SUSTAINABLE PLACES 2023

Development of Numerical Models for Predicting Thermal Performance of Materials with Improved Ecological Footprint as Alternatives to Standard EPS

STEPS – Advanced Production System for the Built Environment Focusing on Productivity and Sustainability

CENTI
Centre for Nanotechnology and Smart Materials

STEPS

Co-funded by:

NORTE2020 PROGRAMA OPERACIONAL REGIONAL DO NORTE

PORTUGAL 2020

UNIÃO EUROPEIA
Fundo Europeu de Desenvolvimento Regional

SUSTAINABLE PLACES 2023

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AGENDA

- About CeNTI
- About STEPS
- Development of Numerical Models for Predicting Thermal Performance of Materials
- Final remarks

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About CeNTI

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and Smart Materials

HIGH LEVEL SHAREHOLDERS

citeve

universidade
de aveiro

CTIC

U.PORTO

CEiiA

Universidade do Minho

Centre for Nanotechnology and Smart Materials

MISSION

- Drive the development of **new materials** **and product or innovation** through all the necessary stages of development;
- **Multi-disciplinary group** (chemistry, physics, engineers, industrial design, electronics and software):
  - **Multicomponent fibres**
  - **Smart materials/devices**
  - **Multifunctional coatings**
  - **Printed and Organic electronics**
  - **Embedded Smart Systems**
- Laboratory validation to **industrialization** (lab2fab);

nano4industry®

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SUBSTRATES

TECHNOLOGICAL FOCUS

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MATERIALS FOR SUSTAINABLE INDUSTRY

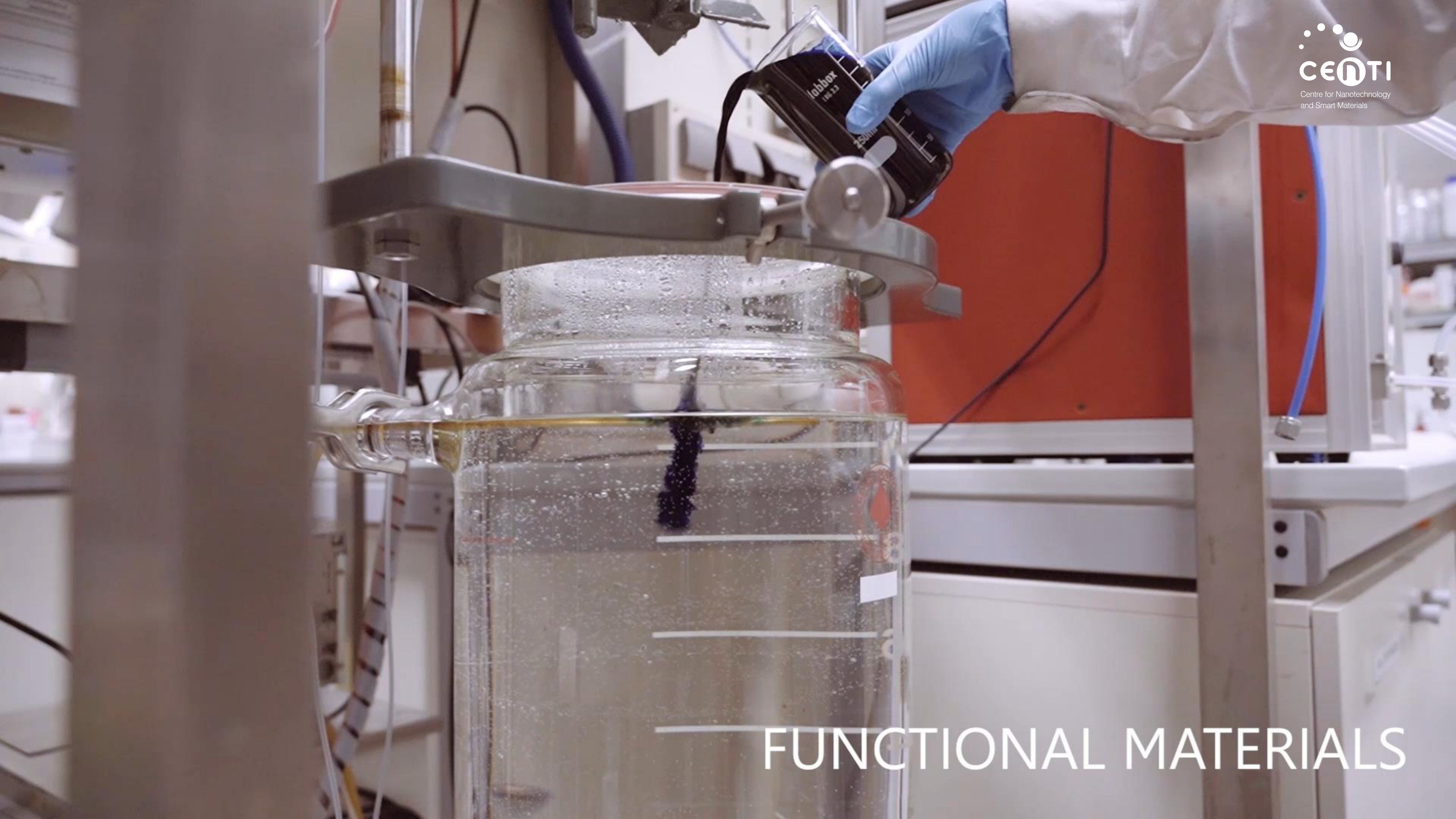
MICROFABRICATION AND PRINTED INTELLIGENCE

NOVEL SUSTAINABLE COMPOSITE FABRICATION AND PILOT LINE

NANOSTRUCTURED SOLUTIONS

ENERGY STORAGE AND MICROGENERATION TECHNOLOGIES

AUTOMATION AND SOFTWARE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FUNCTIONAL MATERIALS

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FIGURES

150
FULL TIME RESEARCHERS STAFF

15-20
MASTER / PHD STUDENTS

3400
CAMPUS (m2)

117
TECHNOLOGY TRANSFER PROJECTS

23
SCIENTIFIC PROJECTS

78
DIRECT CONTRACTS

>250
ACTIVE CLIENTS

52
ACTIVE PATENT APPLICATIONS
40 PENDING, 12 GRANTED

20
JOINT OWNERSHIP APPLICATIONS
18 PENDING, 2 GRANTED

5
CeNTI OWNERSHIP APPLICATIONS
3 PENDING, 2 GRANTED

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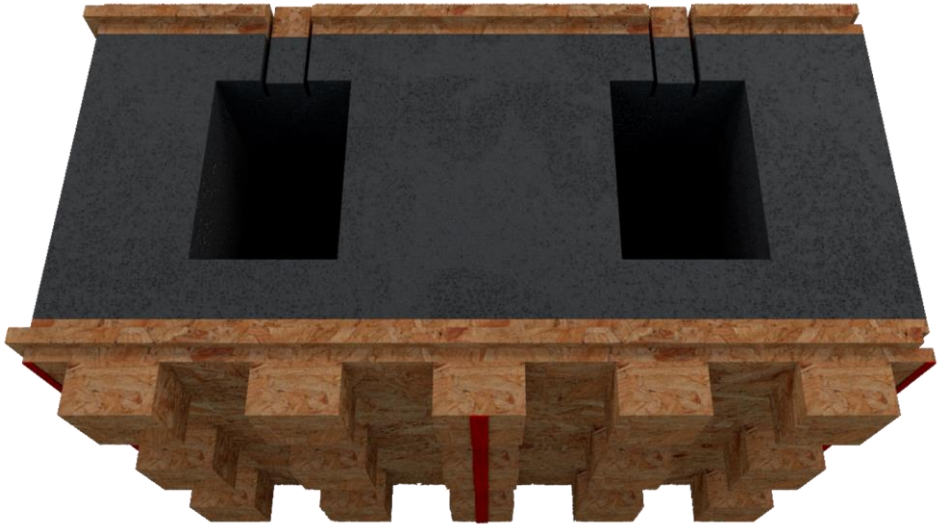
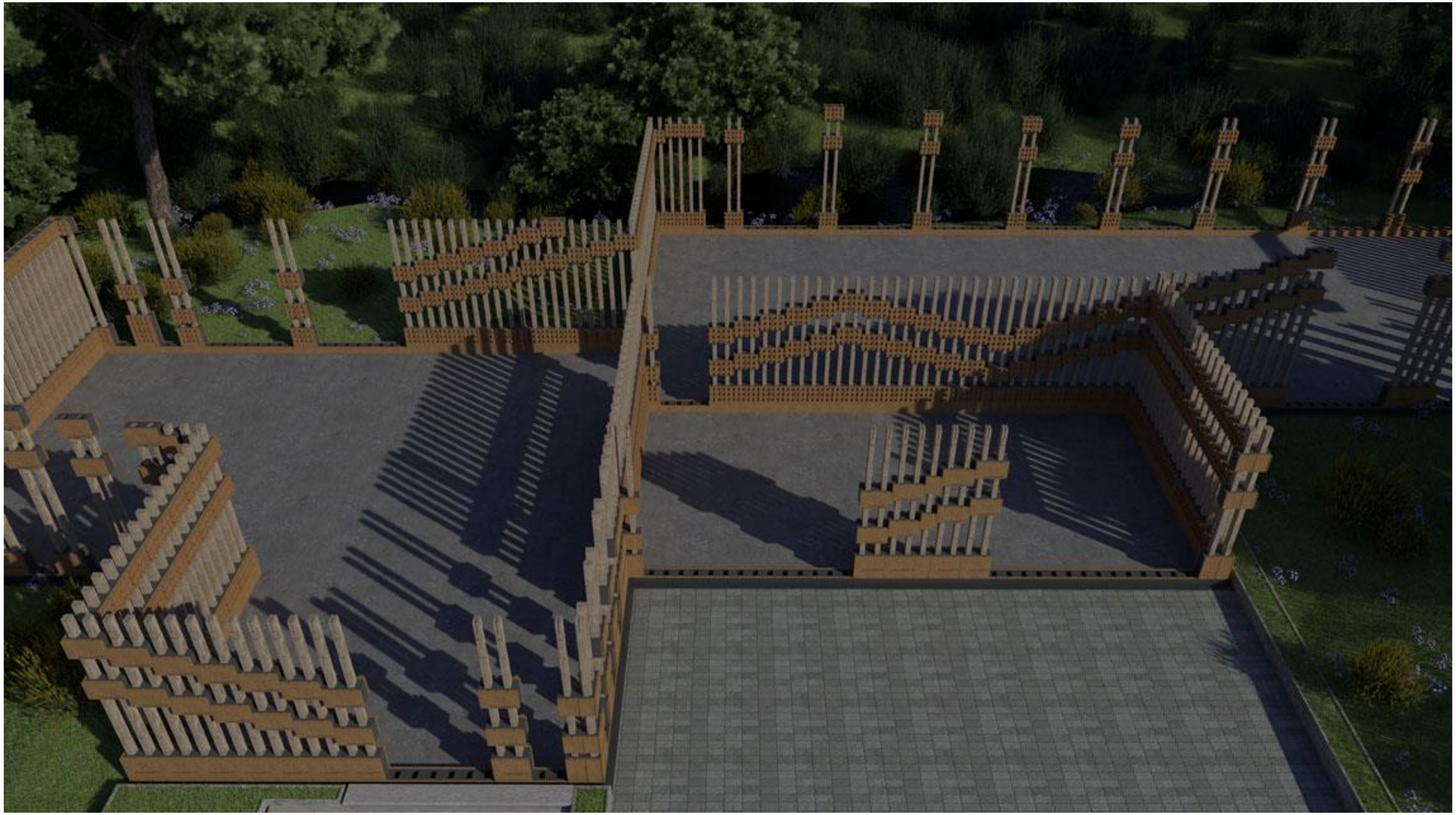
About STEPS

Advanced Production System for the Built Environment Focusing on Productivity and Sustainability

The project aims at the development of a new advanced building production system that makes it possible to reduce, or even eliminate, the environmental impact of the entire production chain that integrates and feeds the construction sector, and substantially increases productivity in the construction industry.

This system – called houseFIT – comprises a technological system of prefabricated components with a high level of automation, light and of reduced dimensions that, as a whole, allows the complete production of buildings in self-construction or using robotic labor.





The STEPS system aims to overcome three fundamental challenges in building production:

1.

Increase in the productivity of the building production process:

- Full mobility of off-site production, to install where raw materials and labor are available;
- The benefits of mass customization without loss of architectural flexibility of the final product.

2.

Substantial reduction of the carbon footprint resulting from the production process, in a global cradle-to-cradle lifecycle perspective.

3.

Democratization of the building production process, through the elimination of all intervening factors between the user and the production of components – the creation of component libraries for BIM will enable users to design the building spatially and functionally, and automatically generate order and associated costs.

STEPS

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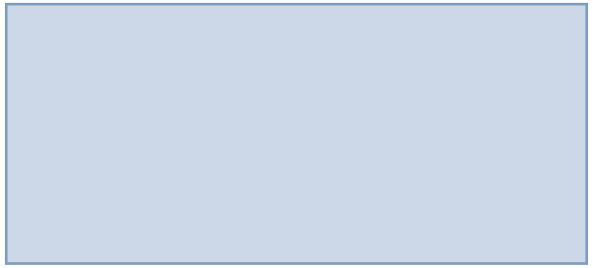
2 different block structures

Mono material



Laminated structure

Materials studied

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Development of Numerical Models for Predicting Thermal Performance of Materials

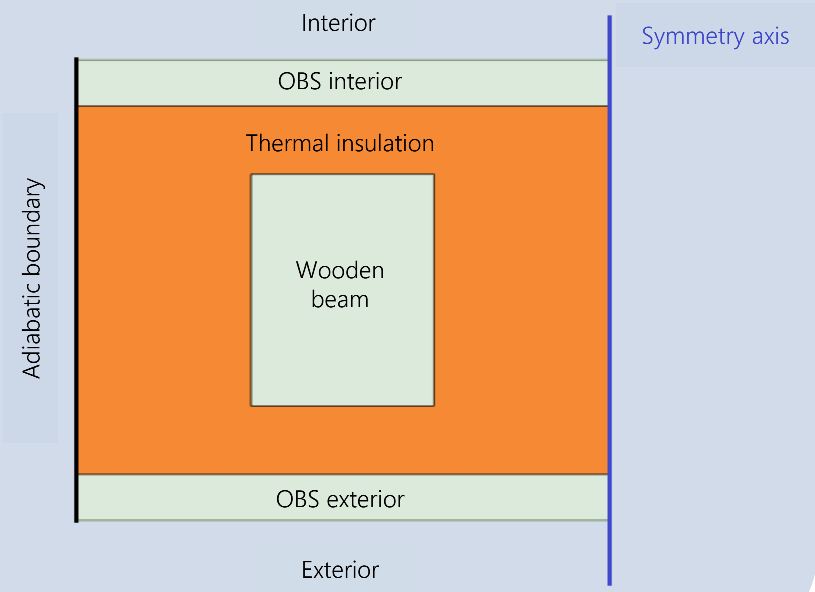
Numerical Models

2D building block simulation model

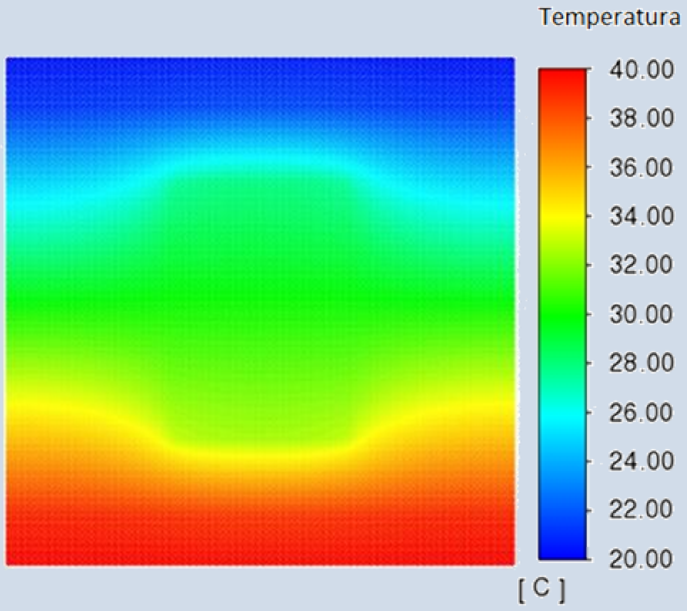
Focus on temperature variation along the thickness of the construction block, only forms of heat transfer are:

- Thermal conductivity;
- Natural convection (convection coefficient of 7,69 $W \cdot m^{-2} \cdot K^{-1}$, on the interior and 25 $W \cdot m^{-2} \cdot K^{-1}$, on the exterior).

Block design:



Results:



Material	(°C) Initial temperature	(°C) Final temperature
EPS	20	30,2
Wooden bean	20	30,2
OSB interior	20	21,1
OSB exterior	20	39,3
Wall interior	20	20,6

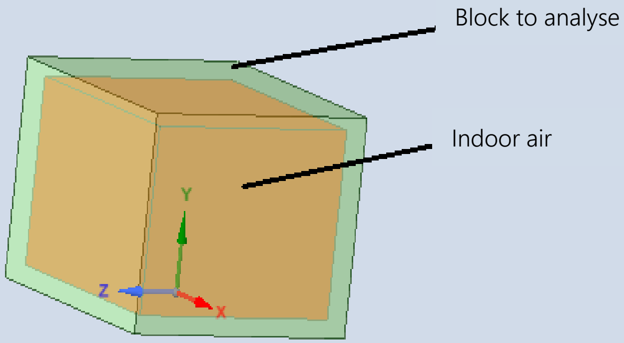
Numerical Models

3D model of a room

Focus on the thermal performance of a room on a summer and a winter day, forms of heat transfer are:

- Radiation;
- Natural convection.

Room design:



Room dimensions: 4 x 4 x 3 m

Thermal power:

Room without refrigeration system

$$Q_{Verão} = Q_{solar}^{rad} + Q_{emitida}^{rad} + Q_{convecção}$$
$$= \alpha S - \varepsilon\sigma\left({T_{ext}}^{4} - {T_{sup}}^{4}\right) - h\left(T_{ext} - T_{sup}\right),$$

Room with refrigeration system

$$Q_{interior} = Q_{emitida}^{rad} + Q_{convecção}$$
$$= \varepsilon\sigma\left({T_{parede\ interior}}^{4} - (293{,}15)^{4}\right) + h\left(T_{parede\ interior} - 293{,}15\right)$$

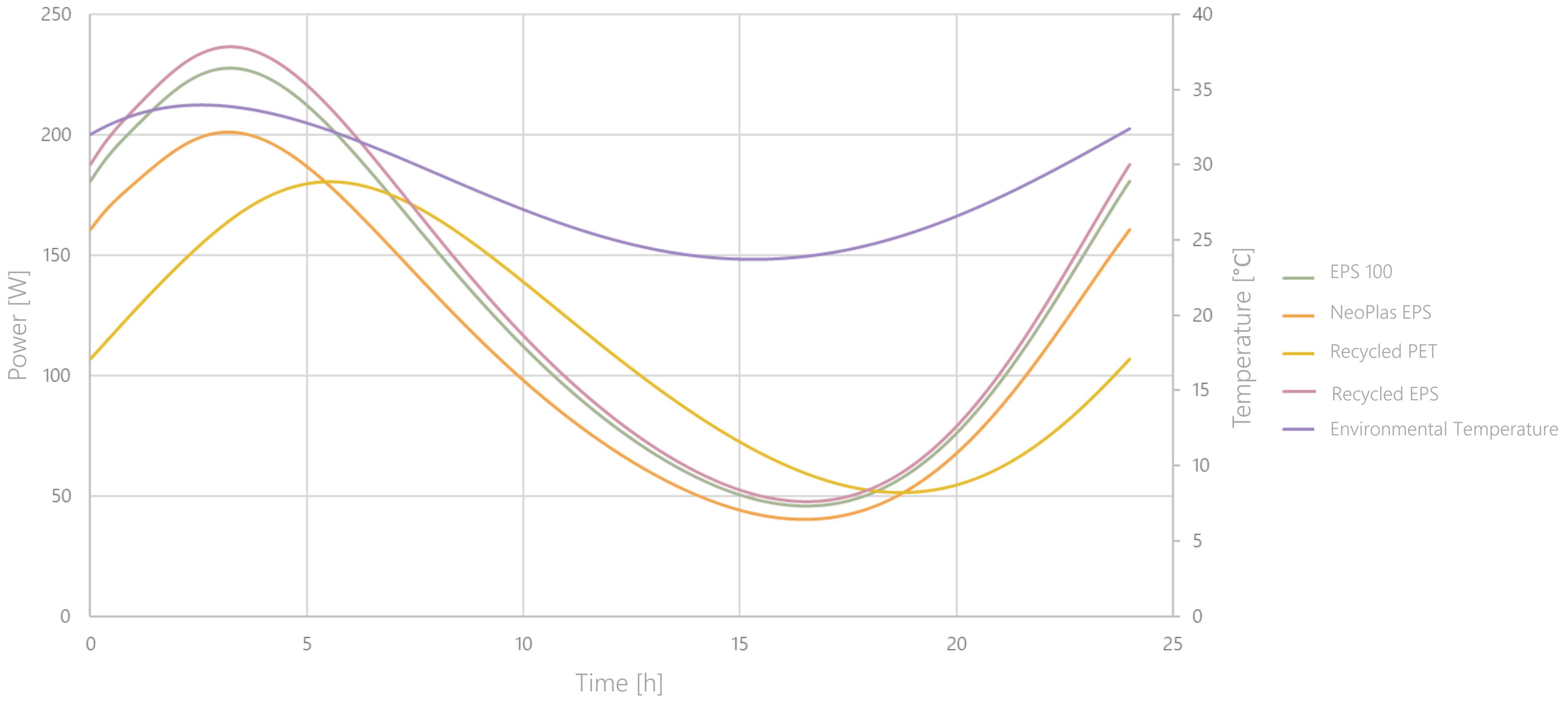
α - room solar absorption
S - solar intensity
ε - emissivity
σ - Stefan-Boltzmann constant

T_{ext} - exterior temperature
T_{sup} - surface temperature (in the room with refrigeration system it's a constant 20°C (= 293,15 K).
h - convection coefficient

Numerical Models

3D model of a room

Thermal power of mono material blocks:



Numerical Models

3D model of a room

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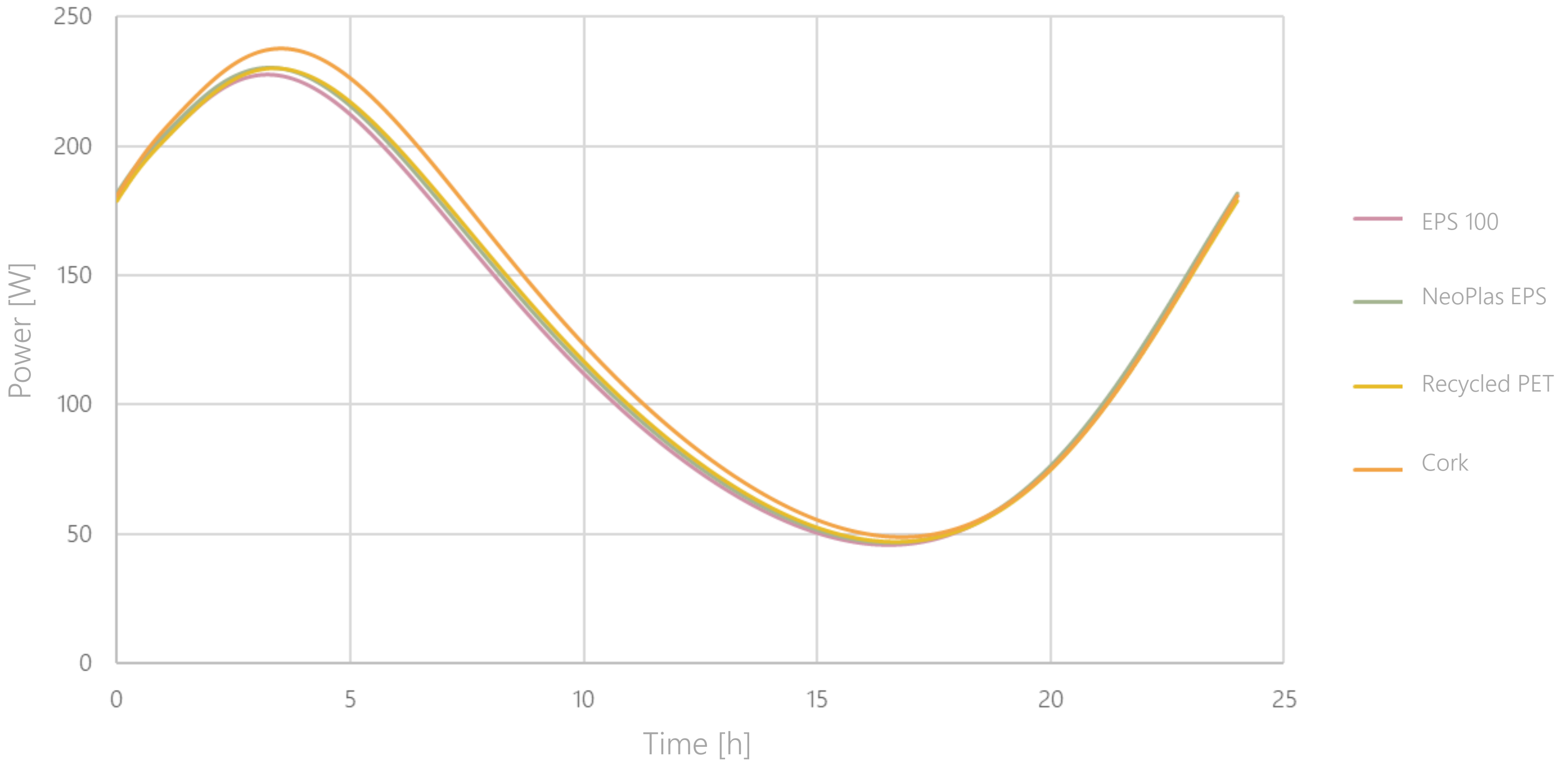
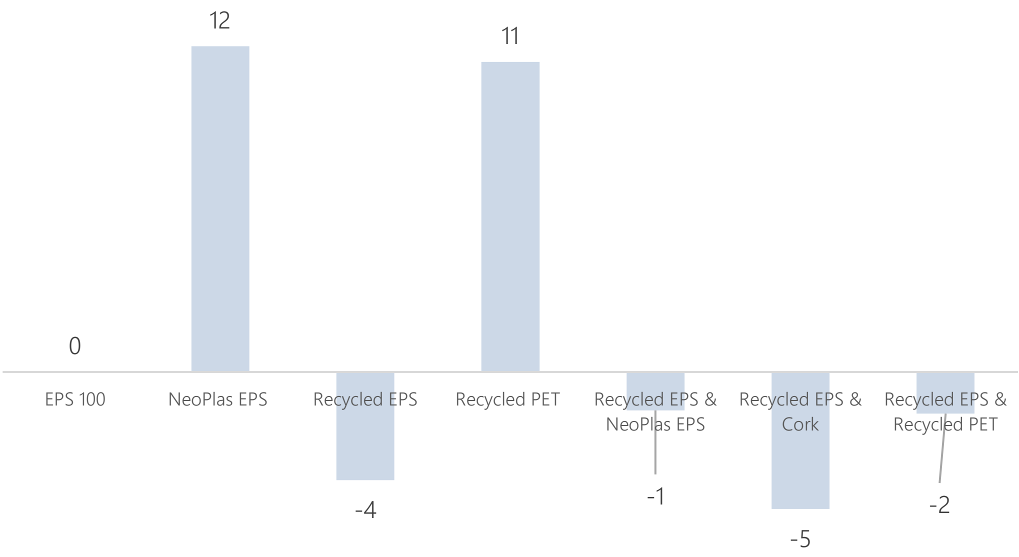
Thermal power of multi material blocks:



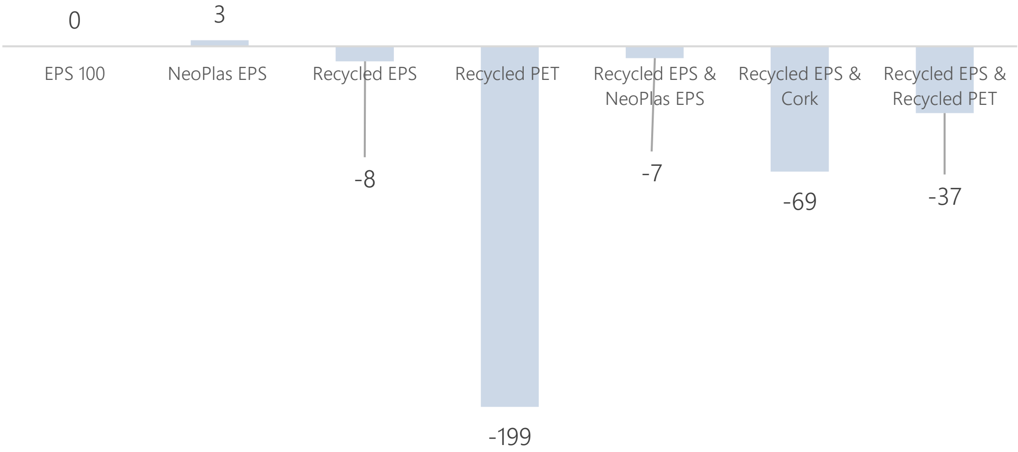
Numerical Models

3D model of a room

Energy assessment [%]



Weight assessment [%]



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Final remarks

With this work we were able to access that:

- NeoPlas is a good alternative to EPS 100, having an energy improvement of 12 % and a weight improvement of 3 %;
- Recycled PET has an energy of 11 % but with it an increase in the wight of the structure by almost 200 %;
- Recycled EPS, and the combination of recycled EPS with NeoPlas EPS, although do not improve the performance of the material has a similar comportment being environmentally conscious materials.

THANK YOU FOR YOUR ATTENTION!

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