1 Peatland mapping

Mapping of peatland was conducted. All the peatland in Etelä Savo region is represented in Figure 1 with all currently harvested peatlands in blue and peatlands over 100 hectares as magenta. Green areas denote the municipalities of Joroinen and Heinävesi, which were removed from Etelä Savo in 2021. Peatlands above 100 hectares for each municipality was taken and Figure 2, 3, 4, 5.

All the peatlands above 100 hectares are represented in Figure 1.

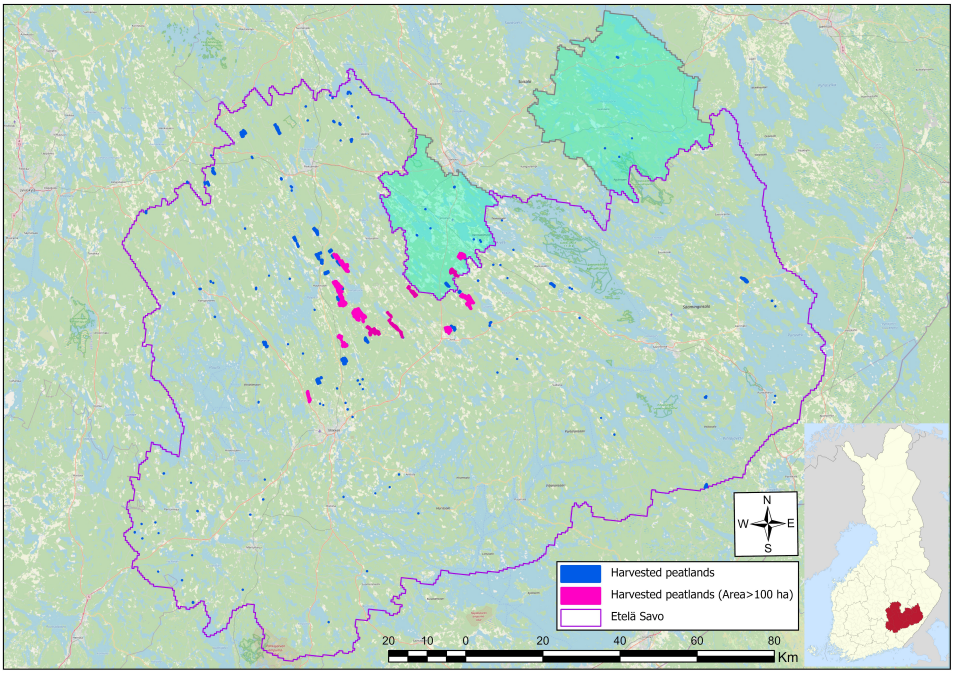

Figure 1: Peatlands in Etelä Savo

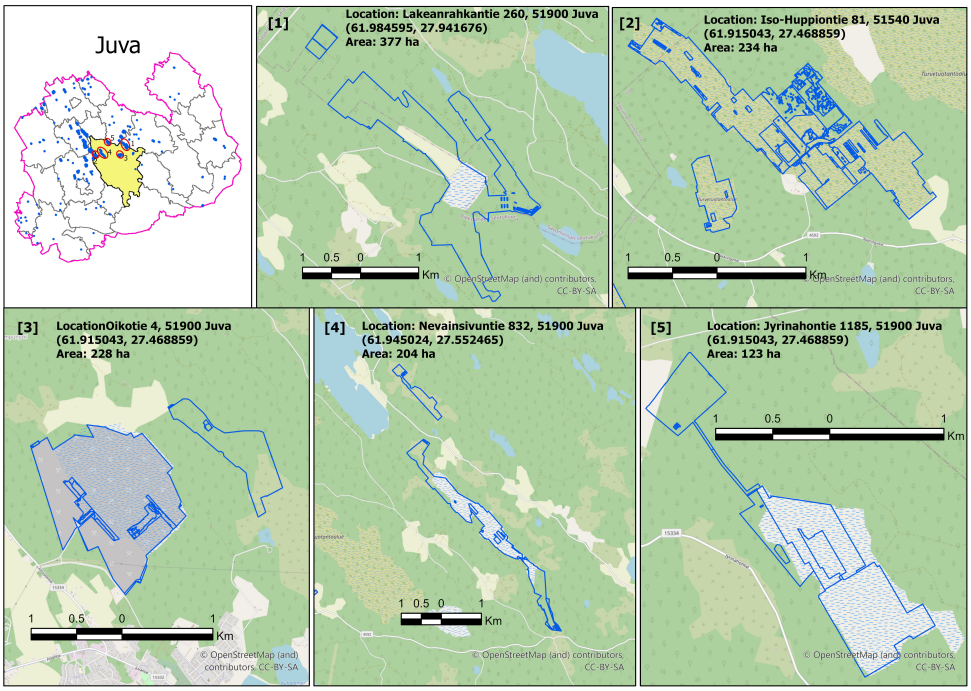

Figure 2: Peatlands above 100 ha in Juva

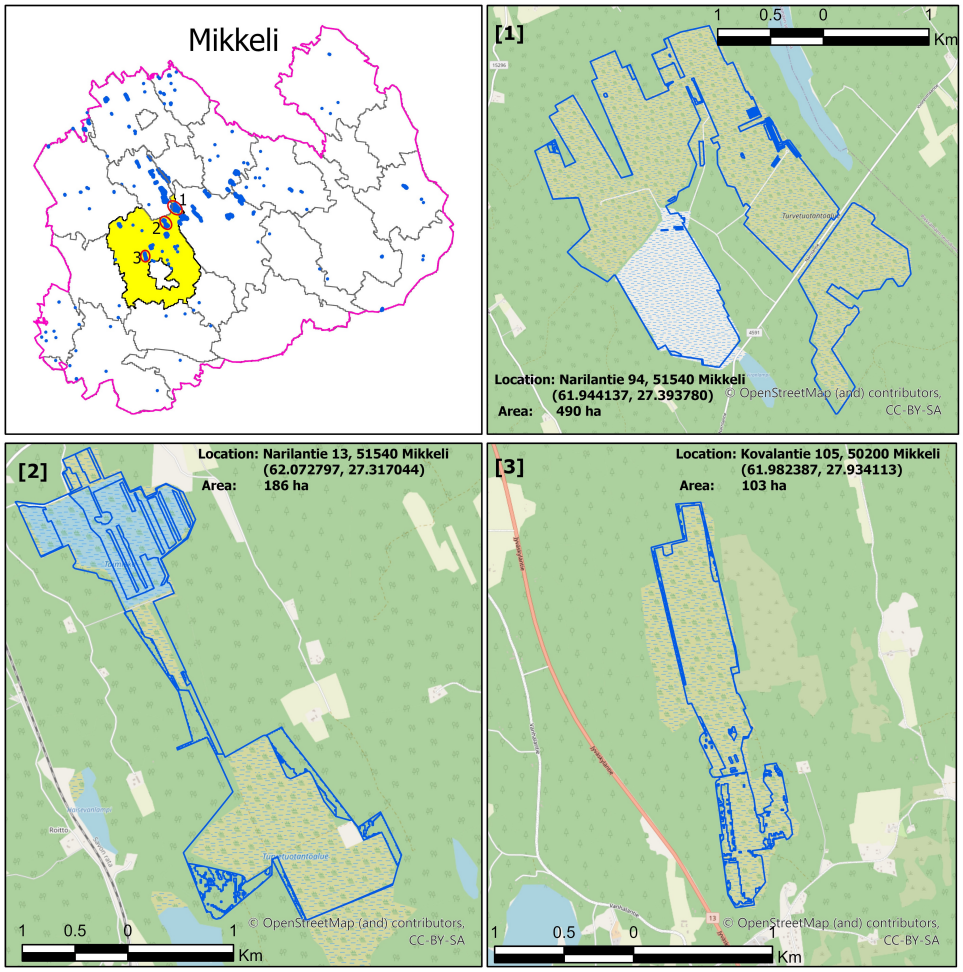

Figure 3: Peatlands above 100 ha in Mikkeli

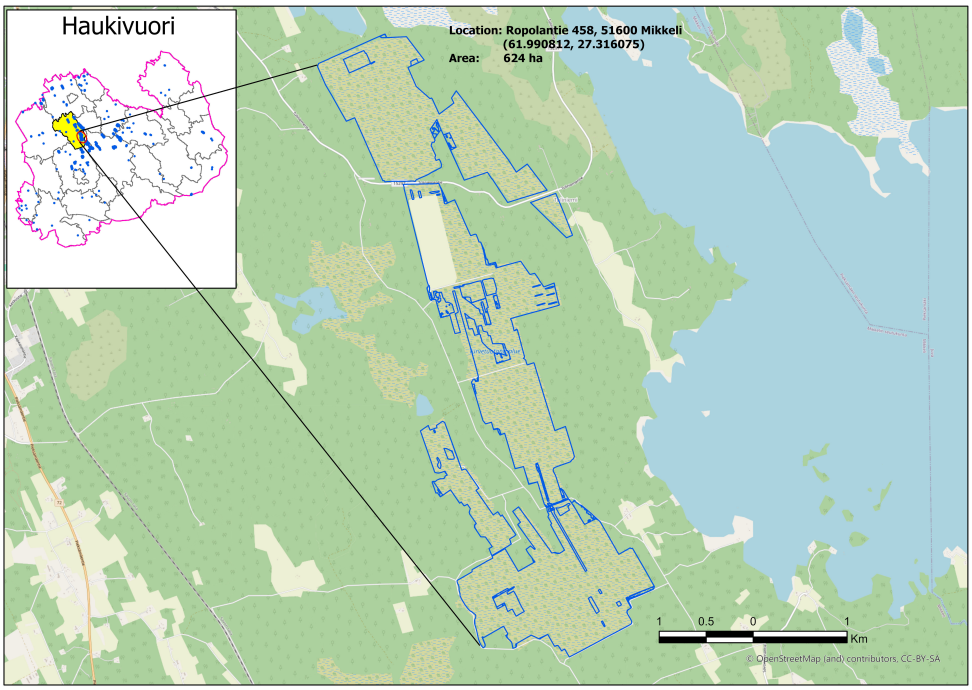

Figure 4: Peatlands above 100 ha in Haukivouri

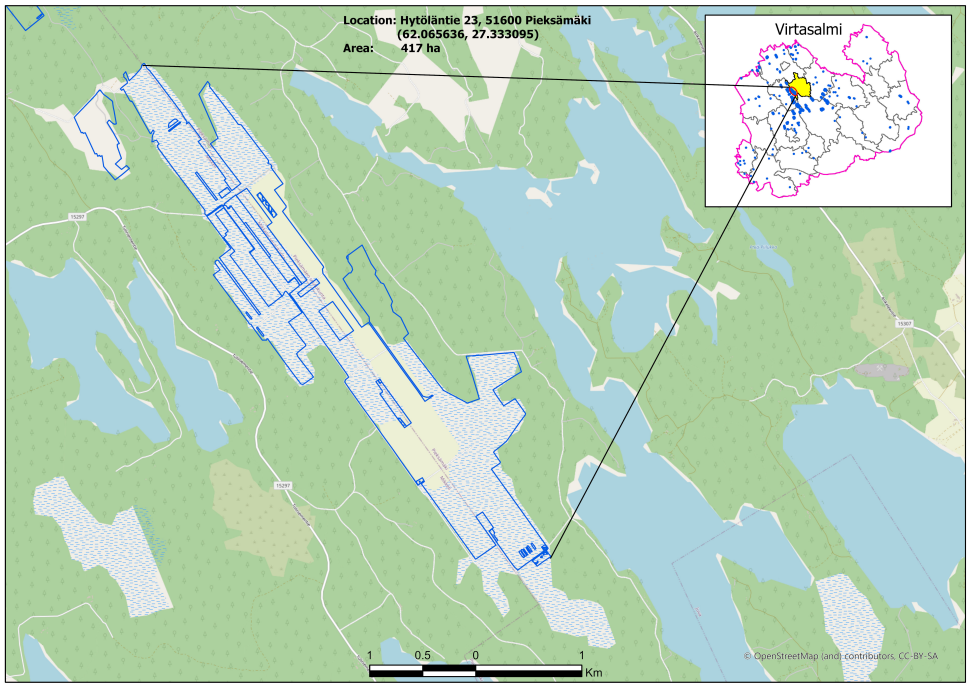

Figure 5: Peatlands above 100 ha in Pieksamäki

2 Affects of halting peat

Table 1: Peat contribution to the economy, yearly (Valonen et al., 2021)

Location	Gross Value (k€)	Processing Value (k€)	Work-years	Locations
South Savo	11 028	1 800	29	11
Mikkeli	10 380	1 513	24	7
Pieksamäki	648	286	5	4

Table 2: Factors for GWP

CO_2	1
CH_4	27
N_2O	273

3 Scenarios

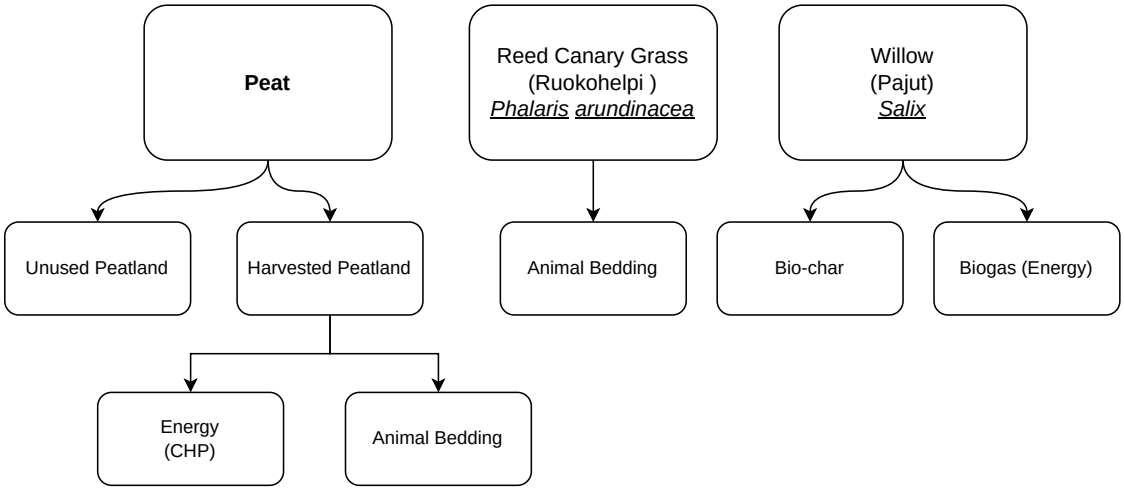

Figure 6: System boundaries and end product scenarios considered in the study

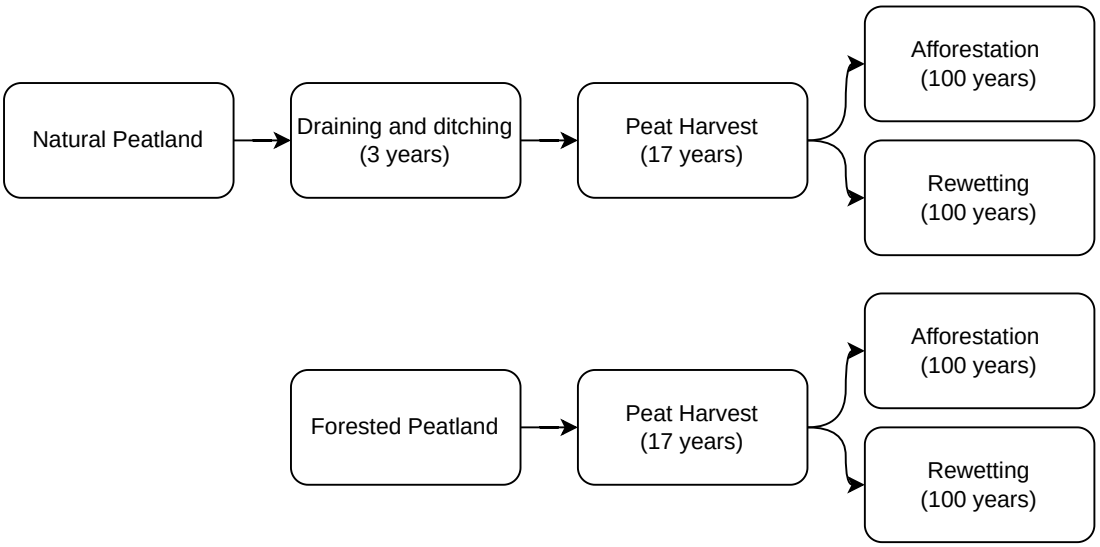

Figure 7: Peat harvest timelines

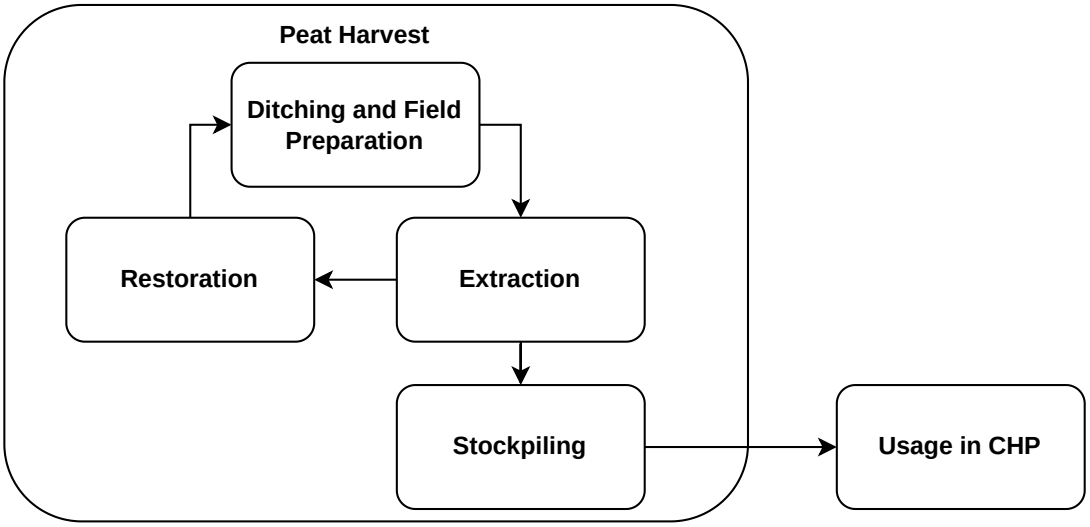

Figure 8: System boundary for peat as energy

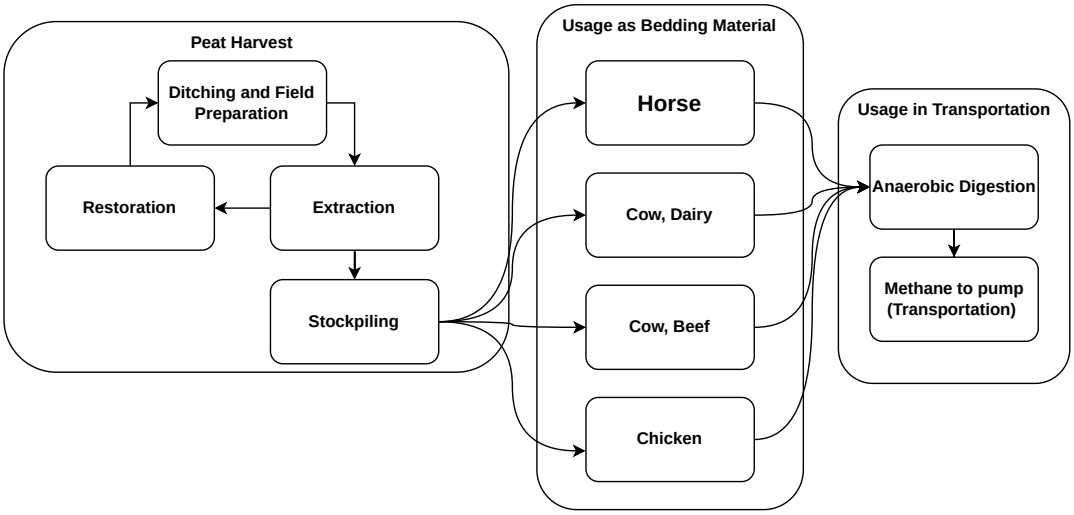

Figure 9: Processes and system boundary in peat as animal bedding material

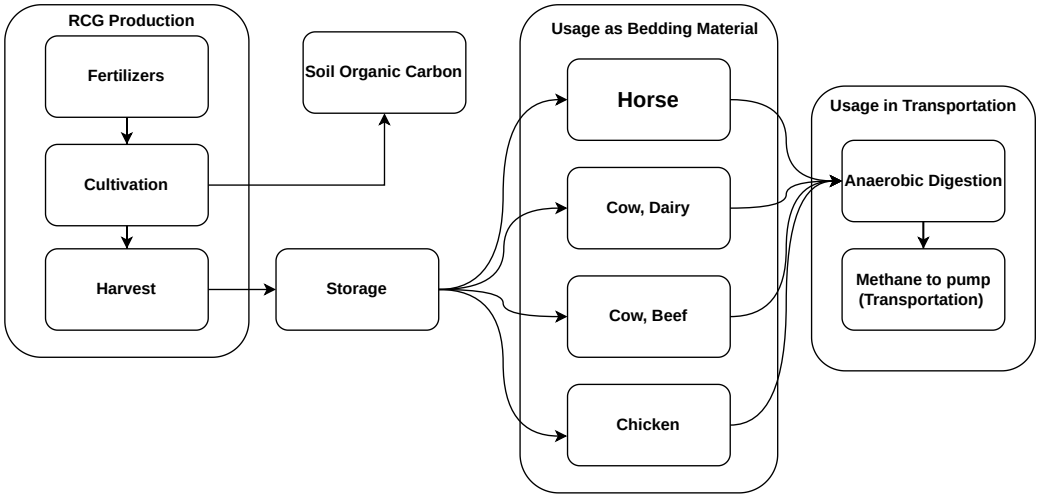

Figure 10: Processes and system boundary in reed canary grass harvest and usage as animal bedding material

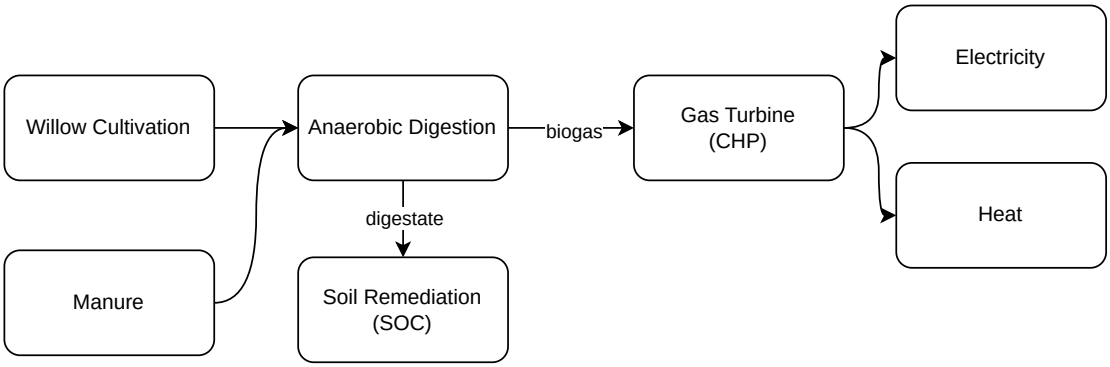

Figure 11: Processes and system boundary in willow usage in energy

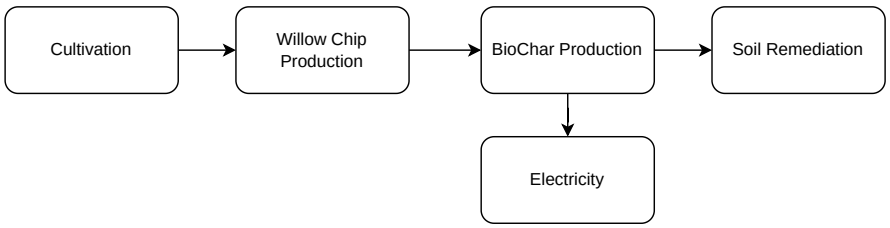

Figure 12: Processes and system boundary Willow usage for biochar

4 Peat

Table 3: Properties of Peat

Source	**VTT**	**Ekono**	**Vapo**
Moisture,w-%	48.5	47.1	45.9
Density as received, kg/m3		330	313
Net calorific value as received, MJ/kg	9.6	9.9	9.8

Table 4: Yearly fuel prices, peat in electricity production.

Year	eur/MWh	€/tonnes	€/m3	€/ha
2022	12.75	37.19	13.02	5100
2023	15.5	45.21	15.82	6200
2024	17.0	49.58	17.35	6800
2025	17.0	49.58	17.35	6800

Table 5: Years taken for each phase of peat lifecycle

	Ditching	Production	Restoration	Total
Nat-extraction-Afforestation	3	17	100	120
Nat-extraction-Rewetting	3	17	100	120
Forest-extraction-Afforestation	0	17	100	117
Forest-extraction-Rewetting	0	17	100	117

* Mälkki and Frilander, 1997

GWP calculation of peat in Table 4 includes average 84km of transportation with a diesel powered truck with a load capacity of 44 Tons.

From Mälkki and Frilander (1997), peat harvested is 300–1000 m^3 per hectare per year. Best case scenario of 1000 m^3 per hectare was assumed. Moisture content of 50% was assumed.

From, Table 5, only 17 out of the whole life cycle is harvested. Adjusted value was calculated by taking this into account

Pellervon taloustutkimus (PTT) modelled the regional economic impacts of halting the use of energy peat. The national impacts were adequate. However, the most significant relative impacts were identified in South-Ostrobothnia. Halting the use also impacts North-Ostrobothnia and Central Finland where peat is extracted. The overall decrease in labour would be 1260 person-work years considering complete value chain of peat. (Valonen et al., 2021)

Table 6: Peat LCA

Process	GWP_{100} [gCO_2eq./MJ]
Peatland	-42.2
Production	14.4
Transportation	0.3
Combustion	107.5
Afforestation	-7.4

Table 7: GWP calculation of peat lifecycle

	CH_4* [g]	CO_2* [kg]	N_2O* [g]	GWP/MWh [gCO_2e]	GWP/m^2/yr [kgCO_2e]	GWP/m^2/yr$_{\text{adjusted}}$ [kgCO_2e]
Nat-ext-Aff	-790	400	16	383038	3.40	23.97
Nat-ext-Rew	-380	420	16	414108	3.67	25.91
For-ext-Aff	-770	400	16	383578	3.49	24.00
For-ext-Rew	-370	420	16	414378	3.77	25.93

* Mälkki and Frilander, 1997

Table 8: GWP of peat, yearly

		GWP/m^2 kgCO_2e	GWP/ha tCO_2e	WEI/m^2 €	WEI/ha €
Harvested	Nat-ext-Aff	23.97	239.70	-1.25	-12,464.32
	Nat-ext-Rew	25.91	259.14	-1.35	-13,475.35
	For-ext-Aff	24.00	240.04	-1.25	-12,481.89
	For-ext-Rew	25.93	259.31	-1.35	-13,484.14
Unused	Natural Peatland	0.12	1.18	-0.01	-61.48
	Drained Forest	0.67	6.66	-0.03	-346.09

Table 9: Scenario summary: Peat Extraction and Afforestation

		Nat-ext-Aff				For-ext-Aff			
v min	€/ha				12,000.00				12,000.00
v max	€/ha				15,000.00				15,000.00
GWP/ha/yr	$kgCO_2e$				23.97				24.00
GWP/ha/yr	tCO_2e				239.70				240.04
WEI/ha/yr	€				-12,464.32				-12,481.89
production	years/years				0.14				0.15
GEImin	€/ha				-464.32				-481.89
GEImax	€/ha				2,535.68				2,518.11
		Horse	Cow,dairy	Cow,beef	Chicken	Horse	Cow,dairy	Cow,beef	Chicken
Methane VA	€/m^3		1.6				1.6		
Methane output	m^3/ha	25.8	36.9	36.9	31.7	25.8	36.9	36.9	31.7
GWP_methane	$kgCO_2e$/yr/ha	0.65	0.92	0.92	0.79	0.65	0.92	0.92	0.79
	tCO_2e/yr/ha	0.000645	0.000923	0.000923	0.000793	0.000645	0.000923	0.000923	0.000793
WEI_methane	€/ha/yr	-0.03354	-0.04797	-0.04797	-0.04121	-0.03354	-0.04797	-0.04797	-0.04121
GEI_methane	€/ha/yr	41.25	58.99	58.99	50.68	41.25	58.99	58.99	50.68
GEI_total (min)	€/ha/yr	-423.07	-405.32	-405.32	-413.64	-440.64	-422.90	-422.90	-431.21
GEI_total (max)	€/ha/yr	2,576.93	2,594.68	2,594.68	2,586.36	2,559.36	2,577.10	2,577.10	2,568.79

Table 10: Scenario Summary: Peat Extraction and Rewetting

		Nat-ext-Rew				For-ext-Rew			
v min	€/ha				12,000.00				12,000.00
v max	€/ha				15,000.00				15,000.00
GWP/ha/yr	$kgCO_2e$				25.91				25.93
GWP/ha/yr	tCO_2e				259.14				259.31
WEI/ha/yr	€				-13,475.35				-13,484.14
production	years/years				0.14				0.15
GEImin	€/ha				-1,475.35				-1,484.14
GEImax	€/ha				1,524.65				1,515.86
		Horse	Cow,dairy	Cow,beef	Chicken	Horse	Cow,dairy	Cow,beef	Chicken
Methane VA	€/m^3	1.6				1.6			
Methane output	m^3/ha	12.9	18.45	18.45	15.85	12.9	18.45	18.45	15.85
GWP_methane	$kgCO_2e$/yr/ha	0.65	0.92	0.92	0.79	0.65	0.92	0.92	0.79
	tCO_2e/yr/ha	0.000645	0.000923	0.000923	0.000793	0.000645	0.000923	0.000923	0.000793
WEI_methane	€/ha/yr	-0.03354	-0.04797	-0.04797	-0.04121	-0.03354	-0.04797	-0.04797	-0.04121
GEI_methane	€/ha/yr	41.25	58.99	58.99	50.68 41.25	58.99	58.99	50.68	
GEI_total (min)	€/ha/yr	-1,434.11	-1,416.36	-1,416.36	-1,424.68	-1,442.89	-1,425.15	-1,425.15	-1,433.46
GEI_total (max)	€/ha/yr	1,565.89	1,583.64	1,583.64	1,575.32	1,557.11	1,574.85	1,574.85	1,566.54

Table 11: Scenario summary: Reed Canary Grass

		Rainfed				Irrigated			
v min	€/ha	450.00				450.00			
v max	€/ha	560.00				560.00			
GWP/ha/yr	tCO_2e	2.38				4.30			
	tCO_2e	-4.06				-3.95			
WEI/ha/yr	€	-123.64				-223.60			
GWP/ha/yr (wSOC)	tCO_2e	-1.68				0.35			
WEI(wSOC)	€	87.27				-18.34			
GEI	€	326.36				226.40			
GEI (wSOC)	€	537.27				431.66			
		Horse	Cow,dairy	Cow,beef	Chicken	Horse	Cow,dairy	Cow,beef	Chicken
Methane VA	$€/m^3$	1.6				1.6			
	m^3/ha	6,292.13	8,999.21	8,999.21	7,731.03	8,727.80	12,482.78	12,482.78	10,723.69
GWP_methane	$kgCO_2e$/ha/yr	314.61	449.96	449.96	386.55	436.39	624.14	624.14	536.18
	tCO_2e/ha/yr	0.3146	0.4500	0.4500	0.3866	0.4364	0.6241	0.6241	0.5362
WEI_methane	€/ha/yr	-16.36	-23.40	-23.40	-20.10	-22.69	-32.46	-32.46	-27.88
GEI_methane	€/ha/yr	10,051	14,375	14,375	12,350	13,942	19,940	19,940	17,130
GEI_total	tCO_2e/yr/ha	10,377	14,702	14,702	12,676	14,168	20,166	20,166	17,356
GEI_total (wSOC)	WEI/ha/yr	10,915	15,239	15,239	13,213	14,373	20,372	20,372	17,562

Table 12: Scenario summary: Peat usage in energy

Price [a]	€/Mwh	17
Yield	Mwh/ha/yr	359.7
Value Added.	€/ha/yr	6115.07
GWP [b]	tCO2e/ha/yr	137,769
WEI	€/ha/yr	-7,163,984
GEI	€/ha/yr	-7,157,869

[a] Energy peat price 2025 (stat.fi)

[b] Combustion of peat only (Grönroos et al., 2013)

5 Reed Canary Grass

Table 13: GWP of RCG production

			Rainfed	Irrigated
Value	v min	€/ha	450	450
	v max	€/ha	560	560
Production	GWP/m^2/yr	kgCO_2e	0.24	0.43
	GWP/ha/yr	tCO_2e	2.38	4.3
	WEI/ha/yr	€	−123.64	−223.6
SOC	GWP/m^2/yr	kgCO_2e	−0.41	−0.39
	GWP/ha/yr	tCO_2e	−4.06	−3.95
	WEI/ha/yr	€	210.91	205.26

Iordan et al., 2023

Calculation of GWP of RCG in Table 4 excludes 50km of transportation using a diesel truck with a payload of 44 Tons with a GWP of 0.07 kgCO_2e per 1000 km. The value of 0.000826 kgCO_2e per square meter of farmed land.

5.1 Usage as bedding material

Table 14: Peat land required for animal bedding, per year

	unit	Horse	Cow, dairy	Cow, beef	Chicken
yearly bedding required	m^3/animal	18	4	5.9	0.007
peatland required per year	m^2	360	80	118	0.14
bedding waste output	t	9.288	2.952	4.3542	0.004438
bedding waste per ha	t/ha	258	369	369	317
bio-methane per ha of peatland	m^3 ha	12.9	18.45	18.45	15.85

Lehtoranta et al., 2021; Laine, 2024

Table 15: RCG required for usage as bedding material, per year

	unit	Horse	Cow,dairy	Cow,beef	Chicken
yearly bedding required	m^3/animal	104	107	89	1
bedding waste	t	53.664	78.966	65.682	0.634
land required (rainfed RCG)	m^2/animal	7,675.87	7,897.29	6,568.77	73.81
bedding waste per ha	t/ha	69.91	99.99	99.99	85.90
biomethane per ha	m^3/ha	6,292.13	8,999.21	8,999.21	7,731.03
land required (irrigated RCG)	m^2/animal	5,533.77	5,693.40	4,735.63	53.21
bedding waste per ha	t/ha	96.98	138.70	138.70	119.15
biomethane per ha	m^3/ha	8,727.80	12,482.78	12,482.78	10,723.69

- 97% bio-methane per hectare of farmland obtained from anaerobic digestion of bedding material waste

- Allocation used to bio-methane from AD from bedding material waste. Waste consists of animal manure and bedding material

6 Willow

VA of willow biofuel in energy (Alberici, Gräf, and Magali, 2023) VA of willow biochar from (Puro.earth, 2021)

Table 16: Economic and environmental impacts of willow to bigoas

v.a_min/MWh [a]	€/MWh	84
v.a_max/MWh	€/MWh	175
energy	Mwh/ha/yr	0.43
v.a_min	€/ha	36.10
v.a_max	€/ha	75.20
GWP100(w/o sinks)[b]	tCO_2e/ha/yr	184
GWP100(including sinks)	tCO_2e/ha/yr	-367
WEI (w/o sinks)	€/ha/yr	-9,568
WEI(including sinks)	€/ha/yr	19,084
GEI min w/o sinks	€/ha/yr	-9,532
GEI max w/o sinks	€/ha/yr	-9,493
GEI min with sinks	€/ha/yr	19,120
GEI max with sinks	€/ha/yr	19,159

[a] Calculated using values from Alberici, Gräf, and Magali, 2023

[b] Calculated from Ericsson et al., 2014

Table 17: Economic and environmental impacts of willow as biochar

Price [a]	€/t drymass	270
Willow yield [b]	t drymass/ha	6
Value added	€/ha	1,620
GWP [c]	ton/ha/yr	7,440
GWP (including offsets) [c]	ton/ha/yr	-6,600
WEI	€/ha/yr	-386,880
WEI(including offsets)	€/ha/yr	343,200
GEI (w/o offsets)	€/ha/yr	-385,260.00
GEI (with offsets)	€/ha/yr	344,820.00

[a] From Puro.earth, 2021

[b] Yield when grown in peatland (Leppäkoski et al., 2021; Laasasenaho et al., 2017)

[c] Calculated using values from Forsström, 2019

7 Summary Comparison

Table 18: Comparison of all alternatives, yearly

	GWP_min tCO_2e/ha	GWP_max tCO_2e/ha	WEI_min €/ha	WEI_max €/ha	GEI_min €/ha	GEI_max €/ha
Peat (unused)	1.18	6.66	-61	-346	-61	-346
Peat (bedding)	239.70	259.14	-13,484	-12,464	-411	2,579
Peat (energy)	138,009	138,028	-7.18E+06	-7.18E+06	-7.18E+06	-7.18E+06
RCG (bedding)	-3.75	4.30	**-255**	71	**10,377**	20,372
Willow(biochar)	7,440	**-6,600**	-386,880	**343,200**	-386,070	**344,010**
Willow(energy)	**-6**	9.56	-9,532	19,120	-9,512	19,140

Table 19: Yearly Yields in Etelä Savo, all harvested peatlands

	GWP_min $ktCO_2e$	GWP_max $ktCO_2e$	WEI_min M€	WEI_max M€	GEI_min M€	GEI_max M€
Peat (unused)	4.77	27	-0.25	-1.40	-0.25	-1.40
Peat (bedding)	966.95	1,045	-54.40	-50.28	-1.66	10.41
Peat (energy)	966.94	1,046	556.73	556.81	-28,953.91	-28,953.90
RCG	-15.11	17	-1.03	0.28	41.86	82.18
Willow(biochar)	30,012.96	-26,624	-1,560.67	1,384.47	-1,557.41	1,387.74
Willow(energy)	-24.20	39	-38.45	77.13	-38.37	77.21

Table 20: Yearly Yields in Etelä Savo, > 15 ha

	GWP_min $ktCO_2e$	GWP_max $ktCO_2e$	WEI_min M€	WEI_max M€	GEI_min M€	GEI_max M€
Peat (unused)	4.15	23	-0.22	-1.22	-0.22	-1.22
Peat (bedding)	841.59	910	-47.34	-43.76	-1.44	9.06
Peat (energy)	841.58	910	484.55	484.62	-25,200.09	-25,200.09
RCG	-13.15	15	-0.90	0.25	36.44	71.52
Willow(biochar)	26,121.84	-23,173	-1,358.34	1,204.98	-1,355.49	1,207.82
Willow(energy)	-21.07	34	-33.47	67.13	-33.40	67.20

Table 21: Yearly Yields in Etelä Savo > 100 ha

	GWP_min $ktCO_2e$	GWP_max $ktCO_2e$	WEI_min M€	WEI_max M€	GEI_min M€	GEI_max M€
Peat (unused)	3.53	20	-0.18	-1.03	-0.18	-1.03
Peat (bedding)	715.75	774	-40.26	-37.22	-1.23	7.70
Peat (energy)	715.74	774	412.09	412.15	-21,431.92	-21,431.92
RCG	-11.18	13	**-0.76**	0.21	**30.99**	60.83
Willow (biochar)	22,215.84	**-19,708**	-1,155.22	**1,024.80**	-1,152.81	**1,027.21**
Willow (energy)	**-17.92**	29	-28.46	57.09	-28.40	57.15

Table 22: Annual GWP in Etelä Savo from peatlands > 100 ha [$ktCO_2e/yr$]

		Juva	Mikkeli	Haukivuori	Pieksamäki	Total
Peat (unused)	Min	1.38	0.92	0.74	0.49	3.53
	Max	7.76	5.18	4.15	2.78	19.87
Peat (bedding)	Min	279.49	186.73	149.57	99.96	715.75
	Max	302.16	201.87	161.70	108.06	773.79
Peat (energy)	Min	279.49	186.73	149.57	99.95	715.74
	Max	302.36	202.00	161.81	108.13	774.30
RCG (bedding)	Min	-4.37	-2.92	-2.34	-1.56	-11.18
	Max	5.01	3.35	2.68	1.79	12.84
Willow(biochar)	Min	8,675.04	5,795.76	4,642.56	3,102.48	22,215.84
	Max	-7,695.60	-5,141.40	-4,118.40	-2,752.20	-19,707.60
Willow(energy)	Min	-7.00	-4.67	-3.74	-2.50	-17.92
	Max	11.15	7.45	5.97	3.99	28.55

Table 23: Annual WEI in Etelä Savo from peatlands > 100 ha [M€/yr]

		Juva	Mikkeli	Haukivuori	Pieksamäki	Total
Peat (unused)	Min	-0.07	-0.05	-0.04	-0.03	-0.20
	Max	-0.40	-0.27	-0.22	-0.14	-1.15
Peat (bedding)	Min	-15.72	-10.50	-8.41	-5.62	-44.77
	Max	-14.53	-9.71	-7.78	-5.20	-41.38
Peat (energy)	Min	160.92	107.51	86.12	57.55	458.19
	Max	160.94	107.52	86.13	57.56	458.25
RCG (bedding)	Min	-0.30	-0.20	-0.16	-0.11	-0.85
	Max	0.08	0.06	0.04	0.03	0.23
Willow(biochar)	Min	-451.10	-301.38	-241.41	-161.33	-1,284.44
	Max	-451.10	-301.38	-241.41	-161.33	-1,284.44
Willow(energy)	Min	-11.11	-7.43	-5.95	-3.97	-31.65
	Max	22.29	14.89	11.93	7.97	63.48

Table 24: Annual GEI in Etelä Savo from peatlands 100 ha [M€/yr]

		Juva	Mikkeli	Haukivuori	Pieksamäki	Total
Peat (unused)	Min	-0.07	-0.05	-0.04	-0.03	-0.20
	Max	-0.40	-0.27	-0.22	-0.14	-1.15
Peat (bedding)	Min	-0.48	-0.32	-0.26	-0.17	-1.36
	Max	3.01	2.01	1.61	1.08	8.56
Peat (energy)	Min	-8,368.93	-5,591.25	-4,478.74	-2,993.00	-23,829.20
	Max	-8,368.93	-5,591.25	-4,478.74	-2,993.00	-23,829.19
RCG (bedding)	Min	12.10	8.08	6.48	4.33	34.45
	Max	23.75	15.87	12.71	8.49	67.63
Willow(biochar)	Min	-450.16	-300.75	-240.91	-160.99	-1,281.75
	Max	401.12	267.98	214.66	143.45	1,142.11
Willow(energy)	Min	-11.09	-7.41	-5.94	-3.97	-31.58
	Max	22.32	14.91	11.94	7.98	63.54

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