sustainability

Comparison of multiple macroalgae cultivation systems and end-use strategies of *Saccharina latissima* and *Gracilaria tikvahiae* based upon techno-economic analysis and life cycle assessment

Jingjing Wu[1], Shane W. Rogers[1*], Rebekah Schaummann[1], Nichole N. Price[2]

[1]Department of Civil and Environmental Engineering, Clarkson University, 8 Clarkson Ave, Potsdam, NY 13699-5710

[2]Bigelow Laboratory for Ocean Sciences, East Boothbay, ME 04544-0380

[*]Correspondence: srogers@clarkson.edu

Table S1 Biomass production and characteristics of *S.latissima* and *G. tikvahiae* as reported in literature; median of fresh biomass was calculated based upon dry biomass and total solids [1–25]

Parameter	**Unit**	***S. latissima***		***G. tikvahiae***	
		Median	**Range**	**Median**	**Range**
Biomass (fresh)	ton/ha·year	37.35	17.5 - 75	11.89	11 - 26
Biomass (dry)	ton/ha·year	6.35	1.5 - 11.2	1.57	0.94 - 2.2
Biomass	kg-FW/m	15.7	3.0 - 28.4	n.a.	n.a.
Total solids	g-DW/g-FW	0.17	0.10 - 0.23	0.13	0.10 - 0.16
Volatile solids	g-VS/g-DW	0.58	0.50 - 0.65	0.62	0.52 - 0.72
Total carbon	mg/g-DW	302.5	251 - 354	282.7	275.0 - 290.4
Total nitrogen	mg/g-DW	23.2	8.3 - 38	34.5	12.0 - 57
Total phosphorus	mg/g-DW	3.9	2.8 - 5	3.0	1.0 - 5.0
Moisture (dried)	%	22	-	22	-
Biomethane potential	L CH_4/kg-VS	260.9	180 - 341.7	205	190 - 220

Table S2 Cost inventories of *S. latissima* and *G. tikvahiae* cultivation based upon a one-hectare sea farm (costs adjusted to 2020 U.S. dollars)

Cost category	Lifespan (year)	Single layer longline (S1) *S. latissima*	Single layer longline (S1) *G.tikvahiae*	Dual layer longline (S2) *S. latissima*	Dual layer longline (S2) *G.tikvahiae*	Single layer strip (S3) *S. latissima*	Single layer strip (S3) *G.tikvahiae*	Dual layer strip (S4) *S. latissima*	Dual layer strip (S4) *G.tikvahiae*
Spool	25	$47.91	N.A.	$95.82	N.A.	$115.50	N.A.	$230.15	N.A.
Settling tube	25	$123.96	N.A.	$247.93	N.A.	$298.84	N.A.	$595.47	N.A.
Settling tube cap	25	$129.92	N.A.	$259.84	N.A.	$313.20	N.A.	$624.08	N.A.
PVC primer and glue	1	$9.94	N.A.	$9.94	N.A.	$9.94	N.A.	$9.94	N.A.
Seeding line	1	$82.12	$82.12	$164.25	$164.25	$197.98	$197.98	$394.49	$394.49
Nursery Electricity	1	$18.21	$18.21	$36.42	$36.42	$42.53	$42.53	$82.12	$82.12
F/2 media	1	$13.66	$13.66	$27.31	$27.31	$32.92	$32.92	$65.60	$65.60
Spoon Labor	1	$180.00	$180.00	$330.00	$330.00	$420.00	$420.00	$810.00	$810.00
Barge	25	$75,000.00	N.A.	$75,000.00	N.A.	$75,000.00	N.A.	$75,000.00	N.A.
Anchor block	25	$2,250.00	N.A.	$2,250.00	N.A.	$2,700.00	N.A.	$2,700.00	N.A.
Anchor chain	25	$54,417.82	N.A.	$54,417.82	N.A.	$65,301.39	N.A.	$65,301.39	N.A.
Anchor buoy	25	$7,499.70	N.A.	$7,499.70	N.A.	$8,999.64	N.A.	$8,999.64	N.A.
Longline	5	$5,748.68	N.A.	$11,497.36	N.A.	$13,858.43	N.A.	$27,614.20	N.A.
Control line	5	$5,748.68	N.A.	$5,748.68	N.A.	$13,858.43	N.A.	$13,807.10	N.A.
Small buoy	25	$6,295.00	N.A.	$6,295.00	N.A.	$7,554.00	N.A.	$7,554.00	N.A.
Buoy maintenance	1	$137.95	$137.95	$137.95	$137.95	$165.54	$165.54	$165.54	$165.54
Drop line	5	$475.60	N.A.	$1,426.00	N.A.	$1,141.44	N.A.	$3,424.32	N.A.
Drop line strengthener	25	$304.22	N.A.	$912.66	N.A.	$730.13	N.A.	$2,190.38	N.A.
Line weight	25	$375.00	N.A.	$750.00	N.A.	$900.00	N.A.	$1,800.00	N.A.
Strip strengthener	25	N.A.	N.A.	N.A.	N.A.	$1,259.52	N.A.	$1,259.52	N.A.
Insurance	1	$4,743.44	N.A.	$4,973.94	N.A.	$5,701.30	N.A.	$6,289.52	N.A.
Boat maintenance	1	$3,750.00	N.A.	$3,750.00	N.A.	$3,750.00	N.A.	$3,750.00	N.A.
Other maintenance	1	$3,466.00	$3,466.00	$3,850.17	$3,850.17	$4,924.49	$4,924.49	$5,904.85	$5,904.85

Bucket	5	$1,190.00	N.A.	$1,190.00	N.A.	$1,190.00	N.A.	$1,190.00	N.A.
Seaweed farm gasoline	1	$293.87	$180.11	$407.62	$246.47	$530.85	$274.91	$748.88	$369.70
Seaweed farm labor	1	$4,800.00	$1,680.00	$6,780.00	$2,460.00	$9,900.00	$3,180.00	$14,520.00	$4,680.00
Lease application	20	$1,500.00	N.A.	$1500.00	N.A.	$1,500.00	N.A.	$1,500.00	N.A.

N.A.: not applicable, equipment for *S. latissima* cultivation was shared with *G. tikvahiae* cultivation

Table S3 Cost and economic value inventories of *S. latissima* and *G. tikvahiae* processing and end-use products for one-kilogram dry weight of harvested biomass (cost adjusted to 2020 U.S. dollars)

Cost category	*S. Latissima*	*G. Tikvahiae*
Transportation, fresh (80 km)	$0.05	$0.07
Transportation, dry (80 km)	$0.01	$0.01
Dryer cost	$0.55	$0.77
Dryer labor cost	$0.09	$0.12
Mill cost	$0.003	$0.003
Mill labor cost	$0.02	$0.02
AD-electricity economic value	$0.07	$0.06
AD-digestate economic value	$0.06	$0.08
Animal feed economic value	$0.85	$0.85
Fertilizer economic value	$4.68	$4.68
Human food economic value	$19.78	$19.78
Dryer*	$10,000.00	
Hammermill*	$3,000.00	

*The capital cost of seaweed dryer and hammermill was not adjusted for 1 kg dry weight of seaweed. The purchase of one dryer and one hammermill was assumed for all scenarios in which the seaweed drying and grinding was required. The lifespan of the dryer and hammermill was assumed to be 10 years.

Table S4 Minimum, mode and maximum values of the triangle distribution applied to the parameters used in the Monte Carlo simulation of one-kilogram dry weight of *S. latissima* and *G. tikvahiae* cultivation and processing costs

	Unit	Min	Mode	Max	Applied scenario
Biomass solid content (*S.latissima*)	% FW	10	17	23	S1-S4
Biomass/m of longline (*S.latissima*)	kg	3	15.7	28.4	S1-S4
Biomass solid content (*G.tikvahiae*)	% FW	10	13	16	S1-S4
Biomass/m of longline (*G.tikvahiae*)	kg	2.92	4.87	6.82	S1-S4
Second/first layer biomass ratio	-	0.5	0.5	1	S2, S4
Biomass solid content after drying	%	5	5	22	P2-P4
Total length of longline (S1)	m	1,860	2480	3100	S1
Total length of longline (S2)	m	3,720	4960	6200	S2
Number of longlines	-	8	10	12	S1, S2

Barge	-	$50,000	$75,000	$100,000	S1-S4
Anchor chain	per m	$53.72	$71.62	$89.53	S1-S4
Seawater depth (anchor chain length)	m	3.43	4.57	5.72	S1-S4
Longline/control line	per m	$1.72	$2.30	$2.87	S1-S4
Seafarm labor wage	per h	$11.25	$15.00	$18.75	S1-S4
Seafarm labor time factor	-	0.75	1	1.25	S1-S4
Transport distance	km	40	80	120	P1
Transport distance	km	40	80	1200	P2-P4
Dryer capacity	tonne/h	0.5	0.5	20	P2-P4
Dryer cost factor	-	0.9	1	1.1	P2-P4
Dryer labor requirement	%drying time	25	50	75	P2-P4
Mill capacity	tonne/h	0.5	1	10	P3-P4
Mill labor requirement	%mill time	25	50	75	P3-P4

FW: fresh weight;

Seafarm labor time factor was used to adjust the total labor time of the offshore seaweed farm; the dryer cost factor was used to adjust the energy cost of the seaweed drying. the factor equates to 1 indicated the value used in the techno-economic analysis

Table S5 Life cycle inventories of one-kilogram dry weight of *S. latissima* and *G. tikvahiae* cultivation through cultivation scenarios S1-S4.

Phase/Process	Material or Energy	Unit	LS	Single layer longline (S1)		Dual layer longline (S2)		Single layer strip (S3)		Dual layer strip (S4)	
				S. latissima	*G. tikvahiae*	*S. latissima*	*G. tikvahiae*	*S. latissima*	*G. tikvahiae*	*S. latissima*	*G. tikvahiae*
Hatchery phase											
Spool	PVC	kg	25	1.17E-04	9.45E-05	1.56E-04	6.53E-04	1.17E-04	9.45E-05	1.56E-04	1.26E-04
Settling tube	PVC	kg	25	3.43E-04	2.77E-04	4.57E-04	1.92E-03	3.43E-04	2.77E-04	4.57E-04	3.70E-04
Settling tube cap	PVC	kg	25	4.87E-05	3.93E-05	6.49E-05	2.72E-04	4.87E-05	3.93E-05	6.49E-05	5.24E-05
Seeding line	Nylon	kg	1	2.34E-04	9.87E-04	3.12E-04	1.32E-03	2.34E-04	9.87E-04	3.12E-04	1.32E-03
Electricity	Electricity	kwh	1	2.27E-02	9.57E-02	3.03E-02	1.28E-01	2.20E-02	9.28E-02	2.84E-02	1.20E-01
F/2-organic	Chemicals, organic	g	1	1.01E-06	4.24E-06	1.34E-06	5.66E-06	1.01E-06	4.24E-06	1.34E-06	5.66E-06
F/2-inorganic	Chemicals, inorganic	g	1	3.55E-05	1.50E-04	4.73E-05	1.99E-04	3.55E-05	1.50E-04	4.73E-05	1.99E-04
Sea site phase											
Barge	Aluminum	kg	25	8.98E-03	7.26E-03	5.99E-03	2.51E-02	3.73E-03	3.01E-03	2.49E-03	2.01E-03

Anchor block	Concrete	kg	25	2.99E-01	2.42E-01	2.00E-01	8.36E-01	1.49E-01	1.20E-01	9.97E-02	8.06E-02
Anchor chain	Steel	kg	25	6.87E-02	5.55E-02	4.58E-02	1.92E-01	3.42E-02	2.76E-02	2.29E-02	1.85E-02
Anchor buoy	Polyethylene	kg	25	1.58E-03	1.28E-03	1.05E-03	4.41E-03	7.87E-04	6.36E-04	5.26E-04	4.26E-04
Longline	Polyester	kg	5	5.58E-03	4.51E-03	7.43E-03	3.11E-02	5.58E-03	4.51E-03	7.43E-03	6.01E-03
Control line	Polyester	kg	5	5.58E-03	4.51E-03	3.72E-03	1.56E-02	5.58E-03	4.51E-03	3.72E-03	3.00E-03
Small buoy	Vinyl-PVC	kg	25	1.56E-03	1.26E-03	1.04E-03	4.36E-03	7.77E-04	6.28E-04	5.20E-04	4.20E-04
Drop line	Polyester	kg	5	3.01E-04	2.43E-04	6.01E-04	2.52E-03	2.99E-04	2.42E-04	6.01E-04	4.86E-04
1" PVC	PVC	kg	25	7.13E-04	5.76E-04	1.43E-03	5.97E-03	7.09E-04	5.73E-04	1.42E-03	1.15E-03
Line weight	Concrete	kg	25	6.79E-03	5.49E-03	9.05E-03	3.79E-02	6.76E-03	5.46E-03	9.05E-03	7.31E-03
Strip strengthener	PVC	kg	25	N.A.	N.A.	N.A.	N.A.	1.15E-03	9.32E-04	7.71E-04	6.24E-04
Bucket	Polypropylene	kg	5	5.87E-03	4.75E-03	3.92E-03	1.64E-02	2.44E-03	1.97E-03	1.63E-03	1.32E-03
Seaweed farm gasoline	Gasoline	L	1	6.41E-02	1.65E-01	5.92E-02	1.51E-01	4.80E-02	1.05E-01	4.53E-02	9.43E-02

N.A.: not applicable

LS: the lifespan of the item in year

Table S6 Life cycle inventories of one-kilogram dry weight of *S. latissima* and *G. tikvahiae* processing and end-use scenarios P1-P4.

Scenario/Process	Material or Energy	Unit	*S. Latissima*	*G. Tikvahiae*
P1 - Digestate				
Transportation, fresh weight	Transport, combination truck	tkm	0.47	0.62
Substitution of electricity	Electricity	kwh	0.56	0.47
Substitution of fertilizer	Urea ammonium nitrate production	as gN	23.2	34.5
Substitution of fertilizer	Diammonium phosphate	as gP_2O_5	3.9	3.0
P2 - Human food				
Drying	Water evaporated	m^3	4.60E-03	6.41E-03
Transportation, dry weight	Transport, combination truck	tkm	0.10	0.10
Substitution of lettuce	Lettuce	kg	5.88	7.69
P3 - Seaweed fertilizer				
Drying	Water evaporated	m^3	4.60E-03	6.41E-03

Mill	Crop grinded	kg	1.28	1.28
Transportation, dry weight	Transport, combination truck	tkm	0.10	0.10
Substitution of fertilizer	Urea ammonium nitrate production	as gN	23.2	34.5
Substitution of fertilizer	Diammonium phosphate	as gP_2O	3.9	3.0
P4 - Animal feed				
Drying	Water evaporated	m^3	4.60E-03	6.41E-03
Mill	Crop grinded	kwh	0.01	0.01
Transportation, dry weight	Transport, combination truck	tkm	0.10	0.10
Substitution of fishmeal	Fishmeal	kg	1.28	1.28

Table S7 Comparison of normalized amounts of each environmental impact of one-kilogram dry weight of *S. latissima* and *G. tikvahiae* cultivation through cultivation scenarios S1-S4.

	Construction		Operation	
	C1	C2	*S. latissima*	*G. tikvahiae*
S1-Single layer longline platform				
Fossil resource scarcity	1.51E-05	1.22E-05	6.41E-07	2.70E-06
Freshwater ecotoxicity	2.19E-03	1.77E-03	5.91E-06	2.49E-05
Freshwater eutrophication	3.14E-05	2.54E-05	1.61E-07	6.79E-07
Global warming	1.44E-05	1.17E-05	8.50E-07	3.58E-06
Human carcinogenic toxicity	2.46E-03	1.99E-03	1.87E-05	7.89E-05
Human non-carcinogenic toxicity	3.80E-04	3.00E-04	2.16E-06	9.10E-06
Marine ecotoxicity	3.57E-03	2.89E-03	1.05E-05	4.41E-05
Marine eutrophication	5.70E-06	4.61E-06	-5.03E-03	-7.49E-03
Terrestrial ecotoxicity	1.90E-04	1.60E-04	2.21E-06	9.32E-06
S2-Dual layer longline platform				
Fossil resource scarcity	1.02E-05	8.23E-06	8.57E-07	3.61E-06
Freshwater ecotoxicity	1.47E-03	1.19E-03	7.89E-06	3.33E-05
Freshwater eutrophication	2.11E-05	1.71E-05	2.15E-07	9.08E-07
Global warming	1.03E-05	8.31E-06	1.13E-06	4.78E-06
Human carcinogenic toxicity	1.65E-03	1.34E-03	2.50E-05	1.10E-04
Human non-carcinogenic toxicity	2.50E-04	2.10E-04	2.88E-06	1.21E-05
Marine ecotoxicity	2.40E-03	1.94E-03	1.40E-05	5.89E-05
Marine eutrophication	3.84E-06	3.10E-06	-5.03E-03	-7.49E-03
Terrestrial ecotoxicity	1.30E-04	1.10E-04	2.95E-06	1.24E-05
S3-Single layer strip platform				
Fossil resource scarcity	6.90E-06	5.57E-06	6.45E-07	2.72E-06
Freshwater ecotoxicity	9.80E-04	7.90E-04	5.86E-06	2.47E-05
Freshwater eutrophication	1.42E-05	1.15E-05	1.62E-07	6.84E-07
Global warming	7.60E-06	6.14E-06	8.36E-07	3.52E-06
Human carcinogenic toxicity	1.09E-03	8.80E-04	1.87E-05	7.86E-05
Human non-carcinogenic toxicity	1.70E-04	1.40E-04	2.12E-06	8.94E-06
Marine ecotoxicity	1.60E-03	1.29E-03	1.04E-05	4.37E-05

Marine eutrophication	2.60E-06	2.10E-06	-5.03E-03	-7.49E-03
Terrestrial ecotoxicity	9.48E-05	7.66E-05	2.16E-06	9.09E-06
S4-Dual layer strip platform				
Fossil resource scarcity	4.71E-06	3.81E-06	8.58E-07	3.62E-06
Freshwater ecotoxicity	6.60E-04	5.40E-04	7.68E-06	3.24E-05
Freshwater eutrophication	9.65E-06	7.80E-06	2.16E-07	9.09E-07
Global warming	5.73E-06	4.63E-06	1.09E-06	4.58E-06
Human carcinogenic toxicity	7.40E-04	6.00E-04	2.46E-05	1.00E-04
Human non-carcinogenic toxicity	1.20E-04	9.68E-05	2.75E-06	1.16E-05
Marine ecotoxicity	1.09E-03	8.80E-04	1.36E-05	5.72E-05
Marine eutrophication	1.77E-06	1.43E-06	-5.03E-03	-7.49E-03
Terrestrial ecotoxicity	6.61E-05	5.35E-05	2.78E-06	1.17E-05

Table S8 Comparison of normalized amounts of each environmental impact of one-kilogram dry weight of *S. latissima* and *G. tikvahiae* processing and end-use through scenario P1-P4.

	P1-Digestate		P2-Human food		P3-Seaweed fertilizer		P4-Animal feed	
Impact category	*S. latissima*	*G. Tikvahiae*	*S. latissima*	*G. Tikvahiae*	*S. latissima*	*G. Tikvahiae*	*S. latissima*	*G. Tikvahiae*
Fossil resource scarcity	-3.60E-05	-5.25E-05	6.90E-04	9.80E-04	9.60E-04	1.33E-03	9.90E-04	1.38E-03
Freshwater ecotoxicity	-2.65E-03	-3.61E-03	-3.71E-03	-3.74E-03	1.05E-02	1.46E-02	1.30E-02	1.82E-02
Freshwater eutrophication	-2.88E-05	-3.91E-05	-1.00E-04	-1.10E-04	1.90E-04	2.60E-04	2.10E-04	2.90E-04
Global warming	-3.19E-05	-3.91E-05	1.70E-04	2.50E-04	2.80E-04	3.90E-04	2.80E-04	4.00E-04
Human carcinogenic toxicity	-9.70E-04	-1.31E-03	1.92E-02	2.75E-02	2.67E-02	3.72E-02	2.75E-02	3.83E-02
Human non-carcinogenic toxicity	-6.10E-04	-8.00E-04	-4.89E-03	-6.23E-03	1.33E-03	1.88E-03	1.88E-03	2.63E-03
Marine ecotoxicity	-4.76E-03	-6.54E-03	-5.77E-03	-5.76E-03	1.62E-02	2.27E-02	2.08E-02	2.90E-02
Marine eutrophication	-5.28E-06	-7.79E-06	-4.50E-04	-5.90E-04	1.41E-05	1.92E-05	1.93E-05	2.69E-05
Terrestrial ecotoxicity	-8.10E-04	-1.17E-03	-1.14E-03	-1.40E-03	2.50E-04	2.70E-04	9.70E-04	1.36E-03

Table S9 List of matched processes in the life cycle inventory database

Material or energy	Inventory detail	Database
Inputs		
Aluminum	metal working, average for aluminium product manufacturing, alloc. default, S	Ecoinvent 3.7
Chemicals, inorganic	market for chemicals, inorganic, alloc. default, S-GLO	Ecoinvent 3.7
Chemicals, organic	market for chemical, organic, alloc. default, S-GLO	Ecoinvent 3.7
Concrete block	concrete block production, alloc. default, S-DE	Ecoinvent 3.7
De-ionised water	De-ionised water, production mix, at plant, reverse osmosis, from surface water-RER	USLCI
Drying	drying of maize grain, alloc. default, S-Quebec	Ecoinvent 3.7
Electricity	Electricity, Eastern US, 2014	USLCI
Gasoline	Gasoline, combusted in equipment-RNA	USLCI
Grinding	Grinding-RNA	Ecoinvent 3.7
Nylon	nylon 6-6 production, alloc. default, S-RER	Ecoinvent 3.7
Occupation, sea and ocean	Resource/in water	USLCI
Rigid polypropylene	Thermoforming, rigid polypropylene part, at plant-RNA	USLCI
Polyethylene terephthalate	Polyethylene terephthalate (PET) virgin resin, at plant, kg-RNA	USLCI
PVC	Polyvinyl chloride, resin, at plant-RNA	USLCI
Steel	Steel, cold-formed studs and track, at plant-RNA	USLCI
Transportation	Transport, combination truck, long-haul, diesel powered, Northeast	USLCI
Avoided products		
Diammonium phosphate	diammonium phosphate production, alloc. default, S-RER	Ecoinvent 3.7
Electricity	Electricity, at Grid, US, 2010	USLCI
Fishmeal	fishmeal; indirect steam dried press cake; at plant; moisture content 5-10%	USLCI
Lettuce	lettuce361 production, alloc. default, S-GLO	Ecoinvent 3.7
Urea ammonium nitrate production	urea ammonium nitrate production, alloc. default, S-RER	Ecoinvent 3.7

Table S10 List of website address of online resources (websites were visited in April 2021)

Item	Website address
Spool - 2 inch PVC Tube	https://www.homedepot.com/p/JM-EAGLE-2-in-x-10-ft-280-PSI-Schedule-40-PVC-DWV-Plain-End-Pipe-531137/100161954
Settling tube - 4 inch PVC Tube	https://www.homedepot.com/p/JM-EAGLE-4-in-x-10-ft-220-PSI-PVC-Sch-40-DWV-Plain-End-Pipe-531103/100156409
Settling tube cap - 4 inch PVC End Cap	https://www.homedepot.com/p/NDS-4-in-PVC-Sewer-and-Drain-Cap-4P06/100172701
Settling tube - PVC primer & glue	https://www.amazon.com/Oatey-30246-Regular-Cement-4-Ounce/dp/B0002YU23O
Seeding line	https://www.amazon.com/SGT-KNOTS-Twisted-Strength-Versatile/dp/B00XBFARBI?ref_=ast_sto_dp&th=1
F/2 media	https://pentairaes.com/proline-f-2-algae-food.html
Nursery labor cost	https://www.indeed.com/jobs?q=lobster+maine&l=
Anchor block	http://gravesconcrete.com/precast-block/
Anchor chain	https://shop.hamiltonmarine.com/products/chain-g-30-sc-1-00-1--mooring-chain--60--drum--37849.html
Anchor buoy	https://www.westmarine.com/buy/taylor-made--sur-moor-taper-buoy--P005_154_003_500?recordNum=32
Longline and control lines	https://www.westmarine.com/buy/new-england-ropes--classic-spun-three-strand-polyester-line-sold-by-the-foot--P002_071_004_004
Small buoy	https://www.amazon.com/attwood-9350-4-Anchor-Buoy/dp/B00HOHAXDG?ref_=fsclp_pl_dp_2
Drop line	https://www.westmarine.com/buy/new-england-ropes--classic-spun-three-strand-polyester-line-sold-by-the-foot--P002_071_004_004
Strengthener - 1" PVC	https://www.homedepot.com/p/1-in-x-10-ft-PVC-Schedule-40-Plain-End-Pipe-531194/202280936
Line weight	https://fagenstrom.co/products/block.html
Bucket	https://www.homedepot.com/p/Leaktite-5-gal-70mil-Food-Safe-Bucket-White-005GFSWH020/300197644
Gasoline	https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=emd_epd2d_pte_nus_dpg&f=a
Crane barge rental	http://dbrcinc.org/EquipmentRates.html
Seaweed farm labor cost	https://www.maine.gov/labor/labor_laws/minwagehistory.html
Barge	https://yachts360.com/how-much-does-a-fishing-boat-cost/
Hammermill	https://www.alibaba.com/product-detail/corn-rice-husk-hammer-mill-also_1600067326470.html?spm=a2700.galleryofferlist.normal_offer.d_title.305e3b02JL6spZ
Drying machine	https://www.alibaba.com/showroom/small-grain-dryer.html

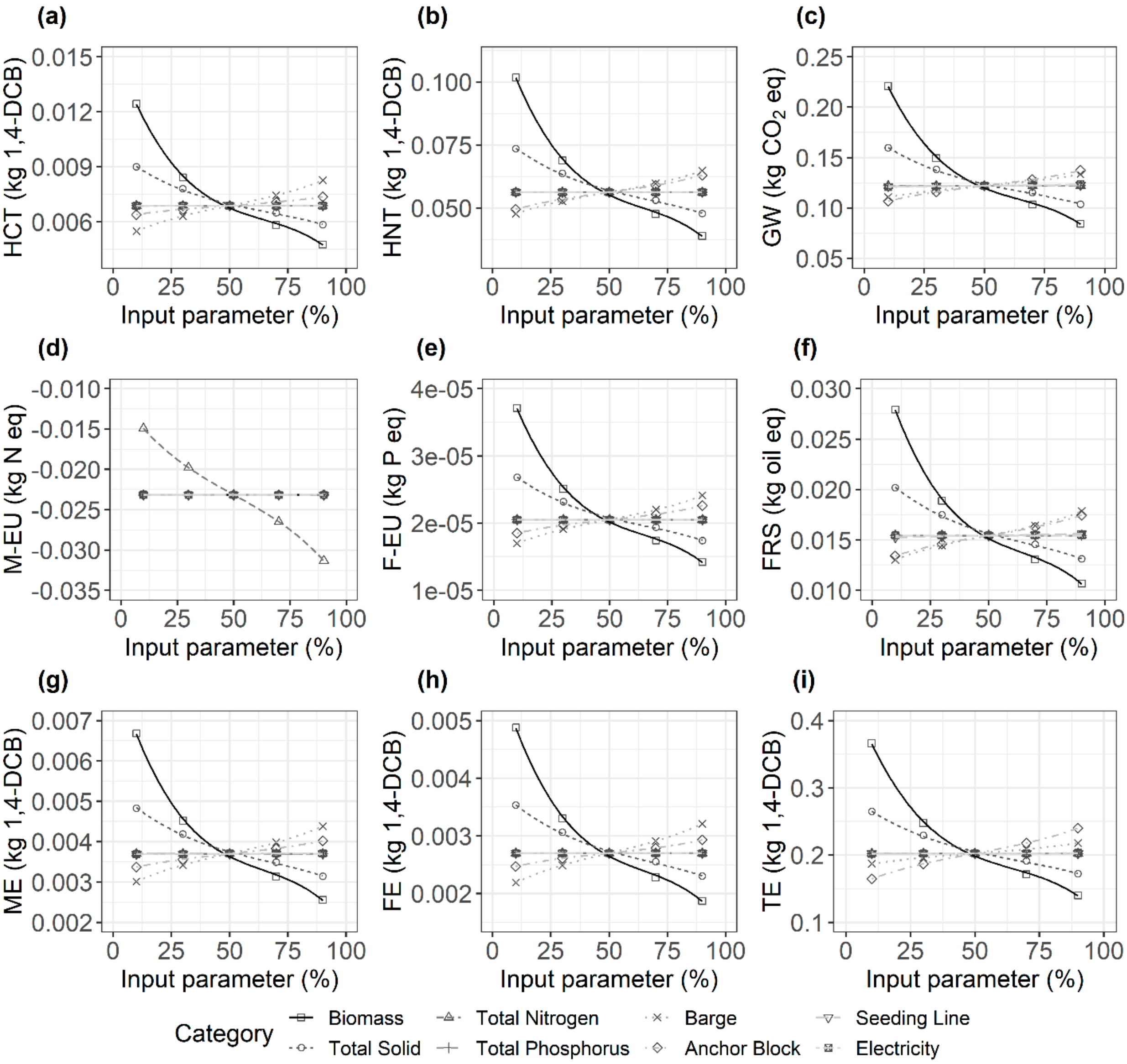

Figure S1 Sensitivity analysis of the LCA for S. latissima cultivation strategy C1 and cultivation platform S1. A triangle distribution was applied on each parameter with min, max, and mode values. The x-axis indicates percentile of the input value in the probability distribution. The 50 percentile values were the values used in the LCA. Only parameters with greater than 1% influence are plotted for each impact category. (a) Human carcinogenic toxicity; (b) human non-carcinogenic toxicity; (c) global warming potential; (d) marine eutrophication; (e) freshwater eutrophication; (f) fossil resource scarcity; (g) marine ecotoxicity; (h) freshwater ecotoxicity; (i) terrestrial ecotoxicity

SI. Equations used for estimation of annual project cost:

$$annual\ project\ cost = ammortization\ cost + O\&M\ cost \qquad \text{Eq. (S1)}$$

$$amortization\ cost = \left(\frac{R}{(1+R)^{LP}-1} + R\right) + cost \qquad \text{Eq. (S2)}$$

Where: R = interest rate as a fraction; LP = lifespan of the project; cost = initial cost + replacement costs – salvage value

$$replacement\ cost = initial\ cost\ \left(\frac{1}{(1+R)^{RS}} + \frac{1}{(1+R)^{2RS}} + \cdots + \frac{1}{(1+R)^{N(RS)}}\right) \qquad \text{Eq. (S3)}$$

$$salvage\ cost = initial\ cost\ \left(\frac{RS + N(RS) - LP}{RS}\right) \qquad \text{Eq. (S4)}$$

Where: N = number of times it is replaced = LP/RS (rounded to an integer); RS = replacement schedule in years.

SI. List of acronyms

AD: anaerobic digester

CHP: combined heat and power

DW: dry weight

FW: fresh weight

LCA: life cycle assessment

LCI: life cycle inventory

LCIA: life cycle impact assessment

O&M: operation and maintenance

USLCI: U.S. Life Cycle Inventory Database

TEA: techno-economic analysis

VS: volatile solids

M-EU: marine eutrophication

F-EU: freshwater eutrophication

GW: global warming

HCT: human carcinogenic toxicity

HNT: human non-carcinogenic toxicity

ME: marine ecotoxicity

FE: freshwater ecotoxicity

TE: terrestrial ecotoxicity

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