Learning by doing: the student's perspective using marteloscopes for carbon modeling

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How it all began…
A trip to the Black Forest

The Rosskopf Marteloscope

https://sites.uef.fi/europeanforestry/2021/04/26/excursion-to-two-marteloscopes-near-freiburg-city/

Why establishing (or re-measuring) a marteloscope is such a good learning experience for students:

Technical Skills

Basic surveying

Tree Measurements

Biodiversity assessment

Quality Assessment

Data management

Management Skills

Site Selection- Criteria, aims, etc.

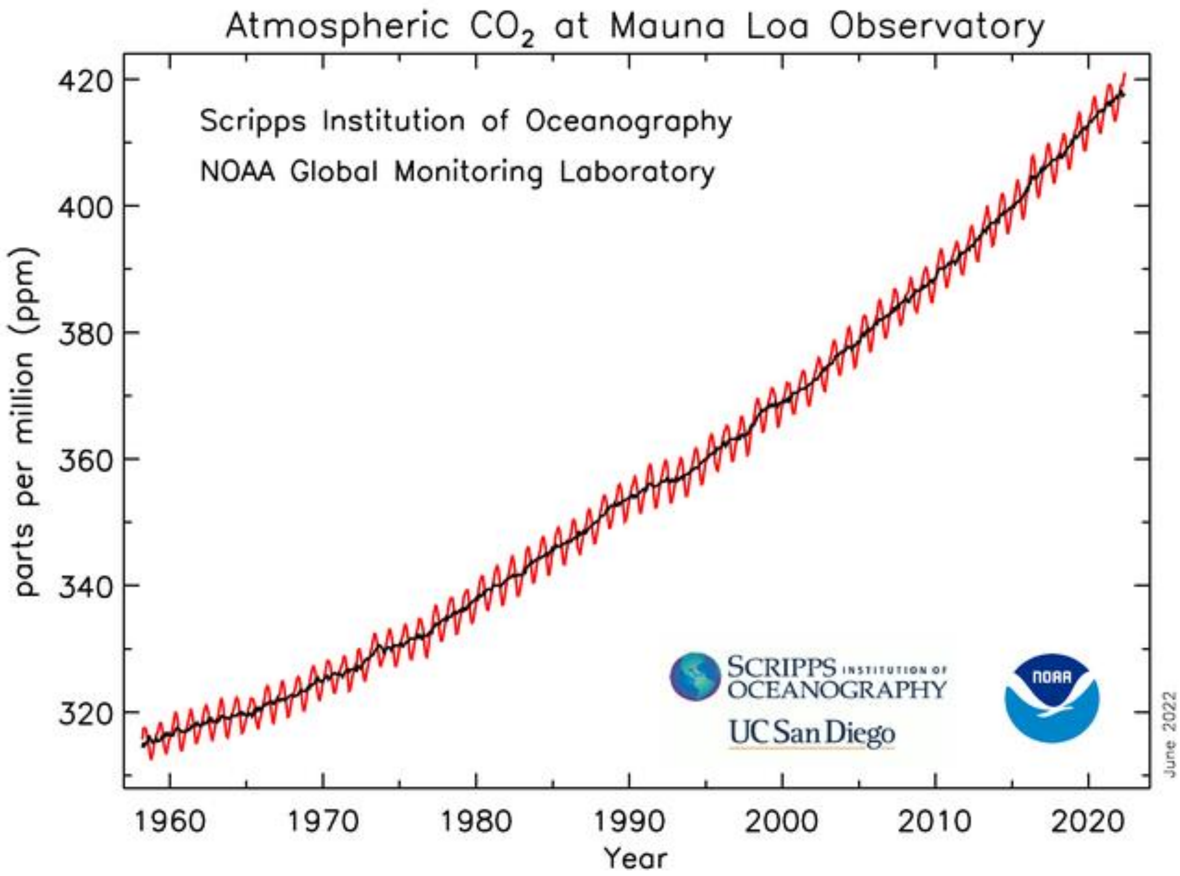
Multi-Stakeholder engagement (Public and private)

Another reason: Individual Tree Data

Tree No	TrSpec	d 1.3 [cm]	h [m]	CBH [m]	QMP	Status	X [m]	Y [m]	BA [m²]	V [m³]
1	Betula	46.6	29.2	11.8	1	1	38.507806	38.550309	0.17055392	3.2371135
2	Quercus	82.76	29.7	11.4	1	1	47.92041	45.143161	0.53794371	9.9975144
3	Quercus	18.1	12.2	0	1	0	46.903342	35.730336	0.02573043	0.2215153
4	Fagus sylvatica	23.95	23.9	4.6	1	1	30.828524	27.171083	0.04505064	0.6448149
5	Fagus sylvatica	18.9	21.2	8.1	1	1	49.845362	32.643431	0.02805521	0.3598675
6	Fagus sylvatica	61.5	27.2	9.6	1	1	40.793043	28.167229	0.29705722	5.1289051
7	Betula	32.25	26.3	12.1	1	1	42.896674	23.478299	0.08168632	1.3964276
8	Fagus sylvatica	11.2	18.4	13	1	1	47.850699	22.803753	0.00985203	0.1083306
9	Quercus	57.35	28.7	10.8	1	1	36.928899	23.052981	0.25831922	4.5315332
10	Fagus sylvatica	11.7	17.2	6.1	1	1	44.852858	21.502978	0.01075132	0.1131477
11	Fagus sylvatica	35.8	28.2	7.8	1	1	32.471514	45.350811	0.10065977	1.688804
12	Fagus sylvatica	25.45	26.2	2	1	1	41.407391	16.833874	0.05087044	0.7823529
13	Fagus sylvatica	27.9	26.3	13.9	1	1	28.085479	23.265676	0.06113618	0.9515707
14	Fagus sylvatica	15.4	19.6	5.7	1	1	48.717705	9.4203795	0.0186265	0.2212686
15	Fagus sylvatica	24.95	26.8	8.2	1	1	29.641431	21.480791	0.04889123	0.7626658
16	Fagus sylvatica	39.75	28.6	10.7	1	1	43.556337	6.7901856	0.12409782	2.1254122
17	Fagus sylvatica	13.5	16.8	7.2	1	1	44.958613	4.1436746	0.01431388	0.1502773
18	Fagus sylvatica	20.65	27.6	4.6	1	1	48.201704	0.8308317	0.03349114	0.5234724
19	Fagus sylvatica	31.45	26	7	1	1	34.796904	14.368314	0.07768393	1.2138109
20	Fagus sylvatica	21.9	26.3	5.7	1	1	47.176404	-1.047975	0.03766848	0.5721697

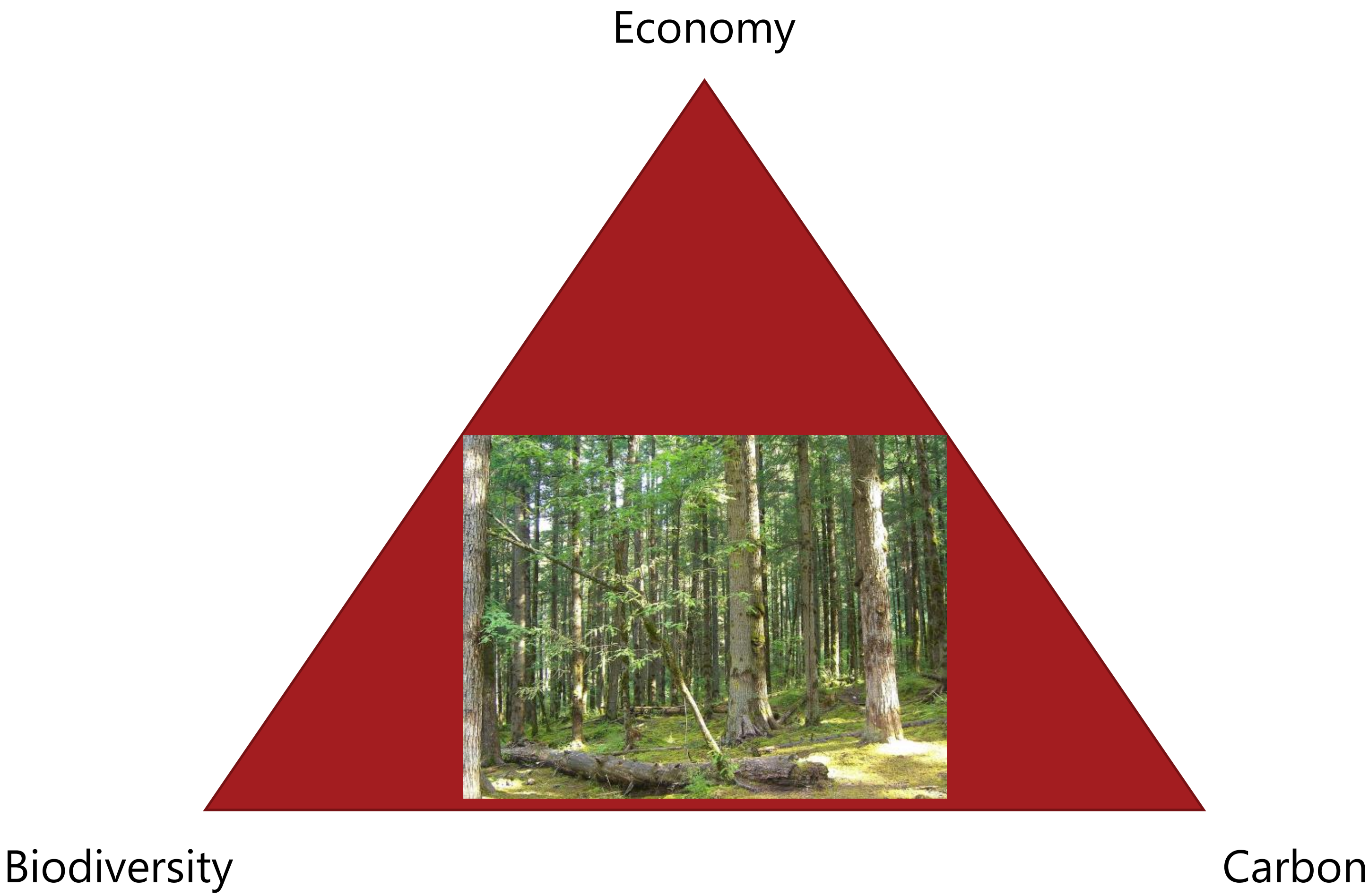
provides many opportunities for research

But a thesis needs a question, or a problem…



https://www.esrl.noaa.gov/gmd/ccgg/trends/

Can we somehow include carbon?



Everyone here knows -

Trees in the forest store carbon…

47%

47

9%

2%

31%

11%

Katja Kejser & Kasper Holst Pedersen

But sometimes it is forgotten that wood outside the forest also stores carbon.

And for every kg of wood used instead, avg 1.2 kg C emission saved.

Leskinen, P., et al. (2018)

How do we go from Knowledge to Practice?

Can we improve the management of our forests for climate impact?

What is the climate impact of a thinning – what is the climate benefit potential of the forest?

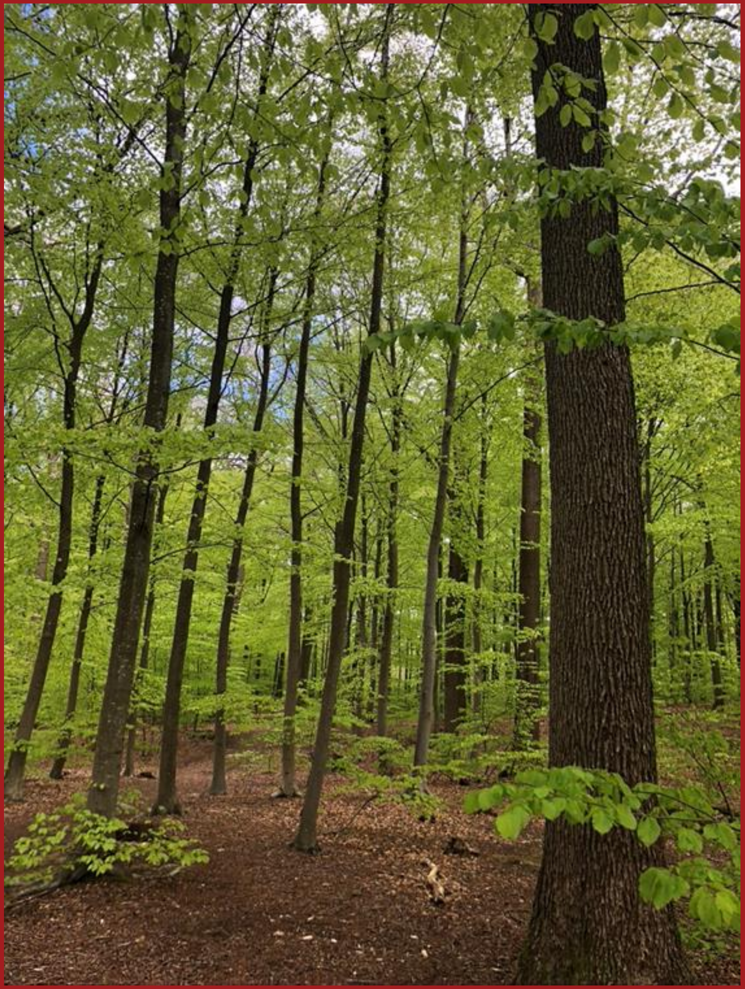
Our aims -

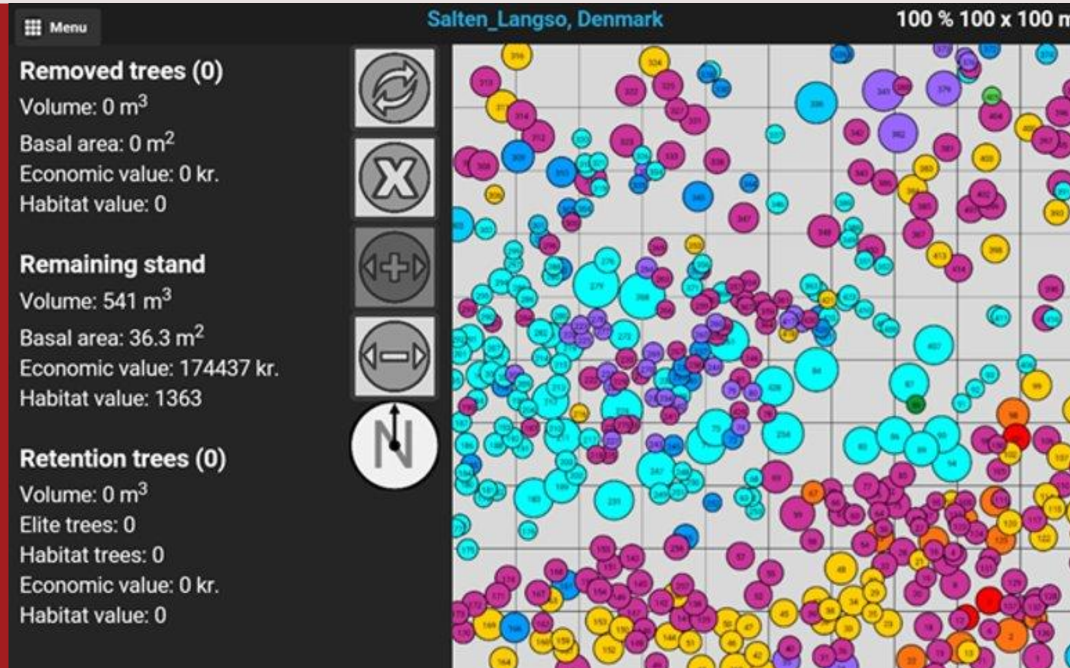
- Establish at least one marteloscope
- Develop a carbon model using marteloscope data
- Use the model to simulate management actions

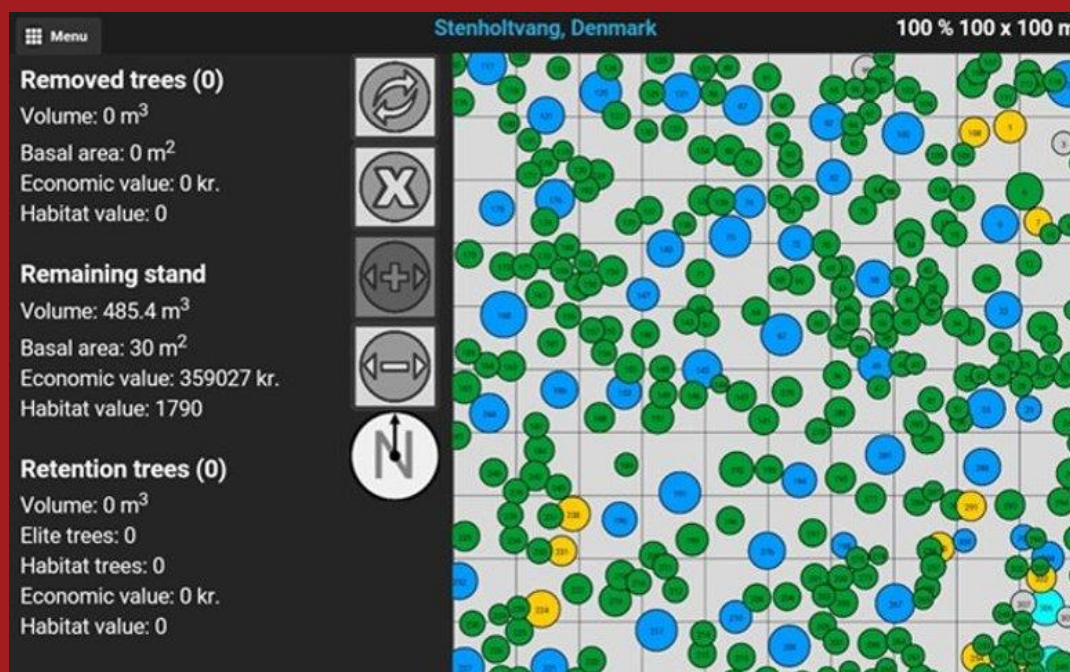
http://iplus.efi.int/marteloscopes-data.html

Salten Langsø

Stenholtvang




Menu
Salten_Langso, Denmark
100 % 100 x 100 m
Removed trees (0)
Volume: 0 m3
Basal area: 0 m2
Economic value: 0 kr.
Habitat value: 0
Remaining stand
Volume: 541 m3
Basal area: 36.3 m2
Economic value: 174437 kr.
Habitat value: 1363
Retention trees (0)
Volume: 0 m3
Elite trees: 0
Habitat trees: 0
Economic value: 0 kr.
Habitat value: 0

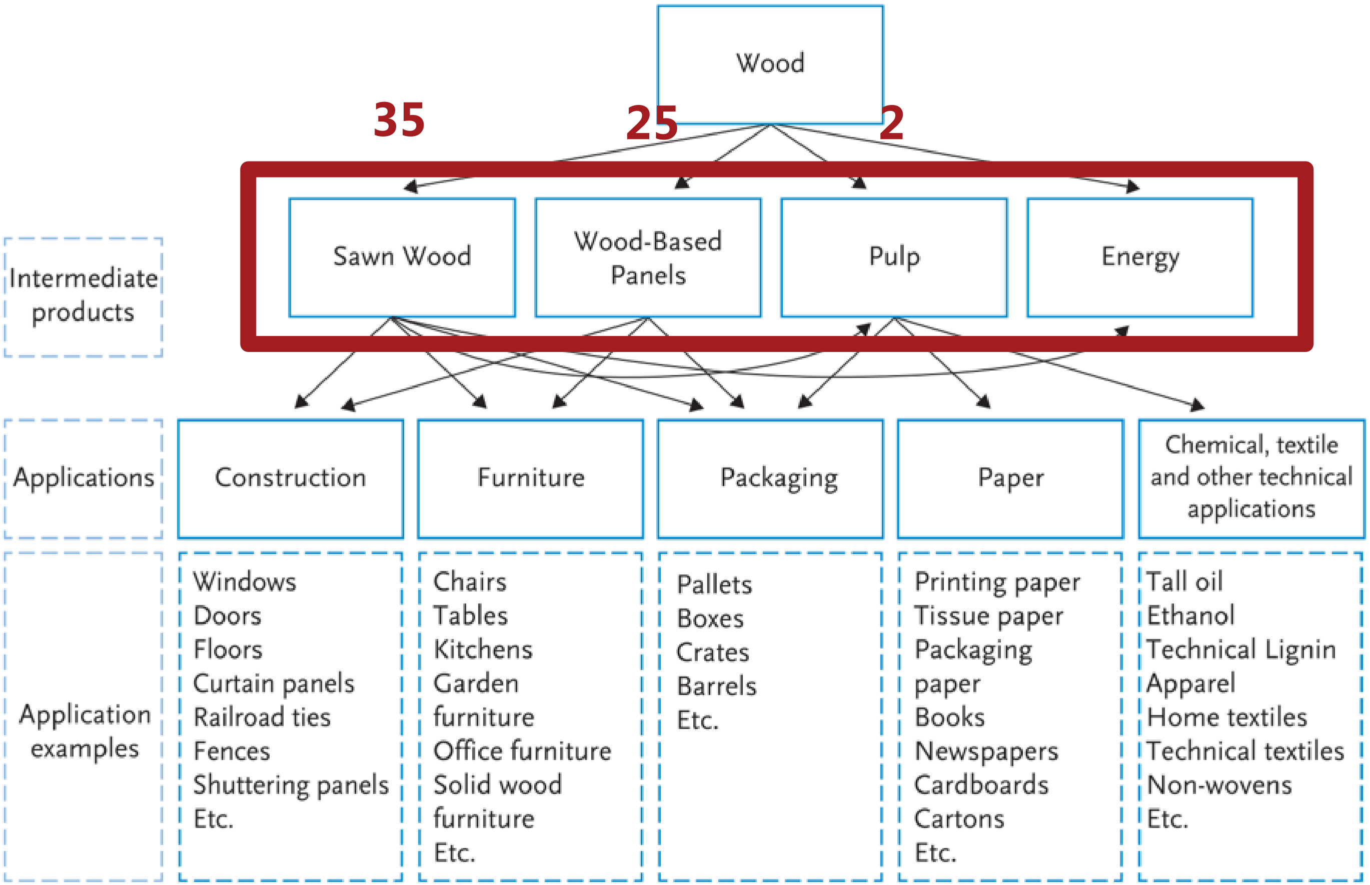

Menu
Stenholtvang, Denmark
100 % 100 x 100 m
Removed trees (0)
Volume: 0 m3
Basal area: 0 m2
Economic value: 0 kr.
Habitat value: 0
Remaining stand
Volume: 485.4 m3
Basal area: 30 m2
Economic value: 359027 kr.
Habitat value: 1790
Retention trees (0)
Volume: 0 m3
Elite trees: 0
Habitat trees: 0
Economic value: 0 kr.
Habitat value: 0

A Natural Starting Point: Carbon Accounting

ipcc

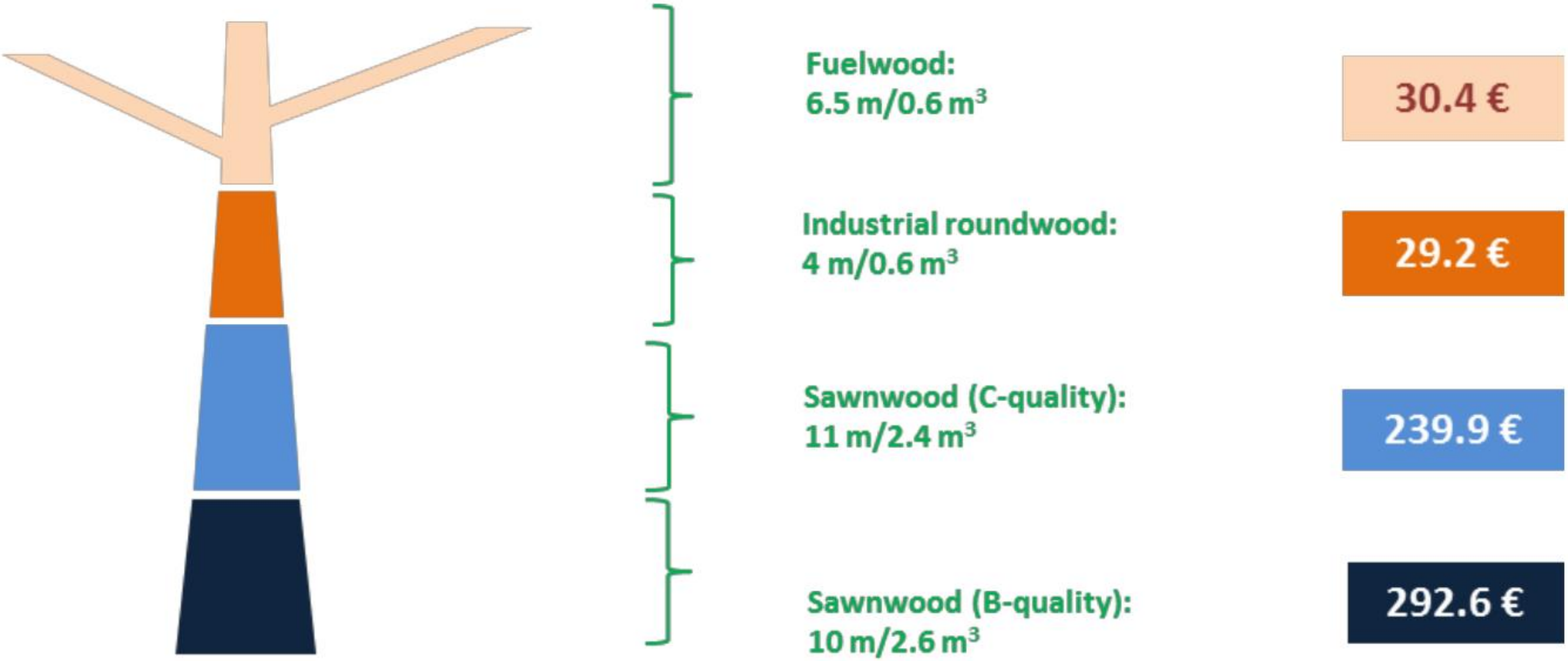
INTERGOVERNMENTAL PANEL ON
climate change

The IPCC and Accounting for HWP



(Leskinen 2018)

Quality Assessment


Fuelwood:
6.5 m/0.6 m³
30.4 €
Industrial roundwood:
4 m/0.6 m³
29.2 €
Sawnwood (C-quality):
11 m/2.4 m³
239.9 €
Sawnwood (B-quality):
10 m/2.6 m³
292.6 €

(Schuck 2015)

Calculations…

$$k = \frac{\ln(2)}{HL}$$

$$V_x = (dm_1/100)^2 * \frac{\pi}{4} * L_x$$

$$Csub_i = Csub_{i,sw} * z_{sw} + Csub_{i,wp} * z_{wp} + Csub_{i,p} * z_{wp} + Csub_{i,f} \cdots$$

$$C_i = B_i * f$$

$$dm_1 = d_{1.3} - L_1/f_T + 0.8$$

$$B_{stem} = \alpha_0(dbh * 1000)^{\alpha_1} * (h - 0.3)^{\alpha_2} + \varepsilon_{stem}$$

$$H_i = \sum_{j=1}^{n} N_j * s_j * (R_j + D_j)$$

$$dm_2 = dm_1 - L_1 * f_t/2 - L_2 * f_t/2$$

$$C_{i,t} = e^{-k_{sw}*t} * C_{i,sw} + e^{-k_{wp}*t} * C_{i,wp} + e^{-k_p*t} * C_{i,p} + e^{-k_f*t} * C_{i,f} \cdots$$

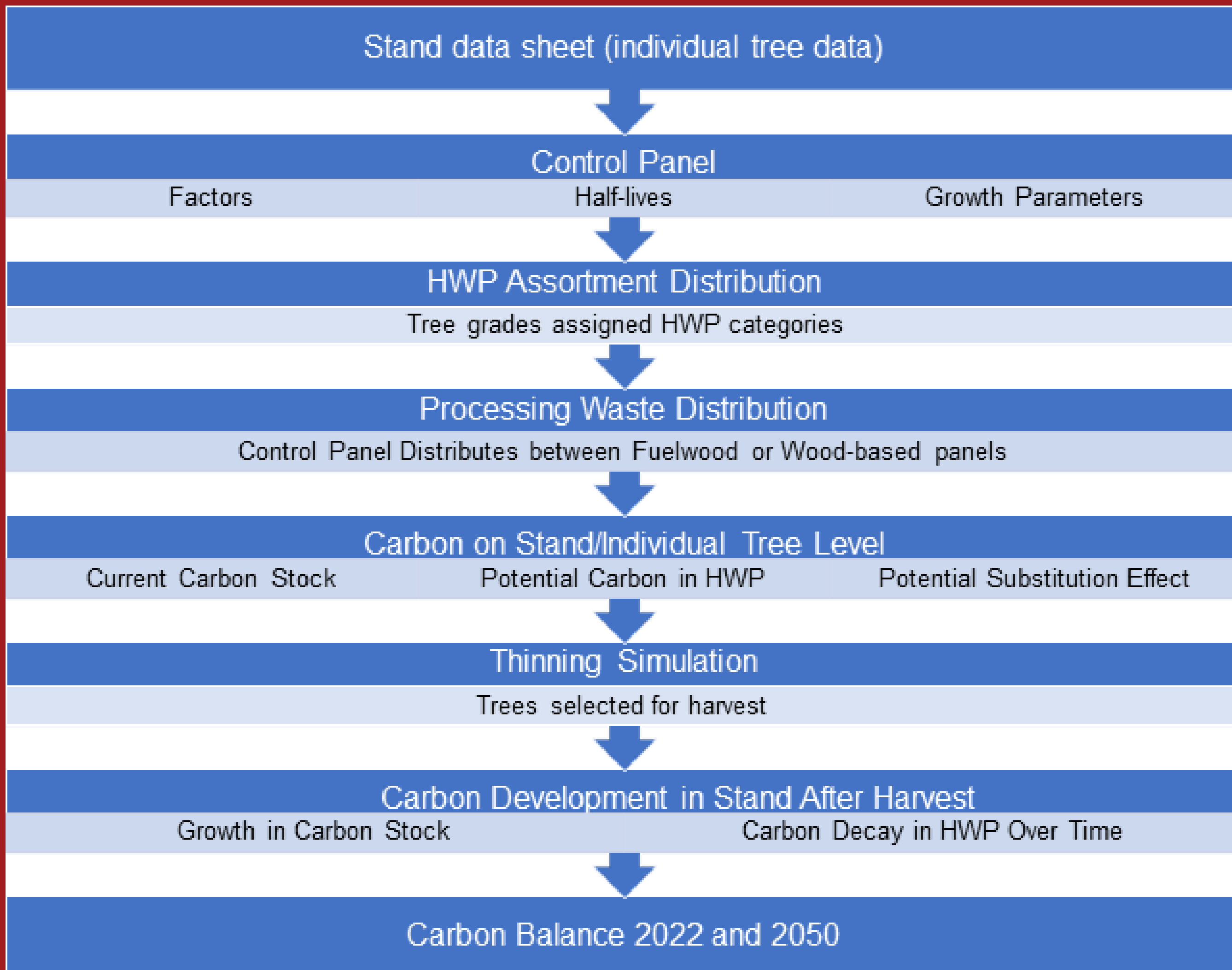
$$B_{crown} = \beta_0(dbh * 1000)^{\beta_1} * (h - 0.3)^{\beta_2} + \varepsilon_{crown}$$

$$dm_2 = dm_1 - L_1 * f_t/2 - (L_2 * f_t/2) * d_{1.3}/h - 1.3$$

$$dm_3 = dm_2 - L_2 * f_t/2 - L_3 * f_t/2$$

$$dm_2 = dm_1 - L_1 * f_t/2 - (L_2 * f_t/2) * d_{1.3}/h$$

The Model


Stand data sheet (individual tree data)
Control Panel
Factors
Half-lives
Growth Parameters
HWP Assortment Distribution
Tree grades assigned HWP categories
Processing Waste Distribution
Control Panel Distributes between Fuelwood or Wood-based panels
Carbon on Stand/Individual Tree Level
Current Carbon Stock
Potential Carbon in HWP
Potential Substitution Effect
Thinning Simulation
Trees selected for harvest
Carbon Development in Stand After Harvest
Growth in Carbon Stock
Carbon Decay in HWP Over Time
Carbon Balance 2022 and 2050

Results

Initial Stand Characteristics

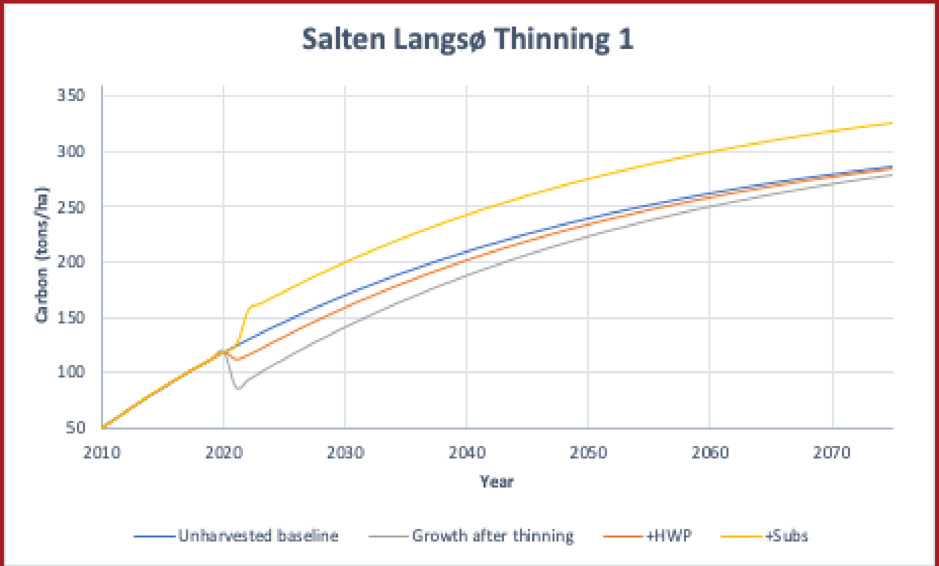
Attributes	Salten Langsø	Stenholtvang
Stem number [n]	429	315
Basal area [m^2]	30.06	36.29
Volume [m^3]	540.96	486.18
Economic Value [DKK]	174,437	359,253
Habitat Value	1363	1829
Carbon [Mg]	120.10	135.40
CO_2-eq [Mg]	440.35	496.45
Carbon Substitution Potential [Mg C]	132.22	128.28

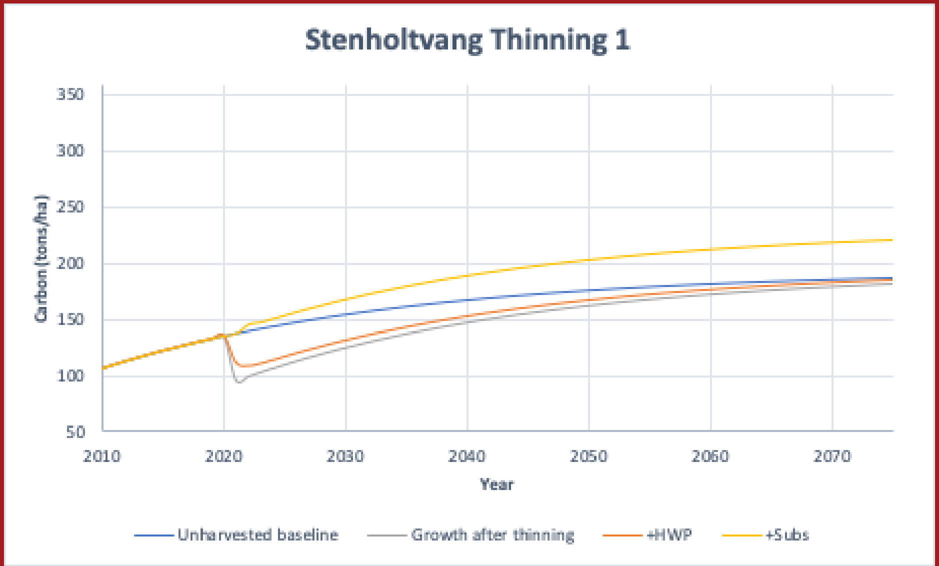
Thinning Results

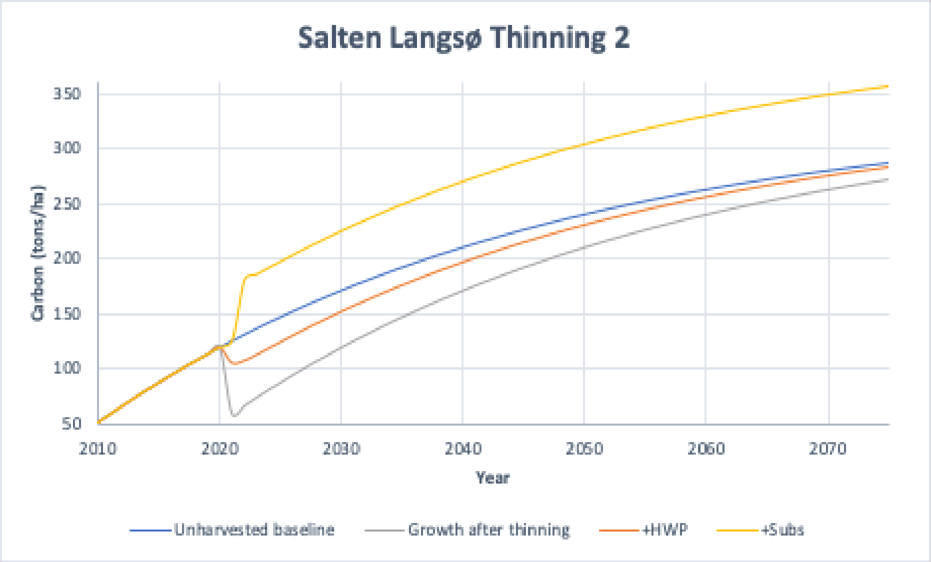
Salten Langsø		Thinning 1		Thinning 2	
Attributes	Initial	Removed	After	Removed	After
Stem number [n]	429	60	369	76	353
Basal area [m²]	30.06	10.42	19.64	18.38	11.68
Volume [m³]	540.96	164.09	376.87	295.25	245.71
Economic Value [DKK]	174,437	46,452	127,984	94,946	79,490
Habitat Value	1363	116	1247	308	1055
Carbon [Mg]	120.1	35.32	84.78	54.25	65.84
CO_2-eq [Mg]	440.35	129.49	310.86	198.92	241.43
C Substitution Potential [Mg C]	132.22	40.02	92.2	72.88	59.35

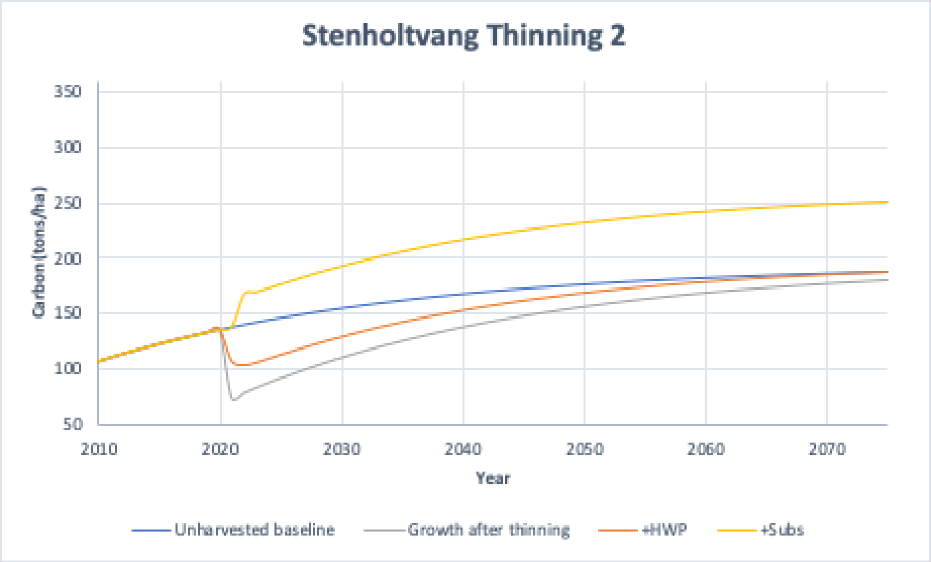
Stenholtvang		Thinning 1		Thinning 2	
Attributes	Initial	Removed	After	Removed	After
Stem number [n]	315	124	191	131	184
Basal area [m²]	36.29	9.07	27.22	13.66	22.63
Volume [m³]	486.18	140.79	345.40	228.63	257.55
Economic Value [DKK]	359,253	55,883	303,369	249,913	109,339
Habitat Value	1829	96	1733	933	896
Carbon [Mg]	135.40	15.82	119.58	64.31	71.09
CO_2-eq [Mg]	496.45	58.00	438.45	235.80	260.65
C Substitution Potential [Mg C]	128.33	36.88	91.45	63.55	64.78

Carbon Balance









What if wood use was more optimal?

Comparable Results?

- Most studies at national scale (related to national carbon accounting)
- Numerous studies have shown substitution effect to be the most significant
- General agreement that putting products into longer lived products preferable to direct to bioenergy (more storage and more substitution)
- Several studies have illustrated the importance of using more accurate tier 3 data for HWP

The Future…