mean ± stdev.
N_2O (gCO_2e MJ^{-1})	2.30 ± 2.04
SOC (gCO_2e MJ^{-1})	−17.73 ± 5.03
WBE1 (gCO_2e MJ^{-1})	−6.34 ± 5.44
WBE2 (gCO_2e MJ^{-1})	28.29 ± 5.44
WBE3 (gCO_2e MJ^{-1})	45.58 ± 5.44
WBE4 (gCO_2e MJ^{-1})	51.48 ± 5.44
EPA Scenarios:	
Barley ILUC (gCO_2e MJ^{-1})	24.6
Barley EPA (gCO_2e MJ^{-1})	49.39±5.04
WBE1 +EPA ILUC	18.26± 5.44
Sorghum ILUC (gCO_2e MJ^{-1})	28.4
Sorghum EPA (gCO_2e MJ^{-1})	44.6±4.47



(**a**) (**b**)

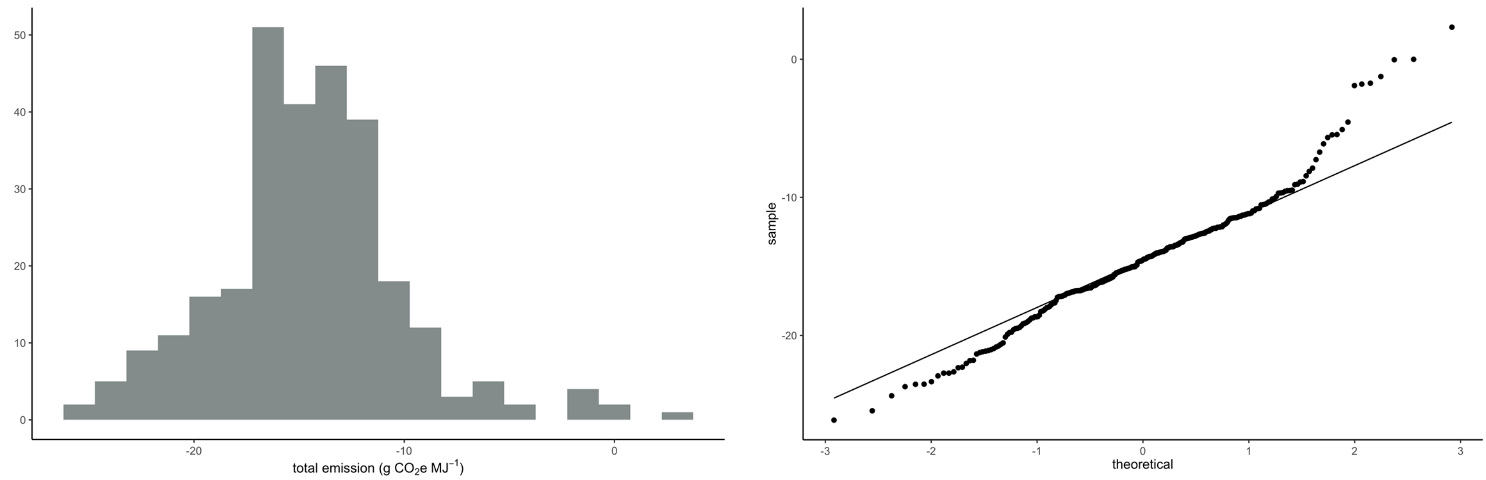
Figure S1. A (**a**) histogram and a (**b**) Q-Q plot of spatially varying soil N_2O emissions (gCO_2e MJ^{-1}) for the studied counties. Total 284 counties are identified with cropland available for growing winter barley. Visual study of the plots suggest we assume data to be normally distributed.



(**a**) (**b**)

Figure S2. A (**a**) histogram and a (**b**) Q-Q plot of spatially changing soil SOC (gCO_2e MJ^{-1}) for the studied counties. The positive value represents net soil carbon increase from WB. A total

284 counties are identified with cropland available for growing winter barley. Visual study of the plots suggest we assume data to be normally distributed.



(**a**) (**b**)

Figure S3. A (**a**) histogram and a (**b**) Q-Q plot of spatially varying total (N_2O + SOC) emissions (gCO_2e MJ^{-1}) for the studied counties. Visual study of the plots suggest we assume data to be normally distributed. Negative gCO_2e MJ^{-1} represents carbon sequestration to soil. A total 284 counties are identified with cropland available for growing winter barley.

References

1. EPA, U. *Notice of Data Availability Concerning Renewable Fuels Produced from Barley under the RFS Program*; EPA-HQ-OAR-2013-0178; U.S. Environmental Protection Agency: July 23, 2013, 2013; pp 44075–44089.