UNIVERSITY OF COPENHAGEN
FACULTY OF SCIENCE


# Use of near infrared spectroscopy for the assessment of waste wood quality to energy use

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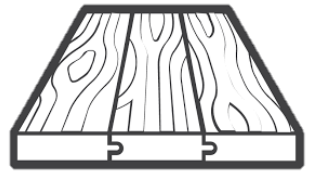
# Introduction in the waste wood world

**Waste wood: why?**

Promote **reuse and recycle of the materials** over the landfill

*Waste Framework Directive (2008/98/EC, European Parliament 2008)*


Increased demand for waste wood by the **panel industry**

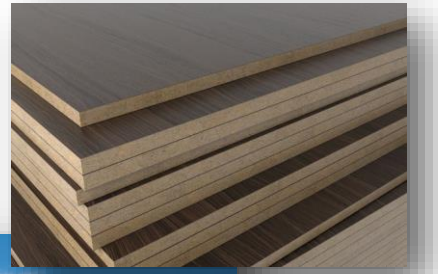


The substitution of fossil fuels through the energy use of wood-based materials for **mitigating GHG emissions**

*EU sustainable development goal, points 7 and 13*

# Aim





## Waste wood: what is it?

1 **Study of the waste wood variability and optimal sampling procedure**

**Reliable and accurate analytical results**

2 **Prediction of the energy parameters of waste wood material**

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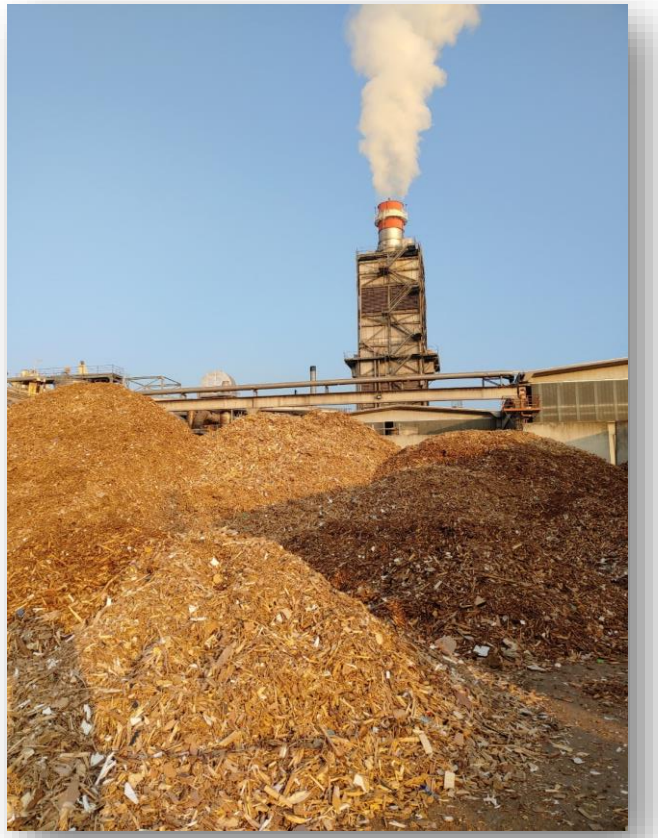
# Sampling procedure (1)



EN-15442:2011 standard (CEN, 2011) with some modifications

**Some numbers:**

- **2 days** of sampling (February 2020)
- **every hour deviation of WW material** from the production stream in an external unloading tank
- **16 lots**
- **24 increments of 10 L material for each lot**

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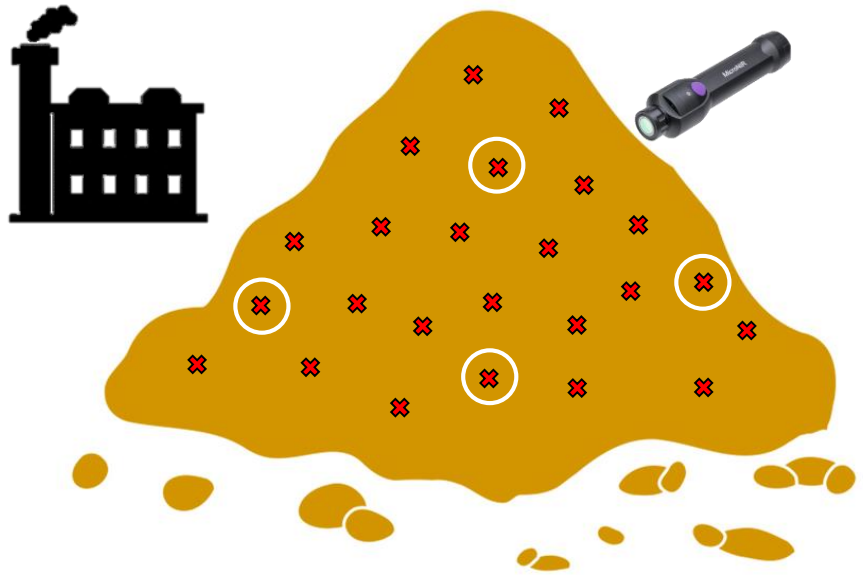
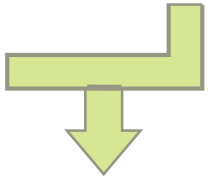
# Sampling procedure (2)

***Panel board company***



16 lots x 24 increments

1 **DT-Sam$_{Tot}$**



subset

16 lots x 4 increments

2 **DT-Sam$_{Red}$**

***Laboratory***

16 lots *x* 4 increments

3 **DT-Lab**

# Lab analysis


1 Moisture content

Technical standard UNI 15443

2 Stabilization and grinding process

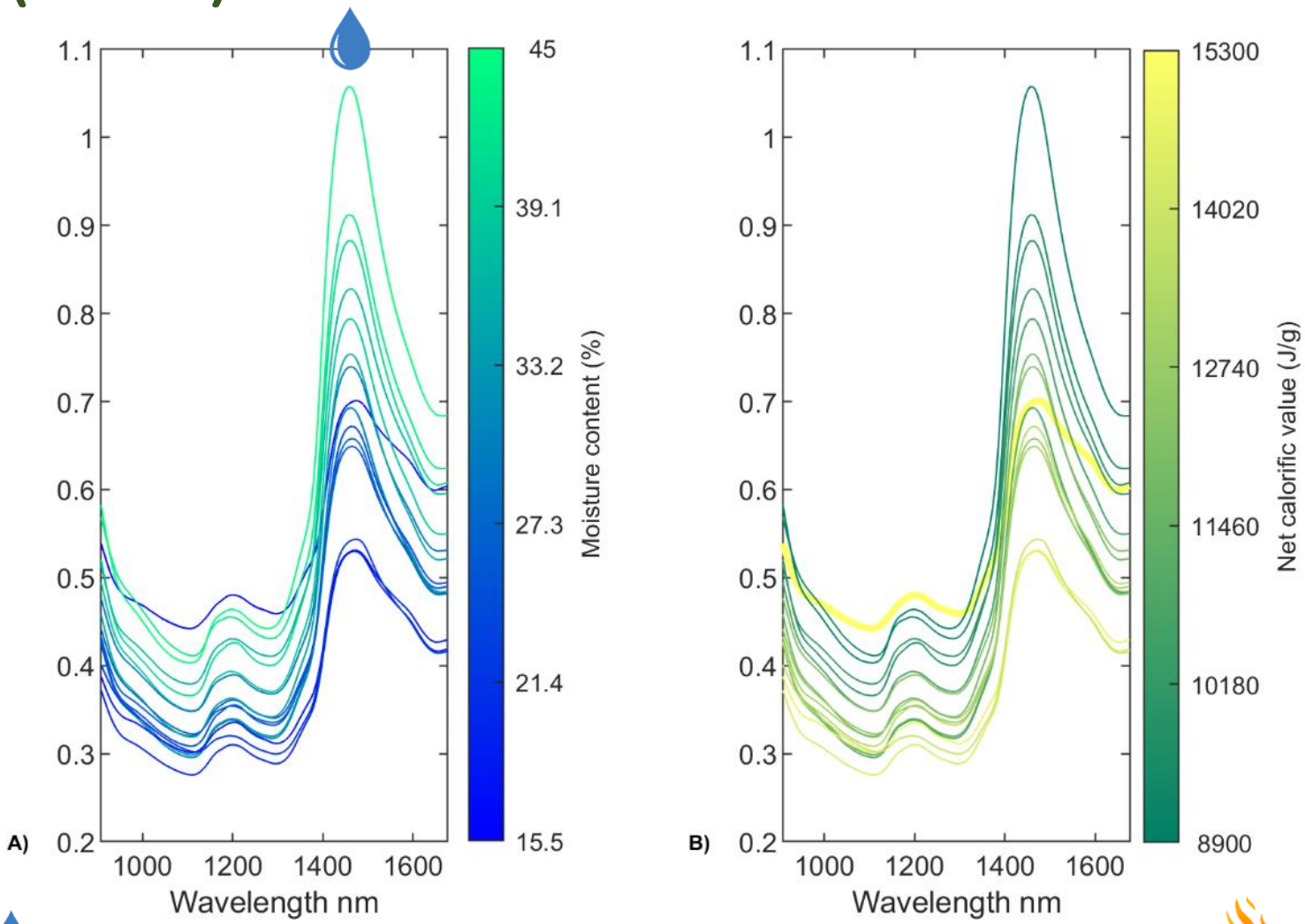
Technical standard ISO 18122

3 Lab analysis

Technical standard ISO 18125

Net calorific value

# NIR spectra (DT-Lab)




**Moisture content**

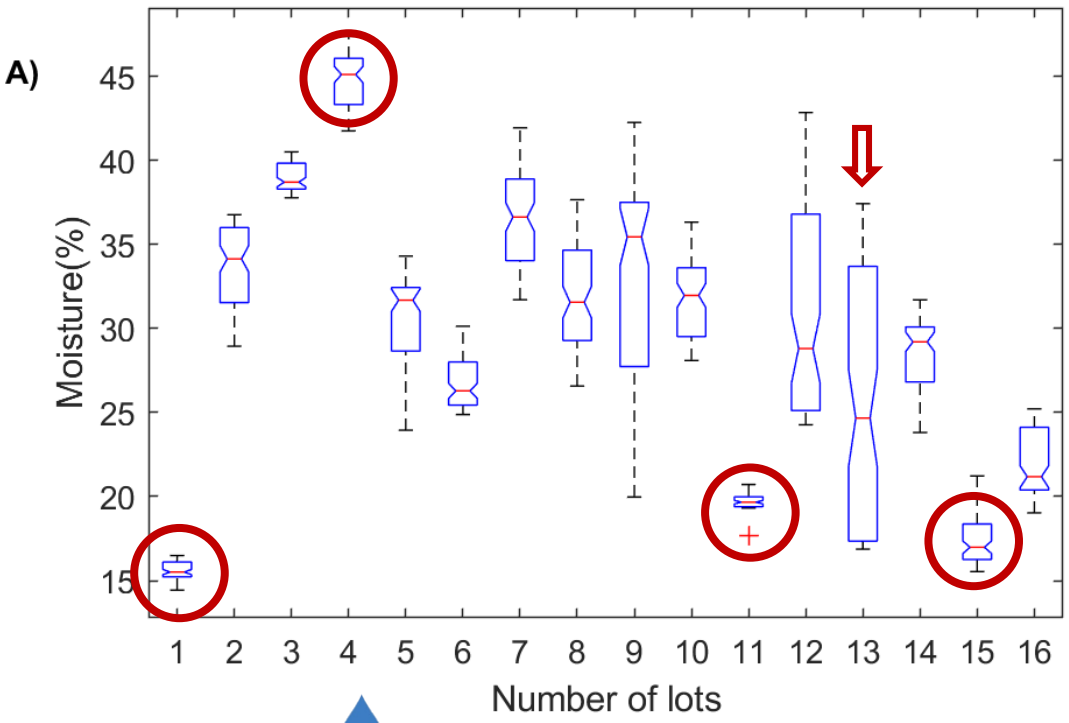
**Net calorific value**

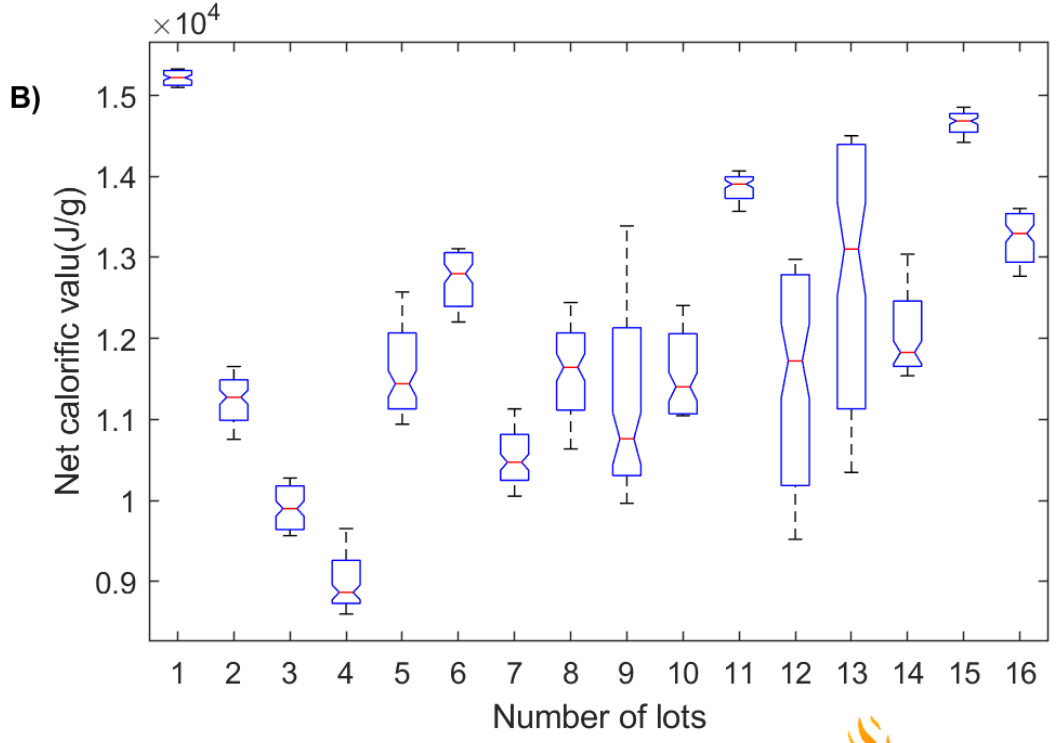
# Lab analysis

| | Moisure content | Net calorific value |
|---|---|---|
| Mean | 29.2 | 12041.5 |
| Std | 8.6 | 1779.7 |
| Min | 15.2 | 8596 |
| Max | 46.1 | 15328 |
| Range | 30.8 | 6732 |

Negative correlation

r = -0.99

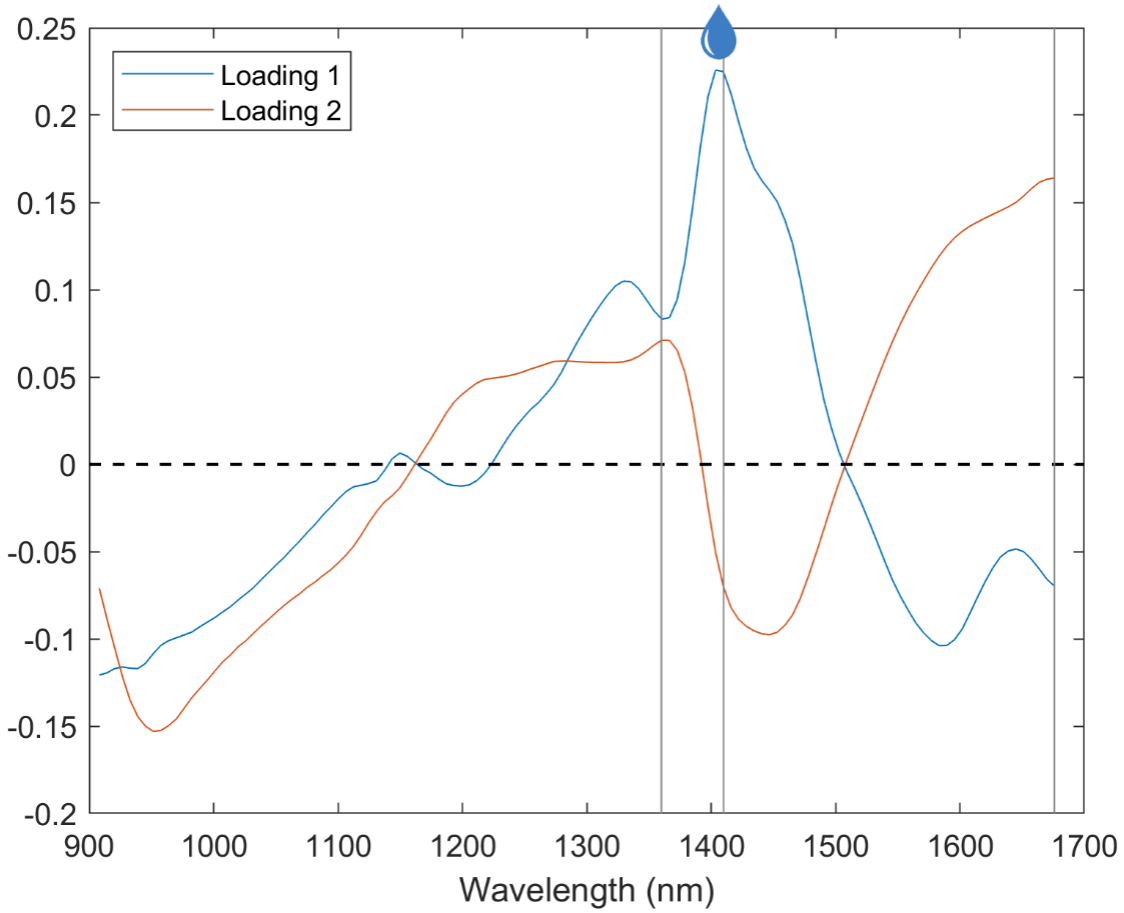


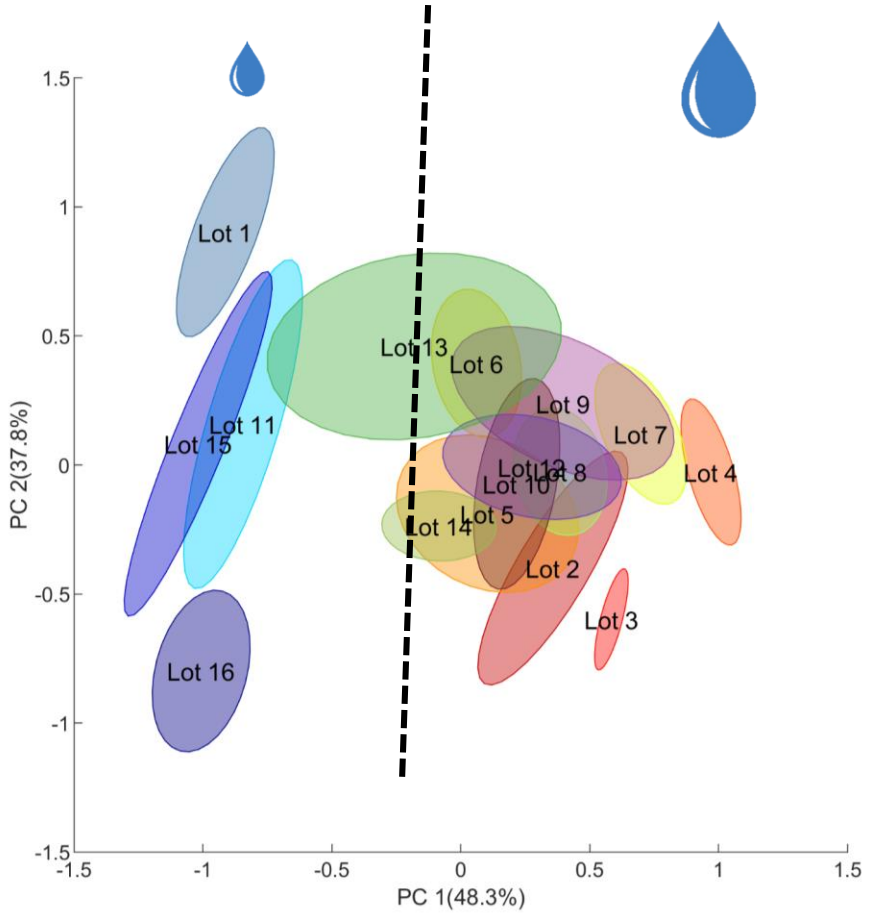




**Moisture content**

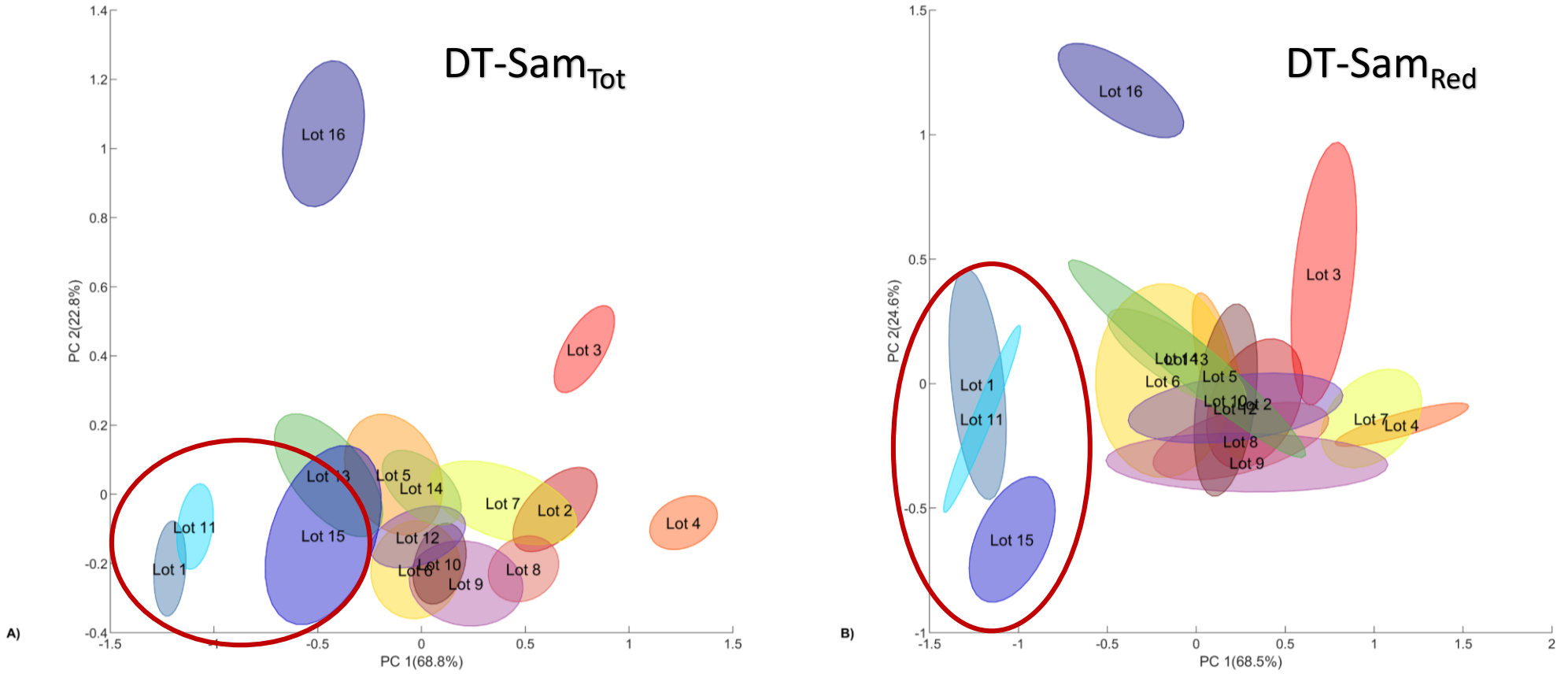
**Net calorific value**

# PCA of DT-Lab

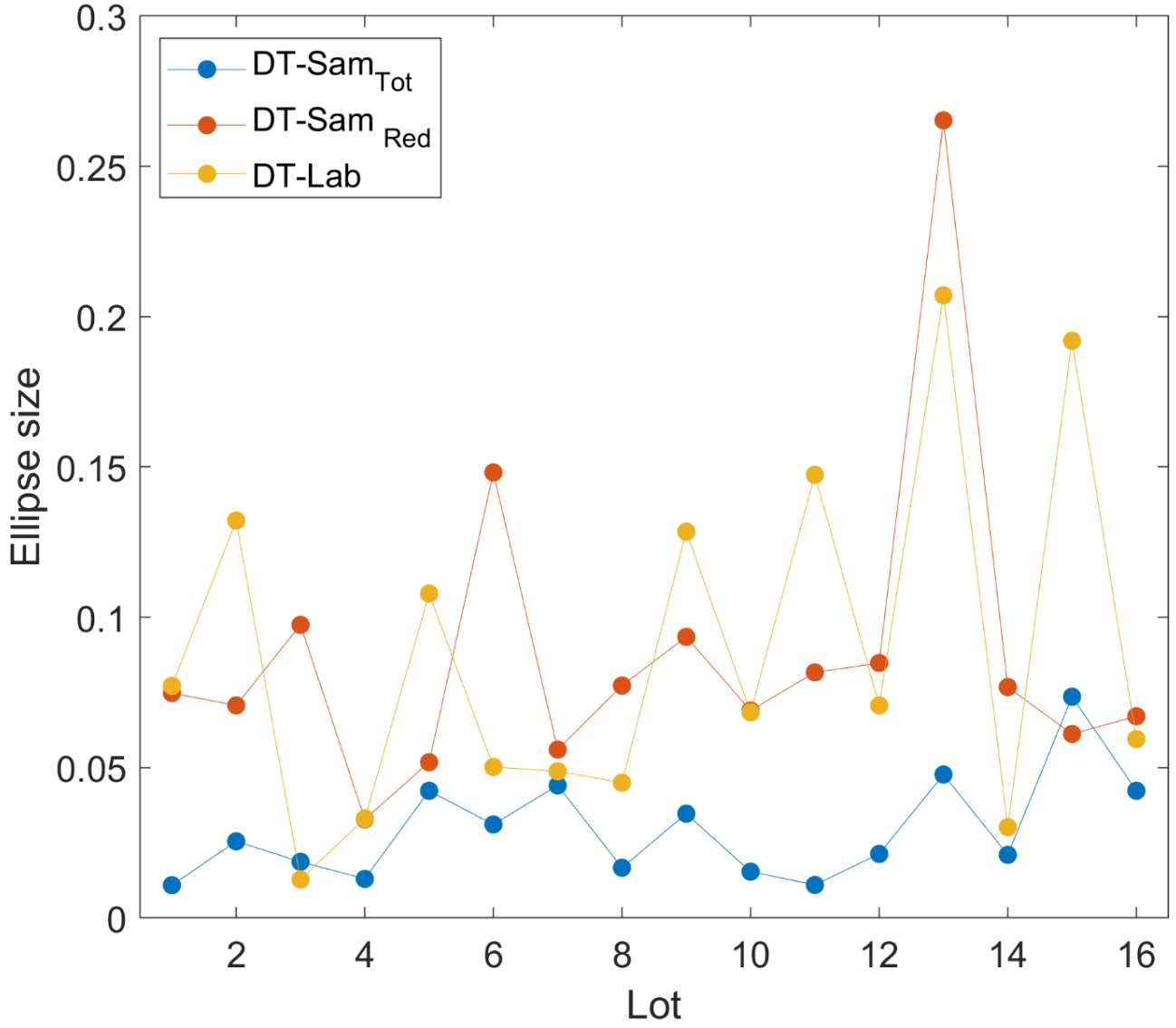

Loading 1
Loading 2
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
900
1000
1100
1200
1300
1400
1500
1600
1700
Wavelength (nm)


Lot 1
Lot 13
Lot 6
Lot 9
Lot 11
Lot 15
Lot 7
Lot 4
Lot 10
Lot 8
Lot 5
Lot 14
Lot 2
Lot 3
Lot 16
PC 2(37.8%)
PC 1(48.3%)
1.5
1
0.5
0
-0.5
-1
-1.5

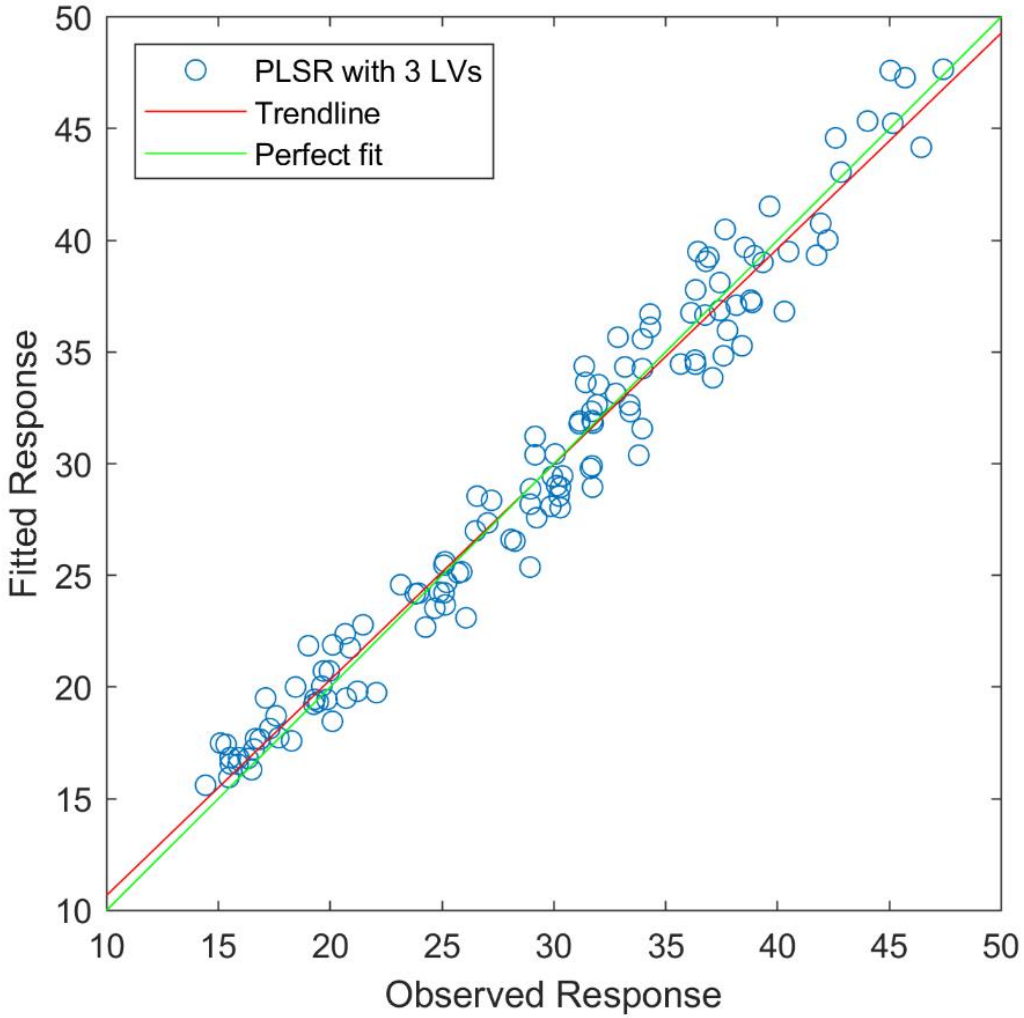
# PCA of DT-Sam


A)
DT-Sam$_{Tot}$
PC 2(22.8%)
PC 1(68.8%)
Lot 16
Lot 3
Lot 13
Lot 5
Lot 14
Lot 7
Lot 2
Lot 4
Lot 11
Lot 15
Lot 12
Lot 1
Lot 10
Lot 9
Lot 8
B)
DT-Sam$_{Red}$
PC 2(24.6%)
PC 1(68.5%)
Lot 16
Lot 3
Lot 1
Lot 11
Lot 6
Lot 5
Lot 10
Lot 2
Lot 12
Lot 7
Lot 4
Lot 8
Lot 9
Lot 15

# PCA of DT-Sam


DT-Sam Tot
DT-Sam Red
DT-Lab
Ellipse size
Lot
0.3
0.25
0.2
0.15
0.1
0.05
0
2
4
6
8
10
12
14
16

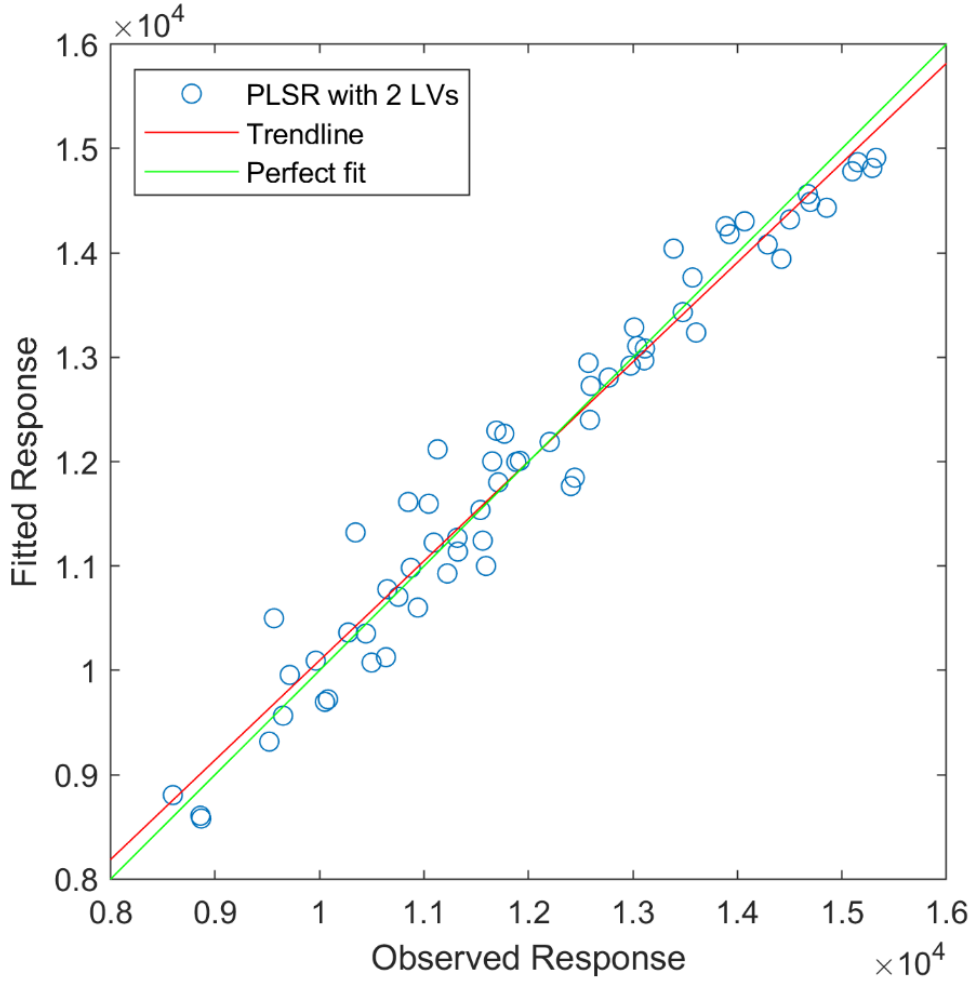
# Prediction of moisture content




| Indices | Moisture prediction |
|---|---|
| RMSECV | 1.34% |
| $R^2$ | 0.98 |
| RPD | 6.82 |

**RPD > 5**
any quality control applications

# Prediction of net calorific value

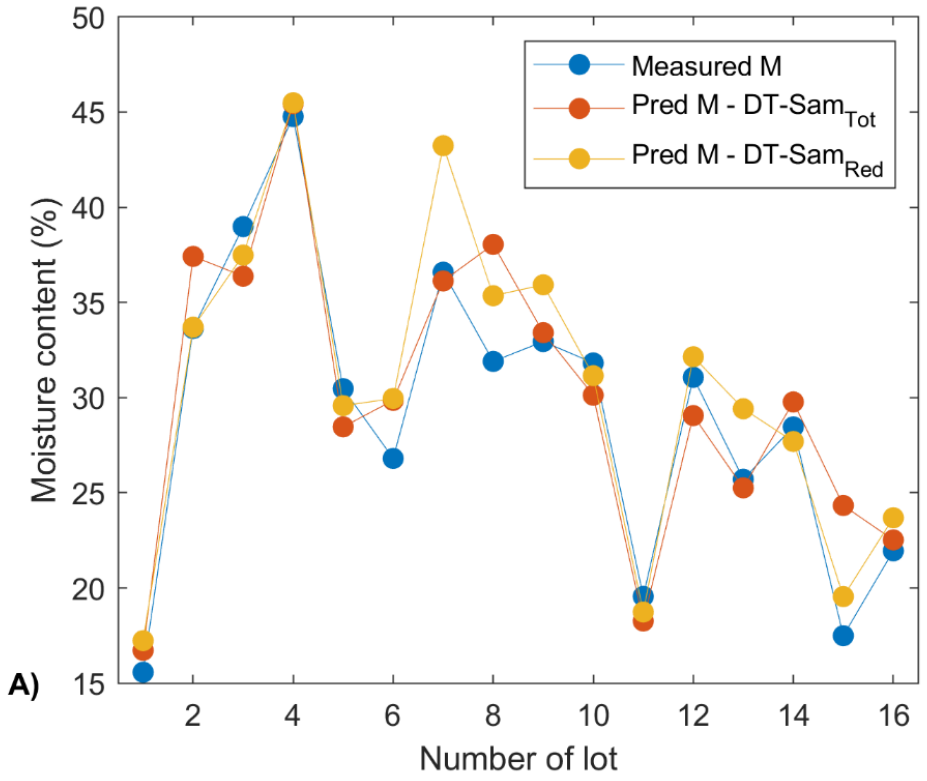


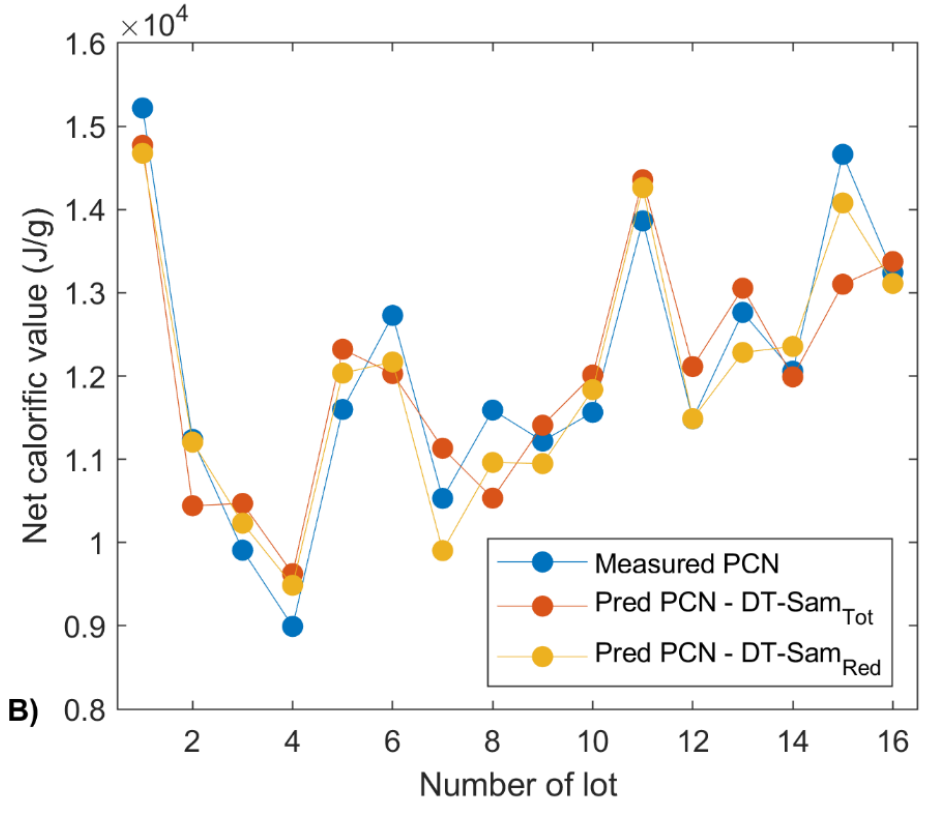

| Indices | Net calorific value prediction |
|---|---|
| RMSECV | 414.65 J/g |
| $R^2$ | 0.94 |
| RPD | 4.29 |

**3 < RPD < 5**
Screening applications

# Test the performance of the models

**DT-Sam$_{Tot}$ and DT-Sam$_{Red}$ as test sets**



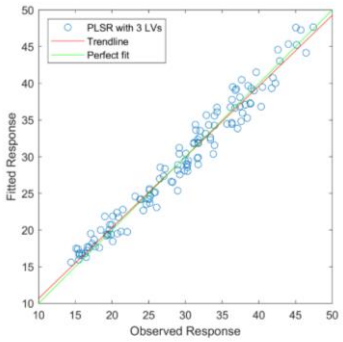

**Four increments, and the corresponding replicates and scans, are able to describe the variability between the lots**

# Linear regression

coefficient of
multiple correlation
**$R^2$ = 0.97**

$$NCV\ (J\ g^{-1}) = a + b\ * M\ (\%)$$

a = 18040.071
b = -205.195




Moisture content model

$$NCV\ (J\ g^{-1}) = a + b\ * M\ (\%)$$

Computation of net calorific value

**Benefits**

- ✓ Maintenance of one regression model
- ✓ No lab analysis

# Conclusions

1 The variation in material composition has been investigated using PCA

- ✓ Samples are located in the scores space based on their **moisture content/net calorific value**
- ✓ The **size of the confidence ellipses** is proportionate to the relative variability within each lot
- ✓ **Four** increments, and the corresponding replicates and scans are able to describe the variability between the lots.

2 Prediction of the energy parameters of waste wood material

- ✓ NIRS allows the rapid assessment of the waste wood and of the suitability of the material for **energy applications**.
- ✓ A **linear regression** can be used for predicting net calorific value from moisture content, improving the quality control and the energy valorization of the waste wood material.

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# Acknoledgments


- The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No. 838560

- Saviola panel board company


WoodSpec

Thank you!!