



## Potential of poplar and willow wood for load-bearing constructions


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Final COST Action E53 meeting  
The future of quality control for wood and wood products  
Our Dynamic Earth, Edinburgh, 4-7 may 2010

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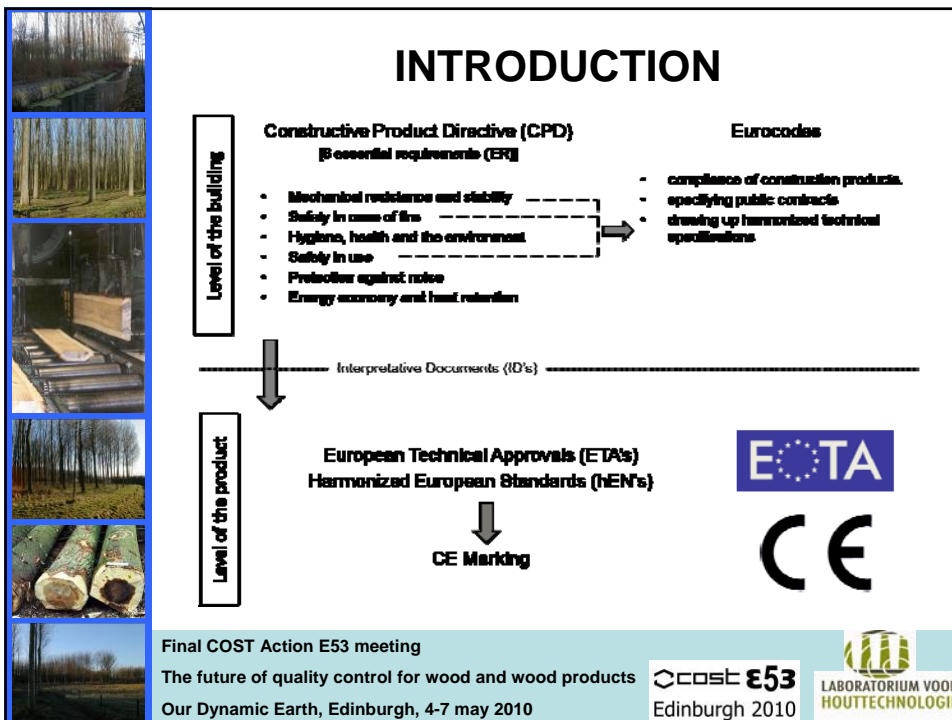
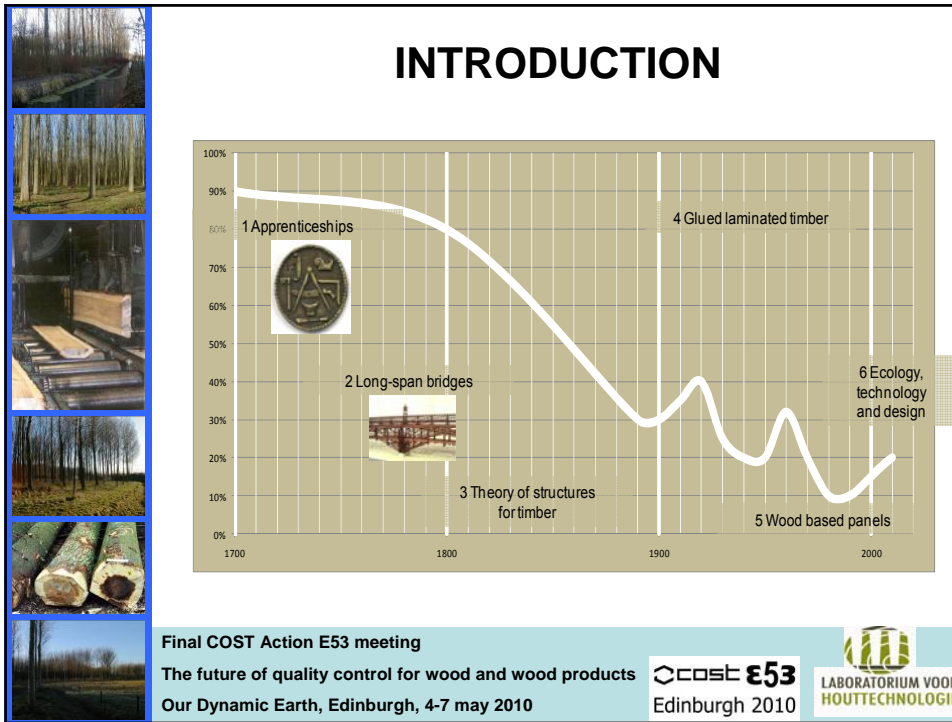
## OUTLINE


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

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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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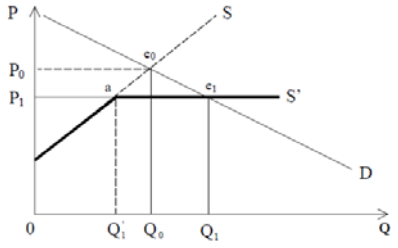
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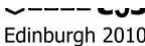

## INTRODUCTION

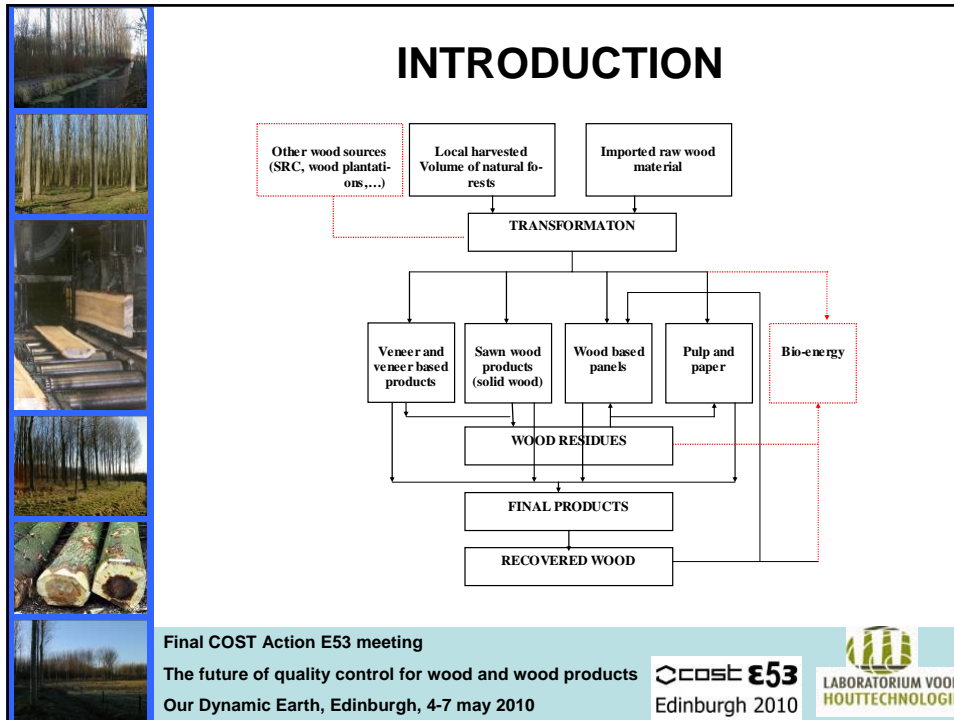
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**INTRODUCTION**

**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:

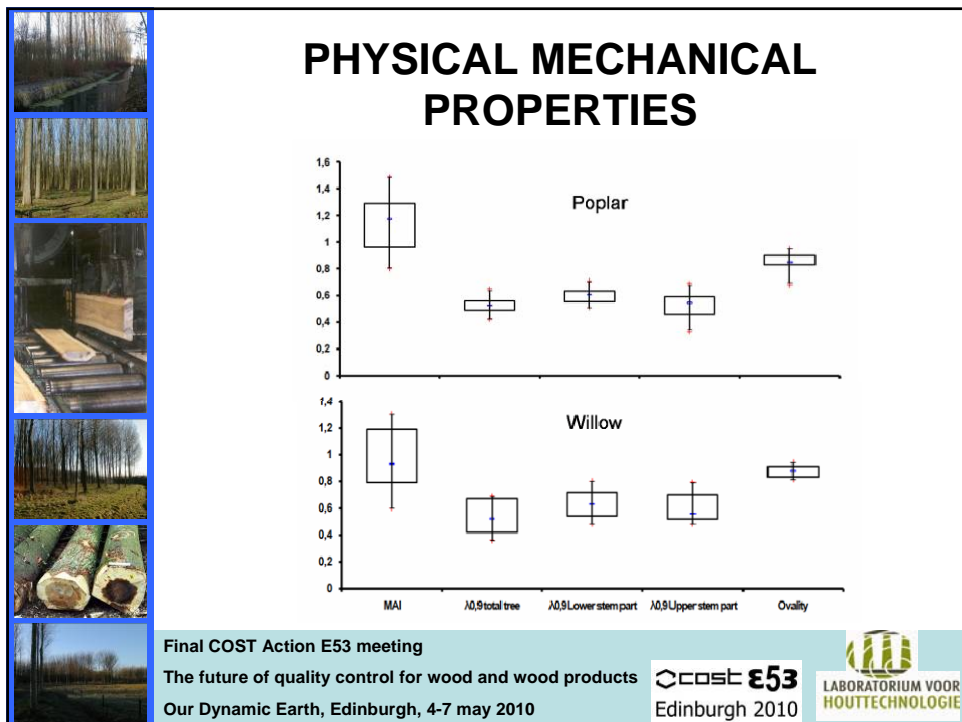
**The possibility to describe the inherent properties of poplar and willow wood with special emphasis on assessing their variability and the possibility to select, control and improve the properties of interest.**

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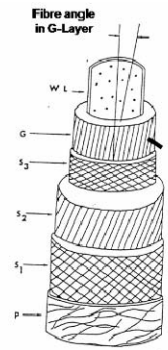
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|   |   |  |                                       |  |                                   |                                    |  |   |   |  |   |   |  |                                     |                                     |   |  |  |  |  |                                 |  |
|---|---|--|---------------------------------------|--|-----------------------------------|------------------------------------|--|---|---|--|---|---|--|-------------------------------------|-------------------------------------|---|--|--|--|--|---------------------------------|--|
|   | <b>Introduction - chapter 1</b>   |  |                                       |  |                                   |                                    |  |   |   |  |   |   |  |                                     |                                     |   |  |  |  |  |                                 |  |
|   | <table border="1"> <tr> <td style="text-align: center;"> <b>Part 1<br/>Poplar and willow wood</b> </td> <td style="text-align: center;"> <b>Part 2<br/>Wood transformation</b> </td> </tr> <tr> <td> <table border="1"> <tr> <td>chapter 2<br/>Botanical background</td> <td>chapter 5<br/>Wood drying</td> </tr> <tr> <td>chapter 3<br/>Intrinsic wood properties</td> <td>chapter 6<br/>Wood grading</td> </tr> <tr> <td>chapter 4<br/>Mechanical properties</td> <td>chapter 7<br/>Preservation and modification</td> </tr> </table> </td> <td> <table border="1"> <tr> <td style="text-align: center;"> <b>Part 3<br/>Constructive products</b> </td> </tr> <tr> <td>chapter 8<br/>Solid timber applications</td> </tr> <tr> <td>chapter 9<br/>Glued laminated timber</td> </tr> <tr> <td>chapter 10<br/>Veneer based products</td> </tr> </table> </td> </tr> <tr> <td style="text-align: center;"> <b>Part 4<br/>Impact on forestry-wood chain</b> </td> <td> <table border="1"> <tr> <td>chapter 11<br/>Wood supply - Forestry factors</td> <td rowspan="2"> </td> </tr> <tr> <td>chapter 12<br/>Wood demand - Economical factors</td> </tr> </table> </td> </tr> <tr> <td style="text-align: center;"> <b>Conclusions - chapter 13</b> </td> <td></td> </tr> </table> | <b>Part 1<br/>Poplar and willow wood</b>     | <b>Part 2<br/>Wood transformation</b> | <table border="1"> <tr> <td>chapter 2<br/>Botanical background</td> <td>chapter 5<br/>Wood drying</td> </tr> <tr> <td>chapter 3<br/>Intrinsic wood properties</td> <td>chapter 6<br/>Wood grading</td> </tr> <tr> <td>chapter 4<br/>Mechanical properties</td> <td>chapter 7<br/>Preservation and modification</td> </tr> </table> | chapter 2<br>Botanical background | chapter 5<br>Wood drying           | chapter 3<br>Intrinsic wood properties     | chapter 6<br>Wood grading   | chapter 4<br>Mechanical properties      | chapter 7<br>Preservation and modification | <table border="1"> <tr> <td style="text-align: center;"> <b>Part 3<br/>Constructive products</b> </td> </tr> <tr> <td>chapter 8<br/>Solid timber applications</td> </tr> <tr> <td>chapter 9<br/>Glued laminated timber</td> </tr> <tr> <td>chapter 10<br/>Veneer based products</td> </tr> </table> | <b>Part 3<br/>Constructive products</b> | chapter 8<br>Solid timber applications | chapter 9<br>Glued laminated timber | chapter 10<br>Veneer based products | <b>Part 4<br/>Impact on forestry-wood chain</b> | <table border="1"> <tr> <td>chapter 11<br/>Wood supply - Forestry factors</td> <td rowspan="2"> </td> </tr> <tr> <td>chapter 12<br/>Wood demand - Economical factors</td> </tr> </table> | chapter 11<br>Wood supply - Forestry factors |  | chapter 12<br>Wood demand - Economical factors | <b>Conclusions - chapter 13</b> |  |
|   | <b>Part 1<br/>Poplar and willow wood</b>  | <b>Part 2<br/>Wood transformation</b>        |                                       |  |                                   |                                    |  |   |   |  |   |   |  |                                     |                                     |   |  |  |  |  |                                 |  |
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|   | chapter 2<br>Botanical background   | chapter 5<br>Wood drying                     |                                       |  |                                   |                                    |  |   |   |  |   |   |  |                                     |                                     |   |  |  |  |  |                                 |  |
|   | chapter 3<br>Intrinsic wood properties  | chapter 6<br>Wood grading                    |                                       |  |                                   |                                    |  |   |   |  |   |   |  |                                     |                                     |   |  |  |  |  |                                 |  |
|   | chapter 4<br>Mechanical properties  | chapter 7<br>Preservation and modification   |                                       |  |                                   |                                    |  |   |   |  |   |   |  |                                     |                                     |   |  |  |  |  |                                 |  |
| <b>Part 3<br/>Constructive products</b>   |   |  |                                       |  |                                   |                                    |  |   |   |  |   |   |  |                                     |                                     |   |  |  |  |  |                                 |  |
| chapter 8<br>Solid timber applications  |   |  |                                       |  |                                   |                                    |  |   |   |  |   |   |  |                                     |                                     |   |  |  |  |  |                                 |  |
| chapter 9<br>Glued laminated timber   |   |  |                                       |  |                                   |                                    |  |   |   |  |   |   |  |                                     |                                     |   |  |  |  |  |                                 |  |
| chapter 10<br>Veneer based products   |   |  |                                       |  |                                   |                                    |  |   |   |  |   |   |  |                                     |                                     |   |  |  |  |  |                                 |  |
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| chapter 12<br>Wood demand - Economical factors  |   |  |                                       |  |                                   |                                    |  |   |   |  |   |   |  |                                     |                                     |   |  |  |  |  |                                 |  |
| <b>Conclusions - chapter 13</b>   |   |  |                                       |  |                                   |                                    |  |   |   |  |   |   |  |                                     |                                     |   |  |  |  |  |                                 |  |
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|   |   |  |                                       |  |                                   |                                    |  |   |   |  |   |   |  |                                     |                                     |   |  |  |  |  |                                 |  |













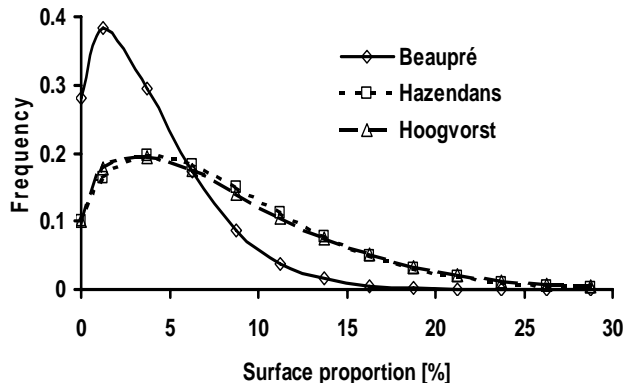
**P: Primary wall**  
**S1, S2, S3 : Secondary wall**  
**G: Gelatinous layer (small fibre angle)**



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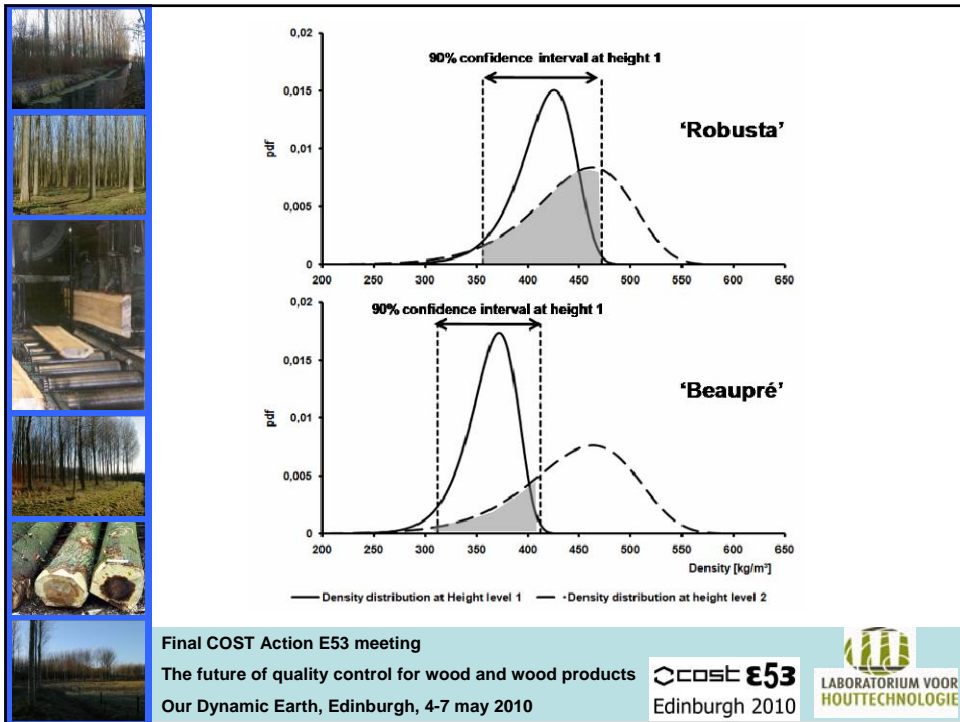
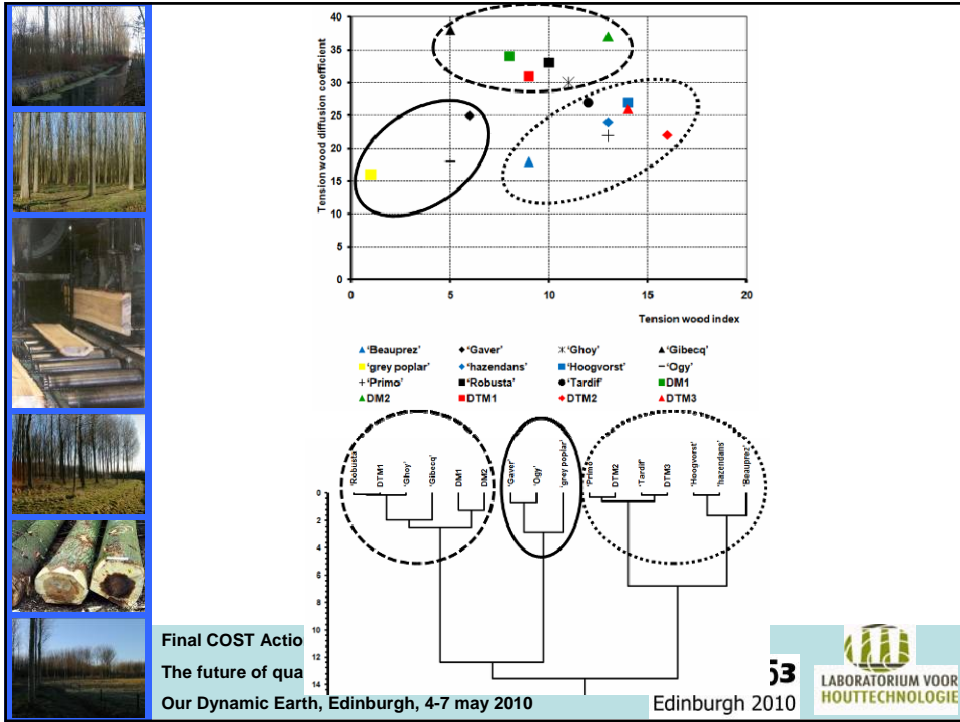


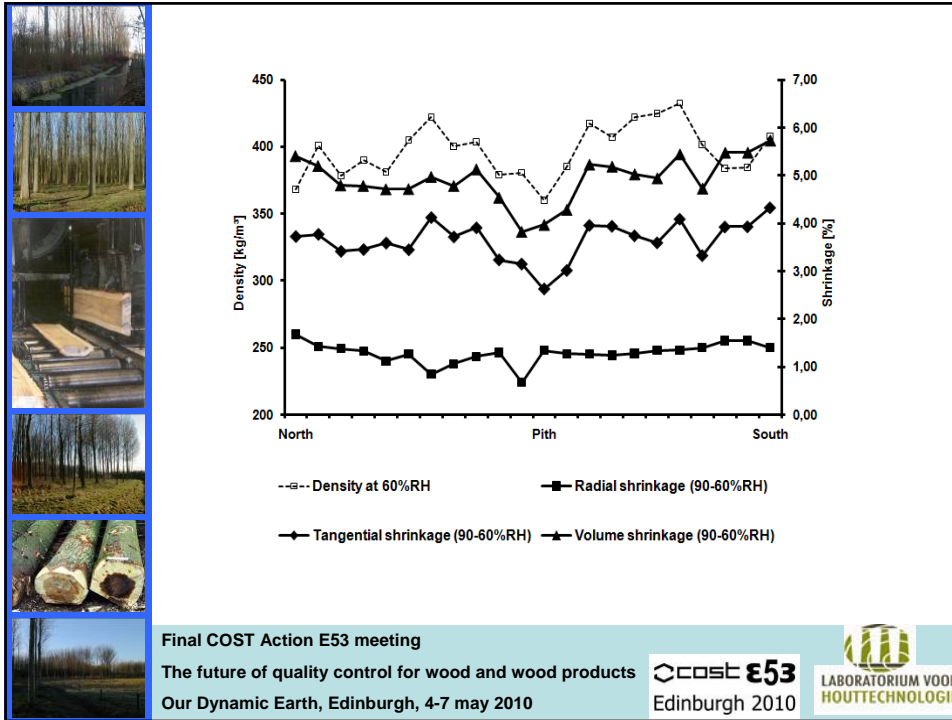


| Surface proportion [%] | Beaupré (Frequency) | Hazendans (Frequency) | Hoogvorst (Frequency) |
|------------------------|---------------------|-----------------------|-----------------------|
| 0                      | 0.28                | 0.18                  | 0.10                  |
| 2                      | 0.38                | 0.18                  | 0.15                  |
| 4                      | 0.30                | 0.19                  | 0.18                  |
| 6                      | 0.20                | 0.18                  | 0.18                  |
| 8                      | 0.10                | 0.15                  | 0.15                  |
| 10                     | 0.05                | 0.12                  | 0.12                  |
| 12                     | 0.02                | 0.10                  | 0.10                  |
| 14                     | 0.01                | 0.08                  | 0.08                  |
| 16                     | 0.00                | 0.06                  | 0.06                  |
| 18                     | 0.00                | 0.04                  | 0.04                  |
| 20                     | 0.00                | 0.03                  | 0.03                  |
| 22                     | 0.00                | 0.02                  | 0.02                  |
| 24                     | 0.00                | 0.01                  | 0.01                  |
| 26                     | 0.00                | 0.01                  | 0.01                  |
| 28                     | 0.00                | 0.01                  | 0.01                  |
| 30                     | 0.00                | 0.01                  | 0.01                  |

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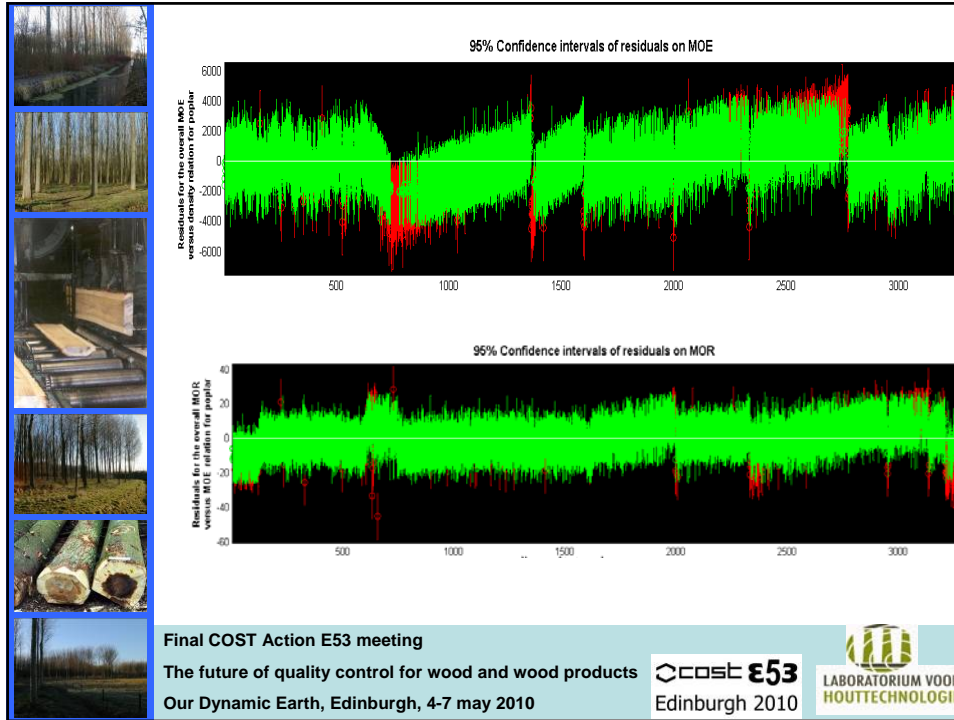
| Clone           |     | Relation MOE to density |                               |             | Relation MOR to density |                               |             | Relation MOR to MOE  |                               |             |
|-----------------|-----|-------------------------|-------------------------------|-------------|-------------------------|-------------------------------|-------------|----------------------|-------------------------------|-------------|
|                 |     | C <sub>MOE,p</sub>      | R <sup>2</sup> <sub>max</sub> | p           | C <sub>MOR,p</sub>      | R <sup>2</sup> <sub>max</sub> | p           | C <sub>MOR,MOE</sub> | R <sup>2</sup> <sub>max</sub> | 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                          | <b>0.07</b> | 0.17                    | 0.53                          | <b>0.08</b> | 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                          | <b>0.90</b> | 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                          | <b>0.12</b> | 0.14                    | 0.29                          | <b>0.24</b> | 0.0078               | 0.90                          | 0.05        |
| 'Fritzi Pauley' | T   | 17.8                    | 0.60                          | <b>0.07</b> | 0.14                    | 0.62                          | <b>0.12</b> | 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                          | <b>0.71</b> | 0.0067               | 0.32                          | <b>0.07</b> |

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

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| Clone  |   | Relation MOE to density |             |             | Relation MOR to density |             |             | Relation MOR to MOE |             |             |
|--------|---|-------------------------|-------------|-------------|-------------------------|-------------|-------------|---------------------|-------------|-------------|
|        |   | $C_{MOE,p}$             | $R^2_{max}$ | $p$         | $C_{MOR,p}$             | $R^2_{max}$ | $p$         | $C_{MOR,MOE}$       | $R^2_{max}$ | $p$         |
| 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        | <b>0.08</b> | 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        | <b>0.10</b> | 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        | <b>0.12</b> | 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        | <b>0.08</b> | 0.0053              | 0.26        | <b>0.07</b> |

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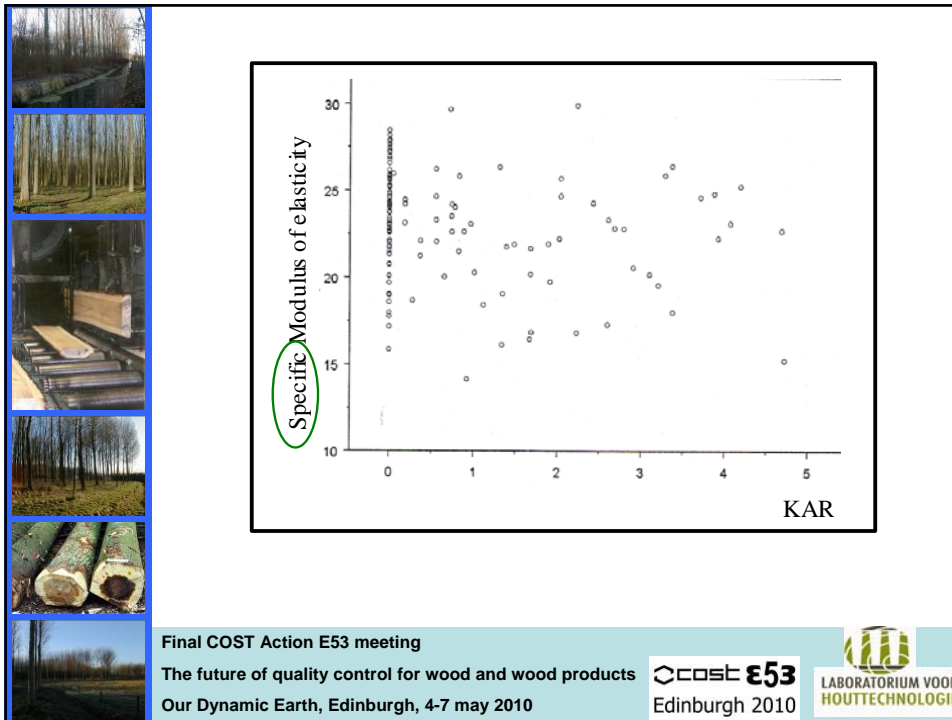
## GRADING

- 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



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|           | 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<sup>2</sup>.

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## VENEER BASED PRODUCTS

| Clone      | Site     | Heartwood proportion | Tension wood proportion | Density              | MOE                  | MOR                  |
|------------|----------|----------------------|-------------------------|----------------------|----------------------|----------------------|
|            |          | [%]                  | [%]                     | [Kg/m <sup>3</sup> ] | [N/mm <sup>2</sup> ] | [N/mm <sup>2</sup> ] |
| 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                   |

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|            |          | 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<br>Sound knots allowed up till 30 mm<br>Defects can be technically repaired            |
| C            | No limit for sound knots<br>Loose knots allowed up till 30 mm<br>No limit on cracks (but cracks are not wide open)<br>Interior plies only |
| D            | Not classified in the above. Can not be used as such (re-cut)<br>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             |

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## LAMINATED TIMBER



|           | Type III | Type II | Type I  | Type I <sup>+</sup> |
|-----------|----------|---------|---------|---------------------|
| 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             |

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## RESULTS AND DISCUSSION

|                              | Ogy        | Gaver      | Statistics<br>Anova/Duncan |
|------------------------------|------------|------------|----------------------------|
| Density [kg/m <sup>3</sup> ] | 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/mm <sup>2</sup> ]     | 8200 ± 221 | 7560 ± 126 | ab                         |
| MOR [N/mm <sup>2</sup> ]     | 68.2 ± 7.4 | 71.8 ± 6.7 | aa                         |

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## OGY


| Type | Glue | Classification based on Beam<br>properties | Classification based on lamella<br>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  |  |   |

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## GAVER


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

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## 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<sup>2</sup>).
- 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<sup>3</sup>/ year in Belgium)

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