H2020 DRIVE 0:

Driving decarbonization of the EU building stock by enhancing a consumer centred and locally based circular renovation process

What was the DRIVE 0 project about?

D1.3 A full publishable report on the project's results

www.drive0.eu

The project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 841850.

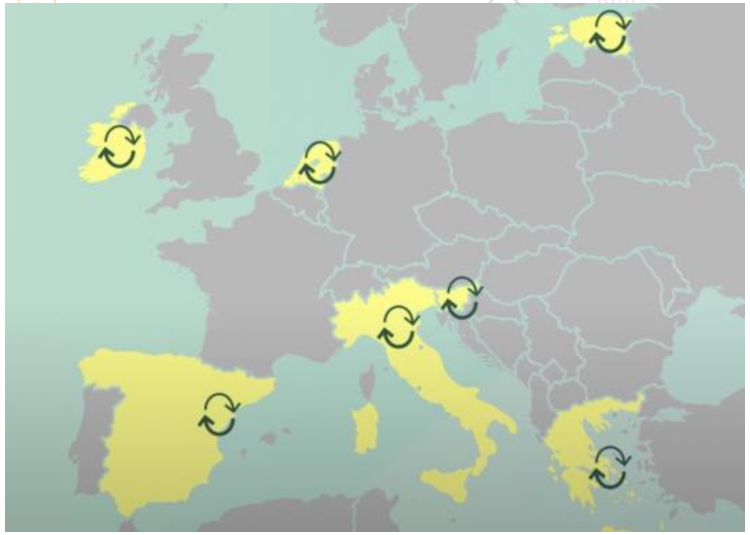
EU Horizon 2020 Project

«DRIVE 0 - Driving decarbonization of the EU building stock by enhancing a consumer centred and locally based circular renovation process»

The DRIVE 0 project deals with the promotion of strategies for the **decarbonisation of the existing building stock** through the implementation of **deep renovation interventions**. The project aims at promoting the adoption of a **circular approach** in renovation processes that, in order to be attractive and effective, must be based on the customer's actual needs.

According to the DRIVE 0 approach, circular retrofitting is based on the use of energy from renewable sources and the use of materials from biological or technical cycles, in which waste production is minimised and **end-of-life strategies with a positive impact** on the **environment** are envisaged.

DRIVE



We want to accelerate deep renovation processes by enhancing a consumer centered circular renovation process in order to make deep renovation environmentally friendly, cost effective and more attractive for consumers and investors.

https://cordis.europa.eu/project/id/841850/it

- **Duration:** 1 Oct 2019 – 31 Dec 2023 (instead 30 Sep 2023)
- **Call for proposal:** H2020-LC-SC3-EE-1-2018
- **Topic:** Decarbonisation of the EU building stock
- **Funding scheme:** IA – Innovation action
- **Key topics:** Circularity, BM, citizens centered, residential b.

DRIVE

DRIVE 0 Consortium

https://www.drive0.eu

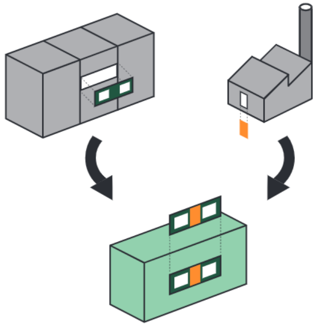
DRIVE

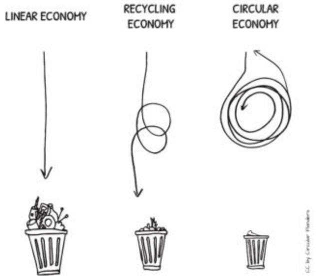
Why is a circular approach needed in construction sector?

- Buildings are responsible for 40% of total energy consumption in the EU
- 60% of the energy used throughout the life cycle of a building is so-called embodied energy
- 50% of the materials extracted in the EU are from buildings
- 25-30% of the total waste generated in the EU comes from construction and demolition processes

Objectives of DRIVE 0

- **Circular renovation**
  1) Re-use and recycling of locally available materials through urban-mining
  2) Use of renewable and environmentally friendly materials
  3) Combination of the two previous actions to implement a circular renovation





- **Development of new business models**
  focused on users/consumers and taking into account principles of circularity

- **Clear information and increased awareness on energy performance**
  for the occupants after the circular renovation has been developed

- **7 demonstration buildings**
  in Estonia, Greece, Ireland, Italy, The Netherlands, Slovenia, and Spain

DRIVE

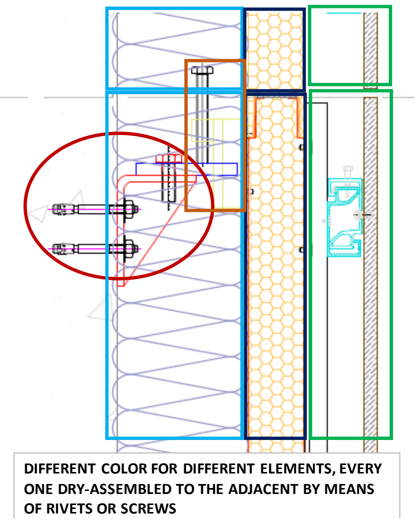
Factory 0 compact installation kits

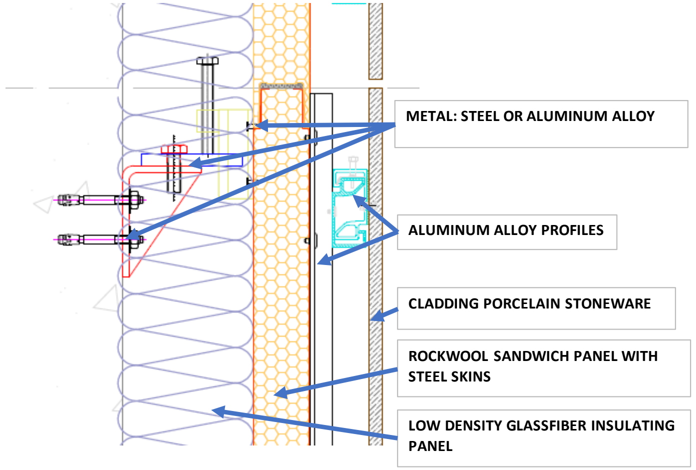
ALIVA Alucovering facade

Measuring circularity

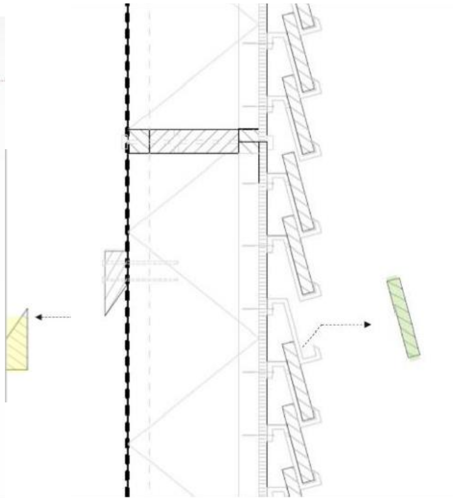
		conventional	2.0 system
End-of-life (element level)	WEBO (NL)	0,83	0,95
End-of-life (material level)		0,74	0,85
Maintanance		0,80	0,95
End-of-life (element level)	TIMBECO (EST)	0,85	0,85
End-of-life (material level)		0,77	0,82
Maintanance		0,83	0,85
End-of-life (element level)	ALIVA (IT)	0,85	0,85
End-of-life (material level)		0,83	0,85
Maintanance		0,88	0,88
End-of-life (element level)	IRISH (IR)	0,45	0,90
End-of-life (material level)		0,71	0,86
End-of-life (element level)	Medianera (SP)		0,93
End-of-life (material level)			0,80
Maintanance			0,97

ALIVA 2.0 system

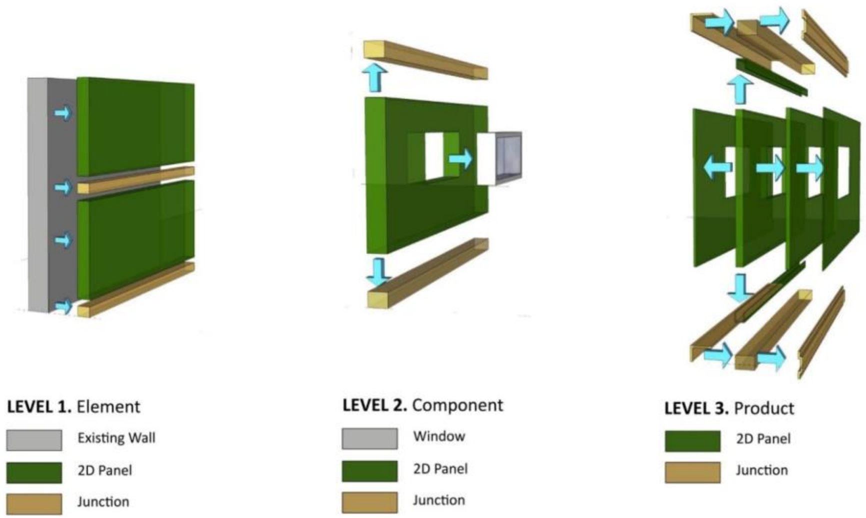


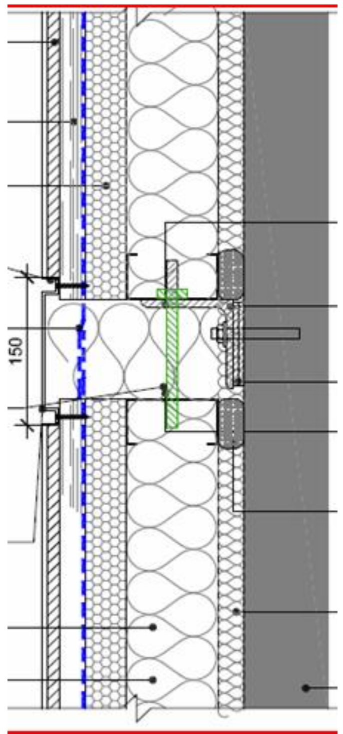


WEBO 2.0 system

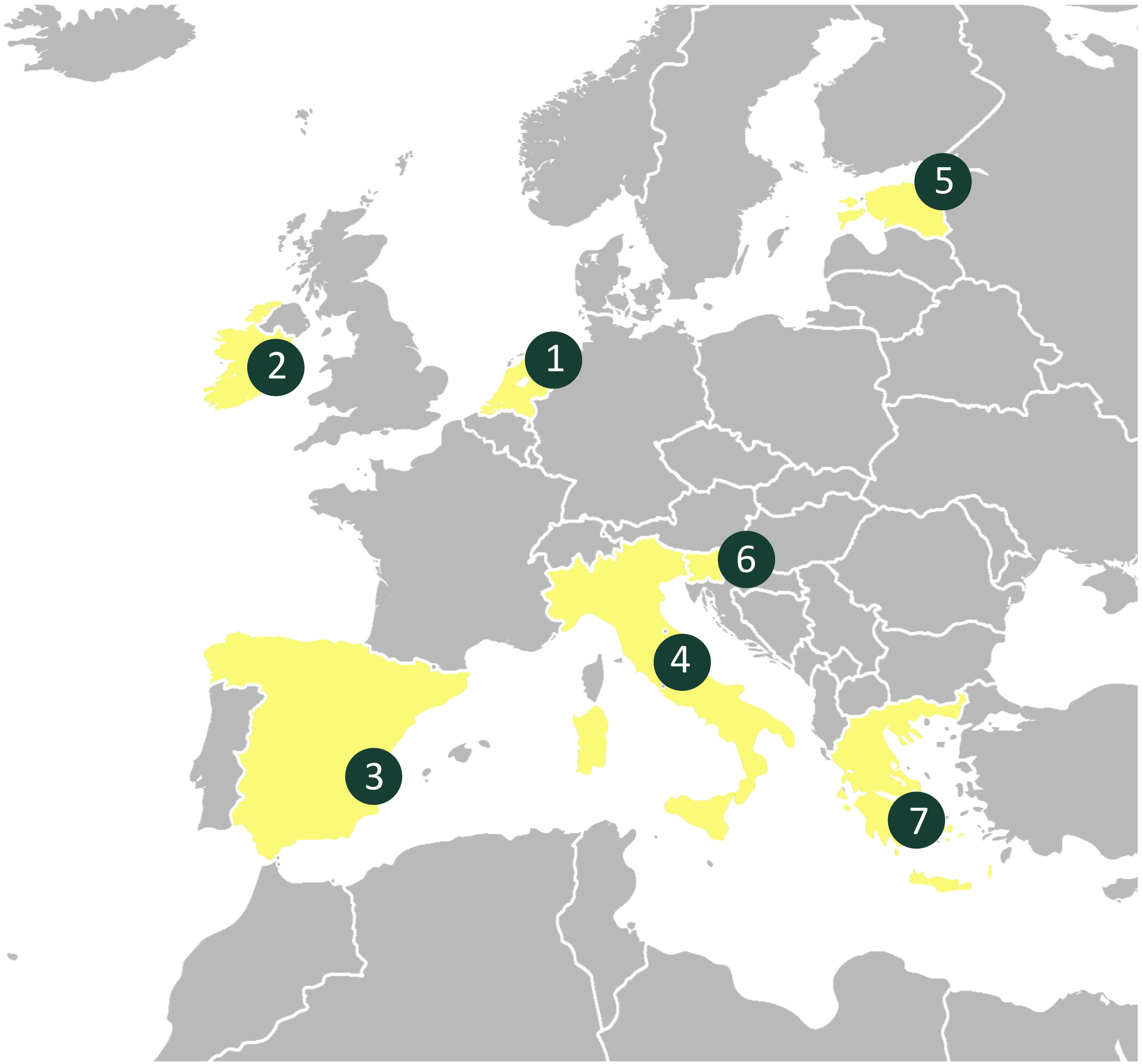


IRISH 2.0 system

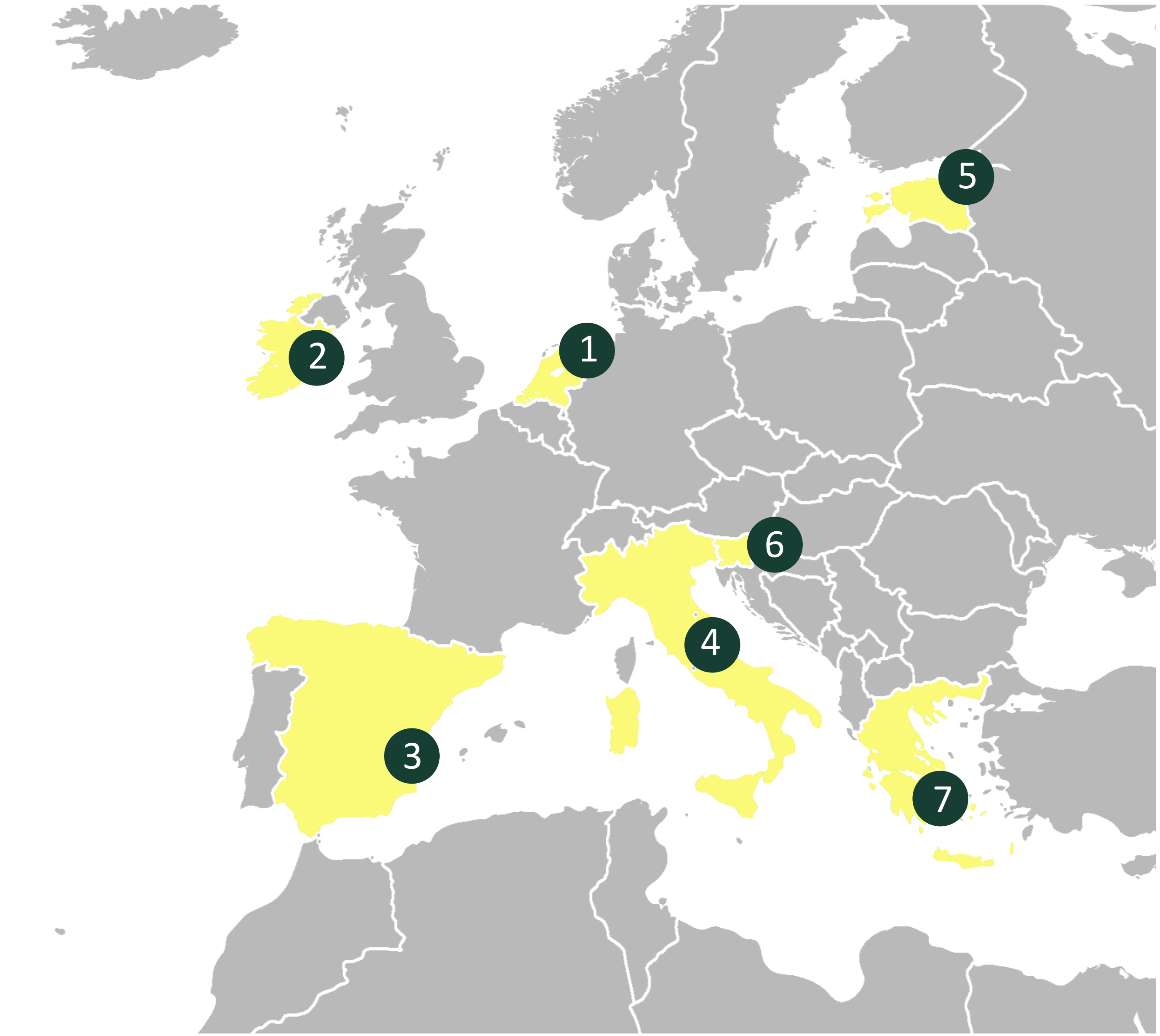




Route from linear to circular - Waste during reprocessing - Impact prefabrication on reversibility - Complexity of production process



DRIVE 0
demo buildings
**before the
renovation**



DRIVE 0
demo buildings
mid/after the renovation

DRIVE

Impact

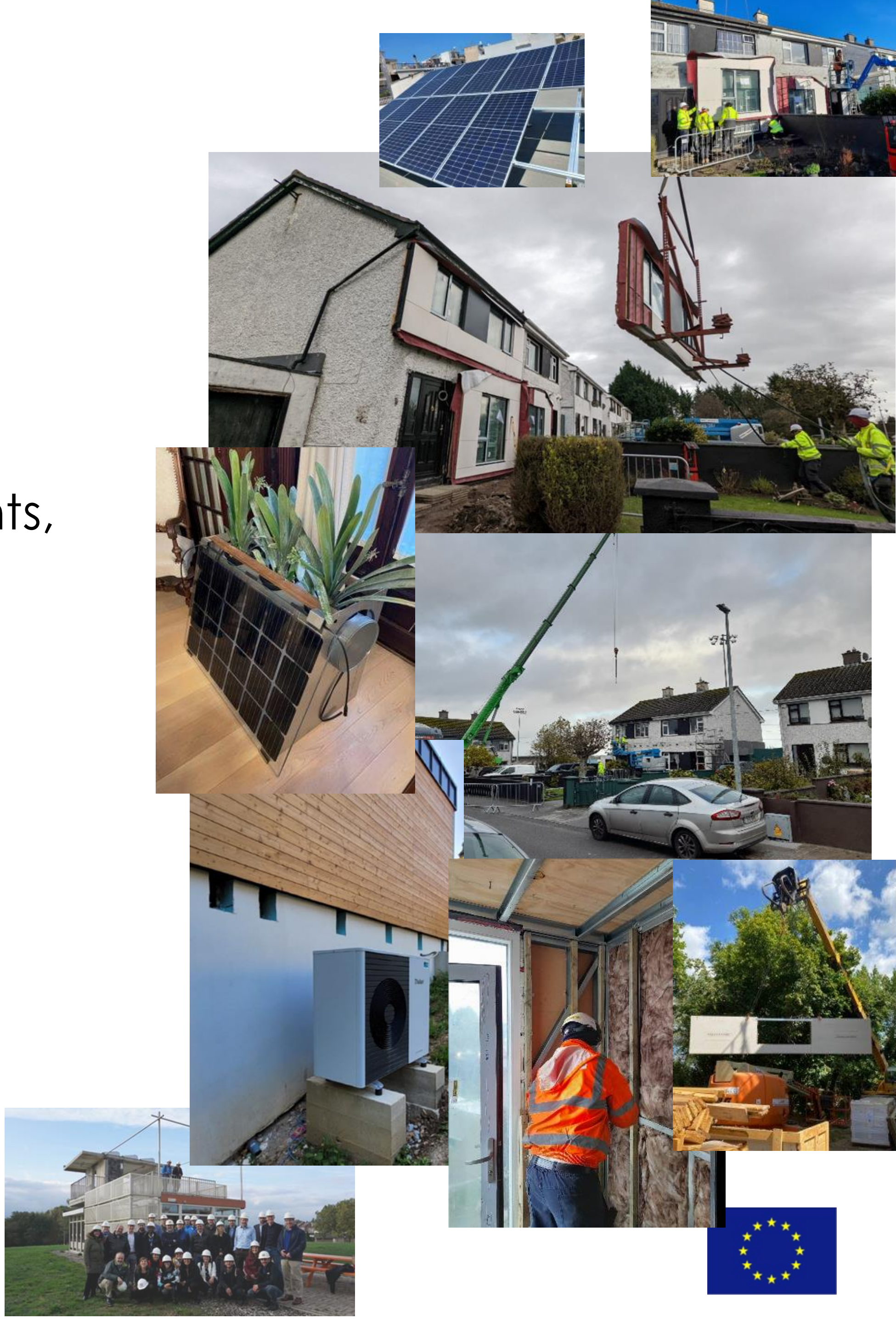
- Circular product (re-)development by WEBO, Timbeco, Factory 0, ALIVA, Vision Built, Knauf Insulation
- Development of user friendly tools & methods for assessing the level of circularity and hence supporting choices in the project development:
  -> EASY tool – simplified method developed for assessing the circularity level of single 2D & 3D solutions or an overall building.
  -> Development of DfD tool – reference details for disassembly, method allowing assessing detachability.
  -> Circular benchmarking of buildings – building environmental assessment, building circularity indicators and DfD criteria.
- The morphological design approach and guidelines for modular, circular deep-renovation approach. Working on new ways of project organizations.
- Proposed **circular business models** for the Drive 0 companies & transition pathways analyses.
- **Different engagement & awareness raising tools** (DIY catalogue, www.circularhomes.eu platform, Circular contest, Drive 0 board game, card game etc.)
- **7 demonstration buildings** in Estonia, Greece, Ireland, Italy, the Netherlands, Slovenia, and Spain.

DRIVE

Final Drive 0 video

To learn more about the Drive 0 project, its 7 circular renovation demonstration projects and final achievements, watch:

[Drive 0 Final video - discover our pilot buildings and prototypes around EU – YouTube]



DRIVE

The next slides provide detailed overview of the Drive 0 results as produced in various Work Packages and reported in diverse deliverables.

For each published deliverable it was produced a summary ppt describing objectives of the Task, main content done in the Task, main outcomes and conclusions of the task.

There is a direct hyperlink available through which a full publishable deliverable can be accessed.

It is recommended to know that deliverables:
D2... – are related to technologies development,
D3... – are related to the circular renovation process developments,
D4... – are related to monitoring and home occupants engagement,
D5... – are related to circular business model developments,
D6... – are related to Drive 0 demonstrations cases, results and impacts in pilots.

DRIVE

D2.1 Report on the assessment available product and technology developments, benchmarking and selection of most favourable and most potential solutions for further development to circular renovation products and a list of criteria/KPI's

Prepared by: Ana Tisov, Peter Op 't Veld (HIA), Albin Rohith, Michiel Ritzen, John van Oorschot, Dario Cottafava (ZUYD)

Submitted to EASME for a review: 6 Aug 2021

- **Objectives & Content of D2.1:**

- The goal of D2.1 is to review the state-of-the-art solutions for deep renovations, including technologies and products, that have been developed, tested and employed over the last decade of EU-funded projects.
- These products were benchmarked on several key performance indicators (KPIs):
  - circularity and potential for circularity (based on the DRIVE 0 D 6.1 'Report on benchmarking on circularity and its potentials on the demonstration sites');
  - total performances;
  - cost effectiveness and cost reduction;
  - time reduction in the total renovation process.

- A list of criteria and key performance indicators (KPIs) is made (part of Task 2.2) for the further product development in Tasks 2.3 – 2.6.

Main outcomes & conclusions of D2.1:

- In task 2.1 about 22 products from H2020 projects and 49 national products in the DRIVE 0 countries have been reviewed and assessed on their potential towards a further circular development.
- Most of these products (about 60) have a certain potential to be further developed or redeveloped to circular products. Sustainable, circular design solutions are the basis for circular business transitions. Despite seeing circular built environment as extremely complex area to address, we can start with relatively cost-efficient easy measures (i.e. technological interventions), which can already double the current circularity levels.
- Considering the input from task 2.1 and 2.2 for the circularity developments within DRIVE 0 following conclusions can be made: The circular developments within DRIVE 0 take place along two tracks which build upon the outcomes as described in this report:
  1. One important track is the product development by the industries working in DRIVE 0 (WEBO, Factory 0, Aliva, Timbeco and Knauf). This track can be divided in two sub-tracks:
     a. Circular product development specifically for solutions to be applied and tested in the demonstrators.
     b. The development of a general (fully) circular product line for further market uptake.
  2. The other track is the general development of circular products and solutions within the project itself in terms of guidance and all the supporting work. More specifically, this report D2.1 is the basis for the tasks 2.3 to 2.6 in work package 2.

Industry	Designed 1-1 for demo	Designed for market	Integrated product level	Component level	Circularity ambition clear	Current circularity level	Circularity potential
WEBO	-/X	X	X	X	yes	2	3
Factory 0	-	X	X	-	partly	2	2 - 3
ALIVA	X	-	-	X	limited	1	2
TIMBECO	X	X	X	-	limited	2	3
Knauf SI	X	X	- (not yet)	X	partly (now limited to product)	2	2 – 3 (as integrated element)

1 = low
2 = medium
3 = high

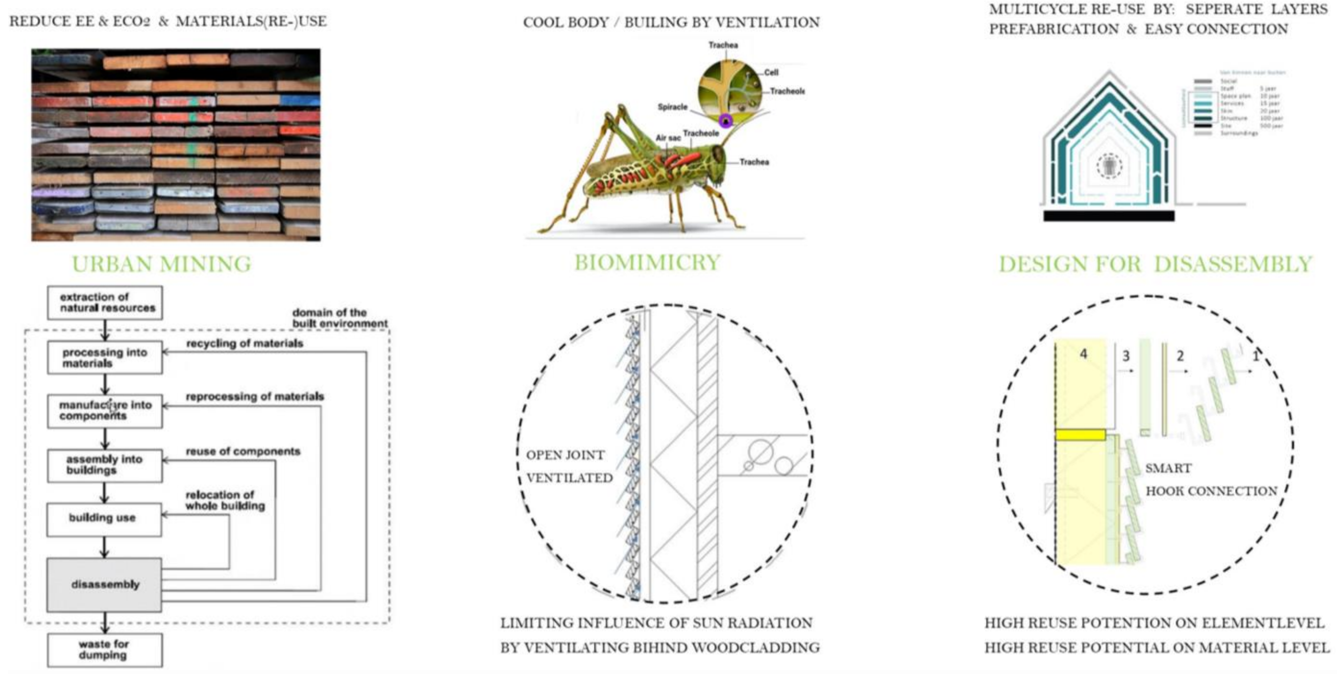
D2.2 A set of circular prefab 2D building envelope elements with case specific solutions

Prepared by:
Zuyd university of applied sciences,
(Michiel Ritzen, John van Oorschot, Ivar Bergmans, Ana Luíza Bitar)

Submitted to EASME for a review:
31 oktober 2022

Objectives & Content of D2.2:

- The report presents a series (5) of circular prefabricated 2D building envelope elements with an **improved level of circularity and energy efficiency** compared to existing renovation solutions.
- The report presents the development of circular prefabricated 2D building envelope elements followed a **three step approach**. Firstly an **inventory** of existing 2D elements, secondly an **improvement of the design** and thirdly, a **test phase** through the realization of a mock-up.
- The report presents the development of a prefabricated 2D building envelopment element which is based on various circular design strategies, including:

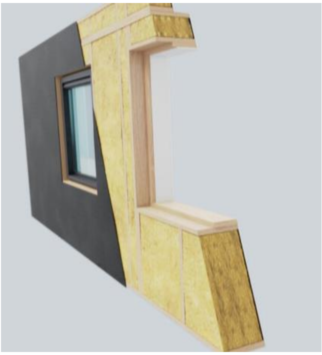


Approach:

Circularity indicators		EE	EC02	DFD
WEBO	NL	X	X	X
TIMBECO	EST	X	X	X
ALIVA	IT			X
IRISH system	IR	X	X	X
Medianera Wall	ES	X		X

Methodology	Urban mining	eco-design	Biomimicry	collaborative design
WEBO	X	X	X	
TIMBECO	X	X		
ALIVA	X			
IRISH system (IRL)	X	X		
Medianera Wall (ES)	X	X		X

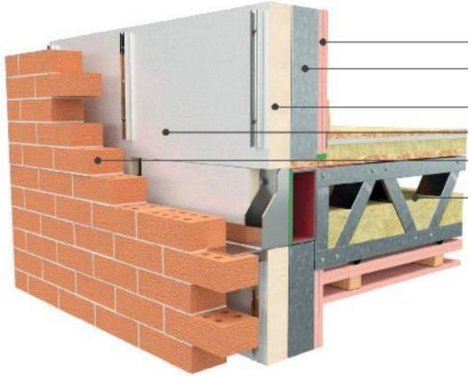
Baseline of 5 prefabricated 2D building envelope elements to be circular improved:



WEBO (NL)

TIMBECO (E)

ALIVA (IT)



IRISH SYSTEM Vision Built

Medianera Wall ES

Main outcomes & conclusions of D2.2:

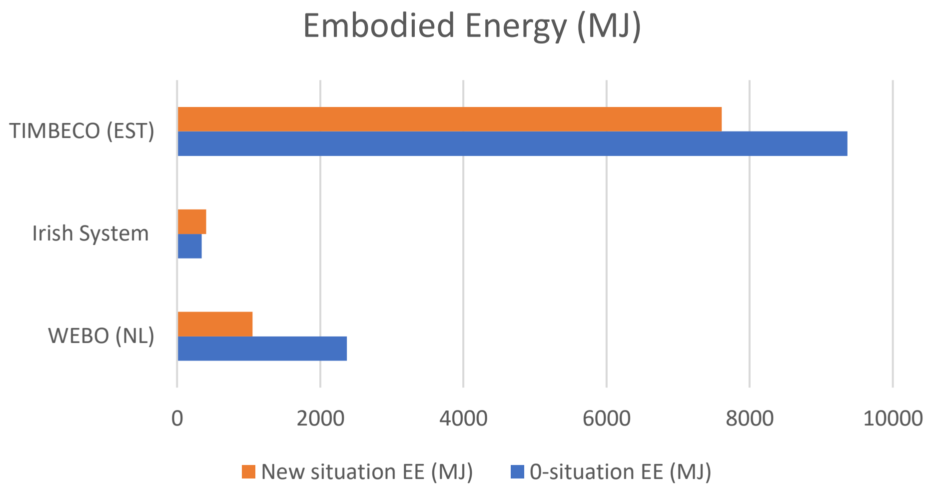
WEBO (NL): Reduction of 56% of the embodied energy and 49% embodied carbon relative to the baseline façade element.

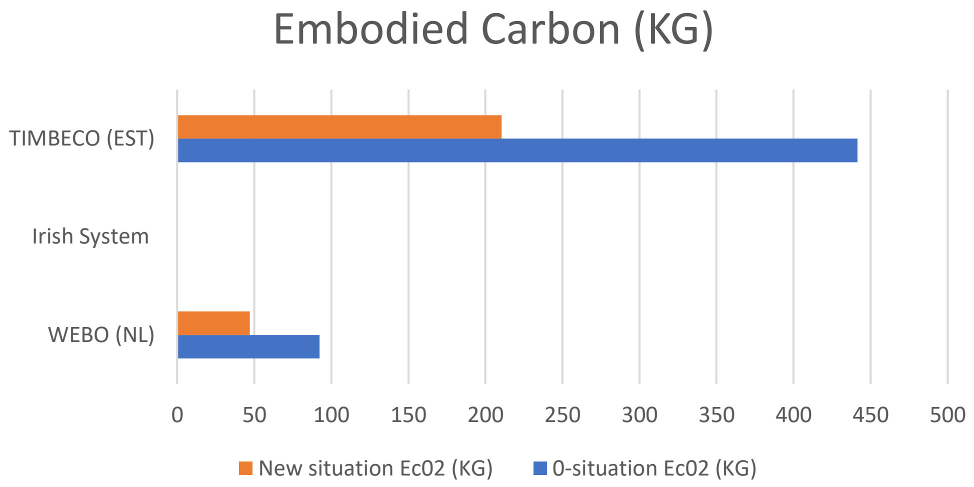
TIMBECO (E): Relative to the baseline, a 2D façade element was developed with a 19% reduction in embodied energy and 52% embodied carbon consumption respectively. The innovated 2D façade element entails an equivalent score on technical reversibility and a 6% improvement on technical reversibility (material level) in comparison to the baseline.

ALIVA (I): *Not considered as an indicator*

VISION BUILT (Ire): Compared to the traditional applied external wall insulation system with rendering the embodied energy of the innovated prefabricated 2D building envelope element increases with 19% and embodied carbon increased even with 256%.

MEDIANERA (S): *Not considered as an indicator*





Main outcomes & conclusions of D2.2:

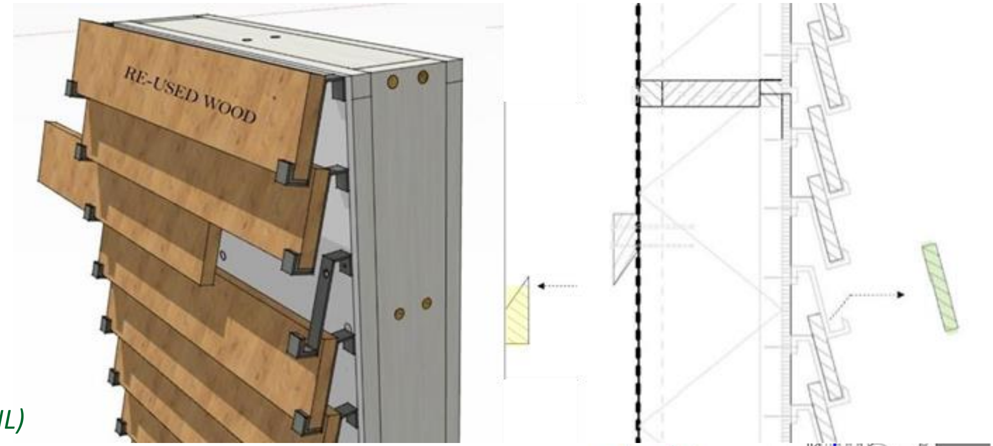
WEBO (NL): The 2D element showcases a 14% improvement of technical reversibility focused on end of life scenario (element level) and subsequently a 15% improvement of technical reversibility (material level) in comparison to the baseline façade element.

TIMBECO (E): The innovated 2D façade element entails an equivalent score on technical reversibility in comparison to the baseline, and showcases a 6% improvement on technical reversibility (material level).

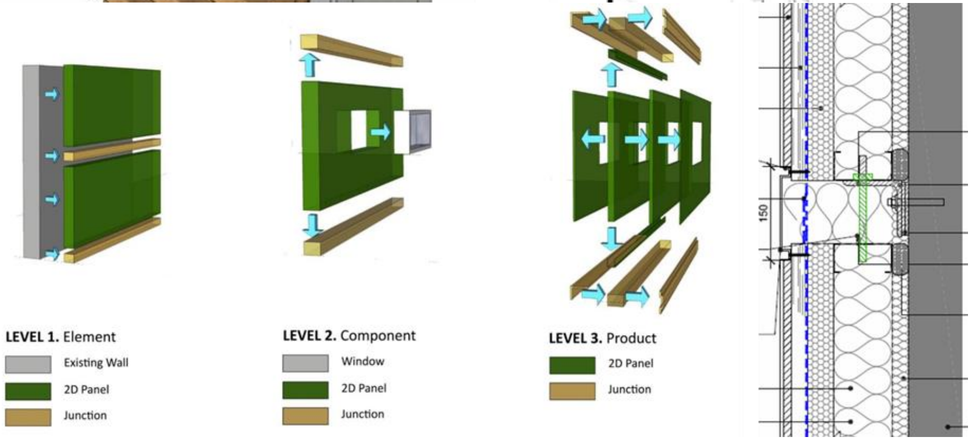
ALIVA (I): The innovated 2D façade element entails an equivalent score on technical reversibility in comparison to the baseline, and showcases a 2% improvement on technical reversibility (material level).

VISION BUILT (Ire): The 2D element scores 100% higher on technical reversibility focused on end of life scenario (element level) and increase 49% on technical reversibility (material level) in comparing to the baseline.

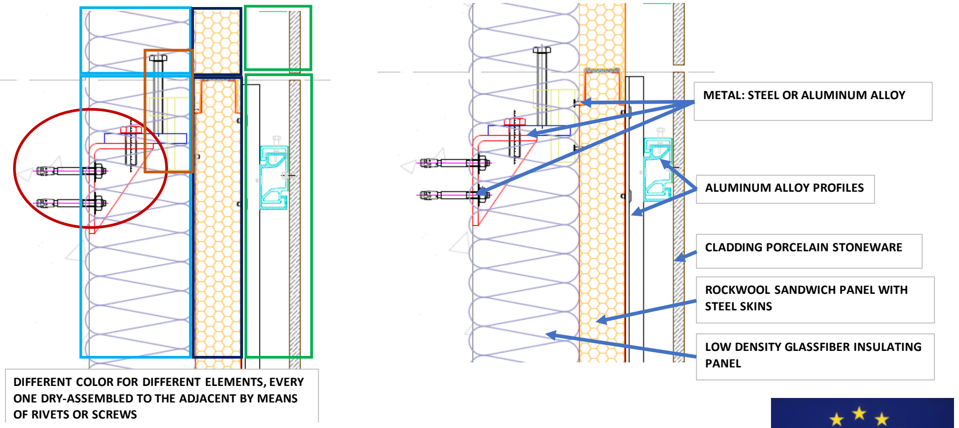
MEDIANERA (S): The 2D façade system consists of a modular set up of three different type of combining three different façade systems: PV panels, opaque cladding and green façade panels. For the integration of PV it was taken into account that single PV panels can substituted when broken maximizing the operational life-cycle of the entire system. Also, PV panels were selected which are easy to repair with a high potential of re-use after its first cycle application in the 'medianera'. Assessing the design for disassembly it was concluded that the innovated 2D façade system scores 0,93 on technical reversibility (element level) and 0,97 on technical reversibility (material level).



WEBO (NL)



TIMBECO (E)



ALIVA (IT)

Main outcomes & conclusions of D2.2:

Route from linear to circular - Waste during reprocessing - Impact prefabrication on reversibility - Complexity of production process

Lessons learnt of D2.2:

- The construction industry still follows a traditional linear production process
- It is especially important when scaling up towards multicycle re-use, that a database is created that maps the flow of materials within a specified region
- Recycling involves specialized (costly) technologies for example with respect to producing and applying wood fiber insulation material from harvested timber
- Plug-and-play connections contributes to multicycle re-use of materials.
- Standards and building codes (Euro coding) complicate the application of technology innovation
- A layered (ventilated) timber structure requires extra material against fire spread
- The transition from linear to circular construction practices is complex due to deep rooted traditional construction practices

D2.3 A Set of circular prefab 3D case specific solutions

Prepared by:
UNIBO University of Bologna,
(Cecilia Mazzoli, Annarita Ferrante)

Submitted to EASME for a review:
30 April 2022

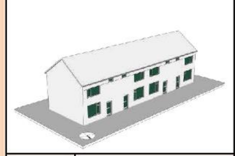
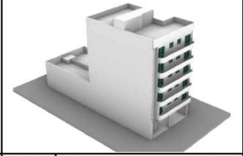
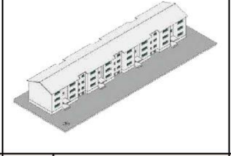
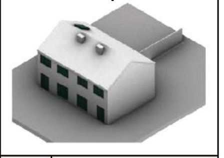
Objectives & Content of D2.3:

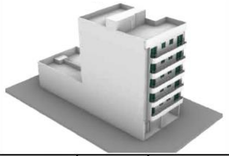
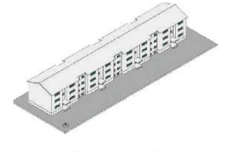
- The report presents the development of a **tool**, easily accessible to all users involved in the deep renovation process without the need for specific training, for **assessing the level of circularity** and hence supporting choices in the building sector. The aim is to increase awareness of circularity and environmental impact for all stakeholders, and hence contribute to global decarbonization.
- The report presents the **technical and regulatory feasibility studies** developed for defining which of the DRIVE 0 demonstrator buildings allow the implementation of the **Add-ons strategy** (derived from the "ABRACADABRA" EU H2020 project, coordinated by UNIBO). Some of these volumetric addition solutions will be digitally applied, while others will be physically realized.
- The report presents a **set of 3D circular solutions** to be implemented for the selected demonstrators, based on the criteria defined consistently with other DRIVE 0 deliverables (D2.2, D3.3, D6.1): Design for Disassembly, Materials origin, and Re-usability. Different intervention scenarios were studied to **analyse the 3D circular solutions in terms of circularity, environmental impact** (through a simplified LCA)**, and cost-benefits** (through a simplified LCC analysis, not presented in the report).

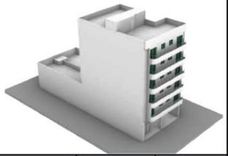
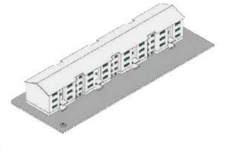
Approach:

Main outcomes & conclusions of D2.3:

- The **simplified method** developed for assessing the circularity level of single 3D solutions or an overall building was **validated** by comparing the EE and ECO2 values obtained with a simplified LCA analysis (conducted with *OneClick LCA software*). The variation between these values is limited to 0-14%.
- The **EBCI values** of the deep renovated state double those of the current state for all demonstrators analyzed (from 0.26-0.33 to 0.50-0.64), leading to renovated buildings corresponding to an average level of circularity.
- The final **set of 3D circular solutions** represent practical examples of different intervention scenarios based on traditional construction techniques and solved by fulfilling the circularity requirements.
- The analyses conducted demonstrate that the **strategy based on implementing 3D circular elements** (ground, façade, aside, and on top add-ons, and assistant building) can effectively enhance the energy performance and the circularity of existing buildings, as well as increase their real estate value.
- The **main barriers** to the implementation of this strategy are linked to the legislative framework and the construction characteristics of existing buildings. The main constraints for the achievement of medium/high circularity are linked to the construction of existing buildings that often is not compatible with the connection systems of new plug&play circular components or that require major reinforcement of the load-bearing structures to support new loads.

EBCI Express Building Circularity Indicator	Dutch pilot		Spanish pilot		Estonian pilot		Irish pilot	
								
	EBCI	CIRCULARITY LEVEL	EBCI	CIRCULARITY LEVEL	EBCI	CIRCULARITY LEVEL	EBCI	CIRCULARITY LEVEL
CURRENT STATE	0,32	LOW	0.26	LOW	0.32	LOW	0.33	LOW
DEEP RENOVATION	0,61	MEDIUM	0.53	LOW-MEDIUM	0.53	LOW-MEDIUM	0.59	LOW-MEDIUM
TOP ADD-ON	0,64	MEDIUM	0.53	LOW-MEDIUM	0.50	LOW-MEDIUM	0.57	LOW-MEDIUM
FACADE ADD-ON	0,61	MEDIUM	0.53	LOW-MEDIUM	0.53	LOW-MEDIUM	0.59	LOW-MEDIUM
ASIDE ADD-ON	-	-	0.53	LOW-MEDIUM	0.53	LOW-MEDIUM	-	-
GROUND ADD-ON	0,61	MEDIUM	-	-	-	-	0.59	LOW-MEDIUM
ADD-ONS COMBINATION	0,60	MEDIUM	0.52	LOW-MEDIUM	0.50	LOW-MEDIUM	0.57	LOW-MEDIUM

GLOBAL WARMING (kgCO2e) Phases A1-A3 (Materials)	Dutch pilot			Spanish pilot			Estonian pilot			Irish pilot		
												
	OneClick LCA	ICE	Variation %	OneClick LCA	ICE	Variation %	OneClick LCA	ICE	Variation %	OneClick LCA	ICE	Variation %
DEEP RENOVATION	18,105	20,969	-14%	113,661	113,884	0%	389,158	371,507	-5%	24,970	22,366	12%
TOP ADD-ON	63,962	58.012	10%	185,122	188,993	-2%	515,577	500,765	-3%	45,053	45,221	0%
FACADE ADD-ON	35,459	39,281	-10%	142,075	135,027	5%	433,010	413,370	-5%	31,333	29,553	6%
ASIDE ADD-ON	-	-	-	178,389	182,741	-2%	398,594	380,380	-5%	-	-	-
GROUND ADD-ON	35,650	35,175	1%	-	-	-	-	-	-	36,165	34,171	6%
ADD-ONS COMBINATION	100,720	93,294	8%	284,400	278,993	2%	575,605	558,356	-3%	61,452	62,646	2%

TOTAL USE OF PRIMARY ENERGY (MJ) Phases A1-A3 (Materials)	Dutch pilot			Spanish pilot			Estonian pilot			Irish pilot		
												
	OneClick LCA	ICE	Variation %	OneClick LCA	ICE	Variation %	OneClick LCA	ICE	Variation %	OneClick LCA	ICE	Variation %
DEEP RENOVATION	305,573	279,834	9%	1,720,014	1,721,699	0%	5,782,669	6,144,591	6%	320,084	336,825	5%
TOP ADD-ON	960,416	955,381	1%	2,828,838	3,001,219	-6%	7,087,984	7,698,780	9%	578,853	653,761	11%
FACADE ADD-ON	492,668	489,696	1%	2,168,769	2,069,560	5%	6,419,805	6,730,221	5%	453,077	450,881	0%
ASIDE ADD-ON	-	-	-	2,408,548	2,603,233	-7%	5,960,449	6,321,324	6%	-	-	-
GROUND ADD-ON	476,606	478,108	0%	-	-	-	-	-	-	553,884	501,668	10%
ADD-ONS COMBINATION	1,351,252	1,439,554	-6%	4,023,966	4,230,614	-5%	8,043,275	8,580,281	7%	939,936	912,712	3%

D2.4 Development of circular modular prefab building platforms

Prepared by:
Renée van Noort, Fact 0

Submitted to EASME for a review:
30 April 2022

Objectives & Content of D2.4:

- Further development of the circular modular prefab building services platforms (iCEM). With emphasis on:
  - Modularity - Adjustable to house and household size ("modularity in space"), use same components across multiple products ("modularity in standardized variety"), future-proof for innovation and replacements ("modularity in time")
  - Miniaturization - Decrease system size to preserve valuable space (on average building costs €2500/m2 in the Netherlands)
  - Circularity - Increase longevity, use circular materials, design for a circular business model

Approach:

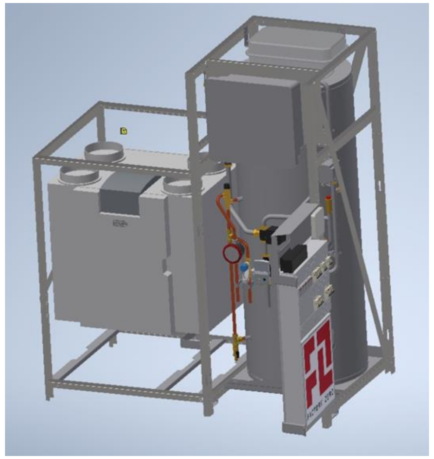
Research & Learning

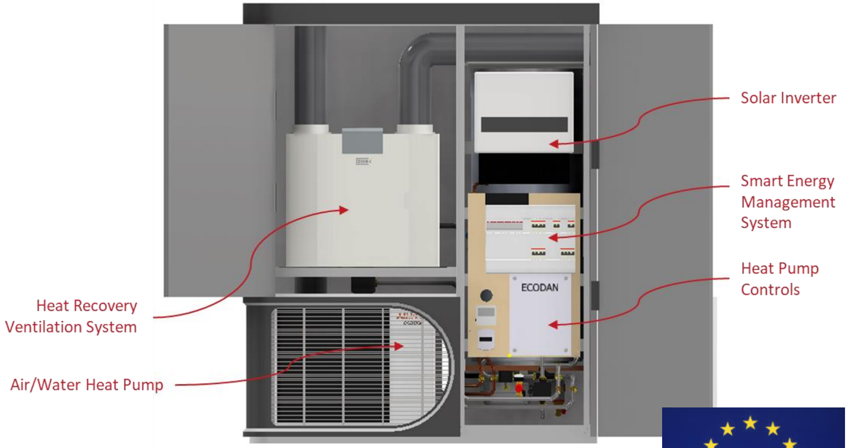
a) Understand European markets

b) Experiences with our existing modules **(Model 1.0)**

c) Circular design solutions and business opportunities **(Model 2.0)**

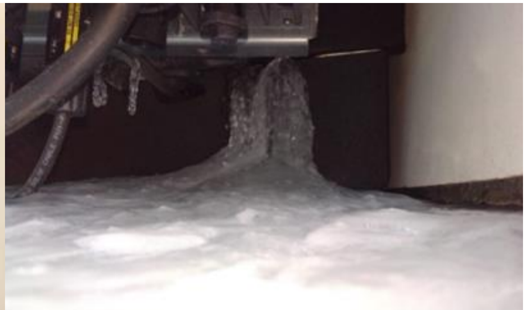
Redesign of iCEM-e and include lessons learned and circular solutions





Main outcomes & conclusions of D2.4:

- Redesign was made. Focus on improving the existing iCEM-e energy module and make sure that all residents who own an existing machine are happy and do not experience any problems.
- Implementation of lessons learned in first design iCEM. The most important being: Copper refrigerant pipes. These are less sensitive for malfunctions.
- Modularity: The first step towards modularity is shown in the design on the right. This design gives the opportunity to fit in different ventilation units and makes it possible to use products from different suppliers. This is an advantage for the current production, but also for the future. When in 5-10 years the ventilation unit must be replaced, this can be any unit.The right part of the iCEM, with the hot water vessel, is more modular in the new design. The electricity is positioned on a “door” to make the access to the water pipes easier. If the hot water vessel needs to be swapped, the door can be disassembled easily.
- The follow-up plan is concerned with fixing the main problems in the units. Therefore, the focus for the coming period is to contact all residents and make sure that they have a good and working machine. This is a major operation and will include many resources.
- Fixing the problems is the highest priority and the development of an improved design is put on hold until everything is taken care of.



D2.5 A set of smart building and installation details for mounting and de- mounting

Prepared by:
ISSO, Noortje Alders & Dennis van der Kooij

Submitted to EASME for a review:
14-4-2022

- **Objectives & Content of D2.5:**
  - *Development of reference details for disassembly; assessing detachability*
  - *Properties and performance indicators for disassembly in reference details*
  - *Checking and calculating building-physical aspects in smart building and reference details*

Main outcomes & conclusions of D2.5:

- *Development of reference details for disassembly; assessing detachability*

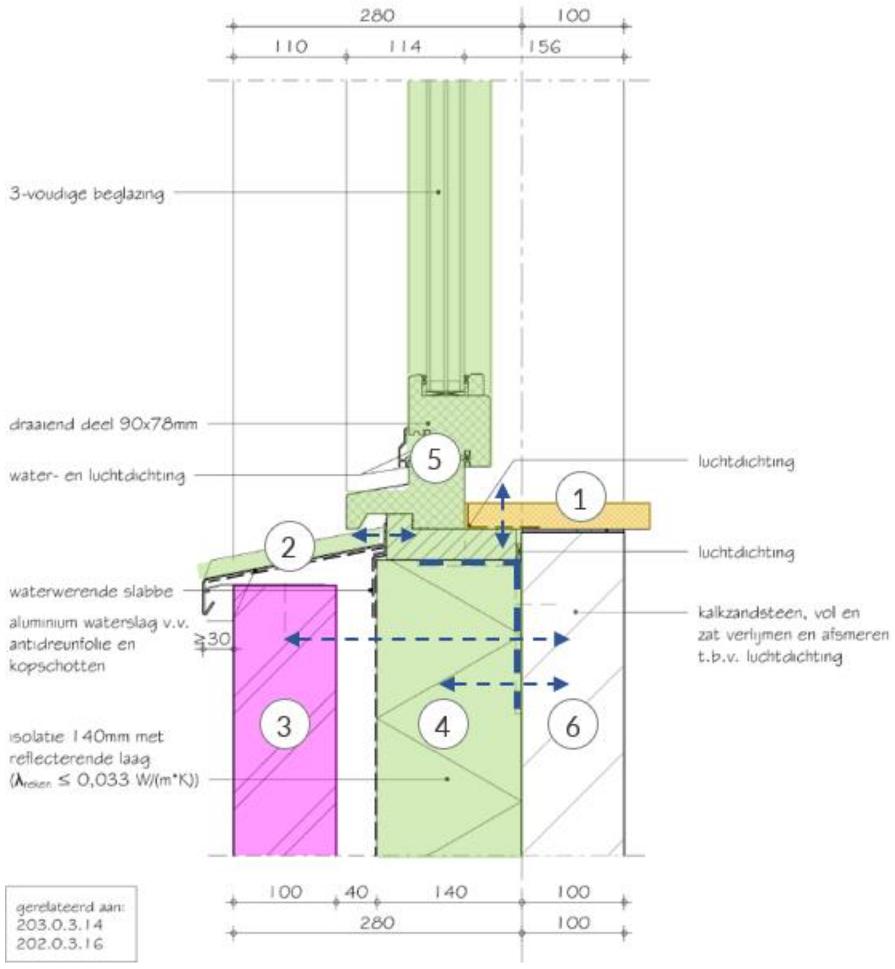
  The methodology shows the potential of assessing the performance of detachability. This can facilitate innovators to improve the assembly of building products to extend the lifespan of the building by maintenance or transformation. The lifespan of products or materials can also be extended by re-use after the lifespan of a building or building part. Furthermore, visualizing the assessment of detachability with the Performance layer in the Reference details can facilitate designers to design for disassembly. The image to the right shows an example.

- *Properties and performance indicators for disassembly in reference details*

  The automation of the methodology with the current reference details and their properties seems to be possible, but further research must point out if these properties are enough to create a disassembly layer in the reference details.

- *Checking and calculating building-physical aspects in smart building and reference details*

  The automation of the calculation of the reference details sound promising, however in practice with the current technological developments it's a laborious process that takes more man-hours and high precision that specialized companies cannot currently deliver. Manual calculations are currently still more efficient and less labor intensive.



D3.1 Morphological design approach & guidelines for circular renovation

Prepared by:
Zuyd University of Applied Sciences, SURD research team (John van Oorschot, Michiel Ritzen)

Submitted to EASME for a review: Aug 2021

- **Objectives & Content of D3.1:**
  - Deliverable D3.1 outlines the morphological design approach and design guidelines for a modular and circular deep-renovation approach enhancing the application of prefabricated building elements.
  - The morphological design approach and design guidelines stipulate the key actions and tasks and relevant output, balancing process efficiency gains, the application of circular building principles as well as an end-user orientation.
  - Deliverable D3.1 presents a framework to evaluate and validate the morphological design approach and design guidelines.

Main outcomes & conclusions of D3.1:

- Deliverable 3.1 presents an overview of the key steps of a modular and circular deep-renovation process rooted in modularity theory and empirics of previously conducted research projects (H2020 MORE-CONNECT; IDES-EDU).
- For each of the key steps of the deep-renovation process the specific actions and tasks are defined as well as the input required to conduct these actions and tasks and the output that need to be generated.
- Suggestions are presented to further test and improve the the morphological design approach and design guidelines.

Input	Actions & tasks	Output
Project brief; DRIVE-0 Deliverable D2.1	T4.1.1 Selection & contracting component suppliers & installers	Signed letters / contracts
Final conceptual design (3.5.1)	T4.2.1 Finalizing design integrating all parts in coherent design according pre-defined design rules	BIM/ifc model
Final conceptual design (T3.5.1)	T4.2.2 Assessment of final design (KPIs)	Building permit

D3.2 Report with a description of the boundary conditions of an enhanced circular renovation process

Prepared by:
Zuyd University of Applied Sciences, (Albin Rohith, John van Oorschot, Michiel Ritzen)

Submitted to EASME for a review:
5 July 2020

Objectives & Content of D3.2:

- This study contributes to the existing body of knowledge concerning the preconditions that need to be met to enhance the deep-renovation process by applying modular product systems.
- By conducting an extensive literature review and three in-depth interviews with front running circular construction firms, we have identified the 7 following preconditions that are essential for enhancing overall quality and efficiency of circular deep renovation projects

Main outcomes & conclusions of D3.2:

Pre-conditions to enhance circular deep renovation processes

- Shift from selling a solution towards selling a standardized product
- Develop a standardized plug and play connector for modular product systems
- obtaining product certification
- Setting sales boundaries
- Avoid working with different sub-contractors
- Product branding
- Smart planning of deep-renovation processes.

The identified preconditions support our hypothesis that enhancing the deep-renovation process by applying modular product systems depend on coherence between the three dimensions of modularity *Product, process & supply chain modularity*.

The research findings further support previous research that suggests that, when products become modular, both the production process and the supply chain set up need to be aligned and this can be achieved by applying the aforementioned preconditions in practice.

D3.3 Tailor made holistic and circular renovation packages for the 7 demonstration cases

Prepared by:
Tallinn University of Technology
(Kalle Kuusk, Targo Kalamees)

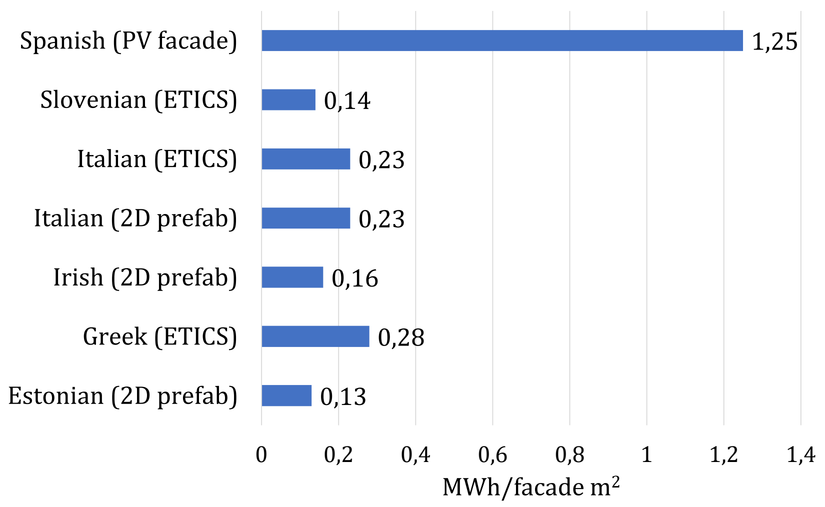
Submitted to EASME for review:
March 2022

Objectives & Content of D3.3:

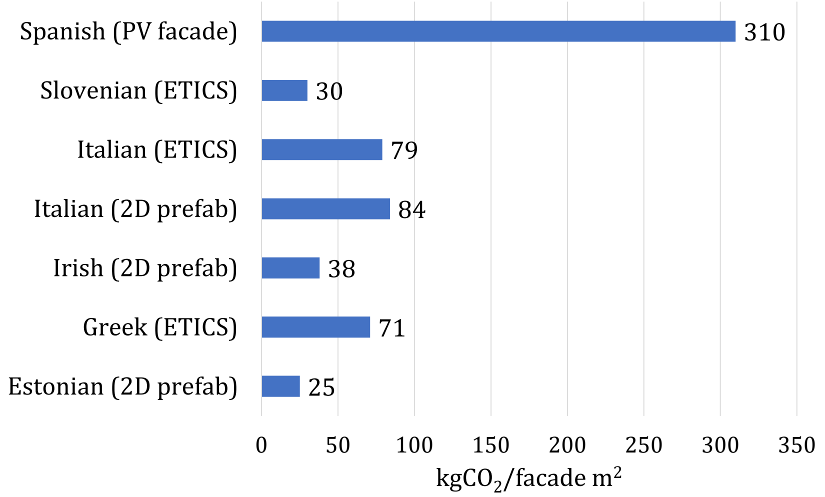
- The report analyzes the circularity of the renovation solutions used for pilot renovations.
- The indicators used to assess the degree of circularity of the renovation concept are Design for Disassembly (DfD) criteria and Building Environmental Assessment (with Embodied Energy and Embodied CO_2 as indicators).
- Methodology is based on research results of DRIVE 0:
  - D3.1 Morphological design approach and guidelines.
  - D3.2 Development of circular renovation process.
  - D6.1 Report on benchmarking on circularity and its potentials on the demo sites.

Main outcomes & conclusions of D3.3:

- Most pilot renovations achieved a high or medium degree of circularity.
- The main advantage of modular prefabricated elements is the greater potential for disassembly and reusability. Prefabricated solutions also allow a wider choice of materials (bio-based insulation materials and cladding) to achieve a low environmental impact.
- The difference between prefabricated and external thermal insulation composite systems (ETICS) in terms of environmental impact is smaller than in terms of disassembly and recovery options.
- Some building materials have excellent properties in terms of circularity; however, for practical reasons, they cannot be used. The main concerns with using recycled or biobased materials are the absence of necessary certificates, fire safety, hygrothermal properties, and higher maintenance need.



Embodied energy of m^2 of façade area



Embodied CO_2 of m^2 of façade area

D3.4 Blueprints for BIM controlled automated production lines for circular renovation products

Prepared by:
WEBO, Bart Voortman, Hannah Voortman

Submitted to EASME for a review:
25-09-2023

- **Objectives & Content of D3.4:**
- In D3.4 the production lines for the prefab renovation elements were adapted to a fully automated BIM controlled process.
- WEBO has set itself the following goals:

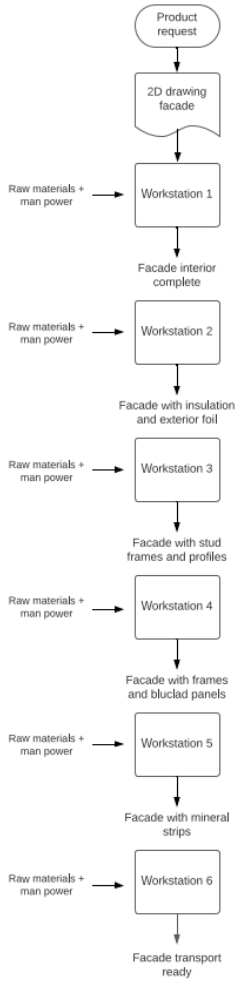
  1. Increase in output: Goal is to achieve an increase in the output of off-site production of façade elements. WEBO aims to generate 50 times more output compared to the current production process.

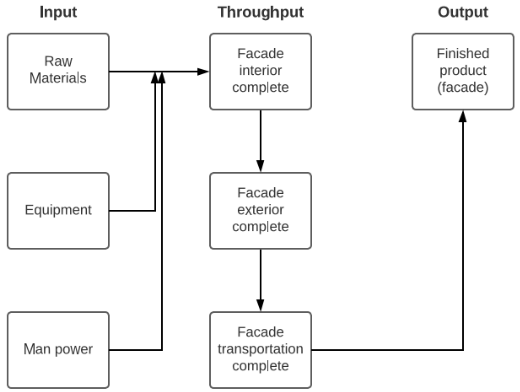
  2. Reduction in manual labour: reduce the amount of manual labour required for the production of façade elements. The target is an 80% reduction in manual work compared to the current process

- WEBO’s objective is to create a blueprint for the design and structure of a fully automated production line

Main outcomes & conclusions of D3.4:

- To come up with a solution, WEBO used the IST-SOLL model otherwise known as the GAP analysis.
- IST – Current situation WEBO
  - Flowchart & Input-throughput-output model
- SOLL – Desired situation WEBO
  - Strategic goal is to increase output for construction-ready modules, specifically aiming for 600 facades and 240 roofs per week.
  - Performance goals include achieving higher speed and matching output with demand
  - The chosen layout type for WEBO is the cell layout
- GAP – difference between current and desired situation
  - GAP analysis identifies a difference of 588 facades per week and 72 additional staff members needed in the desired situation.
  - Various machines and scenarios are considered to bridge this GAP.
  - Scenario 8, a combination of Industrial Manufacturing from Weinmann and Steenstrips Applicatie Robot, is chosen as the most favorable solution





[D3.5 Catalogue with circular concepts: the EU circular renovation atlas]

Prepared by:
Zuyd University of Applied Sciences, SURD research team (Silu Bhochhibhoya, John van Oorschot)

• Objectives & Content of D3.5:

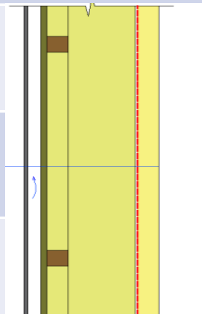
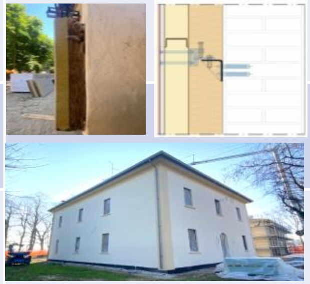
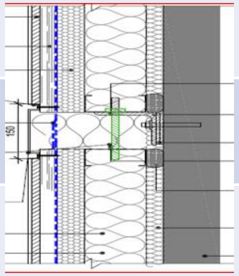
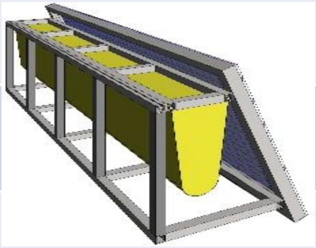
- The report presents an inventories of all the circular renovation solution atlas adopted by the seven pilot project cases.

- The inventories includes three major properties needed for the circular renovation solutions; technical, economical and environmental properties. This add value to the overall objectives of the Drive 0 project which help in accelerate circular renovation processes in order to make deep renovation environmentally friendly, cost effective.

- The report also present the replicability of circular solutions from different climatic zone.

Main outcomes & conclusions of D3.5:

- The report shows the inventories of the general information, technical, environmental and economic performance of the circular solution of seven pilot project case.
- The solutions on this catalogue are tested in cases projects refined and re-tested with lessons and adaptations applied in the demonstrator site. The solutions are proved technically feasible.
- The circular solution atlas can be applicable by the architects, housing association, designer and homeowners to choose the best circular solution in terms of material, product and components (2D and 3D prefabricated facade) that is best suited.
- It is recommended to check the technical, environmental and economic performance of the circular solution. Moreover, it is also recommended that the circular solution should be chosen based on relevance, applicability, accessibility.

	The Netherlands	Estonia	Italy	Ireland	Spain	Greece	Slovenia
Type of Circular Solutions	WEBO 2.0 Prefab (timber) panels	Prefabricated insulation element	Energy refurbishment of facade	2D Wall Cladding Panels and 3D Extension Pod	Photovoltaic planter	Energy refurbishment of façade	Biobased façade
Circular Renovation Solutions	Biobased facade	Prefabricated insulation elements for roof and wall	Plug&Play 2D Prefab	2D Wall Cladding Panels and 3D Extension Pod	Multifunctional product integrating PV production and renaturization	Integrated external thermal insulation (stone wool FKD-S thermal)	Biobased façade
Circular Renovation Solutions Applied	Facade	Roof and wall	Energy refurbishment of existing façades (North and West oriented)	Thermal upgrade of the building fabric	Retrofit of boundary walls, urban space, residential roofs and terraces	Insulation element	New and retrofit
Circular Principles	Reuse	Reuse	Implementation of an innovative circular system (dry and reversible)	DfD at all levels in Hierarchy & Environmental / Biobased Materials	Design for disassembly, local energy production, modular product	Recycle and energy efficient	Diagonal 2H ventilated facade system
Type of materials	Wooden structure + fiberglass insulation + ventilated facade	Wood frame insulated with the mineral wool insulation of 25 cm	(From inside to outside) Glass wool layer (12 cm) + Sandwich panel in rock wool (8 cm) + Fiber cement board "ACQUAPANEL" (1.5 cm). Anchors in steel.	Light Guage Steel, Rockwool Insulation Quilt, Wood Fibre Board, Breather Membranes, Timber Battens, Cement Fibre Board, Metal Trims, Steel Brackets, Roofing Membrane, Metal Eaves, Triple Glazed Windows and Doors	mainly PV panel, metallic structure	Rock mineral wool	Rock Mineral Wool, steel structure, wood planks and Aquapanel boards
							

D4.1 Collection of monitoring methodologies and information services

Prepared by:
Valencia Institute of Building – IVE
Vera Valero, Miriam Navarro, Leticia Ortega, Ana Sanchis

Submitted to EASME for a review:
10 July 2021

Objectives & Content of D4.1:

- This reports presents a collection of measurement protocols, guidelines and/or methodologies related to measurement of comfort, well-being and health of buildings' occupants as well as to identify energy human' behaviours to be measured when evaluating the circularity.

- The report includes a more detailed analysis of each of the 13 different protocols to finally compare them.

- The second part of the report comprises the analysis of monitoring technologies, tools or devices, available in the market, for the monitoring of physical indoor environment Quality IEQ, comfort, and health and well-being parameters as energy (use and cost), water (use and cost), noise level, temperature, lighting and indoor air quality, and any other parameter to be measured when evaluating the circularity

Main outcomes & conclusions of D4.1:

Protocols:

- The documents analyzed cover different objectives and apply to different frameworks.
- In some of them the objective was to define a common and precise methodology that would allow validating the initial hypotheses and obtaining comparable results.
- Other documents analyzed aimed to provide guidance on the steps or processes to be followed, and on the aspects, criteria, and/or variables to be covered when designing a monitoring protocol or plan, for a specific building and project.
- There are also other documents, such as Level(s), which aim to evaluate the sustainable performance of a building, and which define the indicators to be considered, the monitoring options and the reference standards for measuring and calculating them.
- Most of them incorporate some noteworthy aspect to be considered when defining the future *D4.2 Monitoring Protocol*.

Tools:

- There is a wide range of devices that cover practically the entire spectrum of variables to be monitored in a building.
- On the one hand those oriented towards management and monitoring by professionals, with "complex" software for data analysis.
- On the other hand, we find a range of tools and devices aimed at non-professional users, with a green eco-conscious profile, with elegant and attractive designs, usually associated with friendly and intuitive applications (app), which inform about the behavior/consumption of your home/devices, while offering tips to improve their usual practices (energy consumption/environmental quality).

[D4.2 Monitoring Protocol]

Prepared by:
Valencia Institute of Building – IVE
Miriam Navarro, Ana Sanchis, Leticia Ortega
Submitted to EASME for a review:
10 July 2021

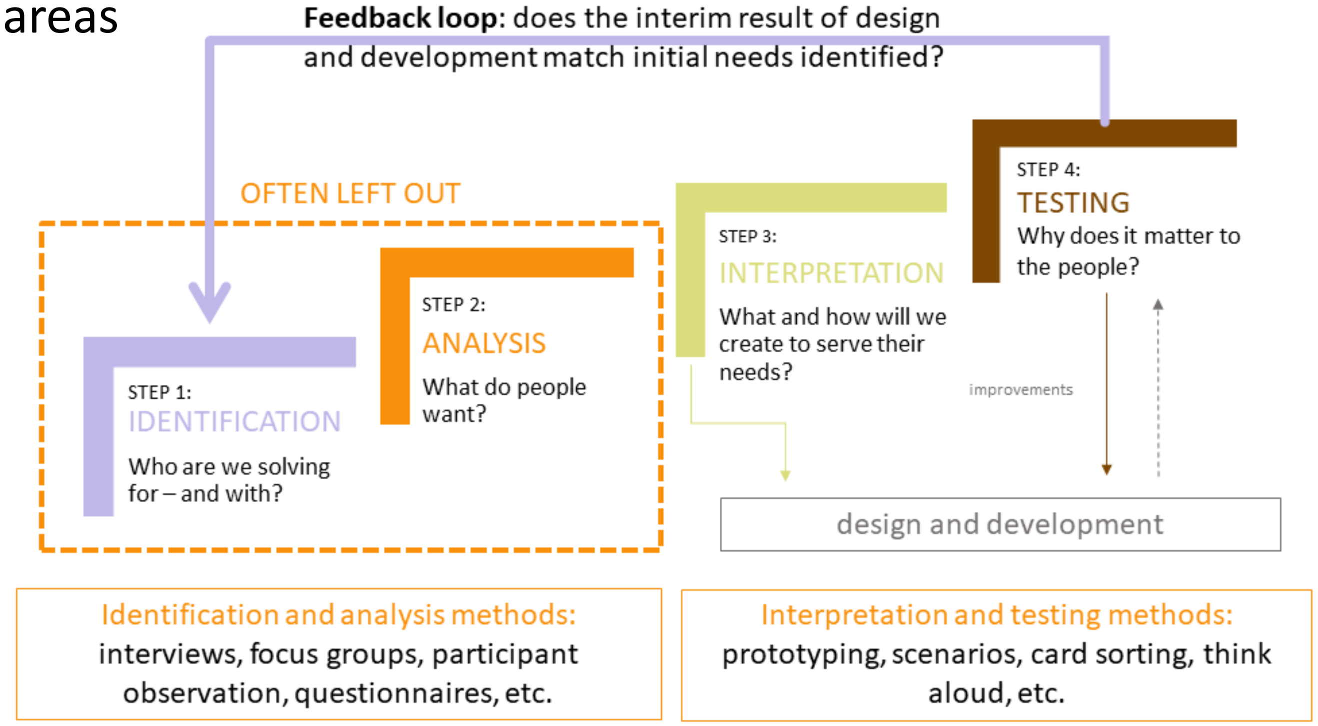
Objectives & Content of D4.2:

- This protocol measures circularity concepts on a dwelling scale for the in-use phase to accomplish these objectives:
  - Awareness, engagement, and self-comparison of owners/ occupants
  - Validation of principles and assumptions to improve circularity implemented in the project.
  - Justification of impacts according to EU-H2020 program.
- Circularity measures will rely on data obtained from:
  - Monitoring building and service performances.
  - Surveying demonstration sites occupants and all the related stakeholders that may have valuable information.

Main outcomes & conclusions of D4.2:

Protocol procedure:

- Selection and characterization of study areas
  - Initial visit
  - Selecting residential units
  - Units characterization
- Monitoring campaigns definition
  - Timeline
  - Duration
  - Administrative guidelines
- Data collection. Areas to cover:
  - Energy
  - Water
  - Materials
  - Well-being
  - Occupant's behavior & consciousness



D4.3 Report on attractive and understandable user information

Prepared by:
Jure Vetršek, Sara Arko Institute for Innovation and Development of University of Ljubljana (IRI UL) with contribution from all project partners

Submitted to CINEA for a review:
25 June 2021

Objectives & Content of D4.3:

The aim was to present to end users meaningful information that can support them in making informed decisions, impact their decision-making related to build environment investments, and even influence their everyday habits and practices related to operation of (circularly renovated) buildings.

Inputs were gained from demo sites ethnography inspired research, moderated events for partners and by following most of the project tasks.

Results from several projects from fields of energy, materials, well being, water end behaviour are examined and useful contents extracted.

Practical and above all understandable to final users aspects of circularity from demo sites environments are integrated, and solutions suggested. Information and results are put in to practice in T4.4.

Main outcomes & conclusions of D4.3:

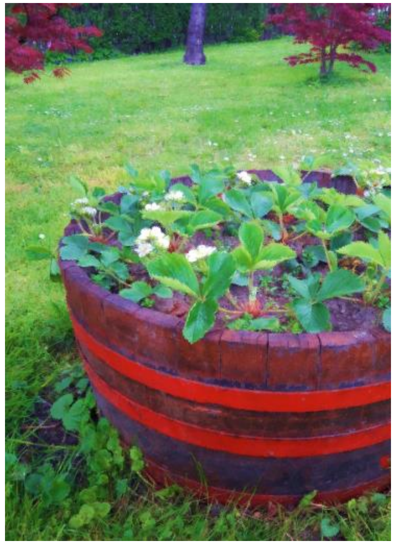
We need to expand the perception of value and integrate materials and energy to have the needed connection and be aware of limitations we have in physical world and improve understanding of circularity. Energy and indoor environmental quality can be coupled with health and well-being which have a higher potential to induce change in behaviour.

A change in the everyday practices and decisions related to circular renovation can be supported by a multi-channel long-term context-customized campaigns. This can be done with tailored advices referring to project topics that provide information that is relatable and meaningful to building occupants and at the same time unobtrusive and understandable. Examples are show in the report.

In the use phase of a building, we focus on human interactions with buildings, technologies, tools, and devices, in order to impact energy and material use and buildings' carbon footprint.

To make circularity in built environment as practical as possible, we propose a so-called Do-It-Yourself catalogue of "micro circularity practices", which presents circular practices in an understandable way, motivates towards creative circular projects, and can function as on-boarding for the platform.

The most straightforward and most often pointed out indicator is related to costs or savings as the most convenient way of evaluating substances and processes.



Existing research shows that there is a growing awareness of and sensibility towards indoor air quality among residents, which may likewise be considered as a relevant and impactful indicator.

D4.4 User centred information service description

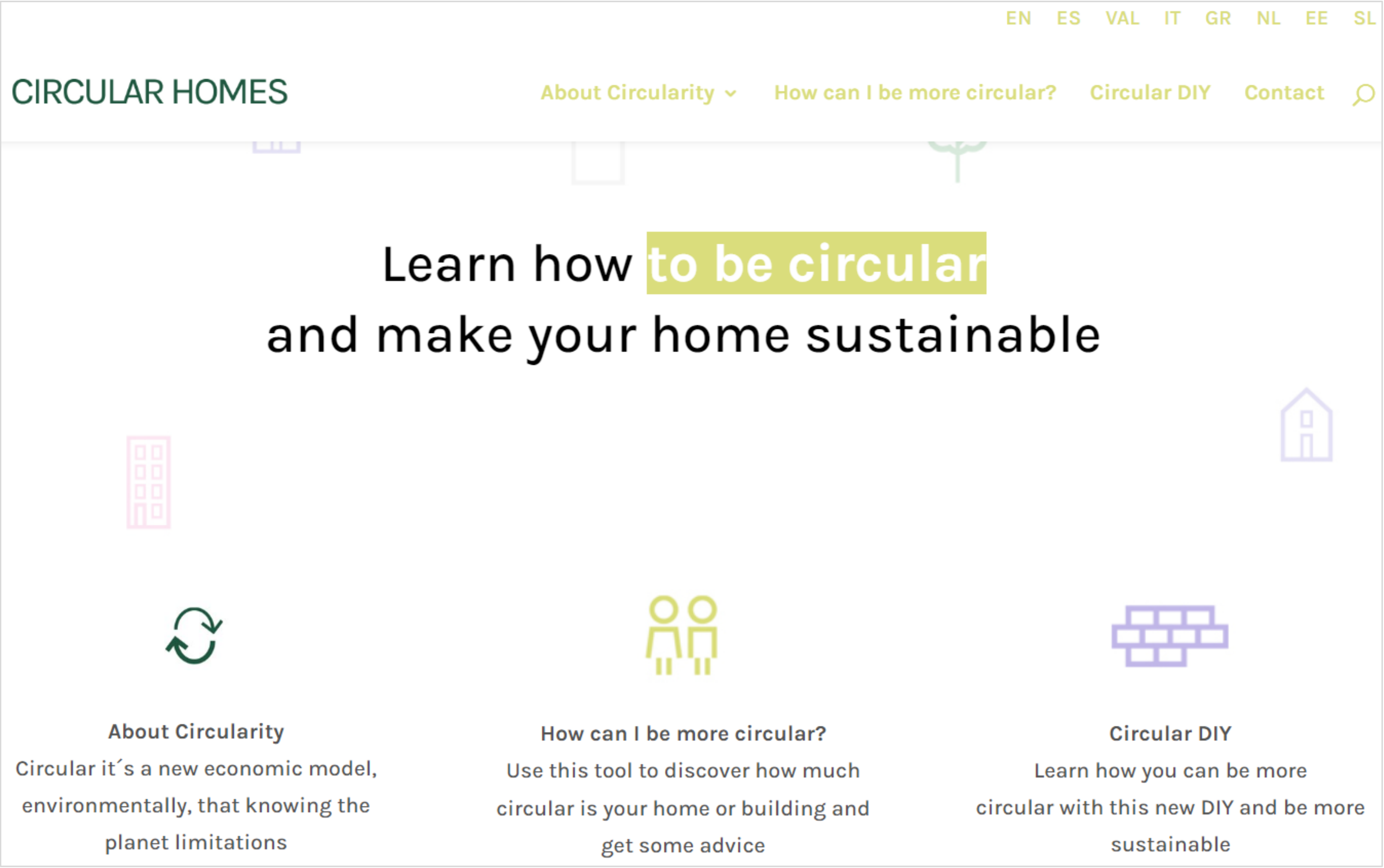
Prepared by:
Valencia Institute of Building – IVE
Miriam Navarro, Leticia Ortega, Diego Sanz
Submitted to EASME for a review:
10 July 2021

Objectives & Content of D4.4:

- Objectives: to foster user centred circular deep renovations using circularity as a driver, as well as create circular awareness by providing consumers and end-users with attractive and understandable information of circular economy applied to the built environment and circular renovations realised in the Drive 0 framework.

- The DRIVE 0 user centred Drive 0 digital platform:
  - Contains understandable information about the circular economy concept applied to the built environment.
  - Creates awareness on circular economy concept and practices as a driver for deep renovation.
  - Provides advice on how to become circular at different levels, from behaviour change to deep renovation.
  - Measures the circularity level of a user based on easy data provided through simple questions.
  - Includes information on circular products to be used in circular renovations.

Main outcomes & conclusions of D4.4: https://www.circularhomes.eu/



D5.1 - Report on the business models employed in each case study

Prepared by:
UNIBO (Task leader) and ZUYD
Submitted to EASME for a review:
30 June 2021

Objectives & Content of D5.1:

- The report presents a comprehensive analysis of the main *circular business models*, which covers the core elements of the main sub-categories and an inventory of the 26 most commonly used business models. Main opportunities and challenges are also discussed.

- An *assessment tool of the 'degree of adoption' of circularity* is proposed. It is applied to the industry partners of DRIVE 0 to show their degree of adoption of circularity, that is, where companies position themselves from a business model perspective in their transition to a circular economy.

- The report also investigates the sources of financing received by DRIVE 0 companies in the process of transitioning to a circular business model and the financial barriers they encountered.

Main outcomes & conclusions of D5.1

Outputs of Task 5.1 include:

- *Questionnaire 1 (On the degree of adoption of circularity)*
- *Questionnaire 2 (On financing circular business models)*

The report classifies companies according to two main dimensions *(value proposition and organization*), assessing whether they achieved:

1) High degree of circularity; 2) Upstream circularity; 3) Downstream circularity; 4) Low degree of circularity.

Outcomes are compared with those self-stated by the companies in order to verify whether the overall degree of circularity resulting from this analysis is the result of the progress made by the companies, or of subjective perceptions, or just the ambition of the companies (overestimation/underestimation in relation to the adoption of circular business models). We also assessed the limitations and critical issues that have emerged and discuss the possibility of formulating new business strategies

Conclusions of D5.1:

- The positioning of each industrial partner, as from the taxonomy obtained through our matrix, and their assessment - in the light of all the information gathered - is a significant starting point for further corporate assessments and recommendations to improve the companies' strategies and policies towards full circularity.
- It opens the way toward a deeper analysis of the existing opportunities and challenges to circular business model innovations.

D5.2 Report on the experimental/lab results on consumers/users behavior and social responsibility

Prepared by:
UNIBO (Task leader)
Submitted to EASME for a review:
30 September 2022

Objectives & Content of D5.2:

Objectives of D5.2 are to understand:

- under which economic conditions “going circular” is an optimal strategy for a firm;
- how consumers/users’ behaviours and attitudes affect business strategies

Such understanding is a pre-requisite to the development of an effective ***circular business model*** (CBM)

Contents of D5.2 are mainly focused on RECYCLING as a prototype CBM.

1. D5.2 presents *an original theoretical model* of *recycling*. A simulation of the industry outcomes is also performed, together with the feedbacks of industry partners regarding their reactions to the challenge of competing in a market
2. Starting from recycling, D5.2 elaborates a simple *questionnaire,* with the objective to analyse how consumption behavior shifts towards a more responsible attitude that puts emphasis on circularity (including also reusing, retaining, repairing and servicing the products).
3. Finally, D5.2 includes *an empirical study* about the main drivers of recycling in the 7 European countries our demonstrators belong to, and *a panel analysis* for EU, to analyse how socio-economic and demographic characteristics in the different countries may impact differently on circularity

Main outcomes & conclusions of D5.2

1. The theoretical model shows a general framework which puts emphasis on – and quantifies - the *economic factors affecting the business model choice of firms* (in terms of efficiency of the circular technology, relative cost of new vs recycled materials, tax rates, demand parameters, organization of markets of recycled items, …). It determines when the resulting market outcome is *linear, semi-circular* or when firms close the loop being *fully circular*. It specifies the *competitive strategy in the market* (see Propositions 1 and 2). It is a pretty general framework that can be extended to other strategies of «cycling».
2. The feedbacks of Drive 0 industry partners reveal the strategies they implemented and how they reacted to the challenge of competing in a market.
3. Of course, how firms will determine (CBM) innovations on *the demand side* is also crucial: in particular, in terms of *consumer offering* or *changing awareness and consumers' behaviours towards circularity*. The survey from the Questionnaire in Part II of D5.2 together with the empirical study in Part III of D5.2 show that various socio-economic and demographic characteristics (in the different countries) may also have a different impact on circularity.

Conclusions of D5.2:

- The positioning of each industrial partner, and their reaction to the challenge of competing in a global market - in the light of all the information gathered - is a significant starting point for further corporate assessments and recommendations to improve the companies' strategies and governmental policies towards full circularity.
- In D5.2 we focused on recycling, but companies may apply this type of argument also to other strategies of "cycling".
- The next step will be to elaborate *a clear connection* between the relevant pillars (under environmental, economic, social and governance perspectives), the variables in each pillar, and how and to what degree each of them affects the degree of circularity.

D5.3. Numerical code for the construction of the Circular Readiness Indicator

Prepared by:
UNIBO
Submitted to EASME:
30 September 2023

Objectives & Content of D5.3:

- Objective of the Report is the construction of a "*Circular Readiness Indicator*" (CRI) for companies in the construction sector. To achieve this aim:

- First, **PART I** provides a comprehensive review and discussion of the most relevant indicators that have been developed in the literature so far, focusing on the methodologies employed in the construction of composite indicators in the context of circular economy (CE) strategies.

- Then, in **PART II** we elaborate a conceptual model and the numerical code to assess the "readiness" concerning CE and CE practices from a multi-tier perspective. We holistically address different aspects of circularity (environmental, economic, socio-organizational) and the interrelations among variables and network of variables relevant for circularity.

- Section 4 presents the numerical code of CRI and Section 5 applies CRI to the selected case studies, which are the main companies involved in the Drive 0 pilots.

Main outcomes & conclusions of D5.3

Outputs of Task 5.3 include:

- *Questionnaire 1 in Annex 1*
- *Elaboration of CRI (Part II, Sections 1, 3 and 4) and Numerical Code (Part II, Section 4)*
- *Application of CRI to the selected Drive 0 case studies in Section 5*

In a nutshell, purpose and characteristics of CRI are as follows:

- assess readiness, flexibility and capacity to adjust and progress to CE

- dimensions beyond environmental variables

- Interrelations among variables and network of variables relevant for circularity

- CRI provides a taxonomy of companies based on their readiness to circularity and allows us to understand which dimensions have to be improved to become top-performer.
- CRI can be used in a dynamic perspective to track the progress toward circularity

EXCEL CODE LINK

Follow-up of D5.3:

The outcome of this Report is useful per se, but will also serve as input for other tasks in Drive 0 - such as Tasks 6.6 and 6.7 - and for overall analysis and policy recommendations (D5.5) to increase the adoption potential and market transition towards a circular deep renovation economy.

D5.5 Booklet with policy recommendations (report)

Drive 0 BOOKLET with policy recommendations (actual booklet)

Prepared by:
UNIBO University of Bologna,
(Cecilia Mazzoli, Annarita Ferrante, Elettra Agliardi)

Submitted to EASME for a review:
21 December 2023

Objectives & Content of D5.5:

D5.5 aims to:

- Propose a meaningful yet **non-exhaustive list of barriers and challenges** that key stakeholders face or expect to face during the conceptualization, design, implementation, planning, and execution phases of a circular deep renovation intervention;
- Suggest **potential solutions and best practices** for facing the barriers identified;
- Propose **possible policy recommendations** on how the key stakeholders can overcome these barriers and related challenges.

Methodological approach:

During the four-year-long project, several project meetings, technical workshops, conferences, and webinars were organized with the aim of sharing opinions and generating a valuable and fruitful discussion about the opportunities and benefits of the adoption of a circular strategy. Critical barriers and threats to the implementation of circularity in the construction sector, at both local/national and international/European levels, emerged. These obstacles are of **technical, regulatory, financial, social, and societal nature**.

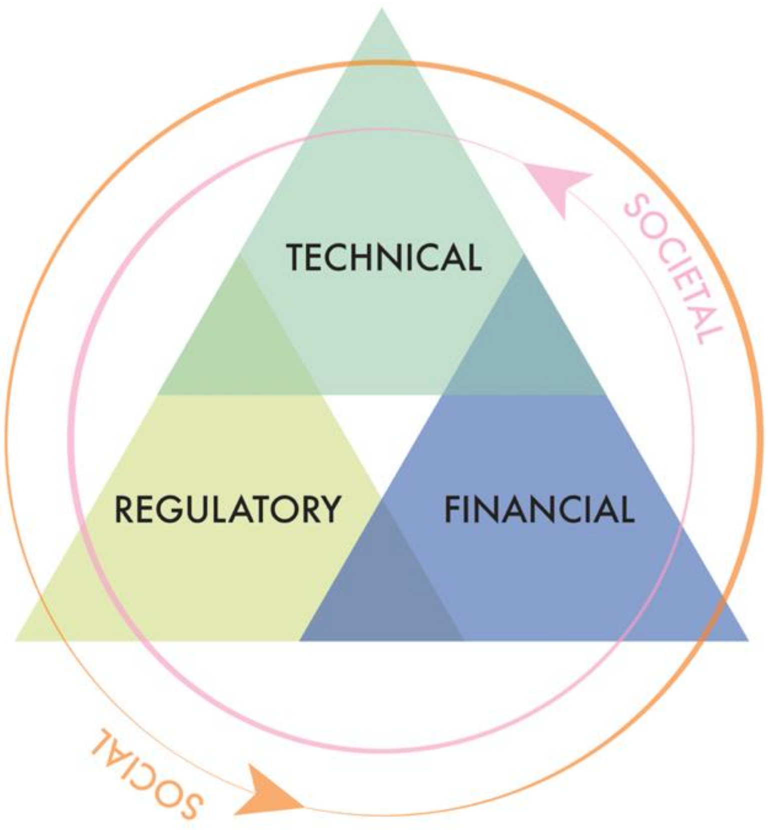
To collect and compile the information contained in this report, the following **sources** have been used:

1. Grassroot and field experience, as well as knowledge coming from UNIBO and the umbrella associations (UIPI, HE, and ACE) partner in the DRIVE 0 project;
2. Desk research (including information from other European projects);
3. Data collected during DRIVE 0;
4. Input and comments collected during all the events above-mentioned.

Drive 0 BOOKLET with policy recommendations - for public shares!

Main outcomes & conclusions of D5.5:

- The main **stakeholders** considered – both **private and public** – have been divided in three wide categories:
  - Private sector;
  - Public, social, and cooperative housing sector;
  - Experts in the construction sector.
- From all the sources collected, a check about the different target groups' perceptions was done to reflect real concerns and obstacles to implementing a circularity strategy. The collected data was proven valuable for developing the DRIVE 0 suggestions and policy recommendations, ensuring that the project results have real **potential to increase awareness and promote the adoption of circular measures** for energy-efficient retrofitting of the existing built heritage.
- The barriers and suggestions in the booklet represent an effective synthesis of the dialogues and discussions that took place during the DRIVE 0 project, embracing the **technical, regulatory, financial, social, and societal issues**. In particular, social and societal aspects are factors that affect all technical, regulatory, and financial obstacles crosswise, varying according to geographical and cultural context.
- A **list of 20 policy recommendations** have been drafted with the aim to provide concrete solutions to overcome obstacles to the widespread adoption of a circular approach in the construction sector. These policies suggest precise actions to spread the principles of circularity and increase their adoption among all key stakeholders involved in the process of deep renovation of the built environment. They also provide concrete examples of viable initiatives and solutions.
- The policy recommendations aim to find ways to finance energy efficiency deep renovation interventions in the building stock through a circular approach to try to achieve the **European Green Deal goals of no net greenhouse gas emissions by 2050**.



[D6.1 Report on benchmarking on circularity and its potentials on the demo sites]

Prepared by:
Zuyd University of Applied Sciences, SURD research team (Dario Cottafava, Michiel Ritzen, John van Oorschot)

Submitted to EASME for a review:
31 Mar 2020

- # Objectives & Content of D6.1:

  - The report presents a thorough literature review related to circularity assessment for the built environment by discussing the current state of the art methodologies and approaches.

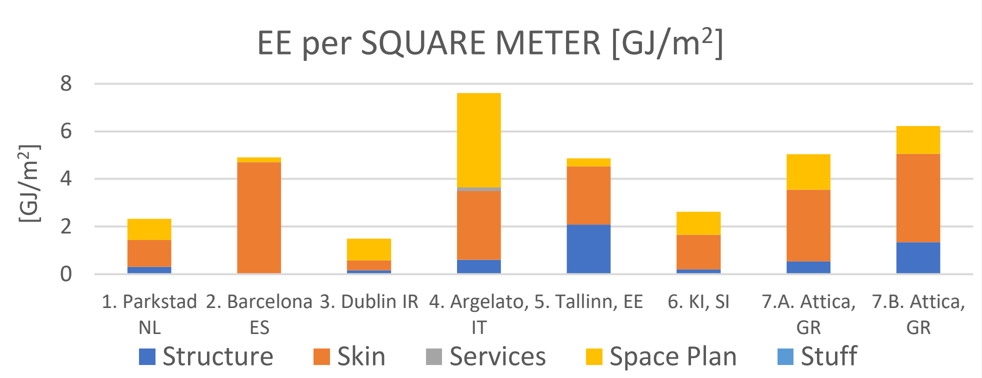
  - The report presents a first benchmark assessment of the circularity of the seven demo sites, by linking:

    - Building Environmental Assessment (with Embodied Energy and Embodied CO_2 as indicators), with
    - Building Circularity Indicators (BCIs), and
    - Design for Disassembly (DfD) criteria.

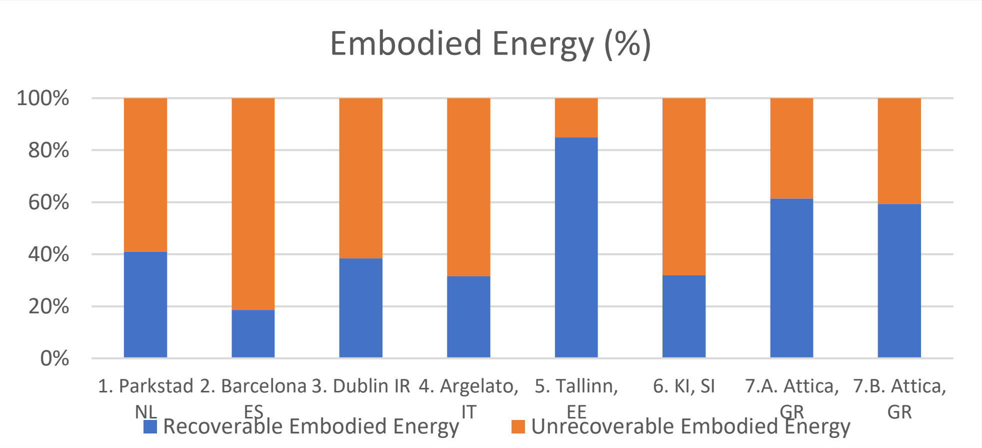
  - The report indicates mass, Embodied Energy, and Embodied CO_2 of the seven demonstrators, recoverable percentage and DfD indications as directions for development of the demo sites.

Main outcomes & conclusions of D6.1:

- Embodied Energy ranges between 1,49 GJ/m2 and 7,60 GJ/m2, while the Embodied CO2 ranges between 0,15 tCO2/m2 and 0,73 tCO2/m2.
- The BCI ranges between 0,28; 0,27; and 0,28 and 0,10; 0,13; and 0,12, with respect to the mass, Embodied Energy and Embodied CO2 respectively.
- The percentage of recoverable materials, in terms of Embodied Energy, ranges between 20% and 85%.
- More precise methodologies with respect to the self-declaration of practitioners and experts are needed to assess the recovering potential of materials.
- The report shows a necessity of criteria to indicate to what extent the DfD indicators relate to a material, a component in and of itself and its relationship to its context



Demonstrators name	Building Circularity Indicator		
	DfD criteria inside MCI		
	Mass	EE	$EECO_2$
1. Parkstad NL	0,14	0,15	0,15
2. Barcelona ES	0,08	0,08	0,08
3. Dublin IR	0,10	0,13	0,12
4. Argelato, IT	0,23	0,22	0,22
5. Tallinn, EE	0,28	0,27	0,28
6. KI, SI	0,13	0,13	0,12
7.A. Attica, GR	0,20	0,20	0,20
7.B. Attica, GR	0,19	0,20	0,20



D6.2 Detailed Monitoring Action Plans for each demonstration case

Prepared by:
NKUA, GRBES research team (Dimitra Papadaki, Chrysanthi Efthymiou, Nikos Barmparesos)

Submitted to EASME for a review:
11 Nov 2020

• Objectives & Content of D6.2:

- The report demonstrates key data concerning the general features of demonstrator buildings and highlights the monitoring campaign, and activity plan for each case study
- The report presents the case-specific Monitoring Action Plans including information on:
  - Monitoring to be conducted
  - Activities planned and conducted
  - Time-schedule of all activities and monitoring procedure
  - Costs per demonstrator /and or per activity
- The report delivers the final Monitoring Action Plans (MAPs) per demonstrator including the signed Informed Consent Forms from users/ owners for the monitoring activity

Main outcomes & conclusions of D6.2:

Monitoring Action Plans (MAP)	❖ Activities per demonstrator / Planning of activities ❖ Risks and current situation (frequent update per LPL) ❖ Schedule –timeframe of activities ❖ Costs ❖ Monitoring of environmental parameters
Consent form (ICF) Obtained by: *Estonia* *Slovenia* *Italy* *Greece* *Ireland*	Prepared for Greek case in consultation with NKUA DPO and experience: ❖ compliant with EU (GDPR regulation) and national regulation ❖ following the guidelines for ICFs described in page 10 of the H2020 guide '*How to complete your ethics Self-Assessment*'. This ICF sent to partners involved in data processing activities for adaptation to a) the monitoring procedures to be followed in their case, b) their national and institutional regulations, where and if necessary c) input also from Data Management Plan D.1.4

Monitoring procedure

Cases	Energy Consumption HVAC	Energy Consumption DHW	Electrical consumption	Thermal comfort (T, RH, air velocity, mean radiant temperature)	Indoor air Quality (CO2, VOCs, PM2.5, PM10, formaldehyde, illuminance, noise, NO2)	Infrared Thermography	Outdoor meteorological Conditions
Netherlands	✓			T, RH	CO2, illuminance		✓
Spain	✓	✓	✓	T,RH	CO2		✓
Ireland	✓	✓	✓	T,RH	CO2, VOCs, illuminance	✓	✓
Italy	simulations	simulations	simulations	T,RH	CO2		✓
Estonia	✓	✓		T,RH	CO2	✓	✓
Slovenia	✓		✓	T, RH	✓	✓	✓
Greece	✓	✓	✓	✓	✓	✓	✓

D6.3 Report and feedback loops of the tests in step 1 - in deep testing in living labs

Prepared by:
NKUA, GRBES research team (Margarita Assimakopoulos, Dimitra Papadaki, Chrysanthi Efthymiou)

Submitted to CINEA for review: M30

• Objectives & Content of D6.3:

- The report demonstrates key data concerning the general features of the demonstrators in DRIVE 0 project and highlights the results of the assessment of the different renovation components for each case study for a future circularity analysis.

- The report aims at collecting and analyzing the different renovation products and concepts as developed in WP2 and WP3 that will be tested under so called living lab conditions

- The aim of this step (Step 1) is a small-scale testing of the products/concepts for in deep testing. These tests should give feedback to WP2 and 3 and can be used to adjust products, components, or total solution packages. Furthermore, based on the results of the current analysis, the demonstrators will decide the final interventions and install the tested technologies/systems in their demonstrators, in a later stage.

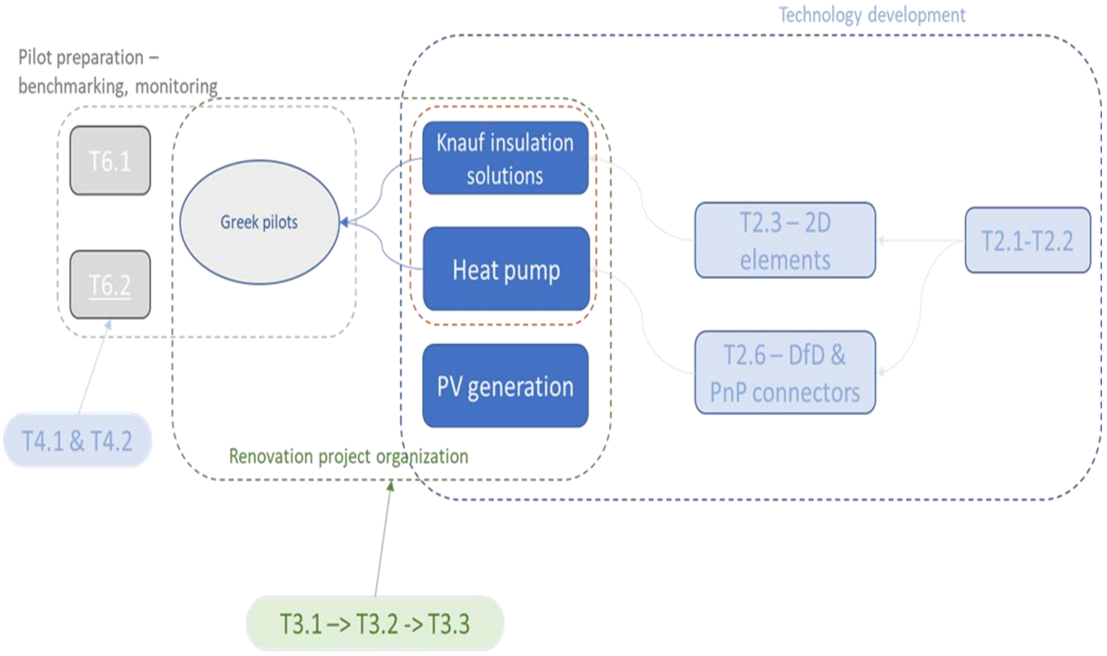
- The report delivers the best and suitable testing method for each case/demonstrator

Main outcomes & conclusions of D6.3:

2 approaches will be presented:

1) Test wall, mock-up : Estonian, Dutch, Irish
2) Simulations (Energy and Environmental LCA): all the rest partners

Feedback loops for all pilots were presented in the following graph and the table was filled it:



Feedback loops between WP2 and WP3 and Further product improvement				
No	LOCATION	Renovation products and concepts as elaborated in WP2 and WP3	Picture of the products	Feedback loops for further product improvement
1	Netherlands			
2	Barcelona, Catalonia, Spain			
3	Dublin South – West Suburbs			
4	Argelato (Bologna), Emilia Romagna, Italy			
5	Estonia			
6	Slovenia			
7	Greece			

D6.4 Seven small scale demonstration sites renovated (step 2) M36 completion; tests M42

Prepared by:
Dimitra Papadaki (NKUA), *Zuyd, IVE, Unibo, IRI UL, TalTech, DIT, WEBO, KI, ALIVA, SALFO, Timbeco, Fact0, PICH, COADY*

Submitted to CINEA for review: M51

- **Objectives & Content of D6.4:**

  - In step 2 the proven renovation solutions (of step 1, D6.3) will be tested in real time demonstrators under inhabited conditions
  - This deliverable is a DEM and is presented in a pdf containing all photos and videos during construction and renovation phase of all DRIVE 0 demonstrators
  - The impact of the DRIVE 0 study and demonstration cases was monitored in detail, not only the achieved energy savings but also the total performance in terms of IEQ, thermal comfort, appreciation by occupants, quality of the renovations works, etc. This is a part of WP4 and 6 and is found in tasks 6.3 and 6.4, on the performances of the developed circular concepts

Main outcomes & conclusions of D6.4:

- All demonstrators completed their construction work and are presented in 6.4
- For the Dutch demonstrator and analytic simulation model is presented.

Case 1: Super circular neighborhood, the Netherlands

Case 2: Photovoltaic planter, Barcelona

Case 3: Residences, Athlone, County Westmeath, Ireland

Case 4: Villa in Argelato, Bologna

Case 5: Apartment building, Saue, Estonia

Case 6: Deep circular energy retrofits of three single family houses, Slovenia

Case 7: 2 Residential apartments in Athens

6.5 Evaluation of the performances of the deployed renovation solutions, tools and information services

Prepared by:
Dimitra Papadaki (NKUA), HIA, UNIBO, TALLIN, ZUYD, IRI, PICH, TUDUBLIN

Submitted to CINEA for review: M51

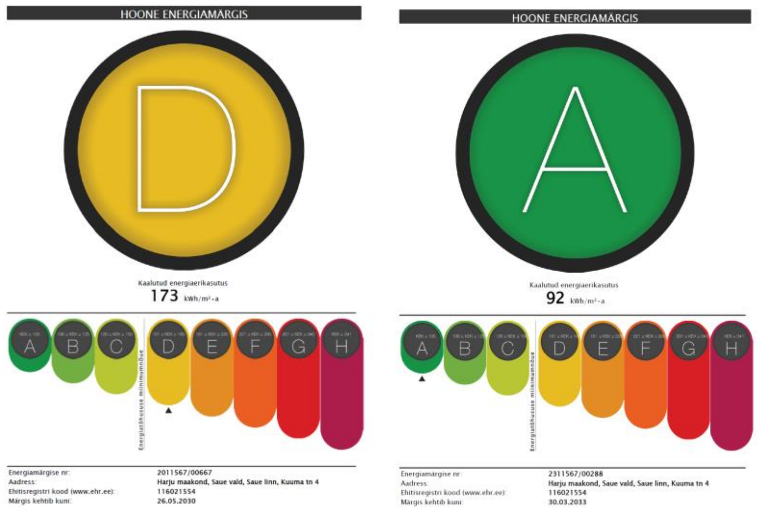
- **Objectives & Content of D6.5:**
  - To provide consumers and potential investors of deep renovation projects with attractive and understandable information of real total life-cycle performances
  - To demonstrate circular renovation solutions in combination with local drivers in live study and demonstration cases: a) Seven live study and demonstration cases demonstrating the working of validated and evidence based operational DRIVE 0 holistic circular renovation packages and supporting business models; b) provide input for the 'EU Circular Renovation Atlas',
  - data related to the ongoing monitoring campaigns utilizing input from methodologies in WP 4 and following detailed case-specific Monitoring Action Plans. These campaigns encompass overall performance monitoring (energy and iAQ), information and communication follow-ups with (end) users, and general user experience
  - Present both qualitative and quantitative monitoring results

Main outcomes & conclusions of D6.5:

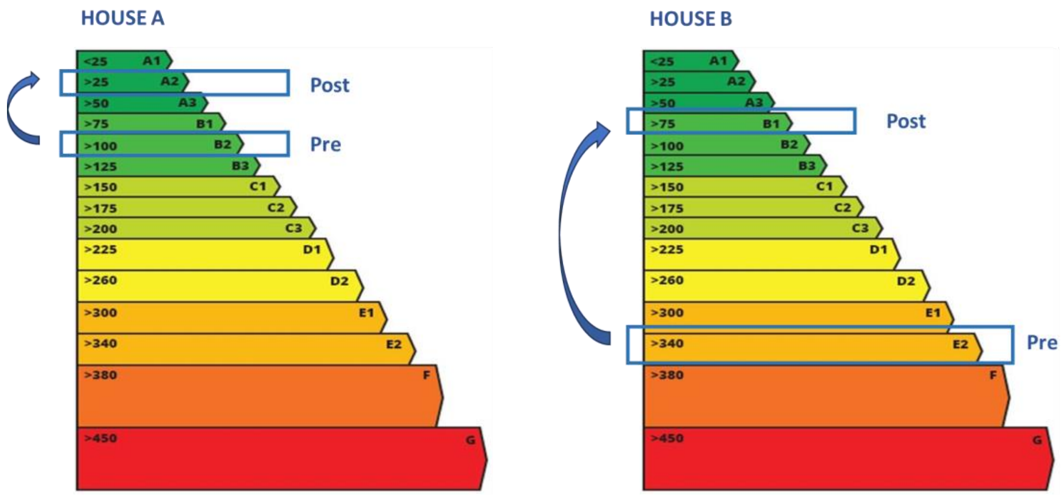
All pilots monitoring results (qualitative and quantitative) according to this table were reported:

- Reporting the social engagement situation (with end users being homeowners, occupants and as well professionals involved in all 7 demonstrator countries
- Results showed a high engagement and several good examples of social engagement
- Reporting of energy savings proved to be very high for all demonstrators
- iAQ results and results from thermographies showed excellent performance of Drive 0 renovation actions

Cases	Energy Consumption HVAC	Energy Consumption DHW	Electrical consumption	Thermal comfort (T, RH, air velocity, mean radiant temperature)	Indoor air Quality (CO_2, VOCs, PM2.5, PM10, formaldehyde, illuminance, noise, NO_2)	Infrared Thermography	Outdoor meteorological Conditions
Netherlands	simulation	simulations	simulations				
Spain	✓	✓	✓	T,RH	CO_2		✓
Ireland	✓	✓	✓	T,RH	CO_2, VOCs, illuminance	✓	✓
Italy	simulations	simulations	simulations	T,RH	CO_2		✓
Estonia	✓	✓		T,RH	CO_2	✓	✓
Slovenia	✓		✓	T, RH	✓	✓	✓
Greece	✓	✓	✓	✓	✓	✓	✓



Energy Performance Certificate before (left) and after (right) the renovation (Estonian pilot)



Energy Performance Certificate before (left) and after (right) the renovation (Irish pilot)

[D6.6 Testing of business models]

Prepared by:
UNIBO (Task leader)
Submitted to EASME for a review:
20 December 2023

Objectives & Content of D6.6:

Objectives of D6.6 is testing the circular renovation concepts embedded in the business models of the Drive 0 case studies. Building on the results of previous tasks in WP5, we develop our testing in 2 phases:

Phase 1

(i) recall assessment of the Degree of Adoption of Circularity, according to the four categories of 'Upstream Circularity'/"Downstream circularity"/"High /Low Degree of Circularity", as from D5.1. This is a first step in evaluating the level of circularity achieved by the business models of companies directly involved in the Drive 0 demonstrators.

(ii) apply the "Circular Readiness Indicator" (CRI) we elaborated in D5.3 to assess the "readiness" concerning CE and CE practices employed in the business models from a multi-tier perspective in the selected case studies. CRI provides a taxonomy of companies based on their readiness to circularity and allows us to understand which dimensions have to be improved to become "top-performer" as far as circularity is concerned.

Phase 2

For each case study, evaluate which specific innovations in circular products/strategies have been introduced by the demonstrators and which are the preliminary outcomes in terms of efficiency and efficacy of their solutions so far.

Main outcomes & conclusions of D6.6

- Most business models we examined follow the **circular design model**, that is, focus on the design phase of the product and ensure that the design of the product, the materials and components used in the production processes, and the product style are carried out in a circular manner. This business model is characterized by high technical impact, medium/low financial and social/organizational impact.
- However, also other aspects are present, related to business models that focus on the **use phase** of the product as well, and ensure that the product undergoes appropriate maintenance, or that the products or the material components can be **reused** or **refurbished** for new products, or **recycled**.
- Our testing is **complementary** to other testing developed in other WPs of Drive 0, where more details are discussed concerning i) the actual technical solutions employed by the demonstrators and ii) new perspectives on further implementations (e.g., D6.7; D6.5). In particular, the testing of business models can be useful for decision making and as a basis for the comparison of effectiveness and impact of exploiting local drivers. It can also serve as input for overall analysis and policy recommendations (D5.5) to increase the adoption potential and market transition towards a circular deep renovation economy.
- Further testing might be implemented in the next years, when data will be available regarding energy savings and possible health benefits to the building owners and users, and when data will be available to test the efficacy of resale markets for circular products and, more generally, on circular supply chains and networks.

D6.7 Evaluation of the impact of local drivers to trigger deep renovation

Prepared by:
Wendy Broers, Dimitra Papadaki Patrick Daly, Anne van Dun, Kalle Kuusk, Clara Mafe, Cecilia Mazzolini, John van Oorschot, Zuzana Prochazkova, Ana Tisov, Jure Vetršek.

Submitted to CINEA for review: M51

• Objectives & Content of D6.7:

- In order to benefit from the efforts to develop a circular deep renovation concept it is important that DRIVE-0 is adopted beyond the demonstrators.
- the drivers and impediments of adoption are assessed as well as the potential of circular renovation, i.e., re-using and recycling (local) materials, within focus groups related to the seven demonstrators.
- The result of this task will inform both construction SMEs and policy makers to increase the adoption potential and market transition towards a circular deep renovation market.
- the evaluation of the demonstration and monitoring of the 7 study and demonstration cases is performed. This evaluation gives feedback for task 3.5 as input for the *EU Circular Renovation Atlas*

Main outcomes & conclusions of D6.7:

Overall, the local drivers and potential on circularity were exploited. In order to increase the adoption potential and market transition towards a circular deep renovation market we recommend the following policy and research actions:

1. Setting up financial incentives to promote the use of circular building elements and materials.
2. Creating more knowledge on the re-use of used (building) materials in (industrialized) building elements and products.
3. Creating more awareness among building owners, governments, and construction industry about the urgency to use less (new) building materials and adopt more circular solutions.
4. Develop circular deep renovation solutions which are financially affordable and reduce inconvenience for the residents during the renovation process.
5. Address the need to reduce energy poverty in relation to low-income and vulnerable households.

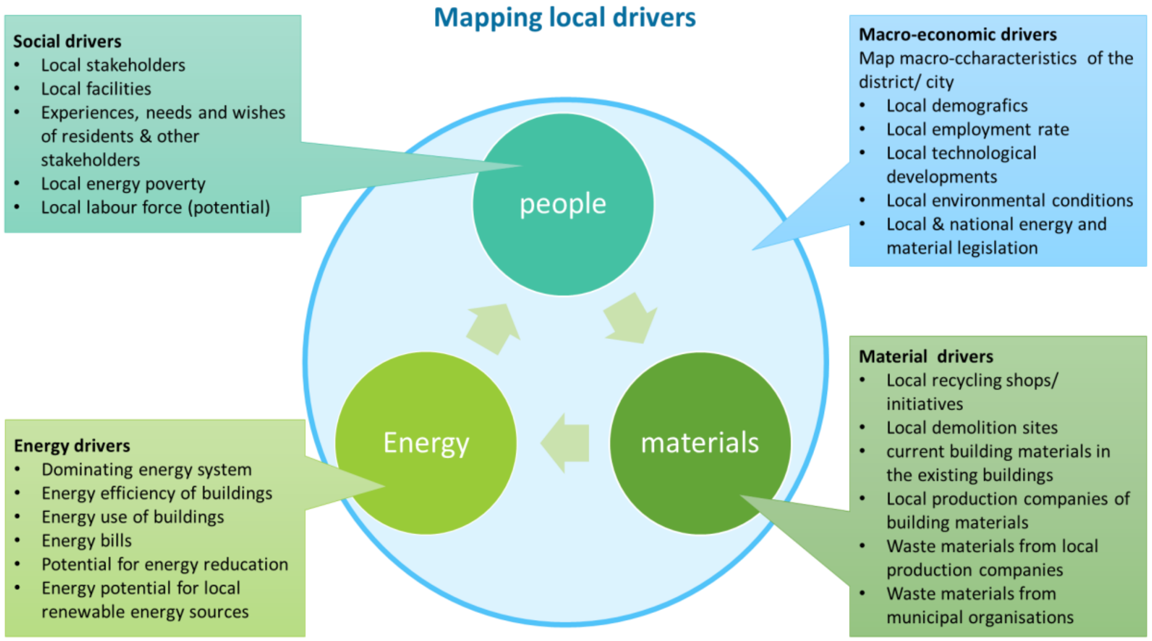


Figure 2.3: Examples of indicators for mapping local drivers

Cases	Primary Energy consumption [kWh/ m2 annually]		Primary Energy Savings after Drive 0 [%]	CO2 emission savings after Drive 0 [%]
	Before Drive 0	After Drive 0		
Dutch	227	0	100	100
Irish HOUSE A: Irish (Calculated)	117	33	72	67
Irish (Monitored/Predicted)	112	88	21	21
HOUSE B: Irish (Calculated)	350	84	76	100
Irish (Monitored/Predicted)	174	73	59	61
Spanish- EcoHub, case B	173	49	72	72
Spanish- Gonsi, case B	105	43	57	57
Slovenian 1 – Zg. Otok	82	41	51	40
Slovenian 2- Sv. Barbara	66	34	50	43
Slovenian 3 - Kandrše	77	45	54	44
Italian	180	54	71	71
Estonian	220	92	58	57
Greek Anavyssos	191	95	50	80
Greek Perissos	144	10	93	89


Let’s keep going circular!
www.drive0.eu