Interreg Sudoe

EUROPEAN UNION

IMIP_
Innovative Eco-Construction System Based on Interlocking Modular Insulation Wood & Cork-Based Panels

European Regional Development Fund

D1.4.1 CRITERIA AND INDICATORS FOR THE EVALUATION OF THE IMIP ECO-CONSTRUCTION SYSTEM VALUE CHAIN

IMIP-SOE3/P3/E0963

Project funded by the Interreg Sudoe programme through the European Regional Development Funds (ERDF)

PROJECT CONTEXT

Project acronym	IMIP
Project title	Innovative Eco-Construction System Based on Interlocking Modular Insulation Wood & Cork-Based Panels
Project code	SOE3/P3/E0963
Coordinator	Universitat Politècnica de València (UPV), ITACA
Duration	1 May 2020 – 30 April 2023 (36 months)
Working Package (WP)	WP.1 Integral design of the sustainable construction system value chain
Deliverable	D1.4.1 Criteria and indicators for the evaluation of the imip eco-construction system value chain
Summary	Document with the information compiled of the set of criteria and indicators to be used for the evaluation of the sustainability of the IMIP Eco-Construction System. The report briefly defines sustainability and triple bottom line framework and the terms criteria and indicators. Thereafter it provides the stages of the IMIP Eco-Construction System value chain along with the definitions of the selected criteria and indicators within the three dimensions of sustainability, i.e., environment, economy and social.
Delivery date	01/2021
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Document ID	IMIP_D141_Indicators

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1 INTRODUCTION

The main objective of the IMIP project is to design, validate and implement an ecological building system based on natural biological materials to improve energy efficiency in public buildings. During the project CLT panels made of Mediterranean pine wood (Aleppo pine and maritime pine) and with an inner layer of expanded cork to improve its performance as thermal insulator and acoustic corrector will be designed. The first step to achieve this objective is the integral design of the IMIP Eco-Construction System value chain, which is the aim of the Working Package 1 (WP1). In this regard the main environmental, economic and social criteria and indicators (C+I) need to be defined for the sustainability assessment of the whole value chain. C+i must be able to capture the impacts of the IMIP Eco-Construction System value chain on sustainability. They need to cover on the one side economic, social and environmental dimensions and on the other side they need to respond to national and international as well as regional and local needs within the value chain (Rametsteiner *et al*., 2006).

The present report provides an overview of the set of criteria and indicators to be used for the evaluation of the sustainability of the IMIP Eco-Construction System. The IMIP Eco-Construction System value chain is a complex one with different stages that involve different aspects such us forest management, raw material processing and building construction, maintenance and disposal. In order to be able to define all C+I related to the whole value chain, this one must be well defined. The report is based on the analysis of literature and policy documents with regard to sustainability indicators related to forestry, construction and energy efficiency.

Chapter 2 briefly defines sustainability and triple bottom line framework and the terms criteria and indicators. Chapter 3 provides the stages of the IMIP Eco-Construction System value chain along with the definitions of the selected criteria and indicators within the three dimensions of sustainability, i.e. environment, economy and social. Finally, Chapter 4 contains summary and conclusions.

2 DEFINITIONS: SUSTAINABILITY, TBL AND C+I

2.1 Defining sustainability and the triple bottom line

For the purpose of the present work we adopt the three-dimensional view of sustainability, based on the United Nations Commission on Environment and Development (UNCED) definition (known as the Brundtland definition). In the UNCED's report *Our common future* (UNCED, 1987) sustainable development is defined as follows: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The sustainable development is thus depicted schematically using three circles for the target dimensions of environment, economy and society. This means that to be sustainable it is necessary to achieve a triple balance between ecologic, economic and social conditions.

The Triple Balance or Triple bottom line (TBL) is an accounting framework originating within a business context by Elkington (1994) that incorporates three dimensions of performance: social, environmental and financial. This differs from traditional reporting frameworks as it includes ecological (or environmental) and social measures that can be difficult to assign appropriate means of measurement. The TBL dimensions are also commonly called the three Ps: people, planet and profits. The main challenge to putting the TBL into practice is to be able of measuring each of the three categories, finding applicable data and calculating a project contribution to sustainability (Slaper and Hall, 2011).

2.2 Defining criteria and indicators

In the UNCED held in Rio in June 1992, 179 countries agreed to develop sustainability indicators as the most appropriate tools for measuring, monitoring, assessing and reporting progress towards sustainability goals. Indicators make complex circumstances measurable and comprehensible to decision-makers and the public (Linser et al., 2018).

Sustainability criteria can be developed to define the sustainability design space and thereby make more use of the detailed metrics such as indicators (Hallstedt, 2015). A criterion is an essential element or condition by which sustainability may be defined (e.g., mitigating and adapting to climate change). An indicator is defined as a

measurement or fact (qualitative or quantitative) that can indicate the state or level of the criterion (e.g., carbon footprint).

3 CRITERIA AND INDICATOR SET

3.1 Criteria of selection for the indicator set

The IMIP Eco-Construction System is based on the following basic principles:

- Use of renewable raw materials, pine wood and cork.
- Stress the proximity (km 0) both of the sites where raw material is extracted, and where the system is produced and consumed.
- Promote local economy by generating an industry that foster economy in the involved regions.
- Minimize the consumption of resources and the generation of waste by developing a modular construction system with the possibility of being industrialized, and by analyzing and optimizing each of the value chain stages taking into account this principle.
- Users health and comfort by producing a building system without toxins and well isolated to reduce energy consumption.

These principles are framed in the Circular Economy and the Bioeconomy. Taking into account that the indicators for the sustainability assessment of the IMIP Eco-Construction System value chain must be consistence with other sustainability indicator frameworks in Europe and globally, must allow inter-sectoral and international comparisons and must be easily understandable, we have adopted as main criteria the challenges identified in the EU Bioeconomy Strategy which are the following:

- Ensuring food security
- Managing natural resources sustainability
- Reducing dependence on non-renewable resources
- Mitigating and adapting to climate change
- Increasing competitiveness and creating jobs

Along to these five criteria we have selected another one focus on ensuring human health and safety. This criterion refers not only to actors involved in the value chain but also building users.

Summing up, the six selected criteria for the evaluation of the sustainability of the IMIP eco-construction system are the following:

- Ensuring food security
- Managing natural resources sustainability
- Reducing dependence on non-renewable resources
- Mitigating and adapting to climate change
- Increasing competitiveness and creating jobs
- Ensuring human health and safety

3.2 Stages of the IMIP Eco-Construction System value chain

As has been previously stated, the IMIP Eco-Construction System value chain is complex, so in order to be able to define all the indicators related to the whole value chain, this one must be well defined. The value chain can be split into the following stages (Von Geibler *et al.*, 2010): resource extraction (forestry), wood and cork processing, IMIP panels manufacturing, construction of buildings, maintenance of buildings and finally recycling and disposal. Figure 1 illustrates the IMIP Eco-Construction System value chain.

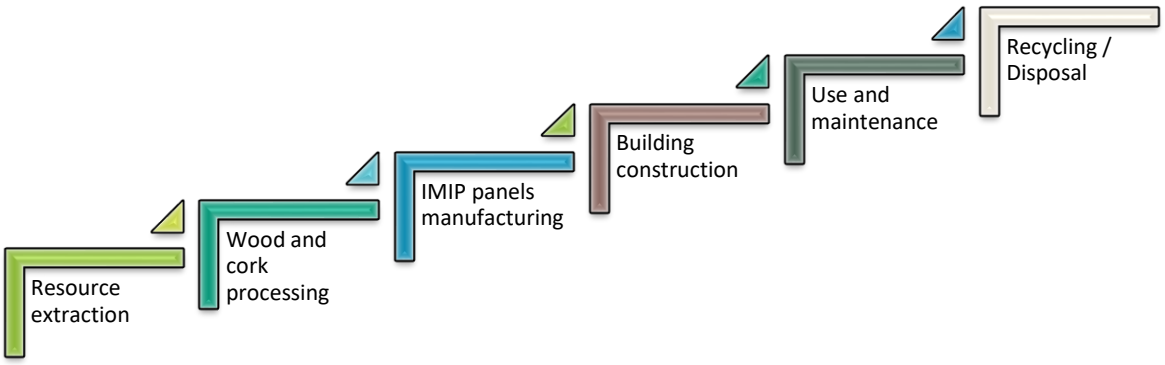

Figure 1: Stages of the IMIP Eco-Construction System value chain.

3.3 Indicator sets for each value chain stage

As Figure 1 shows, the IMIP Eco-Construction System value chain is multisectoral involving different aspects such as forestry, product development and manufacturing, construction and disposal. Each stage of the value chain defined in the previous section consists of a number of interconnected processes that have been identified.

In the following subsections indicator sets selected for each value chain stage at the process level are defined, finishing with a set of indicators related with cross-cutting issues affecting all the defined stages. All these indicator sets have been developed by analyzing literature and policy documents with regard to each topic.

3.3.1 Indicator set related to resource extraction

The resource extraction stage involves two processes: forest development and thinnings and final fellings. For the generations of the list of indicators shown in Table 1 has been consulted the work developed by Linser and O´Hara (2019) and Wolfslehner, *et al.*, (2016).

Table 1: Indicators related to resource extraction.

Process	Criteria	Indicator	Explanation
Forest development	Managing natural resources sustainability	Forest area	Area of forest and other wooded land, classified by forest type and by availability for wood supply, and share of forest and other wooded land in total land area
		Growing stock	Growing stock on forest and other wooded land, classified by forest type and availability for wood supply
		Age structure/diameter distribution	Age structure and/or diameter distribution of forest and other wooded land, classified by availability for wood supply
	Mitigating and adapting to climate change	Forest-related carbon stocks	Carbon stock and carbon stock changes in forest biomass, forest soils and in harvested wood products
Thinnings and final felling	Managing natural resources sustainability	Increment and fellings	Annual fellings as a percentage of annual increment of wood on forest available for wood supply

3.3.2 Indicator set related to raw material processing

The raw material processing stage involves two processes: processing of wood and cork from certified forests and/or from the regions surrounding processing and

manufacturing facilities. After analyzing the work by Rametsteiner et al., (2006) and Von Geibler et al., (2010) two indicators for each material have been selected (Table 2).

Table 2: Indicators related to raw material processing.

Process	Criteria	Indicator	Explanation
Processing of wood	Mitigating and adapting to climate change	Ratio of regionally produced used wood	Ratio of the regionally produced wood to the total wood used
		Ratio of certified used wood	Ratio of the wood produced in certified forests to the total wood used
Processing of cork	Mitigating and adapting to climate change	Ratio of regionally produced used cork	Ratio of the regionally produced cork to the total wood used
		Ratio of certified used cork	Ratio of the wood produced in certified forests to the total cork used

3.3.3 Indicator set related to IMIP panels manufacturing

Four processes have been defined in the IMIP panels manufacturing stage: utilization of sustainable forest products, resource and material consumption, operation costs and production. Table 3 shows the indicator set at process level for this stage (May *et al*., 2017, Rametsteiner *et al*., 2006 and Von Geibler *et al*., 2010).

Table 3: Indicators related to IMIP panels manufacturing.

Process	Criteria	Indicator	Explanation
Utilization of sustainable forest products	Mitigating and adapting to climate change	Ratio of use of low value wood	Ratio of low value wood to the total wood used
		Environmental and healthy surface treatment	Volume of surface treatment free of toxins and contaminant pollutant
		Use of recyclable and reusable wood/cork per panel	Percentage per panel
Resource and material consumption	Reducing dependence on non-renewable resources	Use of wood per panel	Percentage of wood used in each panel
		Use of cork per panel	Percentage of cork used in each panel
		Recycling rate	Volume of waste sent to recovery in ton
		Use of permanent materials per panel	Percentage of permanent material per panel
Operation costs	Increasing competitiveness and creating jobs	Production costs per unit	Direct material cost per panel
		Total production costs	Total costs considering raw material, consumable, etc
Production	Increasing competitiveness and creating jobs	Production volume	Volume of finished products

3.3.4 Indicator set related to building construction

The building construction stage involves three processes: user health and comfort and quality in the construction stage. For the generations of the list of indicators shown in Table 4 has been consulted the work developed by Danso (2018), Araujo *et al*., (2013), Fernández-Sánchez and Rodríguez-López (2010) and Level(s)a common EU framework of sustainability indicators for buildings (Dodd *et al*., 2020).

Table 4: Indicators related to building construction.

Process	Criteria	Indicator	Explanation
Users health and comfort	Ensuring human health and safety	Indoor air quality	Indoor air concentrations of pollutants as radon, CO, or NO_2
		Lightning	Light impact: lLuminous flux per unit area
		Thermal comfort	Satisfaction with the thermal environment. Air temperature
		Acoustic comfort	Airborne noise from exterior
Construction quality	Ensuring human health and safety	Integrated design project	Selection of the optimal cost solutions in the early stages of design
		Commissioning	Verification that all building functions are according to its specifications
	Mitigating and adapting to climate change	Adaptability and renovation	Design for adaptability and renovation
		Increased risk of flood events	Evaluation of the risk that the building will have on aggravating flood events
		Increased risk of extreme weather events	Evaluation of the risk that the building will have on aggravating extreme weather events

3.3.5 Indicator set related to use and maintenance of buildings

The use and maintenance of buildings stage involves three processes: energy efficiency and improvement of living quality. After analyzing the work by Danso (2018), Forsström *et al*., (2011), Von Geibler *et al*., (2010) and Level(s)a common EU framework of sustainability indicators for buildings (Dodd *et al*., 2020); the selected indicators for each process are shown in table 5.

Table 5: Indicators related to use and maintenance of the building.

Process	Criteria	Indicator	Explanation
Energy efficiency	Mitigating and adapting to climate change	Energy consumption	Energy, in kWh, consumed annually in the building
		Specific energy consumption	Ratio of energy consumed to the built area
		Energy intensity of usage	Energy consumed per person hours spent in the building
		Economic energy intensity	Ratio of energy consumption for a given time to the rent in € payable for the same time
		Energy performance index	Ratio of actual energy consumption to the energy consumption of a similar building applying best available technology
Improvement of living quality and safety	Ensuring human health and safety	Living quality	Improvement of the following indicator values: indoor air quality, lightning, thermal comfort, acoustic comfort
		Safety	Toxicity in case of fire and long-term stability

3.3.6 Indicator set related to sustainable disposal of used building material

The sustainable disposal of used building material stage refers to the environmentally sound treatment and disposal of used building material that cannot be reused. Disposal and recycling must ensure that hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against adverse effects, which might result from such wastes. Table 3 shows the indicator set for this stage (Von Geibler *et al*., 2010).

Table 6: Indicators related to disposal of used building material

Process	Criteria	Indicator	Explanation
Disposal and recycling	Mitigating and adapting to climate change	Controlled energy use of non-recyclable materials	Energy used for recycling
		Hazardous waste mass fraction	Ratio of hazardous waste mass to total mass of waste
		Recycling mass fraction	Ratio of recycled solid waste mass to total mass of solid waste
		Disposal mass fraction	Ratio of non-recovered solid waste mass to total mass of solid waste

3.3.7 Indicator set related to cross-cutting issues

This indicator set (Table 7) evaluates in more detail several key topics that transcend each of value chain stages. As such, the indicators in this section can be applied multiple times. For example, employment indicators can be assessed with respect to the forest where wood is harvested or to the industry where IMIP panels are manufactured. Indicators shown in table 7 have been selected after analyzing different published works (Shahbazi *et al*., 2017; Krajnc and Glavič, 2003; Veleva and Ellenbecker, 2001, Dodd *et al*., 2020).

Table 7: Indicators related to cross-cutting issues.

Aspect	Criteria	Indicator	Explanation
Employment	Increasing competitive-ness and creating jobs	Workforce	Number of persons employed and labor input, classified by gender and age group, education and job characteristics
		Working time	Mean weekly working hours
		Contribution to regional employment	Gross output and value added
		Training and education	Number of employees participating in on-the-job training

Aspect	Criteria	Indicator	Explanation
		Wages and salaries per type of skill and gender	Mean monthly earnings per type of skill and gender
Health and safety	Ensuring human health and safety	Occupational safety and health	Frequency of occupational accidents and occupational diseases
Energy	Reducing dependence on non-renewable resources	Share of renewable in gross final energy consumption	Percentage of renewable energy usage, compare to total energy use
		Net energy balance	Difference between the energy produced and the energy it takes to produce it
Water resource protection	Ensuring food security	Water footprint	Amount of water that is consumed and polluted in all processing stages of production
Greenhouse gas balance	Mitigating and adapting to climate change	Global warning potential	Mass of $C0_2$ equivalent in Kg
Waste management	Mitigating and adapting to climate change	Wastewater treatment	Proportion of wastewater safely treated
		Collection and recycling of waste and returned products	Recycling rate and landfilling rate
Transport	Mitigating and adapting to climate change	Reduction and optimization of transport requirements	Energy consumption by transport mode
		Minimizing distances	Km between value chain nodes: forest, sawmilling and cork milling, IMIP panels factory, building location
	Reducing dependence on non-renewable resources	Use of renewable fuels	Fuel consumption per type
Materials	Mitigating and adapting	Materials embodied energy	Energy consumed by all of the processes associated with value chain

Aspect	Criteria	Indicator	Explanation
	to climate change	Ozone depletion potential	Mass of CFC-11 equivalent in kg
		Acidification potential	Mass of SO_2 equivalent in kg
		Eutrophication potential	Mass of PO_4 equivalent in kg
		Photochemical oxidation potential	Mass of ethylene equivalent in kg
		Abiotic depletion	Mass of antimony equivalent in kg
Cost efficiency	Increasing competitiveness and creating jobs	Life cycle costs	Costs that are incurred during each stage of the value chain: resource extraction costs, wood and cork processing costs, design and construction costs, operational and maintenance costs

4 SUMMARY AND CONCLUSION

The criteria and indicators provided in this report is a selection based on the analysis of literature and policy documents with regard to sustainability indicators related to forestry, production, construction and energy efficiency. The basic structure uses the three pillars of sustainability, i.e. environment, economy and society. Within these three dimensions there are six criteria. The indicator set comprises 61 indicators (Table 8) related to any of the value chain stages or to cross-cutting issues affecting all the defined stages.

This report will be used as a reference for the Life Cycle Assessment (LCA) that will be carry out in Work Package 4. During the LCA the indicators from this report will be quantified, through that process some indicators might not be feasible due to time constraints or any other reason, so it is possible that the final set will be somewhat reduced or modified.

Table 8: Overview of the set of criteria and indicators.

Criterion	Indicator	Unit
Ensuring food security	Water footprint	m3/ha, t
Managing natural resources sustainability	Forest area	Ha
	Growing stock	m3/ha
	Age structure/diameter distribution	n° trees
	Increment and fellings	%
Reducing dependence on non-renewable resources	Use of renewable fuels	%
	Use of wood per panel	%
	Use of cork per panel	%
	Recycling rate	t
	Use of permanent materials per panel	%
	Share of renewable in gross final energy consumption	kWh
	Net energy balance	kWh
Increasing competitiveness and creating jobs	Workforce	n° workers
	Working time	h/week
	Contribution to regional employment	%
	Training and education	n° employees
	Wages and salaries per type of skill and gender	€
	Life cycle costs	€
	Production costs per unit	€/unit
	Total production costs	€/costs

	Production volume	€
Ensuring human health and safety	Occupational safety and health	n° accidents & diseases
	Indoor air quality	ppm (parts per million)
	Lightning and visual comfort	lx (ux)
	Thermal comfort	^{o}C
	Acoustic comfort	Decibels
	Integrated design project	Unitless
	Commissioning	Unitless
	Living quality	Unitless
	Safety	Unitless
Mitigating and adapting to climate change	Materials embodied energy	kWh
	Ozone depletion potential	kg CFC-11 eq.
	Acidification potential	kg SO2 eq.
	Eutrophication potential	kg PO4 eq.
	Photochemical oxidation potential	kg C2H4 eq.
	Abiotic depletion	kg Sb eq.
	Global warning potential	kg CO2 eq.
	Wastewater treatment	unitless
	Collection and recycling of waste and returned products	%
	Reduction and optimization of transport requirements	kWh
	Minimizing distances	km
	Forest-related carbon stocks	t C/ha
	Energy consumption	kWh/year
	Specific energy consumption	kWh/m2

	Energy intensity of usage	kWh/person
	Economic energy intensity	kWh/€
	Energy performance index	unitless
	Controlled energy use of non-recyclable materials	kWh/t
	Hazardous waste mass fraction	unitless
	Recycling mass fraction	unitless
	Disposal mass fraction	unitless
	Ratio of regionally produced used wood	unitless
	Ratio of certified used wood	unitless
	Ratio of regionally produced used cork	unitless
	Ratio of certified used cork	unitless
	Ratio of use of low value wood	unitless
	Environmental and healthy surface treatment	t
	Use of recyclable and reusable wood/cork	%
	Adaptability and renovation	Adpatability score (Dodd *et al.*, 2020)
	Increased risk of flood events	Level 1 checklist(Dodd *et al.*, 2020)
	Increased risk of extreme weather events	Level 1 checklist (Dodd *et al.*, 2020)

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