Potential of poplar and willow wood for load-bearing constructions

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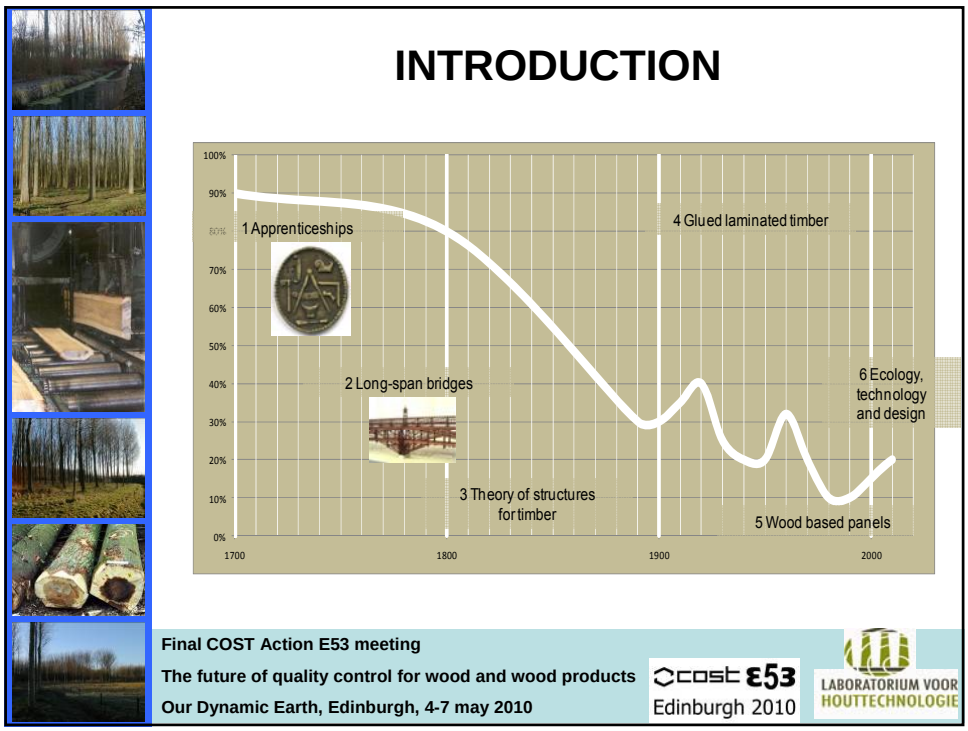
OUTLINE

- **Introduction – Why ?**
- **Selected topics**
  - **Variability physical-mechanical properties**
  - **Grading**
  - **Veneer based products**
- **Conclusions – Economical relevance**


INTRODUCTION
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1700
1800
1900
2000
1 Apprenticeships
2 Long-span bridges
3 Theory of structures for timber
4 Glued laminated timber
5 Wood based panels
6 Ecology, technology and design
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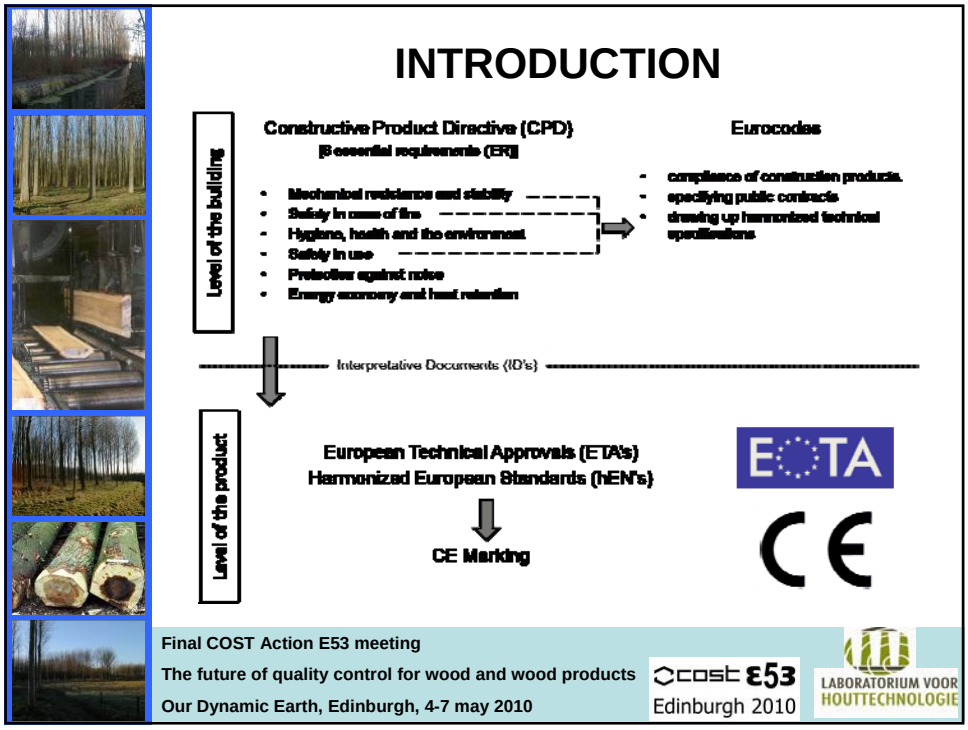
INTRODUCTION
Level of the building
Constructive Product Directive (CPD)
[6 essential requirements (ER)]
Mechanical resistance and stability
Safety in case of fire
Hygiene, health and the environment
Safety in use
Protection against noise
Energy economy and heat retention
Eurocodes
compliance of construction products
specifying public contracts
drawing up harmonized technical specifications
Interpretative Documents (ID's)
Level of the product
European Technical Approvals (ETA's)
Harmonized European Standards (hEN's)
CE Marking
EOTA
CE
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INTRODUCTION

Their main **impact on the forestry-wood chain** :

• Man-made plantations taking pressure away from native forests.

• Quantity does not imply poor quality.

• Environmental discussion will lead to "Save the environment, use wood!"

• New players on the market for the same kind of raw material.

• Narrowing price settings.

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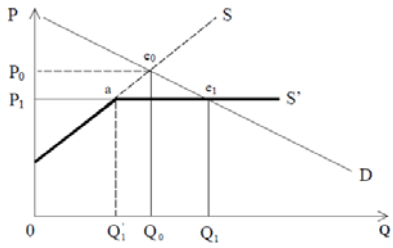

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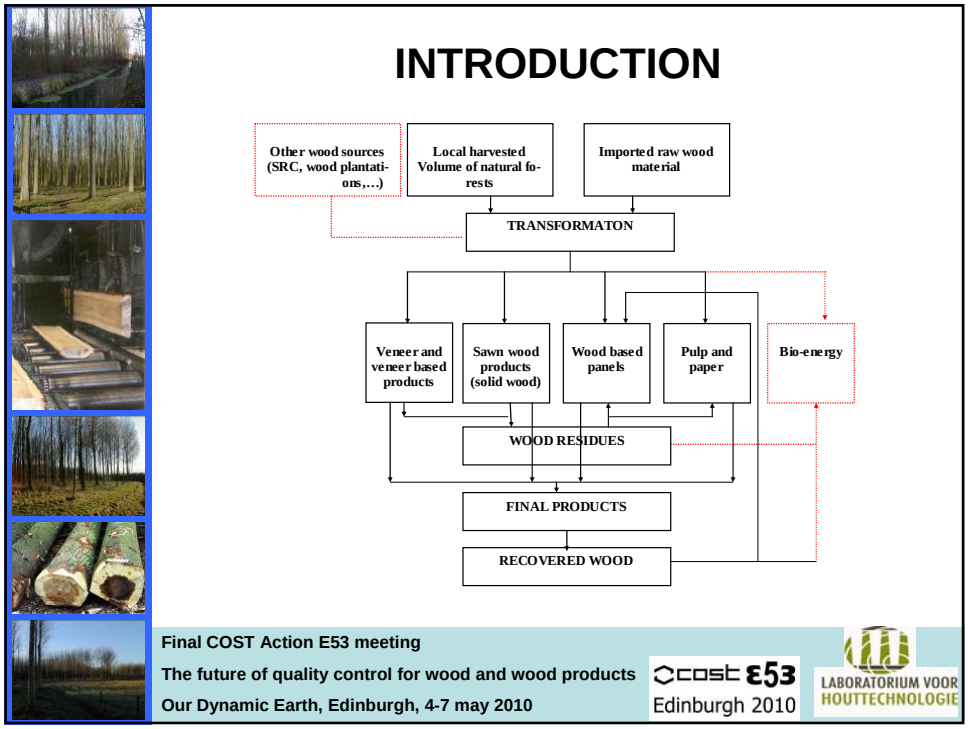
INTRODUCTION
Other wood sources (SRC, wood plantations,…)
Local harvested Volume of natural forests
Imported raw wood material
TRANSFORMATON
Veneer and veneer based products
Sawn wood products (solid wood)
Wood based panels
Pulp and paper
Bio-energy
WOOD RESIDUES
FINAL PRODUCTS
RECOVERED WOOD
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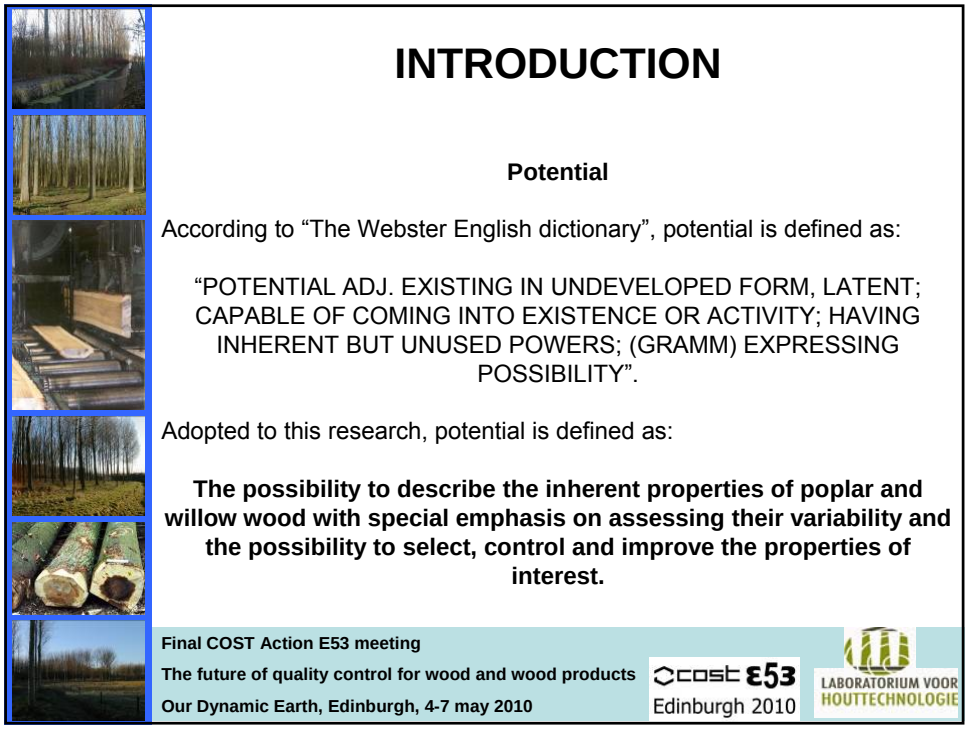
INTRODUCTION
Potential
According to "The Webster English dictionary", potential is defined as:
"POTENTIAL ADJ. EXISTING IN UNDEVELOPED FORM, LATENT; CAPABLE OF COMING INTO EXISTENCE OR ACTIVITY; HAVING INHERENT BUT UNUSED POWERS; (GRAMM) EXPRESSING POSSIBILITY".
Adopted to this research, potential is defined as:
The possibility to describe the inherent properties of poplar and willow wood with special emphasis on assessing their variability and the possibility to select, control and improve the properties of interest.
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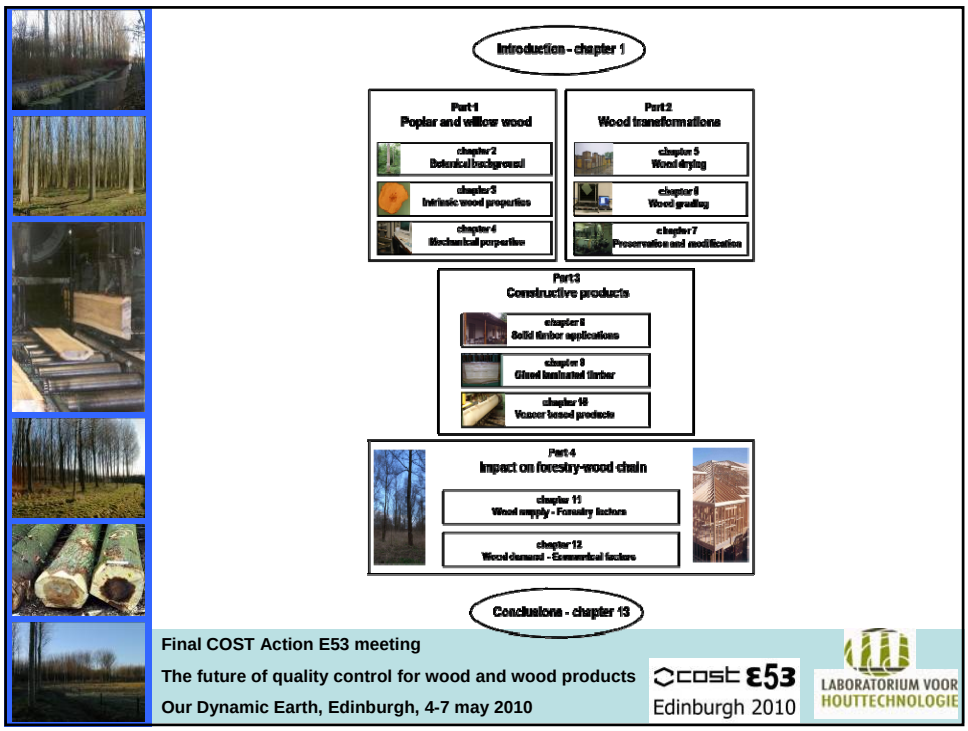
Introduction - chapter 1
Part 1
Poplar and willow wood
chapter 2
Botanical background
chapter 3
Intrinsic wood properties
chapter 4
Mechanical properties
Part 2
Wood transformations
chapter 5
Wood drying
chapter 6
Wood grading
chapter 7
Preservation and modification
Part 3
Constructive products
chapter 8
Solid timber applications
chapter 9
Glued laminated timber
chapter 10
Veneer based products
Part 4
Impact on forestry-wood chain
chapter 11
Wood supply - Forestry factors
chapter 12
Wood demand - Economical factors
Conclusions - chapter 13
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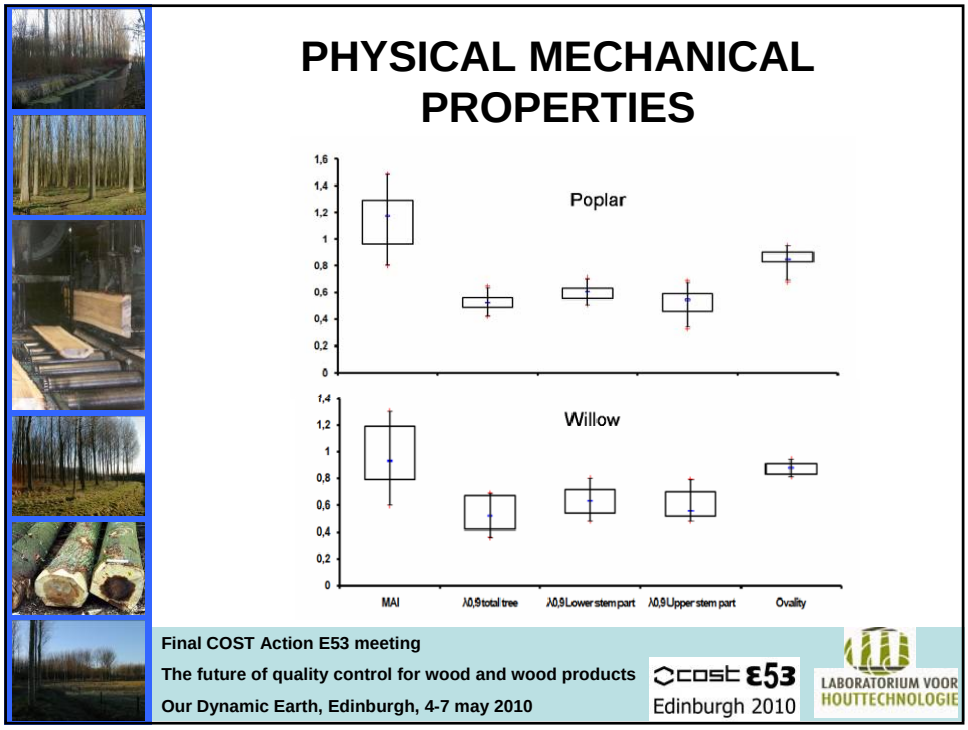
PHYSICAL MECHANICAL PROPERTIES
Poplar
Willow
1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
0
MAI
λ0,9 total tree
λ0,9 Lower stem part
λ0,9 Upper stem part
Ovality
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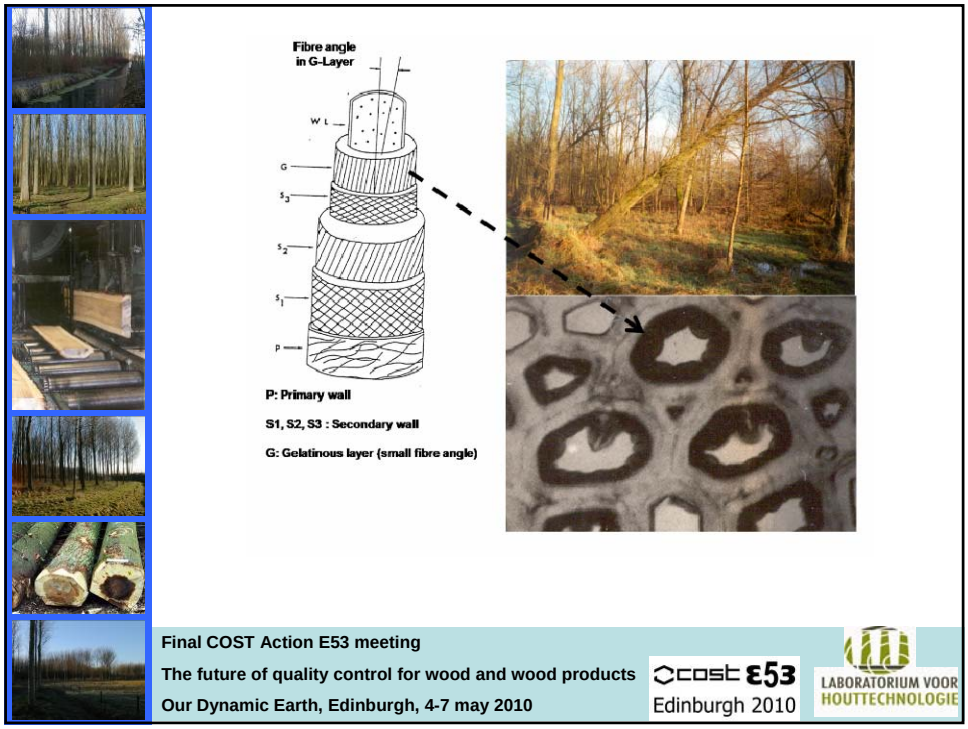
Fibre angle
in G-Layer
W L
G
S3
S2
S1
P
P: Primary wall
S1, S2, S3 : Secondary wall
G: Gelatinous layer (small fibre angle)
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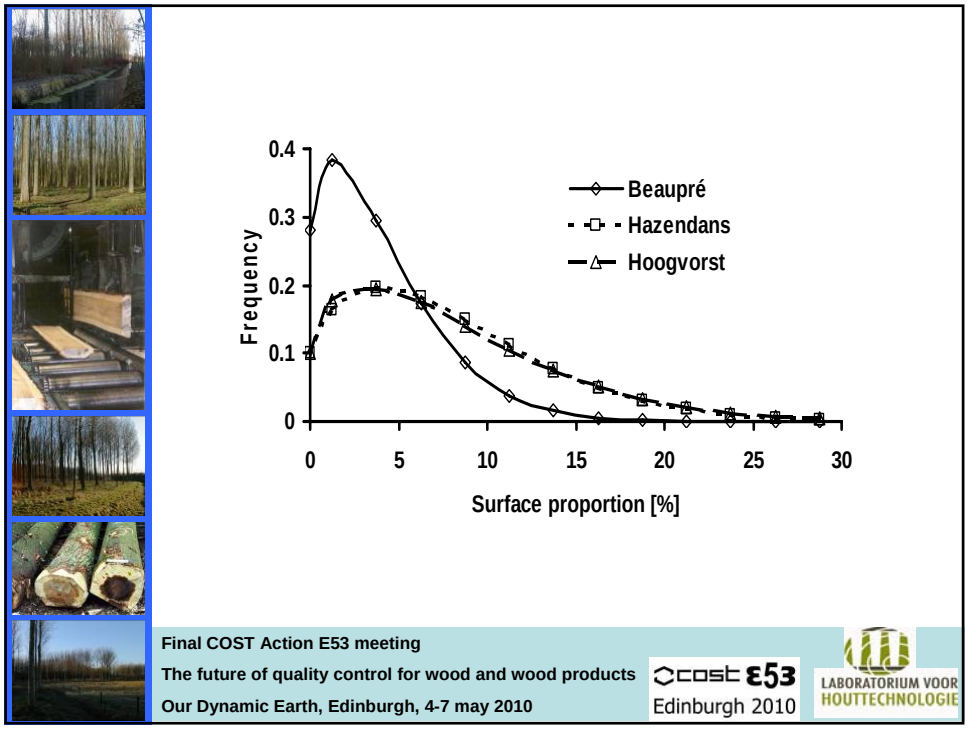
0.4
0.3
0.2
0.1
0
Frequency
0
5
10
15
20
25
30
Surface proportion [%]
Beaupré
Hazendans
Hoogvorst
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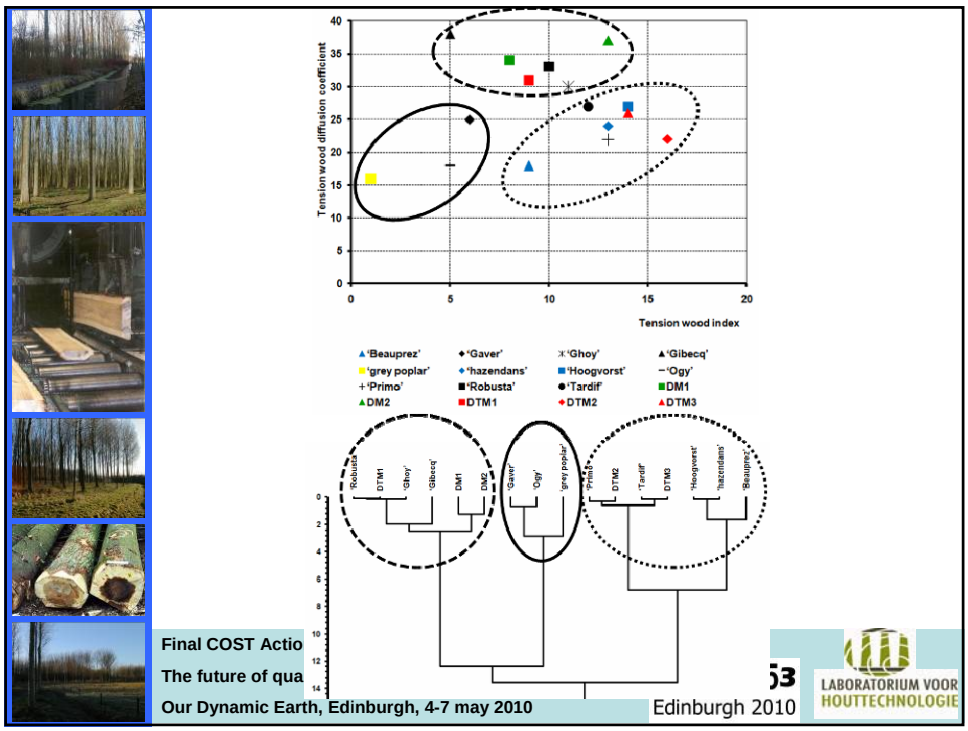
Tension wood diffusion coefficient
Tension wood index
'Beauprez'
'Gaver'
'Ghoy'
'Gibecq'
'grey poplar'
'hazendans'
'Hoogvorst'
'Ogy'
'Primo'
'Robusta'
'Tardif'
DM1
DM2
DTM1
DTM2
DTM3
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The future of qua
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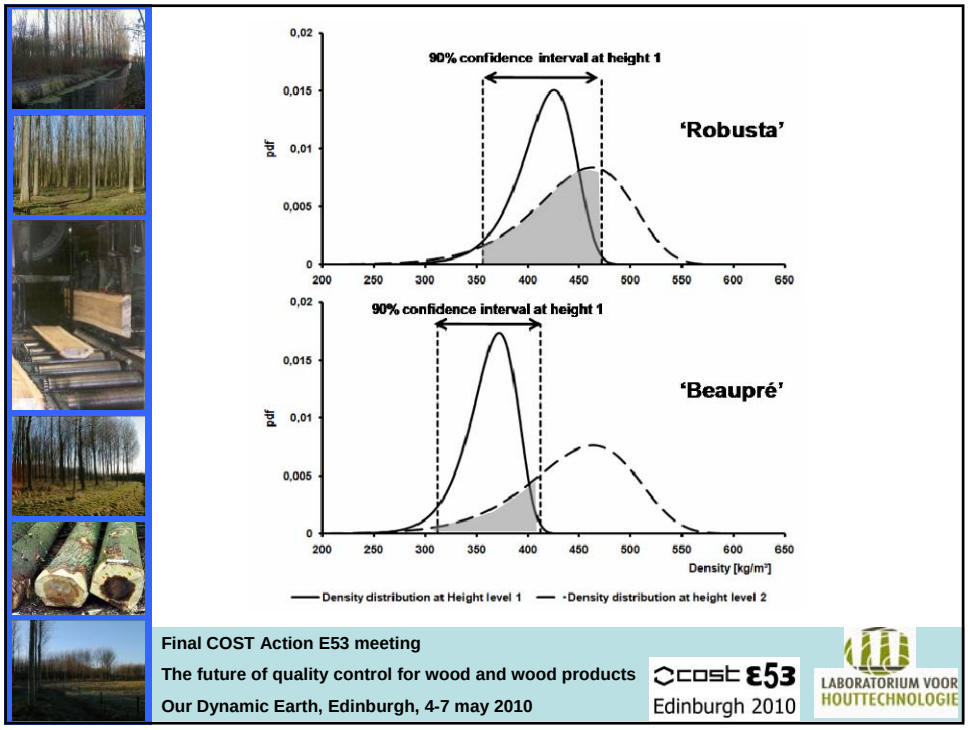
90% confidence interval at height 1
'Robusta'
pdf
90% confidence interval at height 1
'Beaupré'
pdf
Density [kg/m³]
Density distribution at Height level 1
Density distribution at height level 2
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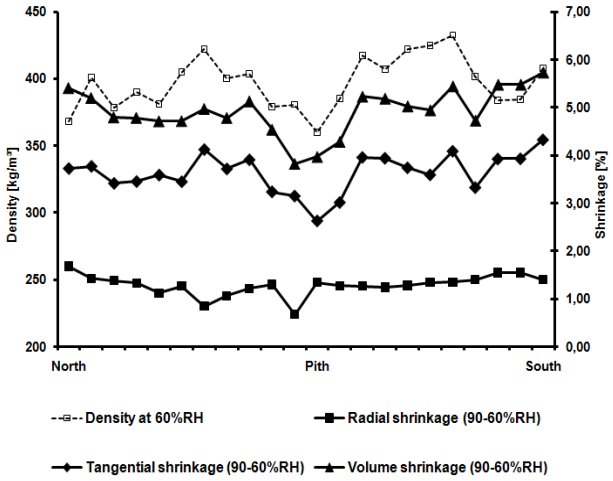

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Clone*		Relation MOE to density			Relation MOR to density			Relation MOR to MOE		
		$C_{MOE,\rho}$	R^2_{max}	p	$C_{MOR,\rho}$	R^2_{max}	p	$C_{MOR,MOE}$	R^2_{max}	p
'Robusta'	DN	21.3	0.46	0.05	0.17	0.38	0.05	0.0078	0.75	0.01
'Gaver'	DN	18.2	0.53	***0.07***	0.17	0.53	***0.08***	0.0091	0.836	0.01
'Gibecq'	DN	18.2	0.48	0.05	0.16	0.45	0.05	0.0090	0.81	0.05
'Ghoy'	DN	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.0088	0.59	0.05
'Ogy'	DN	20.0	0.33	0.05	0.16	0.29	***0.90***	0.0081	0.81	0.05
'Primo'	DN	19.4	0.52	0.05	N.A.	N.A.	N.A.	0.0083	0.62	0.05
'Tardif'	DN									
'Hoogvorst'	TD	15.4	0.61	0.05	0.17	0.61	0.05	0.0078	0.88	0.05
'Hazendans'	TD	16.8	0.56	0.05	0.15	0.50	0.05	0.0087	0.77	0.05
'Beaupré'	TD	18.0	0.67	0.05	0.14	0.59	0.05	0.0079	0.88	0.05
'Trichobel'	T	17.2	0.34	***0.12***	0.14	0.29	***0.24***	0.0078	0.90	0.05
'Fritzi Pauley'	T	17.8	0.60	***0.07***	0.14	0.62	***0.12***	0.0077	0.93	0.05
DTM1	DTM	17.8	0.73	0.01	0.12	0.71	0.01	0.0068	0.86	0.01
DTM2	DTM	18.5	0.89	0.05	0.12	0.90	0.01	0.0070	0.95	0.05
DTM3	DTM	18.0	0.71	0.05	0.13	0.88	0.05	0.0072	0.78	0.05
'grey poplar'		20.0	0.35	0.05	0.13	0.08	***0.71***	0.0067	0.32	***0.07***

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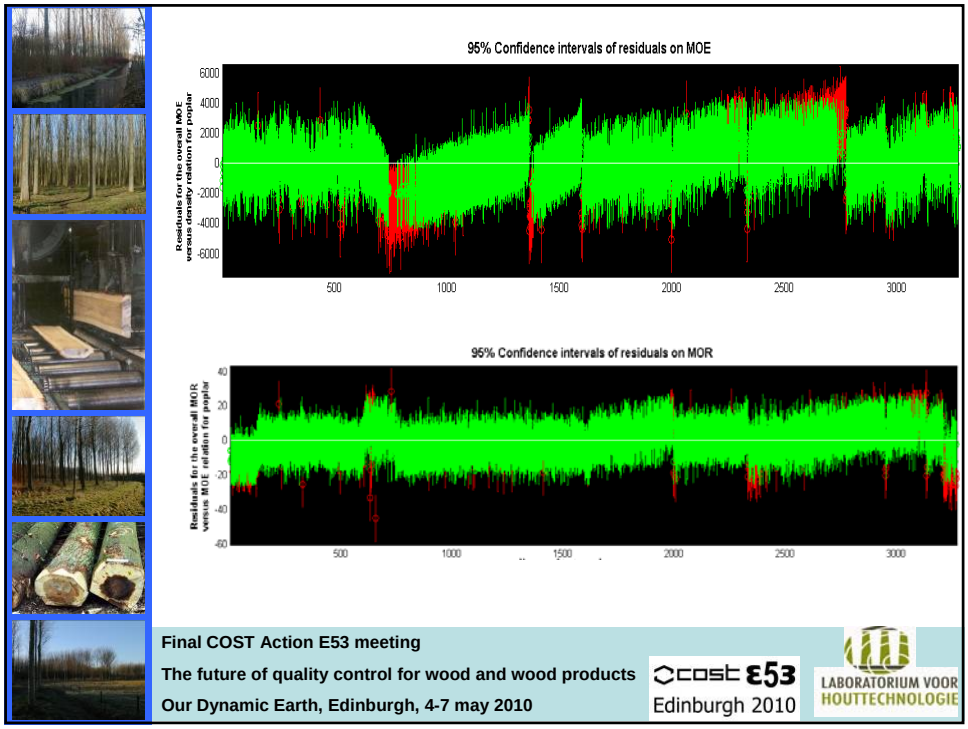

	Density to MOE	Density to MOR	MOE to MOR	Density and MOE to MOR
+	'***Robusta***' (+)	'Primo'	'Hazendans' 'Gibecq' '***Gaver***' (+)	'Hazendans' '***Gibecq***' (+) 'Gaver'
0	'DTM1' 'DTM2' 'DTM3' 'Beaupré' 'Fritzi Pauley' 'Ghoy' 'Gaver' 'Gibecq' 'Primo' Grey poplar	'Beaupré' 'Fritzi Pauley'	'**Robusta**' (-) 'Ogy' 'Beaupré' 'Fritzi Pauley' 'Hoogvorst' 'Trichobel' 'Primo'	'**Robusta**' (-) 'Ogy' 'Beaupré' 'Fritzi Pauley' 'Hoogvorst' 'Trichobel' 'Primo'
-		'DTM1' 'DTM2' 'DTM3'	'***DTM1***' (-) '***DTM2***' (-) '***DTM3***' (-) ***Grey poplar*** (-)	'***DTM1***' (-) '***DTM2***' (-) '***DTM3***' (-) ***Grey poplar*** (-)
/	'***Hoogvorst***' (-) 'Hazendans' 'Trichobel' 'Ogy'	'***Hoogvorst***' (-) '***Robusta***' (+) 'Hazendans' 'Trichobel' 'Ghoy' 'Ogy' 'Gaver' 'Gibecq' Grey poplar	'Ghoy'	'Ghoy'

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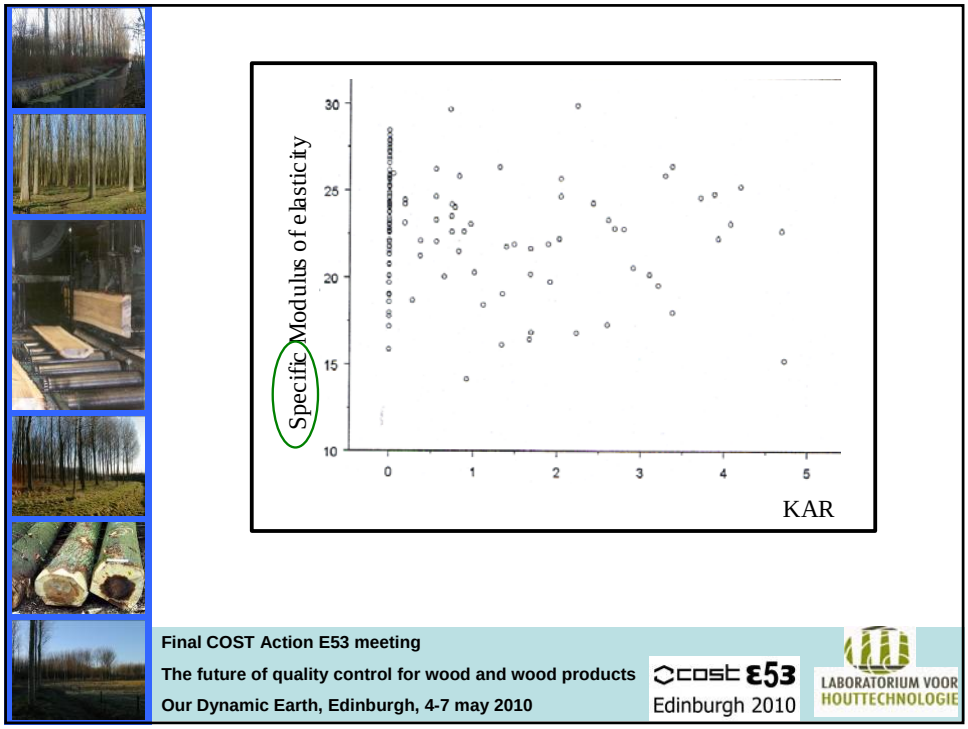
Clone*		Relation MOE to density			Relation MOR to density			Relation MOR to MOE		
		$C_{MOE,\rho}$	R^2_{max}	p	$C_{MOR,\rho}$	R^2_{max}	p	$C_{MOR,MOE}$	R^2_{max}	p
Sem_1	A	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.0082	0.42	0.05
Sem_2	R	16.8	0.40	***0.08***	N.A.	N.A.	N.A.	0.0085	0.48	0.05
Sem_3	A	16.7	0.45	0.05	0.14	0.47	0.05	0.0079	0.49	0.05
Sem_4	A	16.6	0.35	0.05	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Sem_5	A	17.9	0.16	***0.10***	0.13	0.30	0.05	0.0073	0.52	0.05
Sem_6	A	15.7	0.45	0.05	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Sem_7	A	16.2	0.51	0.05	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Sem_8	A	16.4	0.23	***0.12***	N.A.	N.A.	N.A.	0.0082	0.42	0.05
Sem_9	R	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.0085	0.36	0.05
Sem_10	R	16.1	0.67	0.05	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Bree	A	16.0	0.46	0.05	0.09	0.40	***0.08***	0.0053	0.26	***0.07***

GRADING

- Visual grading
  - According French standard (R – C18 – C24)
  - Also attention to tension wood (Wooliness) and grain angle
- Free-free bending frequency (mode 1)
- Destructive testing (manual determination of strength class)
  - Modulus of elasticity
  - Bending strength
  - Shear modulus



	VISUAL			MECHANICAL			MANUAL CLASS DETERMINATION			
	R	C18	C24	R	C18	C24	R	C18	C24	>C24
'Robusta'	35	55	10	11	52	37	10	41	35	14
'DTM'	27	47	26	13	58	29	77	21	12	0

- Drying deformations (here limiting)
- Wrong upgrading due to overall relation (DTM)
- Influence of knots is clonal dependent (limits higher strength classes)
- C18 – C24 grading is realistic when applying to the correct group of clones.
- C30 is theoretically present within poplar universe, BUT grading techniques will need to be adopted to increase current R^2.

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VENEER BASED PRODUCTS

Clone	Site	Heartwood proportion [%]	Tension wood proportion [%]	Density [Kg/m³]	MOE [N/mm²]	MOR [N/mm²]
70 078 /2	Holsbeek	28	24	380	7700	48
70 078 /6	Basilly	48	21	360	7400	47
70 078 /11	Holsbeek	38	29	385	8100	51
	Basilly	41	32	365	7600	48
71 106 /1	Holsbeek	54	42	365	7300	44
71 106 /5	Holsbeek	60	38	345	6900	42
	Basilly	65	35	355	6700	44

		Veneer quality grade				
		A	B1	B3	C	D and NC
70 078 /2	Holsbeek	-	-	35 %	62 %	3 %
70 078 /6	Basilly	3 %	10 %	34 %	49 %	4 %
70 078 /11	Holsbeek	-	7 %	37 %	47 %	10 %
	Basilly	2 %	18 %	30 %	44 %	6 %
71 106 /1	Holsbeek	-	5 %	33 %	62 %	3 %
71 106 /5	Holsbeek	-	2 %	33 %	61 %	3 %
	Basilly	2 %	17 %	47 %	31 %	3 %

Abbreviation	Description
A	Closed veneers, absence of defects, even coloured
B1	Closed veneers, sound knots allowed up till 15 mm
B3	Cracks up till 40 cm (not wide open) but maximum 3 Sound knots allowed up till 30 mm Defects can be technically repaired
C	No limit for sound knots Loose knots allowed up till 30 mm No limit on cracks (but cracks are not wide open) Interior plies only
D	Not classified in the above. Can not be used as such (re-cut) Interior plies only
NC	Not classified (to wet, to small dimensions)

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	DTM	DM	Duncan ranking
Density of the board	485 ± 12	415 ± 21	ab
Modulus of elasticity ⊥	2830 ± 280	2315 ± 64	ab
//	4435 ± 255	3820 ± 246	ab
Modulus of rupture ⊥	28.1 ± 1.8	26.8 ± 2.3	aa
//	44.3 ± 1.4	42.4 ± 2.5	aa

LAMINATED TIMBER

	Type III	Type II	Type I	Type I*
Lamella 5	Grade B	Grade B	Grade A	Grade A
Lamella 4	Grade B	Grade C	Grade B	Grade A
Lamella 3	Grade B	Grade C	Grade B	Grade A
Lamella 2	Grade B	Grade C	Grade B	Grade A
Lamella 1	Grade B	Grade B	Grade A	Grade A

RESULTS AND DISCUSSION

	Ogy	Gaver	Statistics Anova/Duncan
Density [kg/m³]	425 ± 35	422 ± 33	aa
KAR [%]	0.6 ± 1.1	0.6 ± 0.9	aa
Moisture content [%]	8.2 ± 0.2	8.3 ± 0.3	aa
Tension wood [%]	10.5 ± 0.8	5.5 ± 0.5	ab
MOE [N/mm²]	8200 ± 221	7560 ± 126	ab
MOR [N/mm²]	68.2 ± 7.4	71.8 ± 6.7	aa

OGY

Type	Glue	Classification based on Beam properties	Classification based on lamella properties
II	PUR	Not classified	Not classified
II	ISO	GL 24	Not classified
III	PUR		
	ISO		
II	PR	GL 28	GL 24
III	PR		
I	ISO	GL 32	GL 24
	PR		
	PUR		

GAVER

Type	Glue	Classification based on Beam properties	Classification based on lamella properties
III	ISO	Not classified	Not classified
II	ISO	GL 24	Not classified
	PUR		
	PR		
III	PR		
III	PUR	GL 28	GL 24
I	ISO		
	PUR		
I	PR	GL 32	GL 24

CONCLUSIONS - PERSPECTIVES

- Large amount of poplar and willow clones → selection options
- **Variability** of wood basic properties needs to be evaluated, rather than mean values.
- Groups of "processable" clones need to be identified and adopted within selection processes.
- Visual grading is to specific
- Mechanical grading within identified groups → C18 and C24
- C30 grades will need adopted strength relations (increase R^2).
- Laminated beams can be made in very similar way as done for softwoods.
- CE structural plywood and LVL feasible and on market.
- "Today" still enough material on the market (400 000 m^3/ year in Belgium)