Towards circular energy renovations:

Collecting circular scenarios

Work Package 1 | Opportunity map
Activity 1.3 | Collecting circular scenarios

Summary of results
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1.1 Introduction

The project 'Naar circulaire energierenovaties: kansen voor toepassing van circulaire principes bij energetische verduurzaming van gebouwen' (Towards circular energy renovations: opportunities for applying circular principles in energy sustainability of buildings) is a collaboration between Copper8, Stichting W/E Adviseurs, Metabolic, Delft University of Technology, Eindhoven University of Technology (TU/e), NIBE, Constructief, Nieman, Alba Concepts, LBP|SIGHT, SGS Search, DGBC, and Circular Catalyst.

'Collecting circular scenarios' (activity 1.3) is one part of the research project 'Naar circulaire energierenovaties' wich has been led by Eindhoven University of Technology in close collaboration with Stichting W/E Adviseurs and Metabolic.

A start was made to collect ideas on scenarios, where the energy improvement is approached in a more circular way. The expertise of the entire consortium was used in this inventory. The scenarios (see chapters 2 and 3) also look beyond the frameworks limited by current regulations and financial principles, among other things.

Context
In recent decades, much attention has been paid to making the built environment more sustainable. The emphasis here has been on energy sustainability: insulation, sustainable generation, energy storage and the smart exchange and use of sustainable energy sources. In the coming years, we will
continue to make existing buildings more sustainable from an energy point of view. With energy sustainability, we want to reduce the CO2 emissions caused by the use of buildings in the Netherlands. At the same time, the construction activities and materials required for these 'energy renovations' also have a significant impact on our environment. In the interest of our climate goals, it is important to minimize the integral environmental impact of energy renovations and not just look at CO2 emissions during the use phase. This can be done by applying principles of circularity in energy renovations.

Project aim
The purpose of this research project to help building the foundation for circular energy renovations of buildings. The first phase of this project seeks to identify opportunities for 'circular energy renovations' to further reduce the environmental impact of our buildings, usage and construction activities. We will create an opportunities map that forms the basis for an innovation agenda, which in the second phase will be translated into a covenant with parties on the demand side (property owners and managers) and on the supply side (the construction and installation sector), whereby concrete actions are proposed based on their intended impact.

1.2 Approach

'Collecting circular scenarios' has been developed through a workshop, online survey, and through discussions in diverse consortium meetings.

Workshop
To get a first input on the potential range of circular energy renovations a workshop was conducted during the 'Startbijeenkomst Circulaire Energierenovaties' on 10th March 2023 in Amsterdam. Input collected from stakeholders formed the base for setting up a survey.

Survey
An online survey was conducted through LimeSurvey between 16.05.2023 and 14.06.2023. The survey has been shared amongst project partners and beyond. In total 52 survey responses were collected, of which 20 were full responses, and 32 partial responses. All responses have been anonymised. Our gratitude belongs to all who have taken time to answer this survey.

This survey consists of two sets of questions. The first set of questions aims to identify specific circular alternatives for 'conventional' energy renovations for selected archetypes, the second takes a broader perspective seeking to identify opportunities in the larger context of circular renovation practice.

As reference scenario for the 'conventional' energy renovations we propose a "standard" energy renovation level with following minimum values (see

Appendix 1: Reference scenario for the 'conventional' energy renovations).

Circular renovation

There is not yet an unambiguous definition of circular building renovation. This survey considers **circular renovation** as building renovations that reduce the environmental impact over the entire lifecycle of a renovation project, and which applies one or a combination of following **circular design principles.**[1] These design principles have not been developed for renovation, but can be used to differentiate different renovation design strategies:

1. Design with Reuse
2. Design with Biodegradables
3. Design for Reuse
4. Design for Repair
5. Design for Refuse

[1] BTIC. (2021). *BTIC Knowledge and Innovation Program: Circular Design for Buildings and Infrastructure*. Retrieved from https://tki-bouwentechniek.nl/wp-content/uploads/Kenns-en-Innovatieprogramma_BTIC_CirculairOntwerpen_02022021.pdf

1.3 Archetypes

To collect circular alternatives for 'conventional' energy renovations we focused on three different archetypes, that are common in the Dutch Buildings stock, and thus have a huge potential for upscaling.

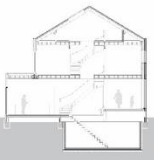
For each Archetype promising circular alternatives for both **building envelope** and **installations** have been collected through following elements:

Envelope

1. **Roof**
2. **Facade (solid / layers)**
3. **Facade (window + frame)**
4. **Floor**

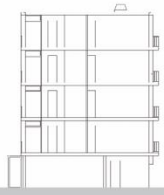
Installations

5. **Ventilation system**
6. **Heat recovery**
7. **Space heating (+cooling)**
8. **Hot water**
9. **PV panels**



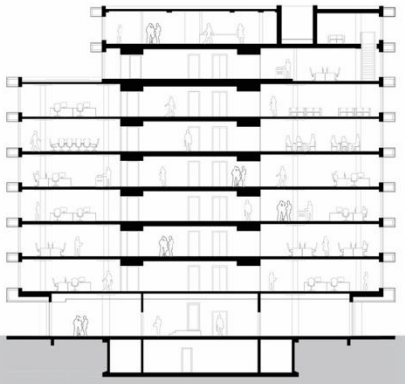
Archetype 1

Rijtjeshuis
(terraced /town house)
1975 – 1991



Archetype 2

Portiekwoning
1946 - 1964



Archetype 3

Office building
1995 - 2001

2 Results circular scenarios

2.1 Archetype 1: Rijtjeshuis (1975 – 1991)

2.1.1 Circular alternatives for building envelope

1.1 ROOF		
Strategy	**Material**	**Product / Supplier**
Design with Reuse	clothing	Metisse
	roof tiles	
	recyled PVB waterproofing	Leadax
Design with Biodegradables	bio EPS	
	bio-based composite (resin)	Duplicor
		Fiberplast (rice husk, orck salt, mineral oil)
	cellulose	
	cork	
	elephant grass	Gramitherm
	flax	Isovlas
	hemp	Thermo Hanf
	mycelium	
	sheep wool	Isolena
	straw (panels / systems)	EcoCocon / StroTec
	wood fibre	Gutex
other	green roof	Roef

1.2 FACADE OPAQUE		
Strategy	**Material**	**Product / Supplier**
Design with Reuse	brick strips	
	clothing	Metisse
Design with Biodegradables	bio-based composite (resin)	Duplicor
		Fiberplast (rice husk, orck salt, mineral oil)
		Beyond Wood
	bio foam (polyactic acid, PLA)	BioFoam
	cellulose	
	cork	
	elephant grass	Gramitherm
	fiber-reinforced cold ceramics material	Kerloc
	flax	Isovlas
	hemp blocks	
	mycelium	
	sheep wool	Isolena
	straw (panels / systems)	EcoCocon / StroTec
	thermally modified wood	
	timber	

	timber frame	Timmerfabriek Frank van Roij
	wood fibre	Gutex
Design for Reuse	dry stacking system	ClickBrick
	modular / prefab	
Other	aerogel	Airofill
	green exterior wall	

1.3 FACADE WINDOW AND FRAME		
Strategy	**Material**	**Product / Supplier**
Design with Reuse	glas	isoMAX
	timber frames (reuse + new)	Repair Care
		Infinity Repair
Design with Biodegradables	bamboo	MOSO bamboo window
	timber	
Other	vacuum glass	Fineo
	tripple glazing	

1.4 FLOOR		
Strategy	**Material**	**Product / Supplier**
Design with Reuse	clothing compressed	
Design with Biodegradables	bio EPS	
	cellulose	
	cork	
	elephant grass	Gramitherm
	flax	Isovlas
	hemp blocks	
	mycelium	
	sheep wool	Isolena
	shells (insualtion)	
	straw	
	wood fibre	Gutex
Other	air cushions	TONZON
	expanded glass granulate	Liaver GmbH
	linoleum	Marmoleum Forbo

2.1.2 Circular alternatives for installations

1.5 VENTILATION SYSTEM	
Strategy	**Product / Supplier**
reuse air ducts and diffusers type C	
reuse air ducts and diffusers when upgrading to type D	
refurbsih and reuse MV box	
balanced ventilation with heat recovery	Zehnder Overflow Technology
systems witout or few channels	Brink
CO2 controlled MV box	
decentralised solutions	
demand control	

1.6 HEAT RECOVERY	
Strategy	**Product / Supplier**
water to water heatpumps	
heat recovery for showers	
systems witout or few channels	
demountable channels and ceilings	
combine with ventialtion systems	
refurbished or re-used WTW HP	

1.7 SPACE HEATING (AND COOLING)	
Strategy	**Product / Supplier**
upgrade existing heating systems instead of replacement	
upgrade existing heating systems with heat pump	
maintenance and repair with remanufactured parts	
focus on lifetime extension of equipment and take back guarantees by manufacturer	
choose combined devices that can heat, cool, and ventilate, rather than separate devices	
use heat pump wit service life control and loose components for repair and replacements	
dry construction underfloor heating system from heatpump	
temperature zoning (we do not need 19C everywhere)	
sun protection instead of cooling (passiv solutions)	
heat pump propane (R290), preferably easy to replace compressor	
heat pump (air-water) + underfloor heating and cooling	
minimise installation capacity	
do not insert underfloor heating everywhere, only were needed and effective	
add sun protection from re-use or re manufactoring	
use heat pump with passive cooling	

1.8 HOT WATER	
Strategy	**Product / Supplier**

electric boiler next to a heat pump or residual heat	
combi heatpump (heating + hot water)	
reused or refurbished boilers	
make existing system hybrid by adding heat pump	
reuse separate boiler if available instead of combi appliance (boiler has much longer life)	
grey water system for toilets	

1.9 PV PANELS	
Strategy	**Product / Supplier**
roofing systems	
low CO2 + recyclyed	Solarge
photovoltaic thermal hybrid solar collector	
use refurbished or re-used PVs (re power)	2ndlifesolar
local production + responsible material sourcing	Elsun
as little PV as possible (not maximum)	

2.2 Archetype 2: Portiekwoning (1946 - 1964)

2.2.1 Circular alternatives for building envelope

2.1 ROOF		
Strategy	**Material**	**Product / Supplier**
Design with Reuse	clothing	Metisse
	roof tiles	
	recyled PVB waterproofing	Leadax
Design with Biodegradables	bio EPS	
	bio-based composite (resin)	Duplicor
		Fiberplast (rice husk, orck salt, mineral oil)
	cellulose	
	cork	
	elephant grass	Gramitherm
	flax	Isovlas
	hemp	Thermo Hanf
	mycelium	
	sheep wool	Isolena
	straw (panels / systems)	EcoCocon / StroTec
	wood fibre	Gutex
other	green roof	Roef

1.2 FACADE OPAQUE		
Strategy	**Material**	**Product / Supplier**
Design with Reuse	brick strips	
	clothing	Metisse
Design with Biodegradables	bio-based composite (resin)	Duplicor
		Fiberplast (rice husk, orck salt, mineral oil)
		Beyond Wood
	bio foam (polyactic acid, PLA)	BioFoam
	cellulose	
	cork	
	elephant grass	Gramitherm
	fiber-reinforced cold ceramics material	Kerloc
	flax	Isovlas
	hemp blocks	
	mycelium	
	sheep wool	Isolena
	straw (panels / systems)	EcoCocon / StroTec
	thermally modified wood	
	timber	
	timber frame	Timmerfabriek Frank van Roij
	wood fibre	Gutex

Design for Reuse	dry stacking system	ClickBrick
	modular / prefab	
Other	aerogel	Airofill
	green exterior wall	

1.3 FACADE WINDOW AND FRAME		
Strategy	**Material**	**Product / Supplier**
Design with Reuse	glas	isoMAX
	timber frames (reuse + new)	Repair Care
		Infinity Repair
Design with Biodegradables	bamboo	MOSO bamboo window
	timber	
Other	vacuum glass	Fineo
	tripple glazing	

1.4 FLOOR		
Strategy	**Material**	**Product / Supplier**
Design with Reuse	clothing compressed	
Design with Biodegradables	bio EPS	
	cellulose	
	cork	
	elephant grass	Gramitherm
	flax	Isovlas
	hemp blocks	
	mycelium	
	sheep wool	Isolena
	shells (insualtion)	
	straw	
	wood fibre	Gutex
Other	air cushions	TONZON
	expanded glass granulate	Liaver GmbH
	linoleum	Marmoleum Forbo

2.2.2 Circular alternatives for installations

2.5 VENTILATION SYSTEM	
Strategy	**Product / Supplier**
reuse air ducts and diffusers type C	
reuse air ducts and diffusers when upgrading to type D	
refurbish and reuse MV box	
balanced ventilation with heat recovery	Zehnder Overflow Technology
systems witout or few channels	Brink
CO2 controlled MV box	
decentralised solutions	
demand control	

2.6 HEAT RECOVERY	
Strategy	**Product / Supplier**
water to water heatpumps	
heat recovery for showers	
systems witout or few channels	
demountable channels and ceilings	
combine with ventialtion systems	
refurbished or re-used WTW HP	

1.7 SPACE HEATING (AND COOLING)	
Strategy	**Product / Supplier**
apply collective system/block heating if possible, lower environmental impact	
upgrade existing heating systems instead of replacement	
upgrade existing heating systems with heat pump	
maintenance and repair with remanufactured parts	
focus on lifetime extension of equipment and take back guarantees by manufacturer	
choose combined devices that can heat, cool, and ventilate, rather than separate devices	
use heat pump wit service life control and loose components for repair and replacements	
dry construction underfloor heating system from heatpump	
temperature zoning (we do not need 19C everywhere)	
sun protection instead of cooling (passiv solutions)	
heat pump propane (R290), preferably easy to replace compressor	
heat pump (air-water) + underfloor heating and cooling	
minimise installation capacity	
do not insert underfloor heating everywhere, only were needed and effective	
add sun protection from re-use or re manufacturing	
use heat pump with passive cooling	

1.8 HOT WATER	
Strategy	**Product / Supplier**
electric boiler next to a heat pump or residual heat	
combi heatpump (heating + hot water)	
reused or refurbished boilers	
make existing system hybrid by adding heat pump	
reuse separate boiler if available instead of combi appliance (boiler has much longer life)	
grey water system for toilets	

1.9 PV PANELS	
Strategy	**Product / Supplier**
roofing systems	
low CO2 + recyclyed	Solarge
photovoltaic thermal hybrid solar collector	
use refurbished or re-used PVs (re power)	2ndlifesolar
local production + responsible material sourcing	Elsun
as little PV as possible (not maximum)	

2.3 Archetype 3: Office building (1992 - 2005)

2.3.1 Circular alternatives for building envelope

3.1 ROOF		
Strategy	**Material**	**Product / Supplier**
Design with Reuse	clothing	Metisse
	roof tiles	
	recyled PVB waterproofing	Leadax
Design with Biodegradables	bio EPS	
	bio-based composite (resin)	Duplicor
		Fiberplast (rice husk, orck salt, mineral oil)
	cellulose	
	cork	
	elephant grass	Gramitherm
	flax	Isovlas
	hemp	Thermo Hanf
	mycelium	
	sheep wool	Isolena
	straw (panels / systems)	EcoCocon / StroTec
	wood fibre	Gutex
other	reflection and convection	roofclix
	green roof	Roef

3.2 FACADE OPAQUE		
Strategy	**Material**	**Product / Supplier**
Design with Reuse	brick strips	
	clothing	Metisse
Design with Biodegradables	bio-based composite (resin)	Duplicor
		Fiberplast (rice husk, orck salt, mineral oil)
		Beyond Wood
	bio foam (polyactic acid, PLA)	BioFoam
	cellulose	
	cork	
	elephant grass	Gramitherm
	fiber-reinforced cold ceramics material	Kerloc
	flax	Isovlas
	hemp blocks	
	mycelium	
	sheep wool	Isolena
	straw (panels / systems)	EcoCocon / StroTec

	thermally modified wood	
	timber	
	timber frame	Timmerfabriek Frank van Roij
	wood fibre	Gutex
Design for Reuse	dry stacking system	ClickBrick
	modular / prefab	
Other	aerogel	Airofill
	green exterior wall	
	circular facade concepts (maintained, reused, updated and recycled)	Alkondor
	passive shading	

3.3 FACADE WINDOW AND FRAME		
Strategy	**Material**	**Product / Supplier**
Design with Reuse	glas	isoMAX
	timber frames (reuse + new)	Repair Care
		Infinity Repair
Design with Biodegradables	bamboo	MOSO bamboo window
	timber	
Other	vacuum glass	Fineo
	tripple glazing	

3.4 FLOOR		
Strategy	**Material**	**Product / Supplier**
Design with Reuse	clothing compressed	
Design with Biodegradables	bio EPS	
	cellulose	
	cork	
	elephant grass	Gramitherm
	flax	Isovlas
	hemp blocks	
	mycelium	
	sheep wool	Isolena
	shells (insualtion)	
	straw	
	wood fibre	Gutex
Other	air cushions	TONZON
	expanded glass granulate	Liaver GmbH
	linoleum	Marmoleum Forbo

2.3.2 Circular alternatives for installations

3.5 VENTILATION SYSTEM	
Strategy	**Product / Supplier**
ventilating on people numbers and occupancy (ot the entire building from 7h-20h)	
good building management system needed where the building can switch on/off	
reuse air ducts and diffusers type C	
reuse air ducts and diffusers when upgrading to type D	
refurbsih and reuse MV box	
balanced ventilation with heat recovery	Zehnder Overflow Technology
systems witout or few channels	Brink
CO2 controlled MV box	
decentralised solutions	
demand control	

3.6 HEAT RECOVERY	
Strategy	**Product / Supplier**
add to existing air handling units	
water to water heatpumps	
systems witout or few channels	
demountable channels and ceilings	
refurbished or re-used WTW HP	

3.7 SPACE HEATING (AND COOLING)	
Strategy	**Product / Supplier**
make actual energy use measurable and inform users about their behaviour	
use air-systems	
good building management system needed where the building can switch on/off	
upgrade existing heating system instead of replacement	
upgrade existing heating system with heat pump	
maintenance and repair with remanufactured parts	
focus on lifetime extension of equipment and take back guarantees by manufacturer	
choose devices in which parts can easily be replaced	
use heat pump wit service life control and loose components for repair and replacements	
add sun protection from re-use or re manufactoring	
use eat pump with passive cooling	

3.8 HOT WATER	
Strategy	**Product / Supplier**
limit points for hot tap water – use over infrastructure for cold tap water	

centralising on a collective system, from reuse if possible	

3.9 PV PANELS	
Strategy	**Product / Supplier**
possibly in facade, combine with sun protection (double functionality)	
low CO2 + recyclyed	Solarge
use refurbished or re-used PVs (re power)	2ndlifesolar
local production + responsible material sourcing	Elsun
as little PV as possible (not maximum)	

3 Identifying opportunities for circular renovations in the larger context of renovation practice.

The last part of this opportunity map explores opportunities to advance circular energy renovations that are not directly related to building elements, but rather to design processes, measurement, supply chains, legal frameworks, or emerging circular business models.

3.1 Measurement:
What opportunities exist to better measure and evaluate circular energy renovations?

- Measuring circularity is important to make weighted choices between processes, products or companies. There is no universally accepted methodology for this. However, there diverse tools, such as scans and databases, that map circularity qualitatively or quantitatively.
- Material passports, calculation methods, BCI calculation by ALBA, etc.
- MPG especially for energy renovations
- Identify and record the "current" situation / quality. List released products and materials and their destination (disposal, treatment and/or processing) and the new products and materials and calculate the environmental impact and/or benefits, both of outgoing and incoming facilities. Although not mandatory, this may be requested by building owners/clients.
- Take the environmental impact of the renovation products into account in every consideration of energy renovations (CO_2 payback time)
- Categorise all existing materials and give materials a circular identity.
- In addition to the environmental impact of materials, measure the environmental impact avoided through energy savings. Award advantage based on location.

3.2 Bio-based materials:
What opportunities exist to boost the uptake of bio-based materials in circular renovation?

- Subsidies, procurement standards, ban on less sustainable materials
- Different design of MPG in which land use and CO_2 sequestration are better regulated.
- Research into energy-saving bio-based materials because they absorb and release moisture and thereby buffer heat.
- Resolve walkability of roof when biobased materials are applied. Application of overhangs better for maintenance and against sun in summer

- Regulate certification much faster than it has been so far!
- Fire and noise tests that it can be done in standard metal stud walls and still achieve e.g. 60-minutes. Suppliers and subcontractors are now acting very difficult with the guarantee.
- Low-rise/single-family dwellings are now most promising because of regulations (think of high-rise buildings and fire safety). In the design process, compare biobased products with fossil products and include pros and cons (also TCO, capillary active)
- In any case, ensure that as many products as possible end up in the NMD. Ensure that environmental and other achievements (advantages and disadvantages) are sufficiently publicised and/or made available to design teams and/or clients. In the procurement process (by clients), selection or award criteria can also be geared to this (valuation, fictitious advantages if demonstrable environmental gains (i.e. bio-based solution) are realised.
- Just ask the question as a client or set a mandatory % from the government
- Regulations, construction benefits via traditional media and education
- Categorise all existing materials and give a materials biobased identity and naming
- Incentive from government, materials passport, building sector adaptation
- BCI tool, GRP materials,

3.3 Re-used materials:
What opportunities exist to boost the uptake of re-used materials in circular renovation?

- Separate pure waste streams, detachability and building passport.
- Build for disassembly and reuse.
- Accept different quality requirements and guarantees.
- Better adapt regulations and valuation. 2nd-hand wood is now poorly valued, because you are not allowed to include the CO2 storage 'again'.
- Align supply and demand; bring both the internal marketplace and external suppliers together on projects. What goes out, can it be reused immediately after repair or reused on another project (e.g. meter boxes, MV boxes, plumbing).
- Harvest maps, making reused materials beautiful again too
- Applying a construction hub, where demolition/harvesting aligns to applying reused materials and expanding stock
- Appreciate the reduction in environmental costs through reuse. These savings can be insightful, and even (fictitiously) discounted. This can be one of the selection or award criteria in the procurement process.
- Timely look for supply from the market, both through "marketplaces", and from suppliers and products that might offer refurbished products.
- Warranty and liability solutions
- Use of mutation homes, repairing more instead of replacing

- Support upscaling

3.4 Legal barriers:
What opportunities exist to overcome legal barriers in circular renovation?

- Make product requirements/warranties for refurbished products more flexible
- Remove resistance caused by aesthetics (e.g. external wall insulation changes streetscape)
- Certification, Building Decree requirements, adjust warranty conditions
- Flora and fauna need to be protected. However, a bat in the cavity can slow things down considerably.
- Certificates e.g. fire safety, capillary active, heat storage
- Important is quality control and assurance. Especially with 2nd-hand products. If things are made demonstrable, there need not be any legal obstacles to this.
- Letting go of certain requirements during renovation (e.g. accept that the temperature in winter can also be a maximum of 19 degrees) - fewer rules (where these are tight, let go as far as possible).
- Make and record clear agreements at the front end of the contract and design phase, discuss and remove barriers with contracting parties and affiliated construction partners beforehand.

3.5 Financial barriers:
What opportunities exist to overcome financial barriers in circular renovation?

- subsidies, (low-interest) loans and obligations
- Establish disposal fee for buildings.
- CO2 tax
- To really drive it, subsidies can of course help, but ultimately the price level for reused materials will have to become the same and/or even more favourable.
- Are there, but not as many as people think. People often think sustainable is expensive. Or reuse I do because it can be done cheaper. And these are not the right settings. You have to see it as a good investment, if only as marketing for client / developer / contractor
- TCO; what do you gain over the longer term, maintenance, replacements, healthier homes. Encourage reuse (less material disposal and addition is also less spend)
- It doesn't necessarily (right) have to be more expensive? And if it is, also focus on the other costs that occur over the whole life cycle of the building and/or products, such as environmental costs (shadow costs). Aim for "fair" pricing of alternatives.
- CO2 shadow price inclusion on embodied carbon
- creating more stock, letting more companies join, matching supply and demand, more stock and more market forces ensure a lower price

- Example role of government
- Value sustainable savings

3.6 Beyond the above:
What other opportunities exist to advance circular renovation?

- making circularity a condition for innovation subsidies
- Change the mindset among government, clients and developers that reuse is better than everything always being new. Builders will then "naturally" follow.
- Propagate the R-model; do you have to replace, if so then circular and biobased. More awareness in design choices and possibilities to apply refurbished products as well.
- make MPG for existing buildings compulsory for energy renovations - use CO2 TVT - steer towards integral solutions between circularity (material) and energy
- Demand-driven development and construction with an integral duty to include circularity in a higher percentage.
- Raising awareness
- Stimulate intrinsic motivation and do not underestimate it, many people are working on it, including residents.

4 Preliminary conclusions

The work in interdisciplinary consortium has been very engaged, productive and full of enthusiasm to advance circular energy renovations. To provide clear recommendations, it would be desirable to align findings of the individual work packages, as there has been no time for this yet.

For now following primary insights could be made:

1 What are the results?

The opportunity map gathered a broad range of approaches to support the development of circular energy renovations. Especially for circular alternatives for building *envelope* there are many biodegradables materials available in the building market. Between the three selected archetypes there are only few differences for the envelope. For circular alternatives for *installations* the situation seems to be less developed yet. Here differences between archetypes are more significant.

2 What are the recommendations?

The opportunity map gathered a broad range of approaches to support the developing circular energy renovations. It can inspire individual and larger property owners to enact circularity in energy renovations.

3 What have we learned?

In the transition towards circular energy renovations there are still a lot of financial and legal barriers that hinder upscaling. There is still a mismatch between ambitious goals and deployed policies. To accelerate the transition voluntary agreements need be replaced by binding legislation and support through financial incentives.

Appendix 1: Reference scenario for the 'conventional' energy renovations

As reference scenario for the 'conventional' energy renovations we propose a "standard" energy renovation level with following minimum values (see below)

Roof	Rc = 3,5 m^2K/W (depending on the insulation material and floor type 8 - 14cm of insulation)
Floor	Rc = 3.5 m2K/W (depending on the insulation material and feed type 7 - 14 cm of insulation under the floor)
Facade	Rc = 1.7 m2K/W (beads, flakes or foam in the cavity wall) NB Only for post-war houses
Panel	If present: insulation value R. = 1 m2K/W (40 mm sandwich panel)
Windows & Frames	U-value frame = 1.4 W/m^2K (HR++ glass)
Ventilation	Balanced ventilation with sensor control in living room and master bedroom

Roof Rc = 3,5 m2K/W (depending on the insulation material and floor type 8 - 14cm of insulation)
Floor Rc = 3.5 m2K/W (depending on the insulation material and feed type 7 - 14 cm of insulation under the floor)
Facade Rc = 1.7 m2K/W (beads, flakes or foam in the cavity wall) NB Only for post-war houses
Panel If present: insulation value R. = 1 m2K/W (40 mm sandwich panel)
Windows & Frames U-value frame = 1.4 W/m2K (HR++ glass)
Ventilation Balanced ventilation with sensor control in living room and master bedroom

(source: Nieman, 2021, Rapport standard en streefwaardes bestaande woningbouw)