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VYTAUTO DIDŽIOJO
UNIVERSITETAS

Vytautas Magnus University
Agriculture Academy

Invasive herbaceous plant biomass utilization for solid biofuel production

Researchers: Gvidas Gramauskas, Algirdas Jasinskas and Kęstutis Romaneckas

Presenter: Gvidas Gramauskas

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Relevance and scientific problem

The problem with the eradication, processing and safe use of invasive herbaceous plants such as Sosnowski's hogweed, giant knotweed and reeds is becoming increasingly relevant. Therefore, it is appropriate to analyse the harvesting of various large-stemmed herbaceous plants and the peculiarities of their preparation for biofuel and their pressing, to investigate the technologies and equipment suitable for processing invasive plants and preparing them for biofuel.

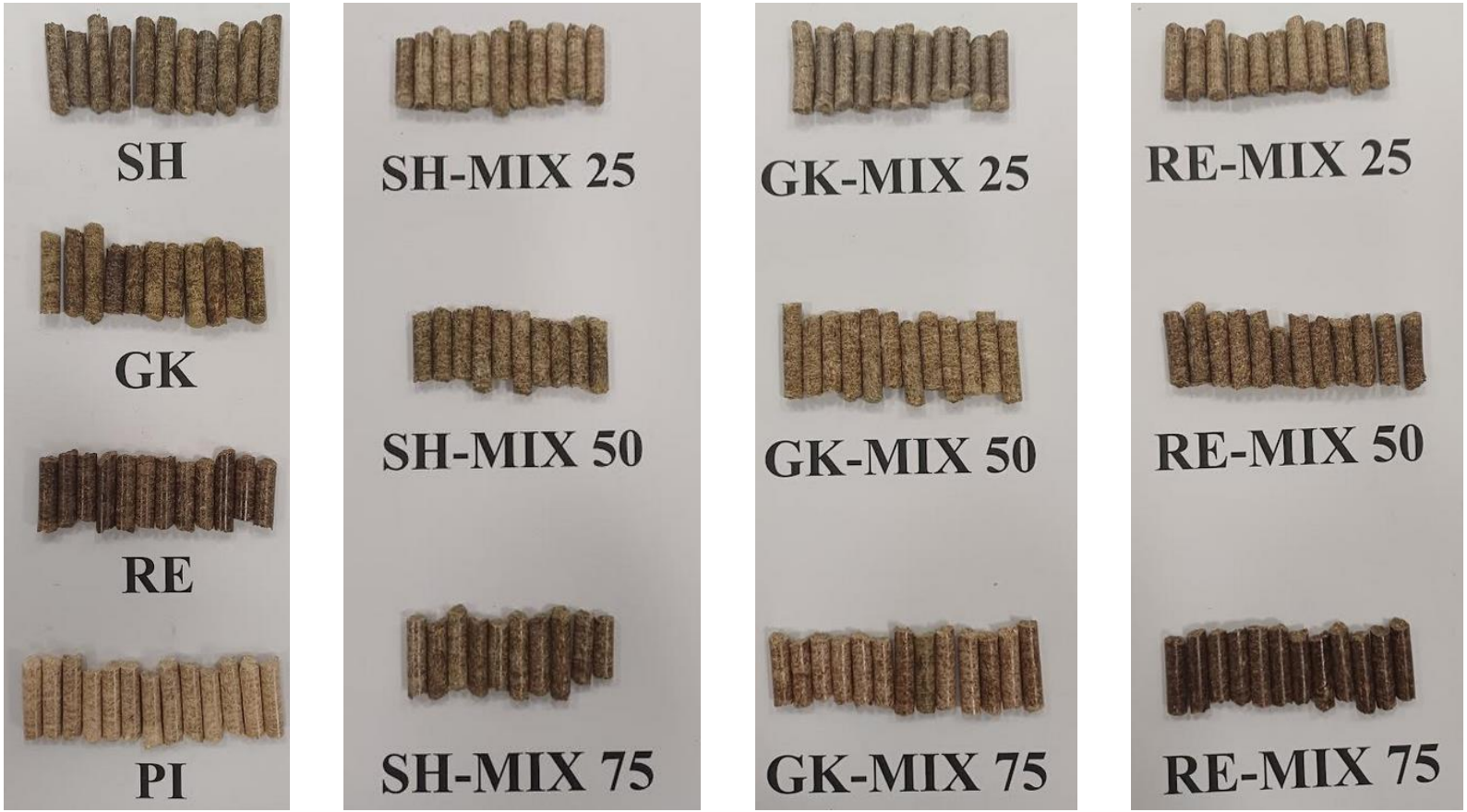


Figure 1. Invasive herbaceous plant and their mixture pellets

Figure 2. Sosnowsky's hogweed (left) and giant knotweed (right) briquettes

Plant species	Pellet parameters				
	Diameter d, mm	Length l, mm	Volume V, m^3	Mass m, g	Density ϱ, $kg\ m^{-3}$
Sosnowky's hogweed	6.2 ± 0.22	23.6 ± 0,93	$(7.5 \pm 0.59) \cdot 10^{-7}$	0.7 ± 0.08	1145.6 ± 37.50 a
Giant knotweed	6.1 ± 0.09	23.1 ± 0.84	$(6.8 \pm 0.25) \cdot 10^{-7}$	0.7 ± 0,04	1227.5 ± 39.82 b
Reed	6.1	22.2	$(5.8 \pm 0.25) \cdot 10^{-7}$	0.6	1198.3
S.H. 25%	6.1	17.5	$(5.2 \pm 0.25) \cdot 10^{-7}$	0.6	1124.8
S.H. 50%	6.1	23	$(6.7 \pm 0.25) \cdot 10^{-7}$	0.8	1188.6
S.H. 75%	6.1	15.9	$(4.7 \pm 0.25) \cdot 10^{-7}$	0.5	1145.8
G.K. 25%	6.1	21.5	$(6.2 \pm 0.25) \cdot 10^{-7}$	0.8	1236.5
G.K. 50%	6	17.8	$(5.1 \pm 0.25) \cdot 10^{-7}$	0.7	1278.0
G.K. 75%	6.1	22.7	$(6.6 \pm 0.25) \cdot 10^{-7}$	0.8	1205.9
Reed 25%	6	19.5	$(5.5 \pm 0.25) \cdot 10^{-7}$	0.7	1221.6
Reed 50%	6.1	20.1	$(5.8 \pm 0.25) \cdot 10^{-7}$	0.7	1154.1
Reed 75%	6	22.2	$(6.3 \pm 0.25) \cdot 10^{-7}$	0.8	1341.0
Pinewood	6.1 ± 0.13	30.7 ± 0.88	$(8.9 \pm 0.83) \cdot 10^{-7}$	1.1 ± 0.14	1182.5 ± 34.46 ab

Table 1. Physical properties of pellets

Plant species	Briquette parameter				
	Diameter *d*. mm	Length *l*. mm	Volume *V*. m^3	Mass *m*. g	Density *ϱ*. kg m^{-3}
Sosnowsky's hogweed and pine mix	80.20 ± 0.25	107.66 ± 21.70	$(4.46 \pm 0.14) \cdot 10^{-5}$	385.56 ± 19.36	866.88 ± 11.49
Sosnowsky's hogweed	80.11 ± 0.32	89.5 ± 25.46	(3.75 ± 1.10) · 10-5	326.30 ± 51.55	867.31 ± 17.97
Giant knotweed and pine mix	80.07 ± 0.35	131 ± 16.14	(5.44 ± 0.22) · 10-5	431.33 ± 40.38	792.84 ± 12.20
Giant knotweed	80.48 ± 0.73	149.66 ± 20.18	(6.30 ± 0.25) · 10-5	467.70 ± 62.65	743.52 ± 60.21
Pine wood	80.38 ± 0.62	142.33 ± 22.72	$(5.93 \pm 0.84) \cdot 10^{-5}$	553.83 ± 53.21	931.64 ± 85.86

Table 2. Briquette physical parameters

Figure 3. Boiler used for combustion and resulting ash

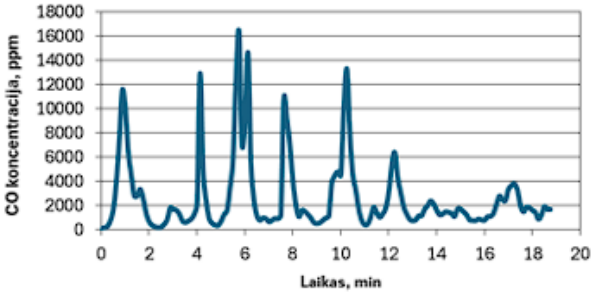


Figure 4. Giant knotweed CO concentration

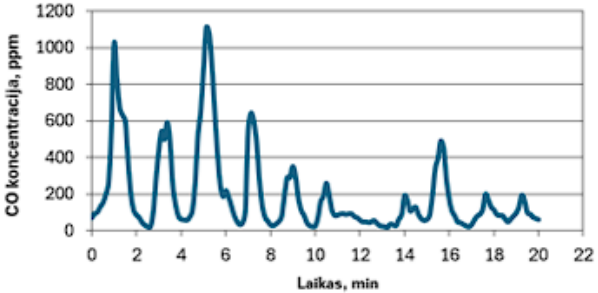


Figure 5. Giant knotweed and pine 1:1 mix CO concentration

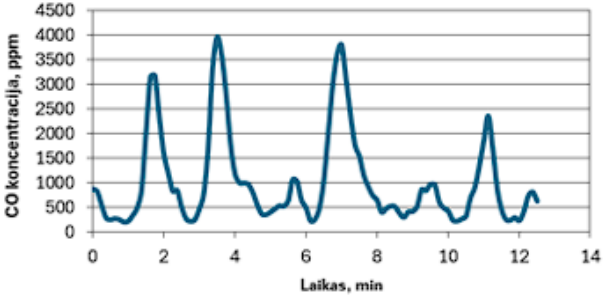


Figure 6. Sosnowsky's hogweed CO concentration

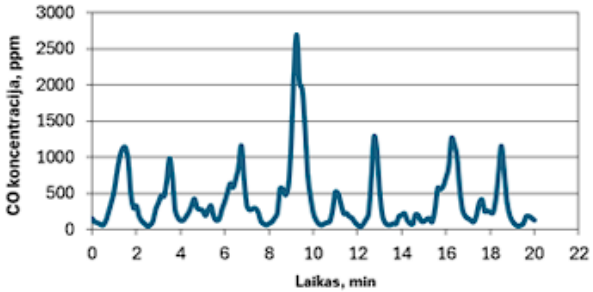


Figure 7. Sosnowsky's hogweed and pine 1:1 mix CO concentration

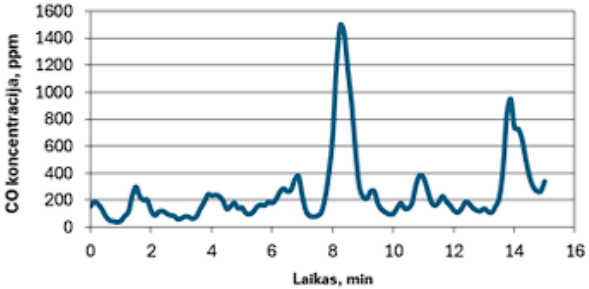


Figure 8. Reed CO concentration

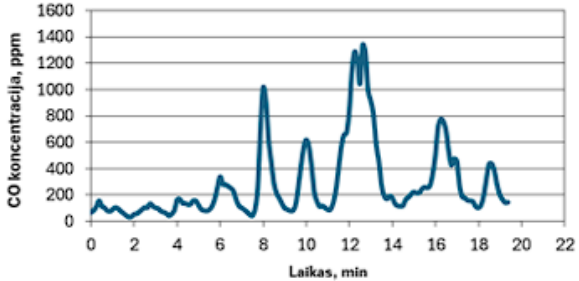


Figure 9. Reed and pine 1:1 mix CO concentration

Parameter	Sosnowsky ´s hogweed	Giant knotweed	Pinewood
	Values		
Ash content, %	7.941 ± 2,20	4.283 ± 0.01	1.137 ± 0.03
Lower calorific value, MJ kg^{-1}	16.884 ± 1.31	18.963 ± 0.28	19.819 ± 0.29
Higher calorific value, MJ kg^{-1}	15.863 ± 1.04	17.739 ± 0.33	18.635 ± 0.33
C, %	48.161 ± 1.66	47.429 ± 1.08	49.532 ± 1.1
H, %	4.564 ± 0.55	5.982 ± 0.43	4.751 ± 0.05
N, %	0.744 ± 0.37	0.711 ± 0.30	< 0.013 ± 0.0
S, %	0.077 ± 0.0	0.051 ± 0.26	< 0.012 ± 0.0
O, %	38.459 ± 0.0	41.553 ± 0.0	43.594 ± 0.0
Cl, %	0.092 ± 0.0	0.261 ± 0.0	0.061 ± 0.0

Table 3. Combustion results

Name	H_2O, %	CO_2, %	O_2, %	CO, ppm	NO_x, ppm	C_xH_y, ppm	SO_2, ppm
Wood pellets	4,6	5,1	13,5	96	55	14	0,0
Pinewood pellets	3,8	4,3	14,7	125	59	9	0,0
Giant knotweed (D.R.)	4,0	4,2	14,3	2667	249	164	3,6
D.R. 75 % + pine. 25 %	3,9	4,1	14,6	1221	131	47	1,4
D.R. 50 % + pine. 50 %	4,2	4,5	14,4	195	111	14	1,0
D.R. 25 % + pine. 75 %	3,9	4,1	14,7	143	59	13	1,9
Soswnowky‘s hogweed (S.B.)	3,7	3,9	15,1	1022	119	29	0,1
S.B. 75 % + pine. 25 %	3,8	3,8	15,1	861	105	36	0,7
S.B. 50 % + pine. 50 %	3,7	4,2	14,8	402	96	18	0,2
S.B. 25 % + pine. 75 %	4,0	4,5	14,4	256	79	13	0,8
Reed	3,5	4,0	15,0	253	174	16	4,1
Reed 75 % + pine. 25 %	3,8	4,0	15,0	232	152	18	8,5
Reed 50 % + pine. 50 %	3,4	3,7	15,5	285	123	25	5,0
Reed 25 % + pine. 75 %	3,9	4,3	14,7	174	113	18	2,3

Table 4. Emissions produced during combustion

Figure 10. Sosnovsky's hogweed research field 2025 1st harvest

Figure 11. Sosnovsky's hogweed research field 2025 2nd harvest

Figure 12. Giant knotweed research field 2025 1st harvest

Figure 13. Giant knotweed research field 2025 2nd harvest

Figure 14. Reed research field 2025 1st harvest

Figure 15. Reed research field 2025 2nd harvest

Figure 16. S.H., G.K. and reed harvested biomass 2025 m. 1st harvest

Month	Sosnowsky's hogweed, g	Giant knotweed, g	Reed, g
April	184,4	294,4	102,3
May	1295	480,3	391
June	1429	1230	1036,5
July	1792	1280	1251,3
August	971	652,2	843,6

Table 5. Invasive herbaceous plant biomass harvested during 2024

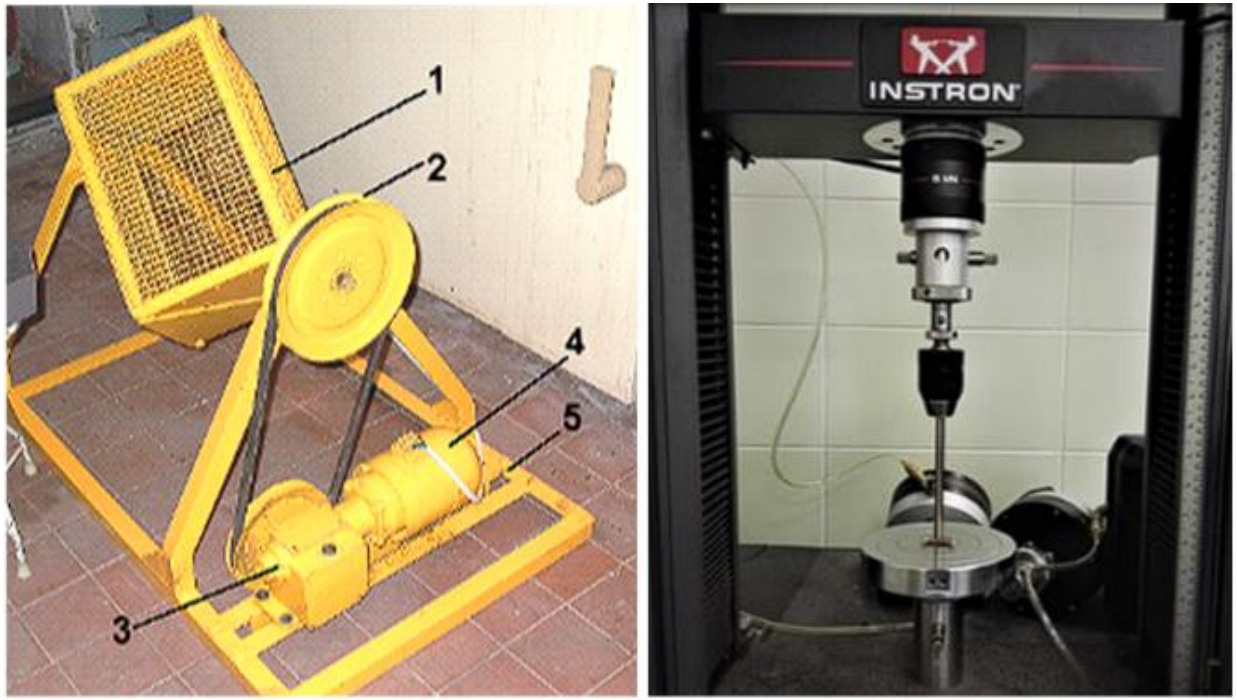


Figure 17. Briquette fragility testing stand: 1 – mesh-covered box for briquettes; 2 – belt drive; 3 – drive; 4 – electric motor; 5 – frame (left); Instron 5965 (right)

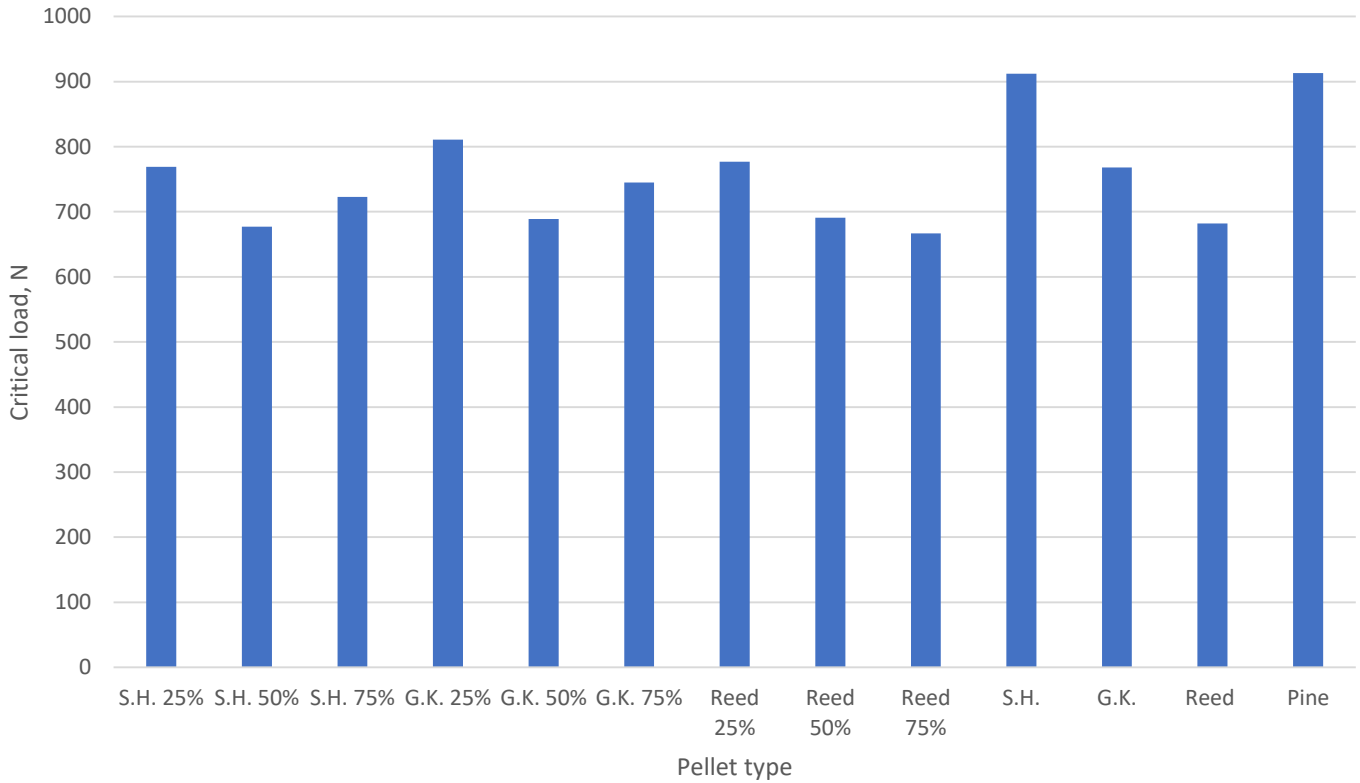


Figure 18. Compressive resistance of pellets test results

Technological process	Energy consumption	
	MJ·ha^{-1}	MJ·kg^{-1}
Total energy consumption of harvesting and transporting invasive plants	2357.6	0.43
Pressed biomass separating, chopping, and transporting	14330	1.433
Biomass drying by reducing moisture by 20%	30233	3.02
Biomass granulating	1900	0.32
Pellet burning in boilers energy consumption	1100	0.18
Sum:		**5.383**
Giant knotweed biomass calorific value		18.96
Boiler efficiency		0.8

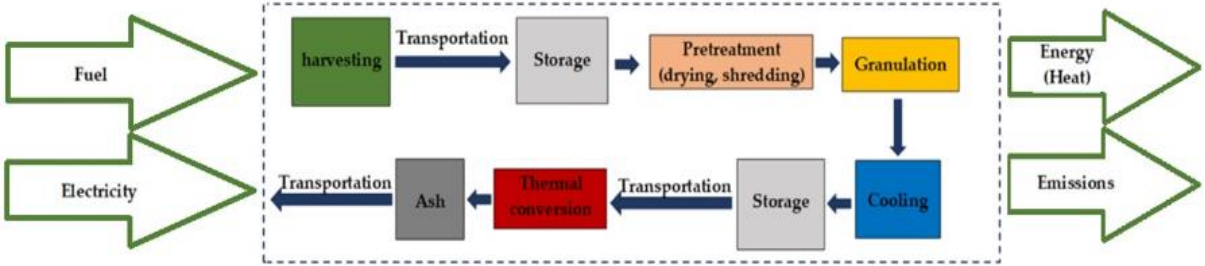
Table 6. Energy costs of preparation of solid biofuel from Sosnovsky hogweed

R= 2.82

Technological process	Energy consumption	
	MJ·ha^{-1}	MJ·kg^{-1}
Total energy consumption of harvesting and transporting invasive plants	1280.16	0.21
Pressed biomass separating, chopping, and transporting	4600	0.77
Biomass drying by reducing moisture by 20%	16730	2.79
Biomass granulating	1900	0.32
Pellet burning in boilers energy consumption	1100	0.18
Sum:		**4.27**
Sosnowsky's hogweed biomass calorific value		16.8
		8
Boiler efficiency		0.8

Table 7. Energy costs of preparation of solid biofuel from giant knotweed

R= 3.16



Impact category	Unit	Sosnowky's hogweed	Giant knot weed	Pinewood
AD	kg Sb_{eq}	1.19×10^{-3}	1.06×10^{-3}	1.01×10^{-3}
ADF	MJ	121.31	107.69	91.99
GWP	kg CO_{2eq}	10.98	9.76	8.47
ODT	kg CFC-11_{eq}	9.12×10^{-7}	8.08×10^{-7}	6.49×10^{-7}
HT	kg 1,4-DB_{eq}	56.36	50.18	47.33
FWAE	kg 1,4-DB_{eq}	35.94	32.03	30.16
MAE	kg 1,4-DB_{eq}	50676.49	45128.05	42436.43
TE	kg 1,4-DB_{eq}	6.08×10^{-2}	5.42×10^{-2}	5.08×10^{-2}
PO	kg C_2H_{4eq}	3.72×10^{-3}	3.32×10^{-3}	2.94×10^{-3}
AP	kg SO_{2eq}	6.07×10^{-2}	5.39×10^{-2}	4.50×10^{-2}
EP	kg $PO_4^-{}_{eq}$	3.43×10^{-2}	3.05×10^{-2}	2.73×10^{-2}

Table 8. Characterized impacts on environment per functional unit