NREP Impact 2020 report

INTENTIONAL & INHERENT

NREP

NREP Impact

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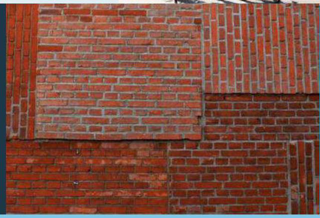

2019 in review

2019 in review

Dear Reader,

The writing is on the wall: the real estate industry must find ways to better address societal challenges - such as providing more people with more affordable ways of living - and it must find ways that enable the industry to have a much smaller resource and CO2 footprint than it does today. For a laggard industry to change, many stakeholders and industry participants will need to jointly act and learn from each other to identify and adopt better solutions. The aim of this report is thus not to simply report numbers, but to provide transparency about how we at NREP approach sustainability, and share our imperfect journey in a way that invites readers to discuss with us so that we can learn from each other. To this end we have complemented high level descriptions, reporting and cases with a deep dive into two of our pioneering upcycling projects - Upcycle Studios and Resource Rows - at a level of detail that we hope creates a hands-on understanding of the lessons learned as well as an indication of what is worth replicating in future projects (and what is not).

The completion of Upcycle Studios and Resource Rows was one of many milestones for NREP in 2019. Upcycle Studios is the first circular commercial scale residential development in the world. The journey leading to this point started already back in 2014 when NREP made the strategic decision to partner with, and invest in, Lendager Group, a world leading consultancy on upcycling of building materials. Despite significant first-time production challenges and project-specific limiting preconditions, Upcycle Studios and Resource Rows demonstrated resource and CO2 savings largely in line with expectations based on prior upcycling projects and testing. The LCA/LCC complemented with evaluation of additional factors indicate varying degrees of impact, complexity, scalability and cost competitiveness for the different upcycling products that were employed, but overall the results indicate that upcycling solutions indeed have potential and should be explored further by the real estate industry as one of the tools to improve its resource and CO2 impact.

Other milestones with regards to environmental sustainability included the start of the construction of Denmark's first grid connected commercial rooftop solar system on five of our logistics properties. Exceeding our targets, the total production from our installed or in construction logistics roof top solar is projected to 240,000 MWh. In 2019, NREP also became the first Nordic real estate company to become a member of the RE100.

With regards to our social impacts, in 2019 we completed or were in construction of 5674 units of residential addressing student housing, community-based living, mixed generation communities, senior housing, care homes or rental apartments catering to people at or below median income. These type of residential products that address underserved needs and societal challenges now make up 53% of our total standing residential portfolio. And we are seeing new exciting opportunities to impact neighbourhoods more holistically - in 2019 we made our first investment in the urban development of Tingbjerg, a socially disadvantaged part of Copenhagen where NREP is working in an innovative partnership with the municipality and two social housing companies.

Looking at our efforts to also influence the direction of the broader industry, in addition to contributing to the work of local green building councils, municipal regulatory development and legislative consultations, NREP has during 2019 contributed to industry and mainstream media on both social and environmental topics. We also stepped up our efforts to present on sustainability at various industry conferences, provide training to service providers and other industry bodies. NREP was also the only real estate investment company that was part of the official program of the 2019 C40 World Mayors Summit, presenting NREP learnings from real estate projects that have adopted new solutions to decrease the embodied carbon footprint of real estate.

In 2019 we continued investing much effort in strengthening our sustainability management framework and systems. Our sustainable development and sustainable operations programs were expanded and reconfigured to enable more scaling of solutions, integration into core processes and IT systems, automation, and knowledge management. Historically NREP has had almost all its focus on identifying impactful solutions and taking actions, with little emphasis on checking boxes. We are still firmly of the view that we do not want to do certifications for sake of certification, but we do see certification schemes as quality catalogues that can support progressive design and impact by enabling more effective communication with contractors, partners, municipalities, investors and other stakeholders that we want to work jointly with to further the sustainability agenda. As such, NREP has in 2019 committed to certifying all our new developments from 2020 onwards and gradually certify all our standing assets. Similarly, we have in 2019 stepped up our ambitions to align with global conventions and reporting standards as part of our impact management and measurement frameworks.

In this report we are also sharing some of our perspectives on our future direction and how we will seek to improve our ability to effectively achieve impact across our business lines in the future. Our staff surveys show that 'impact', 'integrity' and 'progressive' are our team's top associations with NREP today and top priorities for what NREP should stand for in the future. As a company we will seek to be the platform that helps all our staff unleash their potential and make a meaningful difference.

We hope to hear from you and to jointly progress on our future journey to make real estate better.

Sincerely,

Gustaf Lilliehook
Partner
Sustainability and Stakeholder Relations

Illustrative projects 2019

Tingbjerg Urban Development Project
Made our first investments as part of the urban regeneration plan for Tingbjerg, a socially disadvantaged part of Copenhagen

Innovative partnership between the municipality, two municipal social housing companies and NREP to invest in social infrastructure, transportation access, street level environment and properties to re-develop Tingbjerg into an attractive Copenhagen neighbourhood.

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UMEUS student housing Copenhagen Nordhavn
Started construction of UMEUS Nordhavn, affordable student living in a prime central waterfront location in Copenhagen

UMEUS provides modern community-based student living at affordable prices in the Nordic capitals and university cities

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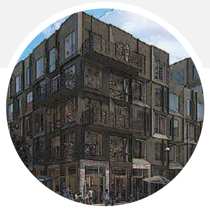

Noli Studios Helsinki Downtown
Opened the first Noli Studios site for your urbanites in downtown Helsinki

Noli Studios services the growing need for flexible, socially connected yet affordable small homes in central locations

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Plushusene community-based living, Naerheden
Started construction of Plushusene mixed-generation development in Naerheden, Copenhagen

Plushusene is a semi-serviced multigenerational community-based living for active seniors and young families

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Altura Carehome Masmo
Started construction of the Altura Masmo care home in Stockholm

Altura partners with local municipalities to address the growing yet underserved need for quality care homes

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UN17 Village Copenhagen
Started detailed studies for UN17 Village development in Copenhagen

Engaging multiple stakeholders, the UN17 Village is an ambitious interpretation of livability and sustainability, using the spirit and intention of each of the UN 17 Global Goals as a starting point and design tool

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Salem wood core net-zero energy solar/geothermal
7 net-zero energy multi-family buildings that pioneer a hybrid of solar PV, solar heat collector and geothermal

Constructed using modular wood core, reducing embodied carbon footprint

Salem multi-family

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Koskelonkuja logistics local deep geothermal
Completed a pioneering medium deep geothermal (2000m) zero emissions heating system

Pioneering deep geothermal heating solutions that reduce CO_2 emissions by up to 95% and energy cost by 20%

Koskelonkuja logistics

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Denmark logistics portfolio 5MW rooftop solar
Started the construction of Denmark's first grid connected commercial rooftop solar system on five logistics properties

Business innovation enabling large scale roof top solar where green power production exceeds local demand

Logicenters portfolio

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2019 project deep-dives : Learnings on upcycling
Upcycle Studios & Resource Rows

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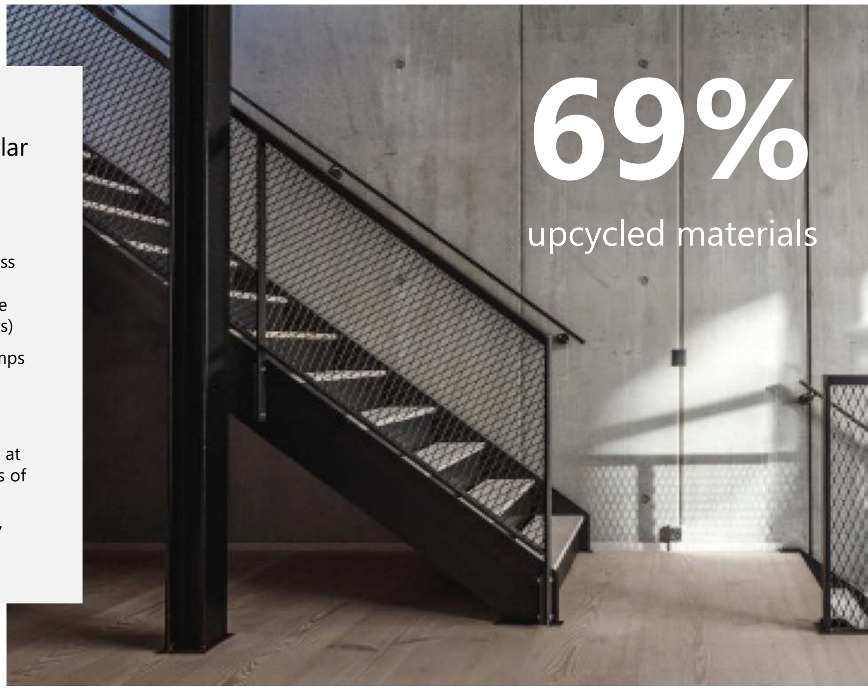


Upcycle Studios
Completed the world's first circular commercial scale residential development

- A groundbreaking 69% of the building mass of Upcycle Studios is upcycled materials (ranging from the concrete structure to the upcycled floors, wall cladding and windows)
- High energy efficiency envelope, heat-pumps and HVAC systems combined with on-site solar for in-use 'circularity'
- Designed for high degree of flexibility to ensure the best possible use of the homes at all hours of the day and in different phases of life.
- Design allows easy end-of life disassembly for a third circular life

Resource Rows
Completed the development of the upcycling project Resource Rows in Copenhagen

- With the Resource Rows project, Lendager and NREP strived to challenge and investigate what a thorough understanding of resources can bring about in terms of value and quality for new constructions
- Project underwritten based on a conventional row house and apartment project i.e. all sustainability actions had to be cost neutral or cheaper compared to a conventional solution in order to be implemented in the final project
- Iterative process with suppliers and partners that initially had different views and constraints with regards to materials upcycling and sustainability

2019-2025 sustainability targets & performance

STRATEGIC GOALS	HEADLINE MEASURES	2025 AMBITION	2019 ACTUAL
SOCIAL: **Provide more people more affordable and fulfilling ways of living**	# user units produced or funded cumulatively 2019 – 2025 (completed or in process) that address socially vulnerable groups or rental that caters to people at or below median income	30,000 units	5,674 units
	• Student housing units	4,000 units	1,350 units
	• Noli Studios	7,000 units	1,184 units
	• Rental apartments catering to people at or below median income	12,000 units	1,999 units
	• Plushusene units	3,000 units	559 units
	• Care home beds	4,000 beds	582 beds
	Aggregate proportion of NREP total residential portfolio	>50%	53%
	% of developments (excl. logistics) featuring indoor climate or community services beyond regulatory requirements	100%	34.8%
ENVIRONMENTAL: **Decrease carbon & resource footprint**	Build less: % of developments (excl. logistics) where property gross area per user/occupant is below relevant industry average / benchmark (thus reducing aggregate need for construction/heating/cooling)	>50%	51.8%
	Embodied carbon: Kg/sqm/year over 50 year life (new developments)[1]	6.5kg	N/A
	Energy-consumption: Energy intensity (kWh / sqm / year) (Electricity, heating & cooling)	CRREM 1.5° target pathway	Resi: 123 kWh Logistics: 80 kWh Other: 134.8 kWh
	CO2 intensity of consumption: % of electricity consumption for standing assets covered by green energy (Estimated)[2]	100%	63%
	CO2 intensity (kg / sqm / year) (Electricity, heating & cooling)[3]	CRREM 1.5° target pathway	Resi: 9.3 kg Logistics: 7.9 kg Othe: 4.2 kg
	On-site renewables: MW capacity installed or in process to be installed[4]	>30 MW	12.6 MW
ECONOMIC: **Resilient strong long term value and returns**	% of new developments and forward purchases addressing structural imbalances and having expected long-term use or incorporating design allowing for economically viable conversion to alternative use[5]	100%	96%
Process	% of new developments having completed or in process to complete certifications (e.g. BREEAM, LEED, DGNB)	100% (2021)	30%
	% of all standing assets held longer than 3 years with certification (build or in-use)	100%	10.5%

1 Standard LCA calculation periods differ between the Nordic countries and between the major certification schemes. The typical periods are 50 years or 70 years, where NREP target is formulated based on the more conservative 50 years.

2 Properties with green grid contracts are 100% green, while other buildings have assumed on average to have the same green electricity proportion as the share of renewable electricity in grid is based on 2018 data from Eurostat. Electricity consumption has been estimated for assets with no data availability based on portfolio intensities by segment.

3 CO2 intensity for standing assets with data coverage for both electricity and heating/cooling consumption. CO2 intensities based on data from The Intergovernmental Panel on Climate Change.

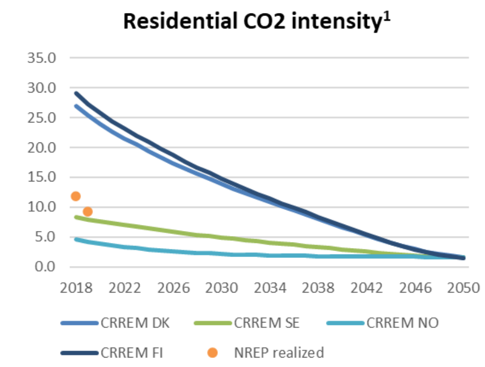
4 Includes projects that NREP has completed or signed and is in process to complete. Total includes capacity installed by NREP on properties that may or may still be in NREP ownership.

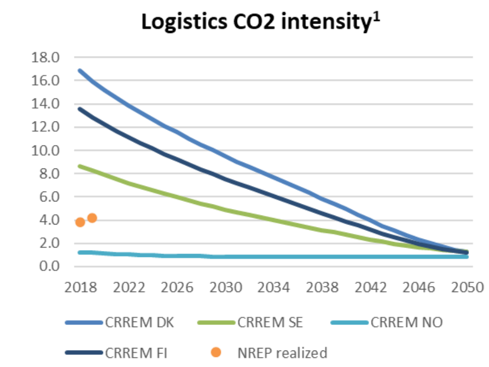
5 The measure provided includes own and JV developments, while the corresponding measure for own developments only is 96%. Systemic challenges defined to include student housing, micro apartment rentals, residential in capital city regions and growth centres, community-based living, senior housing, care homes, schools and modern logistics in the key hubs and corridors, but excludes other segments such as office and retail.

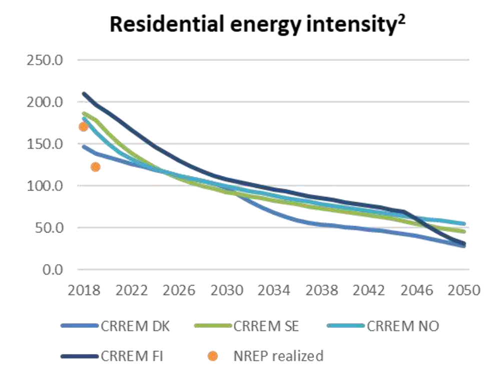
2019 – 2025 sustainability targets & performance

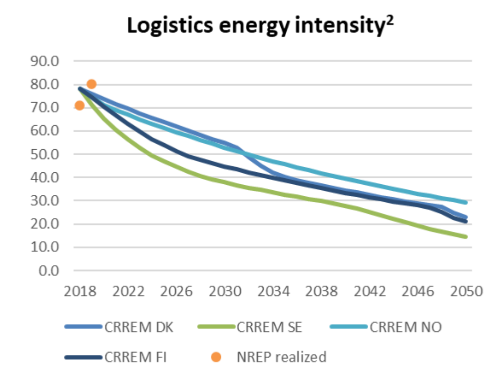
Energy and CO2 intensity pathways

ENVIRONMENTAL: **Decrease carbon & resource footprint**









1 Energy intensity (kWh / sqm / year) (Electricity, heating & cooling)

2 CO2 intensity (kg / sqm / year) (Electricity, heating & cooling). CO2 intensity for standing assets with data coverage for both electricity and heating/cooling consumption. CO2 intensities based on data from The Intergovernmental Panel on Climate Change.

NREP is committed to reduction pathways that support the commitments of the Paris agreement with a target to limit the increase in global temperature to 1.5 degrees.

NREP has adopted the decarbonization pathways of the Carbon Risk Real Estate Monitor (CRREM), which provides tangible target levels for the energy use and emission reductions for each type of property across sectors and geographies. The CRREM framework supports monitoring the energy performance of single properties as well as of portfolios to benchmark their performance and assess transition risk. Our portfolio overall performs in alignment with the decarbonization pathways. We are currently unable to produce realized figures on a national level due to insufficient consumption data.

Logistics roof top solar

260,000 MWh

to be generated from the solar projects installed or in process*

*Estimated production during expected lifetime of 25 years. Total capacity of 12.5 MW, of which 7MW installed in 2019

Our impact philosophy

Our impact philosophy

Impact is intentional and inherent to the core of what NREP is about. We believe that 'making real estate better' is a massive opportunity to enrich people's lives and contribute to a more sustainable world. We also believe that it is an unrivalled opportunity for growth, stable returns and competitive advantage. We are purpose-driven and see a moral imperative. In a laggard real estate industry that largely has been stuck in a short-term narrow view of value creation, we act on an opportunity to take a long-term holistic approach that reconceives customer needs, product solutions and stakeholder collaboration in a way that creates more economic value alongside more value for society.

Society is now breaching well-defined system conditions, causing systemic and growing challenges ranging from greater inequality to climate change. These challenges are also pervasive in the Nordics, with real estate clearly playing a major part of both key problems and key solutions.

But a large part of the real estate industry has remained trapped in an outdated perception of value creation that optimizes for short-term financial performance while ignoring the long-term nature of properties, ignoring users' long-term needs, and ignoring real estate's broader societal impacts and dependencies.

The opportunity to do better and improve the value equation for all stakeholders is clear. The solutions, technologies and capital exist, but bringing them together to reconceive opportunities requires a consciousness and desire to act with a more holistic approach. For example, providing poorer groups of society access to more affordable and fulfilling ways of living is a large and attractive opportunity, but it typically requires collaboration with multiple stakeholders and a longer-term horizon. Similarly there is an abundance of opportunities to achieve better environmental performance while decreasing long–term costs, but short-term mind-sets often get in the way.

Looking forward, while NREP will not alone solve the affordability and other societal challenges of real estate in the Nordics, we are in a position to materially contribute to move the industry in the right direction. And while the direct CO2 footprint of real estate in the Nordics will not change the global war on climate change, the Nordics is fertile soil for pioneering better solutions that can subsequently be adopted by larger markets that do move the needle.

NREP was founded in 2005 based on the observation that there was an opportunity in the Nordic real estate market to make a difference. We have only taken the first steps of a long journey, but in recent years more parts of the value chain are stepping up and it is becoming easier to get traction. Real estate is ready for change and we are ready to lead.

Sincerely,

Claus Mathisen
CEO

Making real estate better
is a massive opportunity to enrich people's lives
and contribute to a more sustainable world

Impact & Returns. Where do we stand?

We are purpose-driven and impact is intentional and inherent to our core business activities, but strong economic sustainability and investment returns is a pre-requisite as without it our direct impacts will not last and our solutions will not scale.

How we strike the balance between the multiple objectives of both NREP and other stakeholders differs between property types as well as individual cases.

On the scale from 'classic investing' to 'philanthropy' (see table below), the majority of our main strategies can be described as 'strategic and intentional' by nature (green color below). Most of our residential strategies, which in total represent 2/3 of our investment program, are addressing structural challenges such as the lack of student housing, affordable rental and care homes. We aim for the majority of our regular multi-family rental products, which is our single largest product segment, to cater to people at or below median income.

A minority of our investments are less inherently impactful, but benefit from the integration of ESG factors (blue color below).

For example, our logistics property business is pioneering on-site renewables in the Nordics by repeatedly launching record-breaking roof-top solar programs or zero-emissions heating through on-site deep geothermal heating.

Our ambition is that 10% of our projects have dramatically stronger social and/or environmental dimensions compared to the industry average building (orange color below), optimizing for environmental or social dimensions in a way that may result in a short-term financial trade off. Examples include the world's first fully on-site upcycled concrete building and the world's first commercial scale fully circular residential development. Such pioneering projects are intended to raise the bar for future projects for both NREP and the real estate industry at large.

CLASSIC INVESTING	TITHING	RESPONSIBLE	SUSTAINABLE	STRATEGIC & INTENTIONAL	IMPACT FIRST	CHARITY ENTERPRISE	PHILANTROPY
Profit motive only Maximize investment return without regard for effects on employees, environment or community	Owners contribute some profits to charity, but there is no intentional or inherently missional nature to the core of the business activities	Investment selection and operations screen for ESG risks	Investments are selected that benefit from the integration of ESG factors and broad-based macro trends, and E&S opportunities are identified and implemented	Investments focus on issue areas where social or environmental needs offer commercial growth opportunites and deliver market rate return	Investments seek to optimize social or environmental needs first and may result in financial trade-off	Charity with a revenue model to sustainably fund its mission	Gifting or grant making to social and environmental causes without regard for financial return

Main strategies
90%

Lighthouse projects
10%

NREP N-Power Fund

What impacts are we seeking?

Increase affordability & accessibility

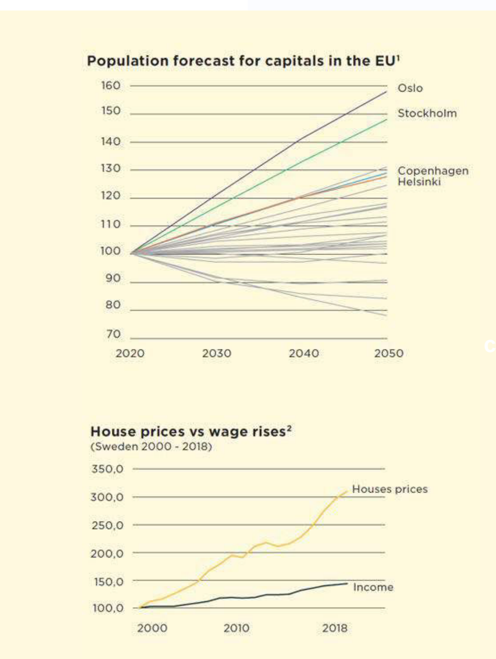
ILLUSTRATIVE CASES ON PAGES 39, 41, 43, 45 & 47

The Nordic capitals are the fastest growing in Europe and are accordingly facing structural challenges. For decades we have not been able to build remotely enough housing to keep up with demand.

With space becoming scarcer and incomes failing to keep up with rising house prices, it has become much harder for a much larger group of ordinary people to find a suitable, affordable place to live. And a particular lack of rentals makes it even less accessible to those unable to buy.

Even in the Nordics, the lack of suitable, affordable housing in the main cities is the foundation of some of our most pressing social challenges. The impacts are felt across age groups and are having a profound effect on the way in which we live our lives.

We see many opportunities for the real estate industry to improve affordability by employing smarter customer centric design (more user value for same cost), more efficient production (lower cost for same quality) and enabling more efficient use by sharing spaces and resources (increased utilization of asset).



1 Source: OECD
2 Source: Statistiska Centralbyrån

"My life work has been focused on how we can develop thriving inclusive cities and neighbourhoods. The complexity is humbling, and success requires a will to truly understand the local context and a multi-disciplinary collaborative approach to provide the solutions. The regeneration of the socially disadvantaged Tingbjerg area in Copenhagen is a case in point. Our innovative partnership with the municipality and two social housing companies unlocked solutions that will set the area on a completely different trajectory than would otherwise have been the case."

Jens Kramer Mikkelsen
Director of Urban Development, NREP

Kramer's urban development experience includes his pioneering work as Mayor of Copenhagen 1989-2004 when he played a central role in the development of the 'Copenhagen Model' for city development. Subsequently, he spent three years at the Ørestad Development Company as well as 11 years as CEO of CPH City & Port Development, the publicly owned company that is charged with shaping the future of Copenhagen.

What impacts are we seeking?

Address the shortage of assisted living for elderly

ILLUSTRATIVE CASE ON PAGE 47

A major demographic shift is underway. Ageing population is a structural challenge in many parts of the world, and no less so in the Nordics. The age group +80 will increase by more than 50% until 2030. And this new elderly generation will have far fewer family members to look after them.

In addition to a growing number of people in need of care home living, the existing stock in the Nordics is generally old and a significant portion will need to be replaced. A large proportion of Nordic municipalities are already experiencing shortages of care homes and are lacking the capital and personnel resources required to enable the construction of a sufficient amount of new care homes. In Sweden, more than 40% of municipalities report an immediate shortage of care home beds.

Furthermore, the living environment is crucial to enable elderly people to stay healthy, social and happy. Traditional home models or care homes often limit individual choice and isolate residents from the local community. The opportunities to do better are already here. New more user centric models are emerging. Collaboration between municipalities, developers, operators and investors with long term mindsets have the potential to unlock the supply.

Source: Statistiska Centralbyrån

"I have worked in care my entire career, and creating better living for our elderly is profoundly personal to me. There is a structural problem that I am worried about, but most people who have been to a couple of care homes probably know that there is also a moral imperative to provide our seniors with a more positive living environment. A care home environment should provide a sense of a stimulating, safe and caring home - not a worn down hospital ward. Our concept is based on methodical research, years of experience from care home operations and meticulous optimisation of a myriad of design and production details that all add up to something that I hope will make a difference."

Dorotea Stellmach
Head of Concept Development, Altura

Prior to joining NREP, Dorotea was Regional Director at Attendo Sverige, the largest care home operator in the Nordics, where she worked for 17 years building the business together with the management team. Before that, she worked at Partena Care.

What impacts are we seeking?

Combat loneliness

ILLUSTRATIVE CASES ON PAGES 41, 43, 45 & 47

More than ever, we are choosing or are forced to live alone, and this trend has been accompanied by an alarming increase of people - young and old – experiencing loneliness.

Single-person households are projected to see faster growth than any other household type in the coming decades. This is true for the Nordics as well as across low-, middle- and high-income countries globally. And research shows that loneliness does not only have profound impacts on our happiness, but also that prolonged loneliness has a large impact on both our mental and physical health, and could even be a greater health hazard than obesity or smoking.

By enabling people to live their own private life but still be part of a "community" and have a social life, shared living and building concepts that encourage interaction could improve the health and well-being of many urban dwellers.

52%
of new households in Helsinki are singles[1]

58%
of 20-29 year olds in Sweden often or frequently experience loneliness[2]

48%
of elderly +80 in Sweden often or frequently experience loneliness[3]

1 Source: HMA Time Series Statistics 2000 – 2016
2 Source: Uppsala University, Lars Tornstam 2010
3 Source: Uppsala University, Lars Tornstam 2010

"To me, sustainability is about rethinking habits and exploring new opportunities. NREP strives to take the lead on inspiring people to healthy and climate-friendly food-habits, but we also see the production, preparation and consumption of food as an important catalyst for connectedness between people in our buildings and communities. I believe it is an important part of how we can breathe life into the spaces we create."

Lena Lee
Food & Beverage

Prior to joining NREP, Lena worked as a professional chef and manager of food concepts. Originally trained at Noma and the Fat Duck, Lena subsequently ran F&B operations and set up new concepts for Løgismose Meyers, Aamanns and Novo Nordisk and hotels such as Hilton and Bella Sky.

What impacts are we seeking?

Help students access positive & affordable living

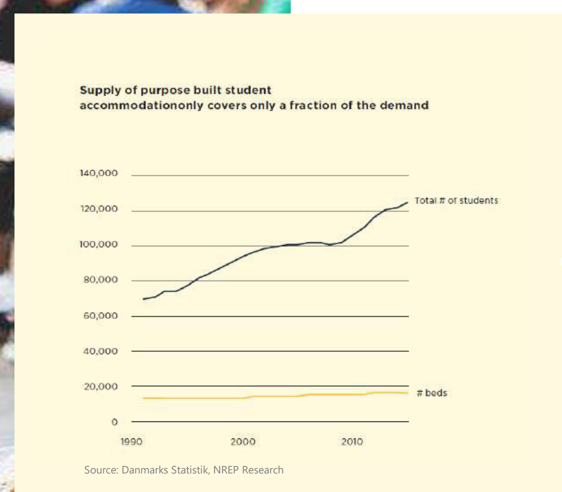
ILLUSTRATIVE CASE ON PAGE 41

Students struggle to find access to affordable student housing in all the Nordic capitals and main university cities, and much of the existing stock is outdated and run down. The student body has grown faster than new supply for the last three decades and is expected to continue to grow. In Copenhagen, there is student housing available for less than 20% of the student body

Nordic students live on limited budgets based on the government provided grants/funding, making regular studios too expensive. Hence, students are forced into poor alternative forms of housing.

Students indicate lack of access to housing as the main cause of stress and poor quality of life. Poor/unstable living conditions also negatively impact academic results.

We see that there are clear opportunities to maximize quality of life within even the Nordic student's limited disposable income levels. We can change the value equation through better understanding of student preferences, emphasis on community rather than large private space; optimization of design and production, and partnering with municipality, university, student unions etc. to jointly identify solutions.



"What we invest in today

will determine the world we live in tomorrow"

GIIN GLOBAL IMPACT INVESTING NETWORK

What impacts are we seeking?

Progress RE industry towards a lower carbon footprint

ILLUSTRATIVE CASES ON PAGES 49, 51, 53, 55 & 57

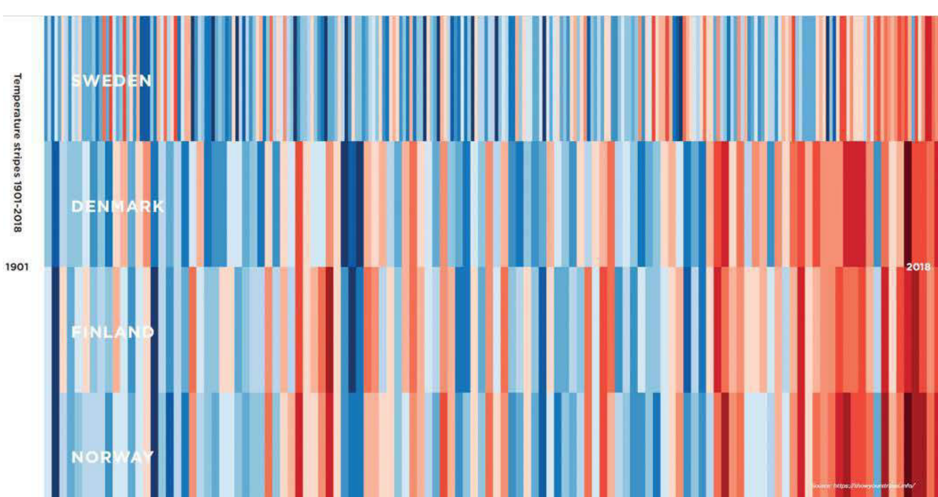
The writing is on the wall – the real estate industry must find more sustainable practices that enable the industry to have a much smaller resource and CO2 footprint.

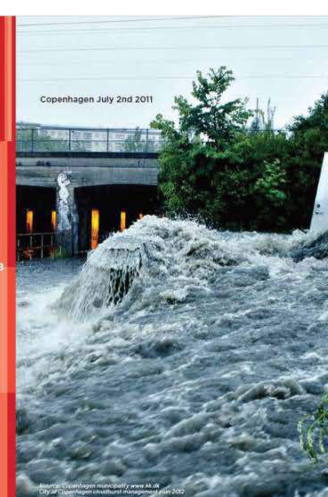
NREP's materiality assessment identified CO2 footprint as our most material environmental impact, with a focus on both 'embodied' and 'in-use' impacts. In the Nordic context the standards for building envelopes are already high, but large improvement opportunities exist with regards to reducing embodied carbon of new buildings, reducing consumption of existing stock and unlocking real estate's potential for on-site renewable energy production through solar, geothermal and heat-pumps.

While the direct CO2 footprint of NREP's real estate projects or the footprint of Nordic real estate as a total will not change the global war on climate change, the Nordics is fertile soil for pioneering better solutions that can subsequently be adopted by larger markets that do move the needle. Hence, looking forward NREP will also seek more indirect impact by influencing the broader industry direction.

40%

of raw materials consumption and CO2 emissions in the Nordics is caused by real estate





"I stepped over to NREP from the renewable energy industry to act on the immense opportunity for real estate to play a role in combating climate change. Technologies to step from being a huge part of the problem to being a part of the solution are already here, but the challenge is to do it in practice. A combination of factors are making it a lot easier said than done, so I am extremely proud of how we in different ways have pioneered on-site renewables production in the Nordics and how we are progressing our program towards carbon neutral or carbon positive buildings."

Johan Hallgren Madsen

Sustainability Manager – Energy

Prior to joining NREP, Johan had a background in the renewable energy industry, most recently working at Ørsted developing and financing large scale offshore wind projects.

"Our community retail centers are often the hearts of the local communities they serve. They do not just fulfill a practical function for people's everyday needs, but also play an important social function that impacts people's quality of life. I believe that all all people need a safe and homely environment in their community, but it is especially important for children and elderly people as they are often restricted in terms of mobility. There is a need to breath new life into many local centers across the Nordics, but it takes hard work and commitment to succeed - I am really proud of the work we do."

Marianne Hoffman
Director Commercial Properties, Sweden

Marianne joined NREP in 2013 and has more than 20 years experience managing and bringing life to retail shopping centres and other commercial properties in the Nordics.

NREP has to date invested in 44 retail centers and is a leading developer and manager of local community shopping centres in the suburbs of the Nordic capitals.

Our impact management framework & strategies

Our business and our impact

At home in the Nordics, NREP is an integrated real estate product innovator, developer, investor and operator.

By designing, developing, refurbishing, managing and investing in properties we are having an impact, both positive and negative.

Intentional and inherent to our core
Impact is intentional and inherent to the core of NREP's business activities. Approximately 2/3 of our business is developing or funding residential properties, predominantly residential properties catering to the needs of specific underserved socially vulnerable user groups or rental catering to people at or below median income. These properties range from serving students in need of affordable community living to elderly in need of a positive care home environment. Related to the community context of residential and as part of larger urban development projects, NREP also invests in local community retail centres and social infrastructure.

Approximately 1/5 of our business is modern logistics properties, where we seek to have a positive impact primarily by building and investing in energy efficient properties in locations that support efficient logistics systems with less drive times, improving the energy consumption of buildings and pioneering on-site renewable electricity production.

NREP's impact strategy and framework
Our sustainability strategy is one of four main dimensions of our 2025 corporate strategy established in 2018 and is integrated with our strategies to achieve strong stable returns, growth as a business and valuable contributions to societal challenges.

NREP's framework for achieving impact is summarized in the graphic 'NREP's impact framework at a glance' on the next page.

Defining our impact and strategic goals
By designing, developing, refurbishing, managing and investing in properties we are having an impact, both positive and negative. We define our impact as positive or negative experiences to people or the planet that occur from our investments or as a result of our actions as an organization or our influence on other stakeholders' actions or systemic changes that occur because of our actions.

Our built environment materially impacts many facets of our lives and the value chains of the real estate and construction industries have large and material impacts on our planet. In dialogue with our stakeholders we have identified our high-level impact goals and focus areas within the UN definitions of sustainability consisting of economic sustainability, social sustainability and environmental sustainability. In 2019 we updated our materiality assessment to more explicitly leverage the governance principles and sustainability objectives articulated by the UN, including the UN Goals for Sustainable Development (the SDGs).

Our overarching economic sustainability goals are to achieve resilient strong long-term value and returns through a focus on addressing systemic challenges and by applying a long-term and full-life-cycle approach to create better solutions. We have identified our overarching social sustainability goal to be to provide real estate that allows more people more affordable and fulfilling ways of living. We seek to achieve this with a focus on addressing underserved needs with affordable customer-centric and community-centric real estate products (SDG 11, impact sub-targets 11.3, 11.6, 11.7), as well as by building environments that support physical, social and mental health (SDG 3, impact sub-target 3.4). We have identified our overarching environmental sustainability goals to be to decrease carbon and resource footprint with a focus on innovating and optimizing building design and materials (SDG 12, impact sub-targets 12.2, 12.5 and 12.8, SDG 15 sub-targets 15.5 and 15.A), as well as ensuring energy efficiency and increase renewables (SDG 7, impact sub-targets 7.2, 7.3 and 7.A).

Our materiality assessment also identified a large number of other impacts of our activities. These are also important and our Environmental & Social Management System addresses the broader definition of sustainability generally adopted by the industry, but we put less strategic focus on these other areas either because they are less material to our context, the cost/benefit trade-off is not strong enough, or the management of the impacts is already part of regulatory requirements or standard industry practices in the Nordics.

Our 2025 strategy review and materiality analysis also identified that NREP should seek to increase its positive impact beyond its direct impacts by engaging more to influence supply chains, industry practices and regulatory frameworks (SDG 17, sub-targets 17.16 and 17.17).

Delivering on our goals
NREP's operational model to deliver on our impact goals is based on the principle that our business lines and product teams need to have the ownership for the activities that deliver impact and sustainability, but the company must centrally develop and provide the solutions, standards, processes and supporting IT systems for effective sustainability and impact management. To build an organization that achieves impact over time, we seek to ensure a focus on the following pillar elements:

1. Desire and entrepreneurial spirit to make a difference
2. Long term holistic approach
3. Focus resources on strategies with Impact
4. Systems, tools & knowledge to act
5. Stakeholder Engagement & Industry Transformation

Continuous strengthening of our management systems, tools and templates to enable our teams to know what to do when, and take action effectively and efficiently is a key priority of our 2025 sustainability strategy. The field of impact and sustainability management is evolving every year and we see the development of our management system as a continuous gradual journey.

Standards and reporting
As part of our efforts to better understand, manage and measure our impact and sustainability we participate in industry initiatives such as the Global Real Estate Sustainability Benchmark (GRESB) and use the framework developed by the Impact Management Project ('IMP') and the IRIS+ (Impact Reporting and Investment Standards) project of the Global Impact Investment Network (GIIN). NREP is a signatory to the UN Principles for Responsible Investing and supports the climate objectives of the Paris agreement.

NREP's impact framework at a glance

	Social		Environmental		Economic	
Goals:	**Provide more people more affordable and fulfilling ways of living**		**Decrease carbon and resource footprint**		**Resilient strong long term value and returns**	
	Address underserved needs with affordable customer-centric and community centric products (SDG 11.3, 11.6, 11.7)	**Build environments that support physical, social and mental health** (SDG 3.4)	**Innovate and optimize building design and materials** (SDG 12.2, 12.5, 12.8, 15.5, 15.A)	**Ensure energy efficiency and increase renewables** (SDG 7.2, 7.3, 7.A)	**Address systemic challenges**	**Apply full life cycle economics and long-term approach to create better solutions**
2025 ambitions: *(select) targets*	30,000 units cumulatively 2019-2025 addressing housing needs of underserved groups or rental that caters to people at or below median income	100% of developments (excl. logistics) feature indoor climate or community services beyond regulatory requirements	6.5kg/sqm/yr embodied carbon of new deveopments	CRREM 1.5^{O} pathway for energy intensity >30 MW new capacity of onsite renewables	100% of developments address systemic challenges and have expected long-term use or incorporating design allowing for economically viable conversion to alternative use	100% of developments and major renovations undergo early stage LCC analysis

Execution: Business line ownership for delivering impact	UMEUS	NOLi Studios	juli living	PLUS HUSENE	ALTURA	woods / NREP RETAIL	LOGICENTERS
	Student housing	Serviced living	Multi-family	Senior living	Care homes	Retail & Office	Logistics

Supporting corporate systems & practices	**Desire and entrepreneurial spirit to make a difference**	**Long term holistic approach**	**Focus resources on strategies with Impact**	**Systems, tools & knowledge to act**	**Stakeholder engagement & industry transformation**
	Capturing the potential for impact requires individuals to have a desire to make a difference, to spot the opportunities and put in the effort it takes to do things in new better ways. NREP will seek to help our people to understand and articulate what impact and sustainability means to their specific roles and we seek to reinforce internal motivation by integrating sustainability into the governance structure, performance management and remuneration framework.	Properties are by nature long term and many of the right decisions that create more value in more sustainable ways require that we take a long-term ownership approach. Taking a holistic approach by working in collaboration and alignment with the interests of all key stakeholders has been a key to NREP's success and will continue to be so.	Our decisions on where we focus our team and financial resources to a large extent determine what impacts we have a chance to achieve. By focusing on select customer groups we are able to go really deep and invest in the 'R&D' it takes to develop insight, capabilities, product solutions and production processes that provides a better proposition to users and our planet.	NREP will seek to significantly and continuously strengthen the IT systems and tool-kits necessary for NREP's teams to know what to do when and have access to plug-and-play solutions that allow them to take action effectively and efficiently.	At the project level, methodical early engagement with our contractors, developers, tenants, municipalities and other stakeholders is key to identify and act on both risks and opportunities. Looking to the future, NREP will also seek to influence the industry agenda and regulatory environment in a broader sense, as we see this as an important opportunity for us to have positive impact beyond our direct projects.

$\underbrace{\text{Systems, tools \& knowledge to act} \quad \text{Stakeholder engagement \& industry transformation}}_{\text{Key areas of improvement opportunity targeted in 2019-2025 business plan}}$

How does NREP make a difference?

When we ask ourselves how we contribute to our impact goals, we are seeking to understand our contributions to outcomes that would not have happened otherwise.

NREP has always been about identifying that gap between how things are and how they could be, and then creating value by doing something about it. NREP was founded in 2005 based on the observation that there was an opportunity in the Nordic real estate market to make a difference with a strategy-driven long-term approach that seeks to achieve economic values alongside value for society. In the Nordic real estate industry, this is not business as usual. It requires us to truly look at real estate as a product in service of its users and society rather than an asset class. And it requires an organization that has different capabilities than what is required to do short-term opportunistic developments, flip assets or look at real estate as a fixed-income substitute. Reflecting both the hard and soft dimensions of qualities that people want from their neighbourhood community, home or workplace, we thus build truly multidisciplinary teams combining real estate and development professionals with high-caliber specialists from a wide range of backgrounds,

Moving from ambitions to actions, NREP contributes to impact in three main ways:

A. Identifying underserved systemic challenges and funding real estate addressing those challenges

To identify what challenges to address and to do it better, we need to ask the bigger questions, challenge status quo and do more research than others. We need to understand the underlying trends shaping our future. Find the problems people need help solving, sometimes before they even know it themselves. Methodical research and analysis to understand those strategic drivers and opportunities has been in the DNA of our team and business since inception. How can we build a better society? What are the perspectives and needs of other stakeholders, such as municipalities and operators, that we need to find solutions to? What is it that people truly need and want from the built environment?

B. R&D to introduce better solutions to the market and build better capabilities

By taking a long term and focused approach to our segments we can invest in the team resources, R&D and capabilities required to create better solutions. We take a methodical and analytical business development approach that truly starts with the customer needs and invests in building business capabilities and value-chain partnerships to provide a better value proposition through design, service and production processes. Some of it is complex, and for many of our solutions our long-term ownership perspective is a pre-requisite. But a large portion is simply about truly understanding what really matters to people and giving them that while avoiding wasting space and resources on things that do not matter to them. Sometimes it does not need to be more complex than that. And when less is more, it is not only more affordable but also often more environmentally sustainable.

C. Put in the resources and operational excellence required to create outcomes that otherwise would not have happened

We cannot only develop smart solutions - making a real difference in real estate requires operational excellence and hands-on hard work on the ground. Great opportunities are rarely easy to act on, if they were, they would have been acted on. And a great solution is not much without the right execution. We are convinced that operational excellence is key, and our focus allows us to develop that in a way that would otherwise not be possible. But we have also built a team that proportionately is much larger than our peers - a lot of what we do is to roll up our sleeves in execution to manage complexity that others are not set up to manage. That's why we love details, love being thorough and love doing it hands on. And then repeating it to refine the process and solutions to create even better outcomes.

Illustrative example: Plushusene

	UNDERSTANDING THE STRUCTURAL CHALLENGES	GATHERING INSIGHTS	DESIGNING SOLUTIONS
ACTIVE SENIORS	• Seniors 55+ make up 30% of total population and accounts for 93% of growth in Denmark until 2030. • Increasing loneliness among seniors • 74 percent of seniors prefer to live in areas with mixed age groups to ensure a lively atmosphere, • Many seniors are living in inadequate housing with high maintenance responsibility. • Seniors seeking more socially connected co-living/co-housing options do not find any supply	• Surveyed 8,000 seniors and 2,000 families • Multiple in-depth focus group studies • Close consultations with US senior housing experts, operators, anthropologists, architects, senior citizen associations, etc. • Site visits to established Danish co-living communities • Engaged top tier strategy consultants in healthcare, public sector and real estate • Teamed up with leading architects and contractors to ensure high quality design • Hired top-CEO from entertainment industry (amusement park) to design and run daily operations	• Providing access to a community and variety of activities, Plushusene help engaging lonely seniors. Studies show that 91% of people living in co-living residential has experienced an increase in the quality of life • The maintenance free units and access to services such as cleaning and gardening leads to seniors having a more hassle-free daily life • Carefully designed efficient units allow seniors to rent an apartment or one-story row house at an affordable price-level • Plushusene is bringing generations together
YOUNG FAMILIES	• Many families are living in areas that aren't conducive to child health, development and well-being • Majority of families report that they are stressed due to daily hassle with practical tasks and inadequate quality time with their children. • New government regulations make it difficult for families to afford buying a row-house in close proximity to Copenhagen and Århus. • Limited supply of newly built sustainable private rental row-houses at affordable price level. • 89 percent of families prefer living in areas with neighbors from mixed age-groups		• A safe co-living environment leads to children being more "socially mature, confident, outgoing, competent, and verbal than their non-community counterparts" • The convenience concept of Plushusene includes communal dining and arranged activities for residents, leading to parents having more quality time with their children. • Plushusene's units are priced at a level that enables average young families to rent a two-story row house with private garden and 3 bedrooms

NREP main strategies to allow more people more affordable and fulfilling ways of living

NREP's main social impact goal is to 'provide real estate that allows more people more affordable and fulfilling ways of living'. This objective is embedded in the core of NREP's business operations focused on affordable student community-based living (UMEUS), flexible affordable serviced living (Noli Studios), affordable rental serving people at or below median income, mixed-generation community living for seniors and young families (Plushusene), senior housing and care homes (Altura).

In addition to focus on individual health and wellbeing, an important part of our approach is to understand how the lives of individual residents are enriched through interpersonal connection and community. Our goal is to create and shape communities that thrive now and in the future. In addition to our living communities, we seek to achieve this objective at a neighbourhood level through our community retail centres as well as when working in partnership with municipalities to develop new urban areas or regenerating existing ones.

	Affordable student community-living	Flexible affordable serviced living	Multi-family rental	Mixed-generation community living for seniors and families	Care homes
Materiality	Students struggle to find acccess to affordable well-located student housing in all the Nordic capitals and main university cities	Young people in the Nordic capital cities are struggling to find affordable and decent living conditions	With supply focused on for-sale market, the lack of suitable affordable rental in the main cities is at the core of many pressing life challenges for families and single person households at or below median income	Loneliness and isolation is a major contributor to poor health and mortality for senior people in the Nordics	Lack of access to assisted living is causing physical and mental health problems for the elderly in need
Strategy	UMEUS UMEUS provides modern community-based student living at affordable prices in the Nordic capitals and university cities	NOLi Studios Noli Studios services the growing need for flexible, socially connected yet affordable small homes in central locations	juli living NREP's largest business activity is focused on providing rental apartments and row-houses catering to people at or below median income	PLUS HUSENE Plushusene is a semi-serviced multigenerational community-based living housing solution for active seniors and young families	ALTURA Altura partners with local municipalities to address the growing yet underserved need for quality care homes
	Illustrative case on page 41	Illustrative case on page 43	Illustrative case on page 39	Illustrative case on page 45	Illustrative case on page 47

Managing and measuring social impact

Investing with impact is an emerging field, and in comparison to understanding financial outcomes there is a need for a much more multi-dimensional approach. NREP has primarily focused on strategies that have a mix of characteristics that intuitively tell us in our hearts and minds that they should have both good financial and societal outcomes. However, in recent years, as the interest from other stakeholders has increased we see a need to understand, articulate and communicate our impacts in a structured manner using data and a common language.

Holistic sustainability certification schemes such as DGNB, LEED and BREEAM provide us with a common language that helps our communication with contractors and other stakeholders on primarily economic, environmental and health dimensions, but these frameworks are not covering the social impact dimensions that we seek to achieve. For these dimensions we seek to align with global best practice in impact management by using generally accepted frameworks for theories of change and measurement based on the emerging Impact Management Project (IMP) and the IRIS+ (Impact Reporting and Investment Standards) project of the Global Impact Investment Network (GIIN). The Impact Management Project (IMP) seeks to build global consensus on how to measure and manage impact, and the IRIS+ metrics and catalogue provides a common language of measurements to the IMP framework.

The IMP framework consists of five dimensions:

- **WHAT:** Identifying the level of outcome(s) one aims to deliver, contribute to, or both, based on how important stakeholders perceive the outcome to be).
- **WHO:** Understanding the baseline characteristics of stakeholders (people or planet) with respect to the outcome.
- **HOW MUCH:** Understanding the degree of change experienced by those affected and identifying how many are affected.
- **CONTRIBUTION:** Comparing performance to understand — in the absence of the resources or possibility to establish a control group — what would have otherwise happened.
- **RISK:** Understanding impact risks.

Source: Impact Management Project

Summary of the IMP framework applied to the primary impact of NREP's main residential strategies is provided below. These primary impact dimensions are complemented by a number of impact enhancing features and initiatives that create positive impacts for the target users as well as different stakeholders ranging from positive impact on the local community context to positive impact on the environment.

We have started taking the first steps, but we are on a learning journey and expect to continuously refine and improve our approach over the coming years.

	WHAT	HOW MUCH	WHO	CONTRIBUTION	RISK
	What outcomes does the effect relate to, and how important are they to the people (or planet) experiencing it?	How much of the effect occurs in the period?	Who experiences the effect and how underserved are they in relation to the outcome?	How does the effect compare and contribute to what would likely occur anyway?	Which risk factors are significant and how likely is it that the outcome is different from expectation?
UMEUS *Student housing* (DK)	Increased access and provision of affordable student housing supporting a higher quality student life experience	*Deep and at scale with duration:* Effects are deep for the target group, profoundly impacting their quality of life and supporting better academic results. Effects have scale, as UMEUS is the largest developer of new student housing in the target market and is changing the market. Buildings expected to provide the benefit for 70 years.	*Underserved:* Nordic students live on limited government incomes and there is a significant lack of suitable rental housing affordable to students.	*Better:* UMEUS new sites would typically not have become student housing had it not been for the initiatives and processes pushed by UMEUS, or UMEUS significantly increases the number of units of a building. UMEUS acquisitions of forwards or standing incentivises supply and continued provision of student housing.	*Low risk medium term, medium risk long-term: NREP cannot control long-term management at which time the* price point may change
NOLi Studios *Young urbanites flexible affordable rental* (FI, DK)	Increased access and provision of suitable positive community-connected living for young people moving to the capitals in need of flexible affordable rental	*Deep and at scale:* Effects are deep for the target group, profoundly impacting their quality of life. Noli Studios offers a product that is not otherwise available in the target markets of Helsinki and Copenhagen, but there are substitutes. Buildings are expected to provide the benefit for 70 years.	*Underserved:* Young people moving to he capitals from other cities typically have uncertain job security and limited budgets, without ability to buy or sign long leases, but there is no other supply serving that need	*Better:* Noli Studios' concept is unique in its markets and able to offer flexible living at a fraction of the price of other short-term offers. The projects would not happen without Noli Studios' actions.	*Low risk medium term, medium risk long-term: NREP cannot control long-term management at which time the* price point may change

Managing and measuring social impact

	WHAT	HOW MUCH	WHO	CONTRIBUTION	RISK
	What outcomes does the effect relate to, and how important are they to the people (or planet) experiencing it?	How much of the effect occurs in the period?	Who experiences the effect and how underserved are they in relation to the outcome?	How does the effect compare and contribute to what would likely occur anyway?	Which risk factors are significant and how likely is it that the outcome is different from expectation?
juli living Multi-family rental (SE, FI, DK, NO)	Increased access and provision of rental catering to different types of households at or below median income	*Deep or moderate depth of impact, but low to moderate scale:* Effects are deep or moderate for the target group, profoundly impacting their quality of life, but there are substitutes and our impact on the broader challenge is not at scale. Buildings expected to provide the benefit for 70 years.	*Served and underserved:* Lower and middle income people are both expected as tenants. The demand from lower and middle-income people in need of suitable rentals in our target geographies is significnatly underserved.	*Probably better:* NREP is often able to create rental properties in locations that would otherwise have been developed to sell. Thus NREP's involvement increases the access to rentals. NREP typically improves the utilization of square meters and increases the number of units provided in a given buliding in a meaningful way, thus improving affordability.	*Low risk medium term, medium risk long-term:* Rents are fully rent controlled in Sweden and partially in Denmark, while there is very little regulation in Finland. NREP cannot control rents of future owners, thus long-term price point may change
PLUS HUSENE Mixed generation co-housing (DK)	Increased access and provision of mixed-generation community co-housing for seniors and young families, providing synergies addressing loneliness and life stressors	*Deep and at scale:* Effects are deep for the target group, profoundly impacting their quality of life. Plushusene offers a product that is not otherwise available in the target market Denmark, but Plushusene will only be able to address a small portion of the demand for mixed generation co-housing in Denmark.	*Served and underserved:* The group of seniors suffering from loneliness and in need of living with a connection to other seniors and younger generations is underserved as there is no other provider in the target market. Financially the target group includes both low and middle income households.	*Better:* The provision of mixed generation co-housing would not have happened wihtout Plushusene's involvement. Plushusene concept is unique in its market and provides a community connectedness that the target group deems to significantly mitigates loneliness and improves their quality of life.	*Medium risk:* The community synergies for higher quality of life for the residents is dependent on successfully attracting the right mix of tenants and successful community management.
ALTURA Care homes (SE, DK)	Increased access and provision of positive care home living	*Deep, at scale and with duration:* Effects are deep for the target group, with access to care home living when needed and access to a positive care home environment profoundly impacting their quality of life. Altura's business plan will be a significant contribution to address the lack of care homes. The buildings are expected to provide the benefit for 70 year buliding life.	*Underserved:* Targeted people live in municipalities where there today is a lack of care homes, thus they are struggling to get access to care home living when their physical condition dictates that they are in need of such. Existing stock provide dismal living environments. The lack of care home living is expected to increase over the next decade as demand is expected to increase by 50%, at the same time as 25% of existing stock will need to be replaced.	*Probably better:* Altura has invested significant R&D into design that is providing a higher quality of life compared to standard market offering. NREP has also invested in R&D of design that lowers care home operating costs and of production processes that allow lower construction costs, thus improving overall economics. A portion of Altura's projects would not have happened without Altura's role and initiative, but some would albeit with other cost or design.	*Low risk:* Standardized buildings with low risk of cost overruns. From a user perspective, the cost is almost entirely government funded, and for those that are poor the cost is fully government funded.

NREP key strategies to reduce CO2 footprint

ILLUSTRATIVE CASES ON PAGES 47, 49, 51, 53 & 55

To make informed decisions and actually change the way we build, NREP believes that doing Life Cycle Assessment of different alternatives at very early stages of a project is key to actually change the way we build. The window of opportunity to make changes to a building concept, design and materials closes very early in the development process. Strengthening NREP's capabilities in this regard is an important part of NREP's strategy to further improve its future practices.

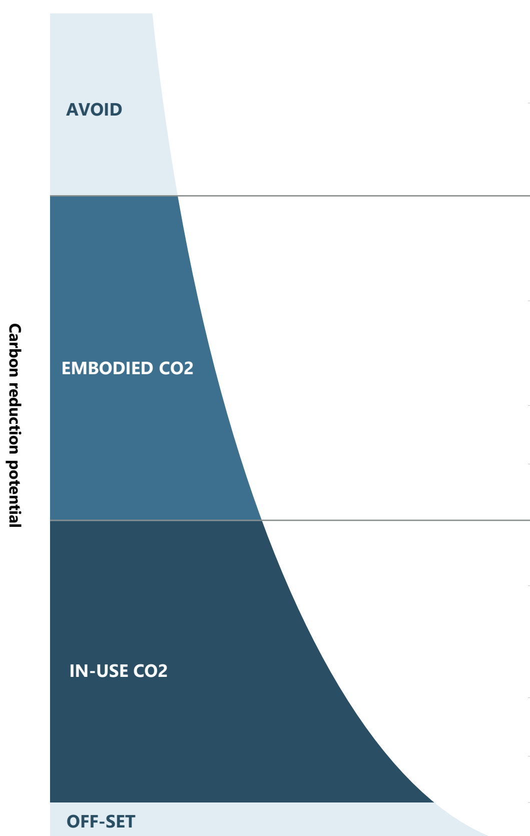
An important lever for NREP's efforts to decrease aggregate embodied carbon and in-use CO2 footprint is to optimize the use of every square meter to decrease the aggregate building body required to address the same need.

In the Nordics, the in-use energy efficiency standards with regards to envelope design for new buildings are very high, thus leaving only marginal improvement potential. In those areas where district heating is not green, an alternative lever is to use highly efficient electric-based HVAC and heat-pump systems (85% of grid electricity is green in the Nordics).

For standing older buildings, tenant behavioral change programs in combination with continuous improvement programs and energy retrofits are the main focus areas for decreasing consumption.

Going beyond mere energy efficiency, we are seeking to deploy on-site solar or geothermal renewable energy production. This is supplemented with that we should procure green electricity from the grid across all of our portfolio where we control it.

While we offer off-set schemes to tenants in certain products, this is not a major strategy.



Build nothing	Increase utility of existing buildings, thus mitigating aggregate need to build new
Build less	More quality of life or utility in less space per person reduces the total need for construction (embodied carbon) and reduces heating/cooling energy need per person
Build clever	Reduction of resource use • Design to reduce materials volumes • Design for longer life, flexibility and adaptability • Pre-fab and other low-waste production process
	Substitution of materials • Cross-Laminated Timber structures • Upcycling, recycle, reuse materials/structures • Natural or innovative materials
	Design for positive end-of-life impacts • Design for dis-assembly and re-use, materials passport
Build efficiently	Reduction of construction stage impacts (electricity, transports etc.)
Reduce in-use energy	Design or deep retrofit with energy efficient envelope & HVAC
	Continuous assesment of energy efficiency in portfolio ▪ Efficient operations through monitoring and servicing ▪ Lighting systems, installations and appliances ▪ Behavioral changes, green leases
On-site renewables	On site solar, deep geothermal
Green source	100% green grid electricity
Green off-set	

"With an entrepreneurial background from the proptech- and service-sectors, I am very excited to be part of NREP's efforts to reconceive the offering and solutions that our modern residential platform can provide to people. I believe that NREPs plans to scale up the use of technological solutions to decrease our carbon footprint holds huge potential. To me, our ambition to provide carbon neutral housing is simple and powerful, and I believe many of our tenants share that feeling."

Perttu Rönkkö
Head of Nordic Residential Products and Operations

Perttu has a diverse entrepreneurial background. Prior to joining NREP Perttu was leading Mount Kelvin, a prop-tech company developing smart building software enabling energy savings and better user experiences. In addition Perttu has launched several consumer services companies, ranging from online gaming to one of the largest dental care chains in Finland. .

Illustrative 2019 projects

ILLUSTRATIVE CASE:

Using the UN Global Goals as a design tool

UN 17 VILLAGE
- Using the UN Global Goals as a starting point and design tool

PROPERTY SUMMARY

Fund **NREP NSF3**
Property type **Residential**
Investment year **2018 – 2019**
Construction year **2020 – 2023**
NLA residential **35,000 sqm**
Units **464**
All in development cost **€168 million**

In 2019, NREP started the detailed studies for the UN 17 Village development in Copenhagen

BACKGROUND

- Real estate profoundly impacts our lives, societies and planet on a broad spectrum of direct and indirect dimensions that we often fail to consider. UN17 Village is an ambitious interpretation of "livability and sustainability" that uses the spirit and intention of each of the UN 17 Global Goals for Sustainable Development as starting point
- UN17 Village is a large scale residential project designed for a mixed group of users, including underserved groups such as divorced, active seniors (55-75 years), seniors (+75) and disabled people

PROJECT PROFILE

- The project comprises 35,000 sqm and ~464 apartments
- The building plot is one of the best locations in the local area with unobstructed access and views to vast nature areas as well as proximity to public transport
- Developed design and construction process toolkit based on the UN Global Goals
- Focus on not only developing a sustainable building, but also to support a sustainable lifestyle for residents and visitors
- DGNB Gold

UN17 Village impact and sustainability ambitions

Illustrative examples from first stage of concept design

SOCIAL

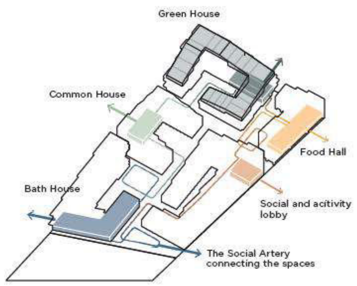
Product design addressing needs of specific underserved groups. Large communcal facilities, spaces and activities encouraging connectedness.

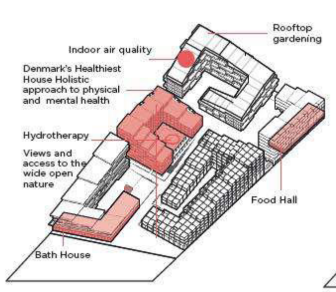
HEALTH

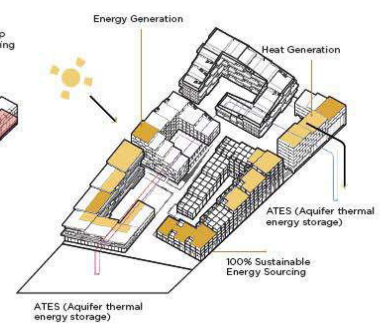
Reducing indoor pollution by up to 60% and an indoor climate and design that encourages physical and mental health

ENERGY

Meets high energy efficiency standards and has on-site renewables production.







MATERIALS

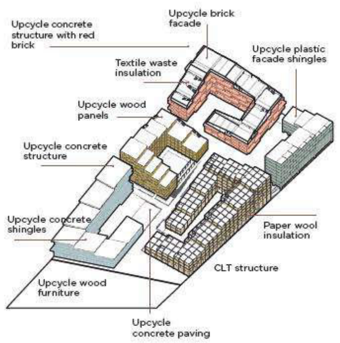
Incorporates CLT as a carbon negative material as well as locally procured and upcycled building materials.

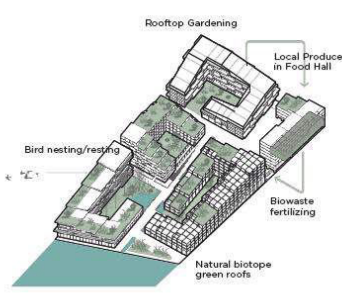
BIO

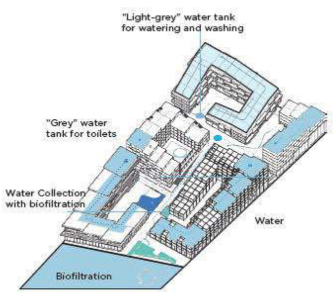
Provide a regenerative landscape with wind and drought tolerant local species, low maintenance needs and improval of bio-diversity on site.

WATER

UN17 expects to anually collect up to 1.5 million liters of water, which is recycled and used for irrigation and recreational uses.







ILLUSTRATIVE CASE:

Regenerating disadvantaged neighborhoods

TINGBJERG REGENERATION

A holistic and collaborative approach

PROPERTY SUMMARY

Residential development
Location **Tingbjerg Copenhagen**
Construction year **2020-2024**
Units in total **1000**
NLA total **~100,000**
NLA phase 1 **~20,000**
Investment phase 1 **€46 million**
Investment cost/SQM **€2,333**

In 2019, NREP signed its first investments in the urban regeneration plan for the Tingbjerg area in Copenhagen

BACKGROUND

- Tingbjerg is a thriving low income neighborhood in Copenhagen. People do want to live here, but all stakeholders agree that there is a need for a more holistic approach in order to set Tingbjerg on a positive path of upward social mobility
- 2,300 apartments today with 7,000 people on waiting list
- Tingbjerg is experiencing strong demand for better quality living than the existing housing in the area, which is old and 100% social housing
- Infrastructure limited and retail locations are suffering due to low density

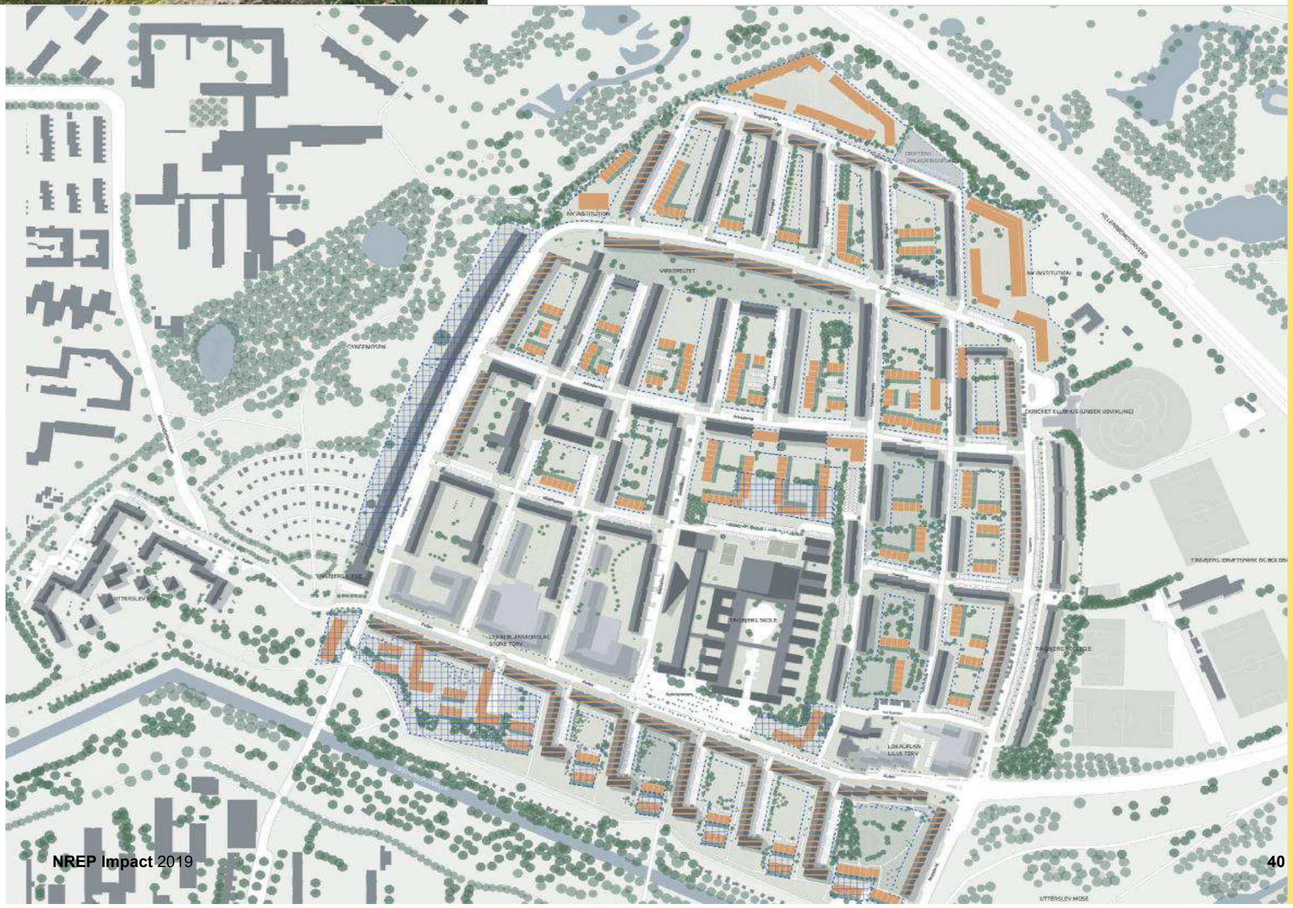
THE PROJECT

- NREP formed a unique development partnership with the municipality and the two municipal social housing companies that own all buildings and land in the area
- NREP will primarily be developing new homes to allow for upward social mobility in the area
- In order to take a holistic approach to create a positive vibrant street level life in the neighborhood, NREP controls the required retail in the area
- The municipality is committed to investing in infrastructure, access roads, light-rail, improved social services etc.

Multiple levers for neighborhood regeneration

engaging multiple stakeholders in collaboration

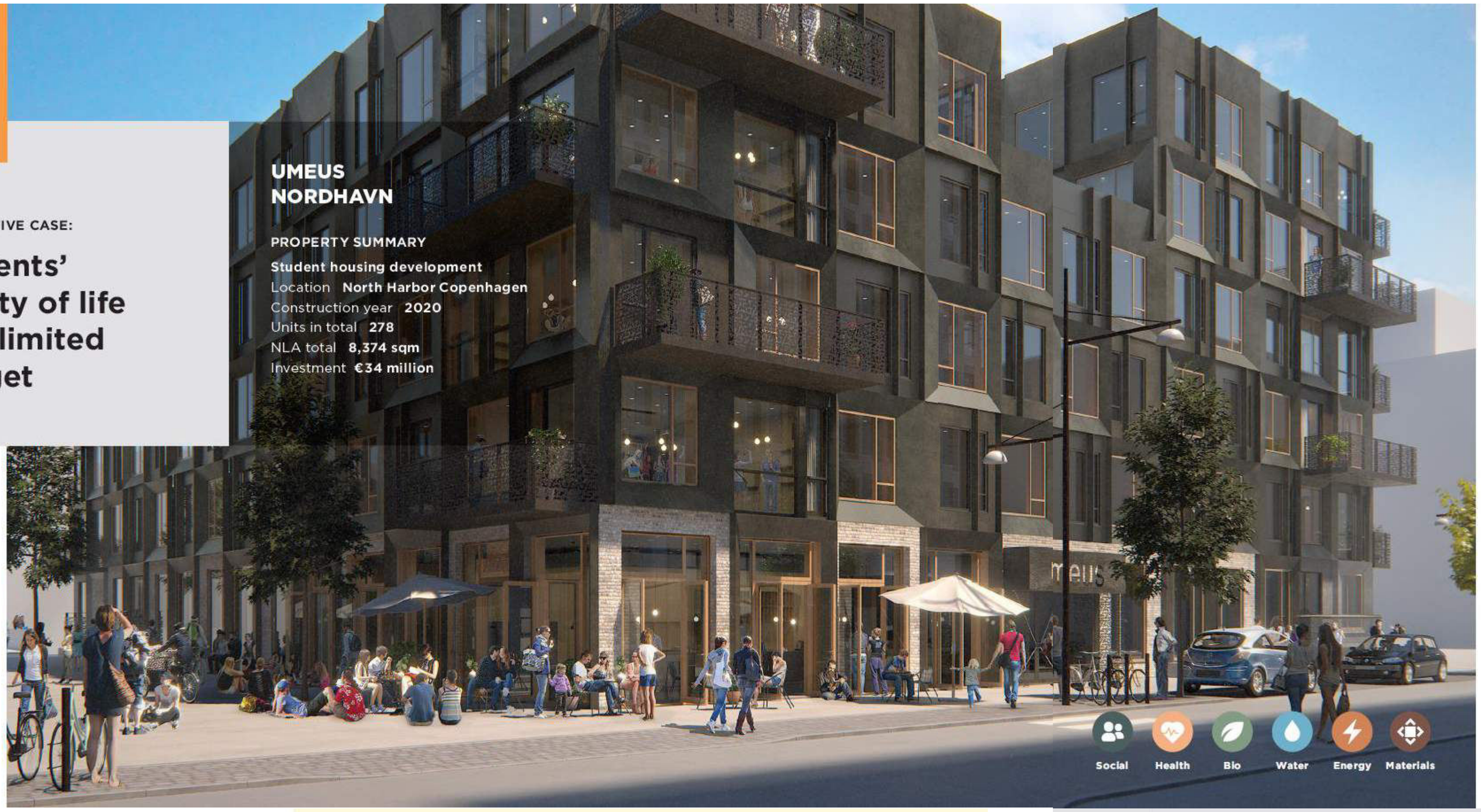
LEVERS	
Improve infrastructure	✔ New roads/bike trails to Brønshøj/Husum
New functions	✔ New culture hall and artist studios
Conversion of outside areas	✔ Breakdown and remodel open areas
Mix housing and ownership	✔ Full ownership row houses
Renovation and upgrades	✔ Ongoing renovations Improv. outdoor areas
Physical and social effort	✔ Ongoing social effort from KAB/fsb
Private/public sphere change	✔ Breakdown and remodel open areas
New communities	✔ Community promoting concepts
Diverse area boundaries	✔ Access ways to adjacent areas
Branding	✔ New neighborhoods and communication
Demolition	✔ Select buildings on the main street and western part
Attractions	✔ Ongoing discussions



11 SUSTAINABLE CITIES AND COMMUNITIES

ILLUSTRATIVE CASE:

Students' quality of life on a limited budget



UMEUS NORDHAVN

PROPERTY SUMMARY

Student housing development

Location **North Harbor Copenhagen**

Construction year **2020**

Units in total **278**

NLA total **8,374 sqm**

Investment **€34 million**

In 2019, NREP started construction of UMEUS Nordhavn, affordable student co-living in a prime central waterfront location in Copenhagen

UMEUS

BACKGROUND

- Students struggle to find access to affordable student housing in all the Nordic capitals and main university cities, and much of the existing stock is outdated and run down. In Copenhagen, there is student housing available for less than 20% of the student body.
- Working in close dialogue with municipality and other stakeholders to enable offering students higher quality living at an affordable monthly cost, NREP is developing the UMEUS Nordhavn project at a prime waterfront location
- The site is located at the waterfront in the exclusive Aarhusgade neighborhood next to some of the most expensive residential in all of Denmark
- Seller of the plot was By & Havn (the state and municipality owned land-holding entity responsible for the strategic development of Copenhagen), which NREP has a strong relationship with through several projects

THE PROJECT

- Highly efficiently designed and furnished rooms and common areas to maximize the 'user value' to cost ratio
- Other facilities include (non-exhaustive): reception, entertainment lounge, quiet study zone, group rooms, fitness, laundry, roof terrace, etc.
- Key levers to enable affordability included:

(a) flexibility by authorities to allow increasing the number of units from less than 100 to 277;

(b) highly efficient unit design; and

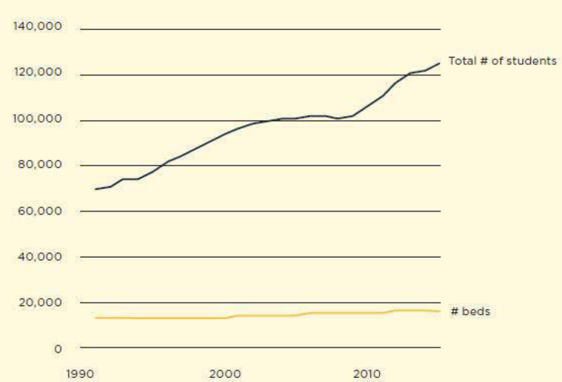
(c) acquisition on favorable terms conditional on student housing use

A structural challenge

A STRUCTURAL CHALLENGE

- Student housing only available for 20% of the student body in Copenhagen
- Existing offering is mostly outdated and run down
- The student body has grown faster than new supply
- Nordic students live on limited budgets based on the government provided grants/funding, making regular studios too expensive
- Students indicate lack of access to housing as the main cause of stress and poor quality of life
- Students currently deselect Copenhagen due to high cost of housing
- Poor/unstable living conditions impact academic results

Supply of purpose built student accommodationonly covers only a fraction of the demand



1. What students want?

(conditional on absolute limitation of budget – NREP surveys and research)

AFFORDABLE RENT IS PRE-REQUISITE	COMMUNITY IS KEY	THE JOINT KITCHEN IS IMPORTANT	LOCATION MUST BE IN THE CITY	THE ROOM IS LESS IMPORTANT	REPUTATION

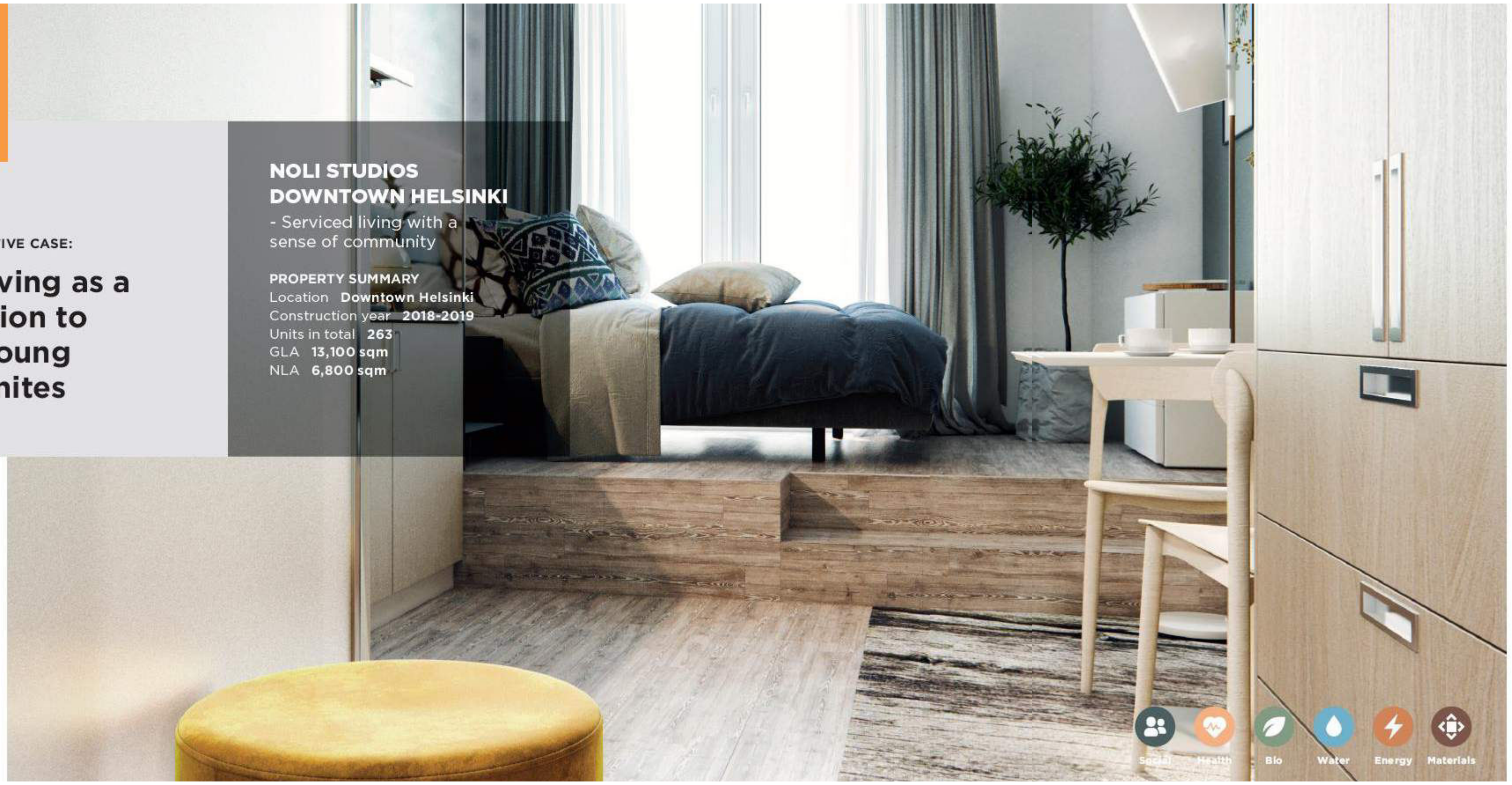
2. How can we provide higher quality housing within limited budget?

UNDERSTAND STUDENT PREFERENCES	OPTIMIZE DESIGN AND PRODUCTION	STAKEHOLDER COLLABORATION TO ENABLE BETTER PRODUCT FOR STUDENTS
Emphasis on community rather than large private space allows changing the value equation	Relentless pursuit of optimizing solutions and maximizing the 'user-value: cost' ratio	Partnering with municipality, university, student unions etc. to jointly identify solutions, thus achieving flexibility on rezoning, terms and unit size regulations

Serviced student co-living concept adapted to Danish students' preferences to maximize quality of life within limited disposable income levels

ILLUSTRATIVE CASE:

Co-living as a solution to for young urbanites



NOLI STUDIOS DOWNTOWN HELSINKI

- Serviced living with a sense of community

PROPERTY SUMMARY

Location **Downtown Helsinki**
Construction year **2018-2019**
Units in total **263**
GLA **13,100 sqm**
NLA **6,800 sqm**

NOLi Studios

In 2019, NREP opened the first Noli Studios site in downtown Helsinki

BACKGROUND

- More and more people are moving to Helsinki, but there is a limited supply of flexible yet affordable accommodation for young urban professionals
- By making significantly more efficient use of space with smart studio design and actively managed shared spaces and services, Noli Studios is able to offer flexible, affordable high quality living with an opportunity to be part of a community

THE PROJECT

- Located in a highly regarded residential and commercial area close to Helsinki CBD and prime waterfront; ideal location for serviced living
- The asset is a former office building suitable for conversion
- Sustainability as a key criterion for building operations. Initiatives range from using 100% green electricity to recycling, minimizing plastic waste and being able to compensate for the CO2 footprint of one's home.

Noli Studios provides young professionals an affordable and flexible home with extensive services and a sense of community

UNDERSTANDING THE STRUCTURAL CHALLENGES

- Urbanization with more people moving to Helsinki
- Hard to find an affordable place to stay and to have a community to relate to
- Share of employees in temporary and part-time contracts has increased to almost 1/3
- Many people need flexible living, but the typical minimum duration for rental contracts is 12 months
- The few existing serviced apartment players are serving companies and have too high prices for private individuals

GATHERING INSIGHTS

- Based on a local "Future living trends" study conducted by NREP, the most important themes will be flexibility in living, co-living and sustainability.
- Benchmarking and site visits of co-living concepts and serviced apartments
- Joint ideation and concept development with leading architects and interior designers
- Active dialogue with the municipality

DESIGNING SOLUTIONS

Community

- Shared dining, gym, office and lounge areas allowing for natural encounters
- Hosts organize community activities in collaboration with our partner network

Services

- Restaurant, working and meeting spaces, gym and sauna
- Bi-weekly cleaning-service included in the studio price
- Staff available daily to support guests and to organize community events
- Shared resources: bikes, utilities, car sharing service

Flexibility & Pricing

- Pricing comparable to regular studio but with extensive services
- Fully flexible bookings
- No deposits or down payments

Sustainability

- Efficient use of space and shared resources. Easy recycling opportunities
- 100% green electricity
- CO2 footprint compensation

3 GOOD HEALTH AND WELL-BEING

ILLUSTRATIVE CASE:

Mixed generation co-living

PLUSHUSENE NÆRHEDEN

PROPERTY SUMMARY

Residential development
Location **Høje Taastrup**
Construction year **2019**
Units in total **138**
Plot size **18,500 sqm**
GLA total **~12,240 sqm**

In 2019, NREP started construction of Plushusene mixed-generation development in Naerheden, Copenhagen

PLUS HUSENE

BACKGROUND

- Plushusene seeks to solve the most important challenges in the daily life of active seniors (e.g. loneliness and inadequate housing) and young families (e.g. stress and prioritizing the children) by providing efficient modern rowhouses and apartments in a sustainable co-living community, enabling connectednes, and convenience in a multi-generational environment

THE PROJECT

- The project in Nærheden was sourced through dialogue with the municipality and Realdania, a member-based philanthropic organization that supports projects in the built environment
- Immediate access to commuter train station and a 20-minute commute from Copenhagen city center
- Together with Lendager and SLA Architects, a unique co-living community has been designed. The site consists of 138 units, being a mix of row houses and apartments, and a large common house
- DGNB Gold
- Designed to minimize maintenance, ensuring residents will have a hassle-free daily life
- The 600+ sqm common house has a large area for communal dining, a lounge area, a gym hall, fitness center and guest rooms. The common house will be a natural extension of the residents' own homes – this is the place people will meet on a daily basis for dinner and activities based on shared economy principles

Multi-generational community brings benefits to both seniors and young families

UNDERSTANDING THE STRUCTURAL CHALLENGES

ACTIVE SENIORS

- Seniors 55+ make up 30% of total population and accounts for 93% of growth in Denmark until 2030.
- Increasing loneliness among seniors
- 74 percent of seniors prefer to live in areas with mixed age groups to ensure a lively atmosphere,
- Many seniors are living in inadequate housing with high maintenance responsibility.
- Seniors seeking more socially connected co-living/co-housing options do not find any supply

YOUNG FAMILIES

- Many families are living in areas that aren't conducive to child health, development and well-being
- Majority of families report that they are stressed due to daily hassle with practical tasks and inadequate quality time with their children.
- New government regulations make it difficult for families to afford buying a row-house in close proximity to Copenhagen and Århus.
- Limited supply of newly built sustainable private rental row-houses at affordable price level.
- 89 percent of families prefer living in areas with neighbors from mixed age-groups

GATHERING INSIGHTS

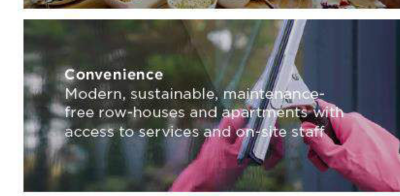
- Surveyed 8,000 seniors and 2,000 families
- Multiple in-depth focus group studies
- Close consultations with US senior housing experts, operators, anthropologists, architects, senior citizen associations, etc.
- Site visits to established Danish co-living communities
- Engaged top tier strategy consultants in healthcare, public sector and real estate
- Teamed up with leading architects and contractors to ensure high quality design
- Hired top-CEO from entertainment industry (amusement park) to design and run daily operations

DESIGNING SOLUTIONS

- Providing access to a community and variety of activities. Plushusene help engaging lonely seniors. Studies show that 91% of people living in co-living residential has experienced an increase in the quality of life
- The maintenance free units and access to services such as cleaning and gardening leads to seniors having a more hassle-free daily life
- Carefully designed efficient units allow seniors to rent an apartment or one-story row house at an affordable price-level
- Plushusene is bringing generations together

- A safe co-living environment leads to children being more "socially mature, confident, outgoing, competent, and verbal than their non-community counterparts"
- The convenience concept of Plushusene includes communal dining and arranged activities for residents, leading to parents having more quality time with their children.
- Plushusene's units are priced at a level that enables average young families to rent a two-story row house with private garden and 3 bedrooms

3 KEY PRODUCT CHARACTERISTICS



ILLUSTRATIVE CASE:

Housing a growing elderly population

3 GOOD HEALTH AND WELL-BEING

ALTURA MASMO STOCKHOLM

- Addressing the increasing social challenge of an ageing population

PROPERTY SUMMARY

Care home development
Location **Masmo, Huddinge Municipality** (greater Stockholm)
Construction year **2019-2022**
Rooms in total **79**
NLA total **~6,100**
Investment **€26 million**

Addressing a structural challenge

- Almost half of Sweden's 290 municipalities are already today reporting a shortage of care home apartments
- 1/3 of the total population growth until 2030 is driven by the 80+ age group, which will increase by more than 50% until 2030
- Furthermore, the current care home stock is often outdated from a working force as well a resident perspective, causing personnel being spread too thin, having too little time to give quality care to residents
- Historically, municipalities have built new care homes on one-off bespoke basis, often at a high cost due to that a lack of the necessary specialist expertise resulted in a need for mid-process changes to specifications
- There is a large need to accelerate the build-out pace and improve production design and efficiency, but there are also clear opportunities to significantly optimize and standardize production processes

GROWING AGING POPULATION

+

IMMEDIATE SHORTAGE

+

REPLACEMENT OF EXISTING CARE HOMES

In 2019, NREP started construction of the Altura Masmo care home in Stockholm

ALTURA

BACKGROUND

- Lack of access to assisted living in many Nordic municipalities is causing physical and mental health problems for the elderly in need
- In Sweden, the age group +80 will increase by more than 50% by 2030 and already today more than 40% of municipalities report immediate shortage of care home beds
- Huddinge Municipality, bordering Stockholm City, had a large need for care home apartments and also faced an issue with land plots being handed back in the recent residential decline in Sweden
- Working in collaboration with key stakeholders (developer, operator and municipality) Altura managed to turn a struggling residential development into a successful 3D parcelled care home and condominium project

THE PROJECT

- Altura customer centric design such as higher than average ceiling height, cooling (important for elders during warm summers) etc.
- Optimisation of design and sqm usage to create more positive user experience, operationally efficient product for operators and economic sustainability
- Creating a mixed care home and residential project helped create a positive vibrant living environment for the elderly, solve an income issue for the municipality and unlock a struggling project for the developer

PARTNERING WITH MUNICIPALITIES AND OPERATORS TO PROVIDE BETTER CARE HOMES FOR LESS

Homelike living quarters

Evidence based design process, with a special focus on people with dementia

Peaceful and active garden

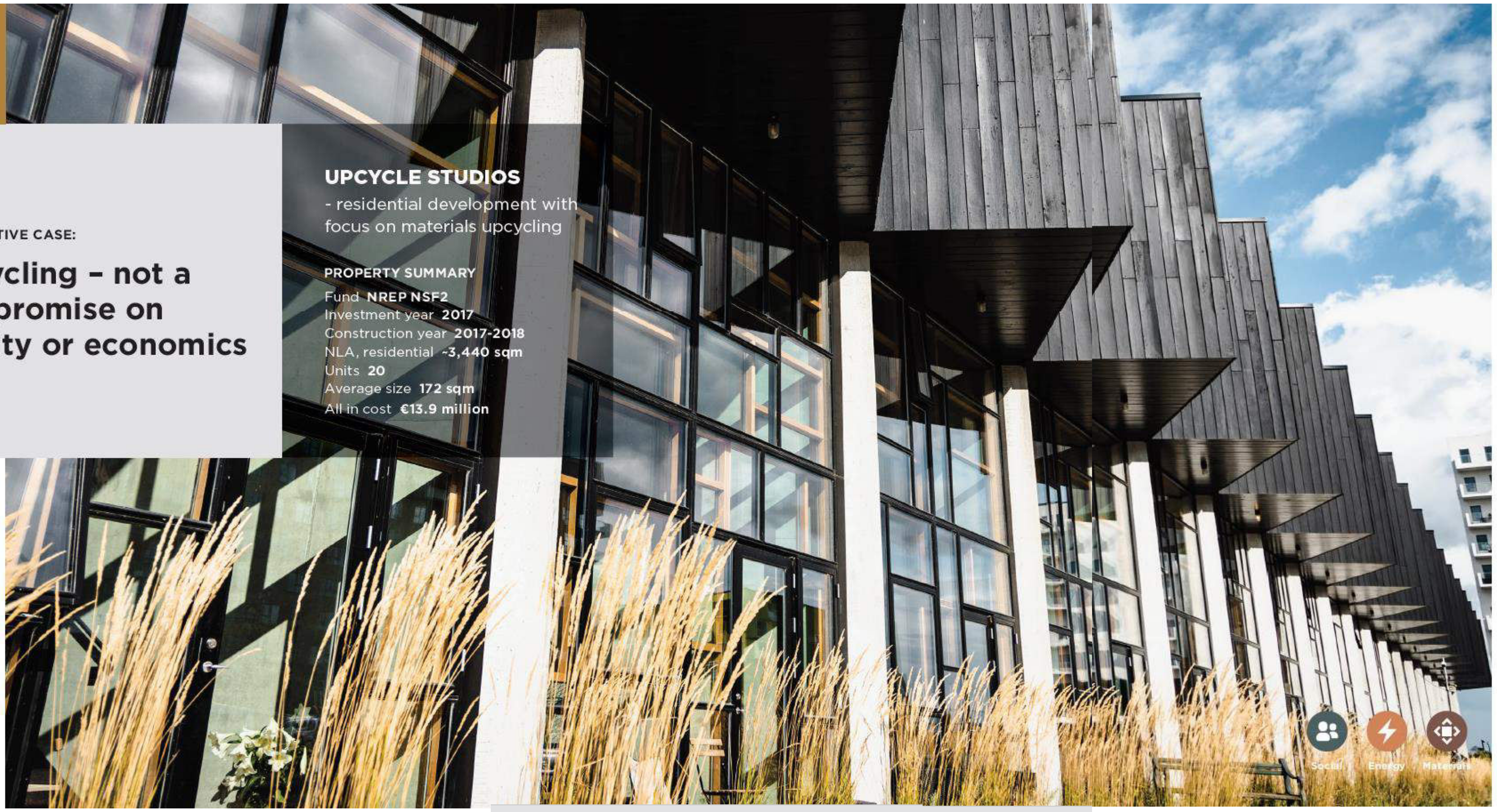
Research shows that greenery is beneficial for the health of residents

Financially conscious building

Optimized modular production and design, with layout that allow for optimized staffing levels

ILLUSTRATIVE CASE:

Upcycling – not a compromise on quality or economics



UPCYCLE STUDIOS

- residential development with focus on materials upcycling

PROPERTY SUMMARY

Fund **NREP NSF2**
Investment year **2017**
Construction year **2017-2018**
NLA, residential **~3,440 sqm**
Units **20**
Average size **172 sqm**
All in cost **€13.9 million**

In 2019, NREP completed the development of the pioneering Upcycle Studios in Copenhagen

BACKGROUND

- Real estate accounts for 40% of humanity's raw materials consumption[1] and 50% of the real estate sector's CO2 emissions are caused by the materials and energy used in construction
- In many parts of the Nordics, the embodied carbon makes up close to 75% of the full life-cycle CO2 emissions of new buildings
- Upcycling solutions to achieve more sustainability without compromising on quality or economics exist. But the first steps of change are challenging and changing production methods requires collaboration by private and public stakeholders along the full value chain
- Upcycle Studios was the first fully circular residential development, using upcycled solutions ranging from the concrete structure to the upcycled floors, wall cladding and windows

THE PROJECT

- Emphasis on materials upcycling, resource efficiency, energy efficiency and minimizing carbon footprint
- Facilitating sharing economy between residents, because the basic idea of access instead of ownership is embodying several essential aspects of sustainable development
- Designed for high degree of flexibility to ensure the best possible use of the homes at all hours of the day and in different phases of life. The units can be used as a combined housing and workshop for creative freelancers or self-employed entrepreneurs, but also as one dwelling for large families or divided into two separate apartments
- Project underwriting based on a conventional row house project i.e. sustainability actions had to be cost neutral or cheaper than conventional alternatives in order to be implemented in the final project
- Iterative process with suppliers and partners that initially had different views and constraints with regards to materials upcycling and sustainability

1 Source: Yahya, K.; Boussabaine, H., 2010

Upcycled materials
is not a compromise on quality

The interior of Upcycle Studios with upcycled concrete structure, upcycled wood floors and wall cladding, and upcycled windows - Processed by Lendager.

MATERIALS

Building waste today represents a huge untapped resource, which was exploited in the construction of Upcycle Studios.

Examples include:

- 75 percent of the windows come from abandoned buildings in North Jutland, Denmark
- 1.400 tons of upcycle concrete was casted from very durable concrete waste from the construction of Copenhagen Metro
- The wood for floors, walls and facades was produced of offcuts (i.e. would otherwise have been discarded as waste) from Dinesen, a high-end floor producer

ENERGY

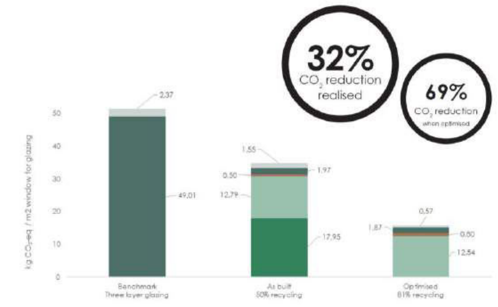
Through the design of the building envelope and use of efficient ventilation, heat recycling and solar technologies it is possible to lower the energy consumption for the operation of the homes.

SOCIAL

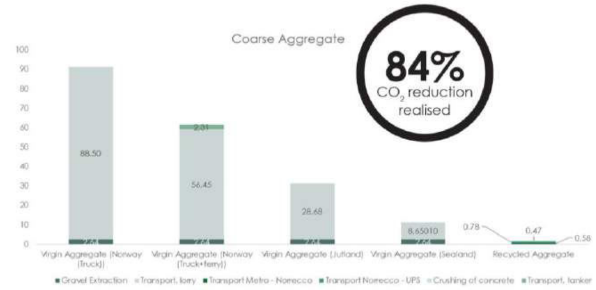
Communities are developing around the concept of sharing resources, which has the benefit of providing economic and social benefits for all parties.

UPCYCLE LCA RESULTS

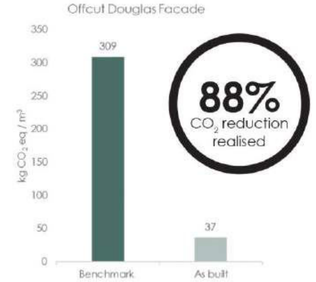
WINDOW PANES



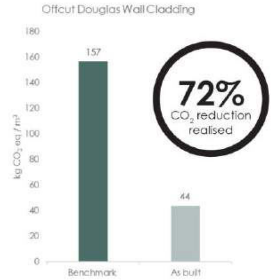
CONCRETE AGGREGATE



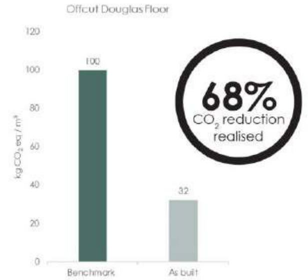
DOUGLAS FACADE



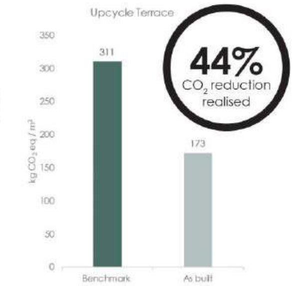
WOOD WALL CLADDING



DOUGLAS FLOOR



UPCYCLE TERRACE



12 RESPONSIBLE CONSUMPTION AND PRODUCTION

ILLUSTRATIVE CASE:

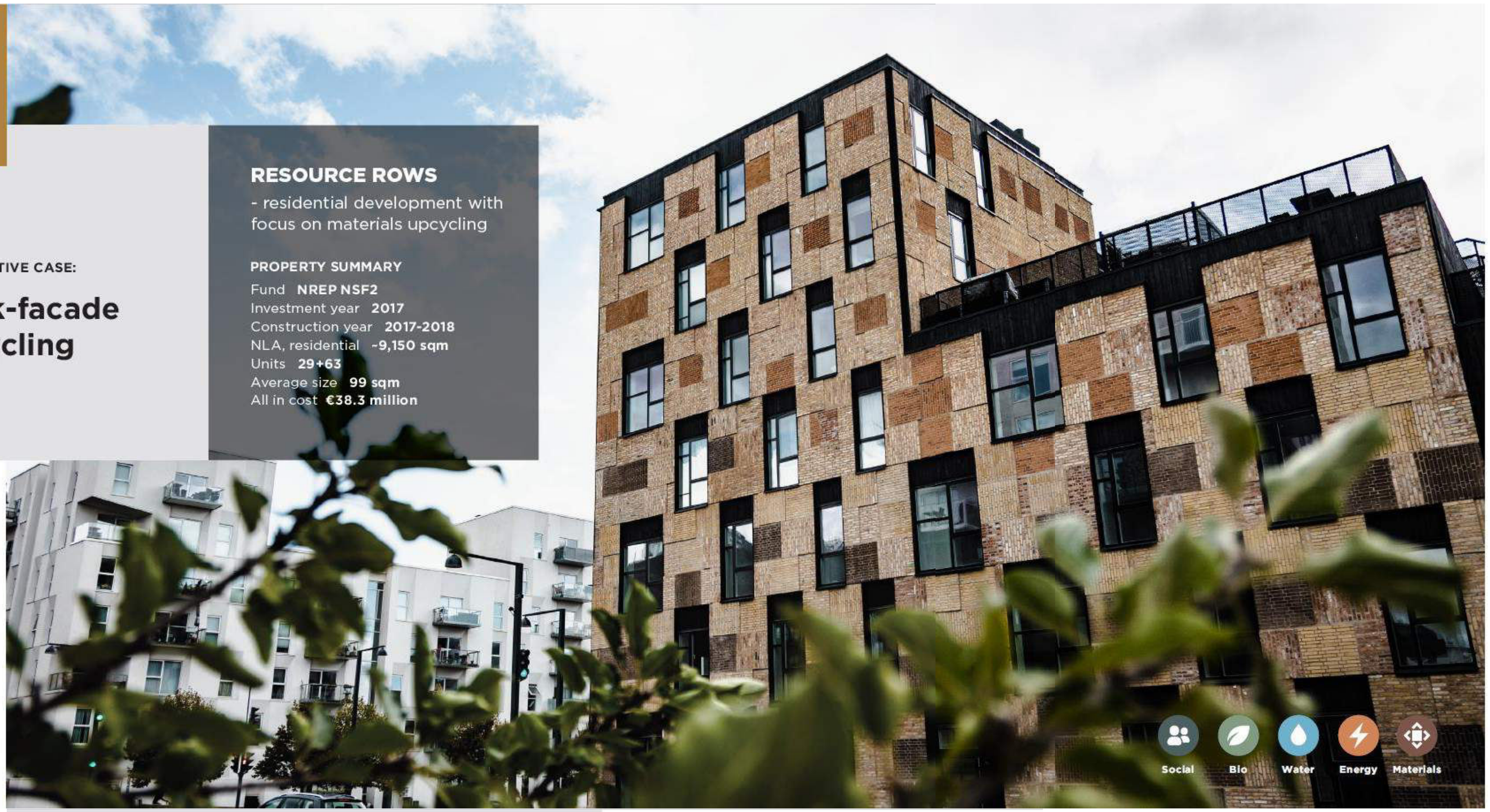
Brick-facade upcycling

RESOURCE ROWS

- residential development with focus on materials upcycling

PROPERTY SUMMARY

Fund **NREP NSF2**
Investment year **2017**
Construction year **2017-2018**
NLA, residential **~9,150 sqm**
Units **29+63**
Average size **99 sqm**
All in cost **€38.3 million**



Social – The Sharing Economy proves that it is practical to allow resources that are otherwise used only occasionally to be shared by people other than the owner. This provides an economic incentive to all parties involved and it brings neighbors together.

Bio – The integration of green infrastructure acts as a common thread throughout the settlement, with large bio-diversity green areas and 800 sqm for growing food.

Water – Reuse of water is an important part of Resource Rows' identity. For non-potable uses, tap water is replaced with rainwater that is collected from solar cells and other unused "clean" roof surfaces. This results in economic savings on utility costs for the residents.

Energy – Design of the building envelope and use of efficient ventilation, heat recycling and solar technologies lower the energy consumption required for the operation of the homes.

Materials – Building waste today represents a huge untapped resource, which was exploited in the construction of The Resource Rows. By reusing the walls from the abandoned dwellings as new facade elements, CO2 and use of materials were minimised, while also getting a new building with history and character from day one. One example in this project, is the upcycle bricks from the historical Carlsberg-breweries.

BRICKS FROM THE HISTORICAL CARLSBERG BREWERIES

Since the 1960s it has no longer been possible to recycle individual bricks, because the mortar is stronger than the actual brick. The bricks for The Resource Rows are thus cut out in modules, processed and stacked to create the new walls of the new building. This innovative approach makes it possible to recycle bricks and give them many lives instead of just one, which results in a reduced CO2 emission in the construction phase.

Lendager ARC and Lendager UP have in collaboration with Carlsberg Byen cut out brick modules from Carlsberg's historical breweries in Copenhagen. The rest of the bricks for The Resource Rows come from various old schools and industrial buildings around Denmark.

In The Resource Rows we also used upcycled wood from the construction of the Copenhagen Metro. Lendager sourced and processed the third party wood waste to turn it into both beautiful and sustainable materials in the project's facades and interior.

In 2019, NREP completed the development of the upcycling project Resource Rows in Copenhagen

BACKGROUND

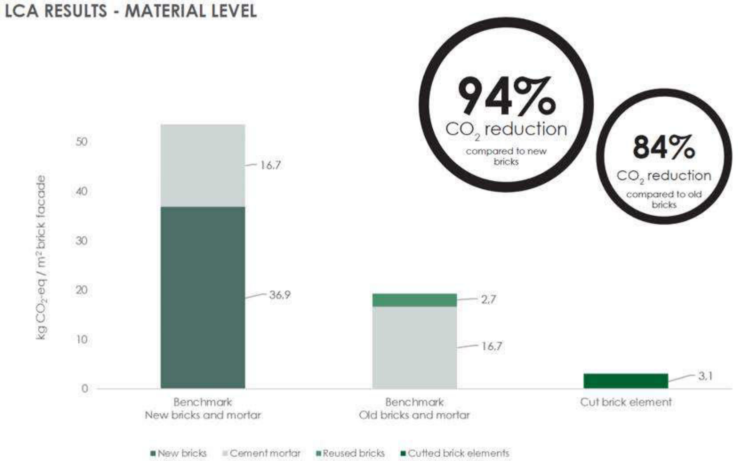
- Real estate accounts for 40% of humanity's raw materials consumption1 and 50% of the real estate sector's CO2 emissions are caused by the materials and energy used in construction
- With the Resource Rows project, Lendager and NREP strived to challenge and investigate what a thorough understanding of resources can bring about in terms of value and quality for new constructions

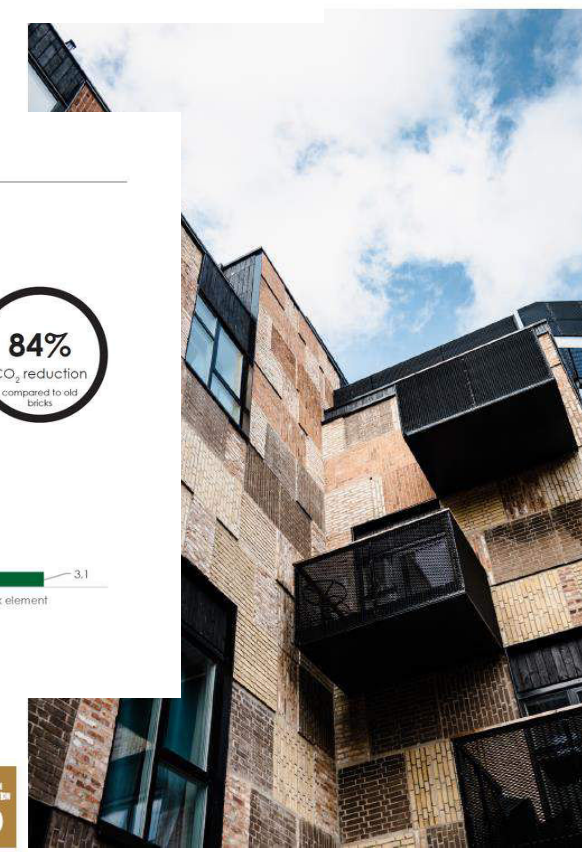
PROJECT PROFILE

- Residential rental project comprising 29 row houses and 63 apartments in Ørestad, an increasingly popular location of Copenhagen with green areas, good access to public transportation and biking distance to downtown Copenhagen
- Resource efficiency and optimization formed the underlying concept of the project
- Project underwritten based on a conventional row house and apartment project i.e. all sustainability actions had to be cost neutral or cheaper compared to a conventional solution in order to be implemented in the final project
- Iterative process with suppliers and partners that initially had different views and constraints with regards to materials upcycling and sustainability

UPCYCLE BRICK WALL

LCA RESULTS - MATERIAL LEVEL





12 RESPONSIBLE CONSUMPTION AND PRODUCTION

ILLUSTRATIVE CASE:

Wood core construction and pioneering hybrid solar/geothermal net-zero energy solution

NORRA VITSIPPAN, SALEM
-residential project with focus on sustainability and modularization

PROPERTY SUMMARY
Fund: **NSF4**
Transaction year: **2019**
Completion: **2021**
NLA residential: **6,356 sqm**
Units: **108**
Average size **59 sqm**
Purchase price incl. development cost: **€ 25.3 million**
Equity: **€ 8.1 million**

The Vitsippan wood core modular residential project outside Stockholm pioneers a unique combination of geothermal, solar collectors and solar cells to achieve both low embodied carbon and net-zero energy consumption

Background

- 40% of the energy consumption in Europe can be related to the construction sector
- Prefabricated construction modules in wood can help reduce the carbon footprint of buildings
- By combining efficient envelopes and modern HVAC and renewable energy technologies, net-zero energy consumption can be achieved locally in multifamily developments

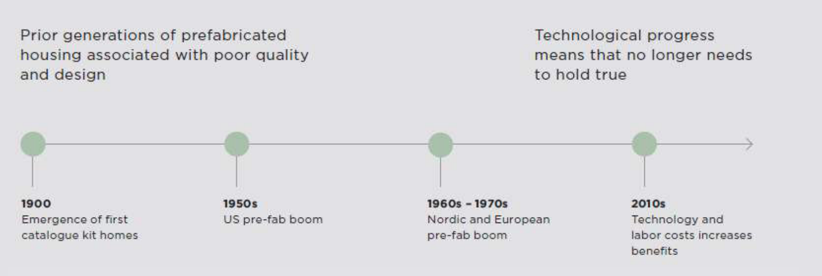
The project:

- Development of 7 multifamily buildings and a total of 108 apartments in Salem, a small family-friendly commuter suburb 30 minutes outside of Stockholm
- The project uses modern modular construction in wood to reap the benefits of industrialization and sustainable materials
- The project reaches net zero energy partly though a hybrid solar and geothermal system where high temperatures from solar collectors on 3 buildings are stored and utilized to increase the temperature from geothermal as well as for warm water production
- To fully reach net-zero, solar cells on 4 buildings produce electricity used in operation and apartments. Excessive electricity production is sent out to the grid
- A flexible number of electric car chargers to correspond with future demand
- The project is a forward purchase

Modern modular is an opportunity for the future

- New materials, technology and logistics enhance design, quality and cost

DESIGN	More upfront design that will go faster as designs are repeated
FOUNDATION	Same process but done in parallel with offsite manufacturing of modules
OFF-SITE MANUFACTURING	Enhanced safety and productivity due to closed, repeated and predictable work climate in factory with less waste, rework and pollution
ON-SITE ASSEMBLY	Fast assembly possible with little or no MEP personnel coordination on site with less noise, dust and transportations

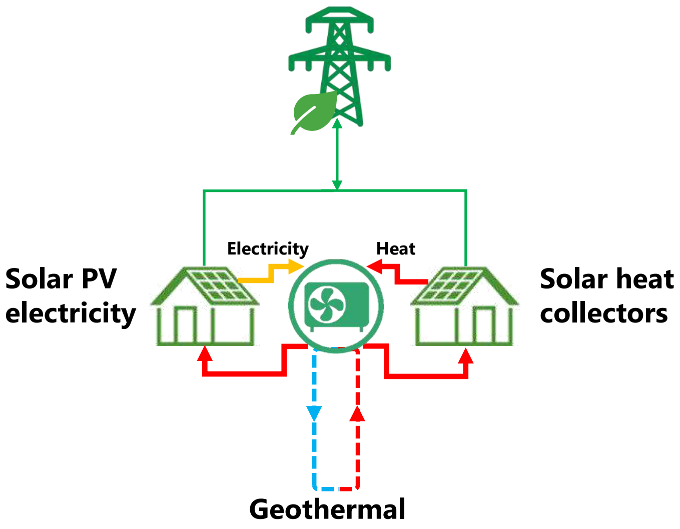


Source: McKinsey Report – Modular Construction: From projects to products (June 2019)

Hybrid solar PV, solar heat & geothermal

- Combining solutions for net-zero energy

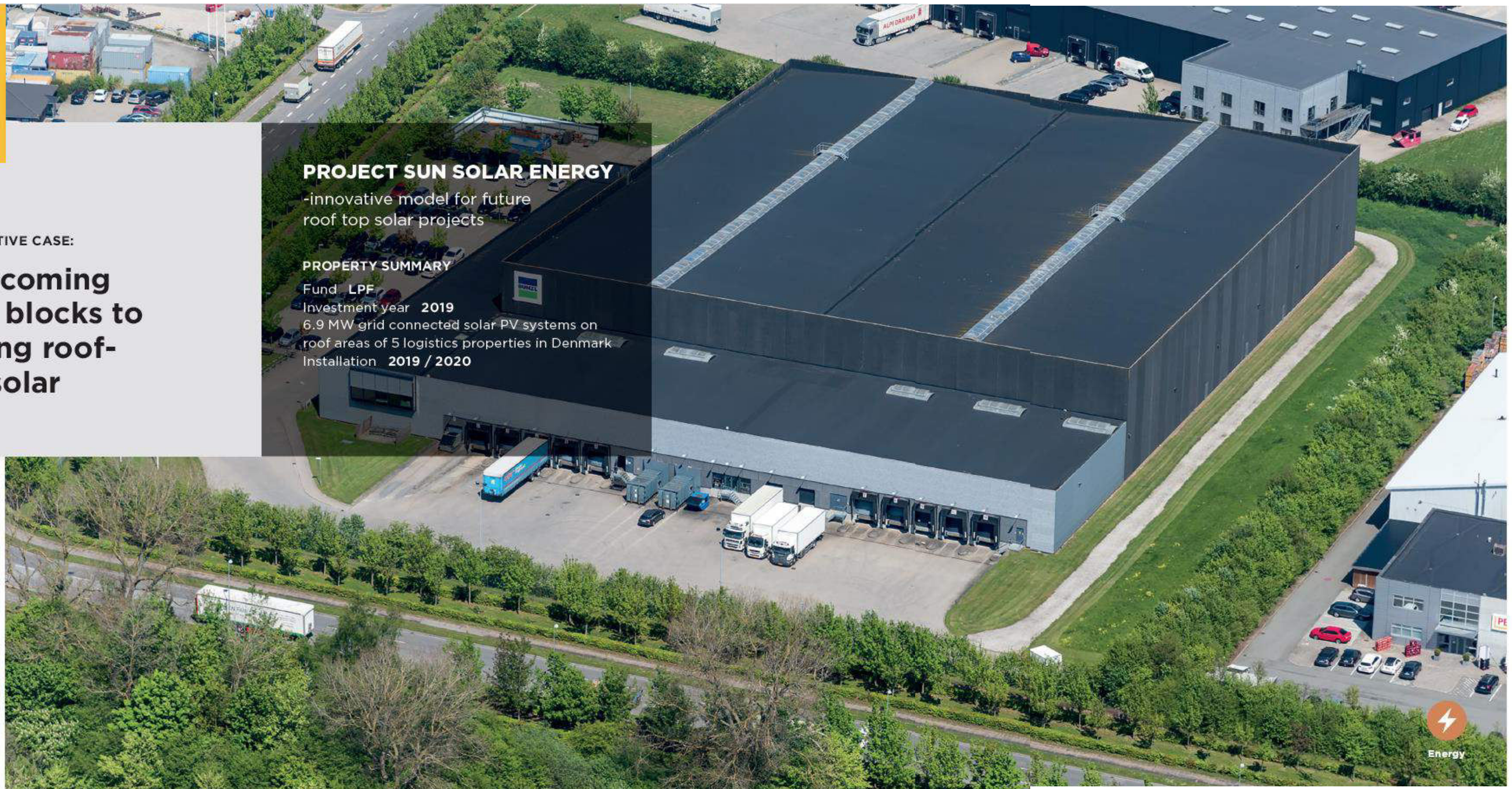
- High temperatures from the solar collectors are stored directly in the water/brine heat tanks. For 7-8 months a year solar heating alone manages to heat the storage tank above 60ºC without supplementary energy from the heat pump.
- When the heat pump is operating it uses local solar PV electricity to the extent possible combined with preheating of the brine fluid from the solar heat collectors before it enters the heat pump
- When the warm water/brine storage tank is fully heated, solar heat is being used to recharge the borehole or ground loop. In this way the temperature recovers in the energy storage faster and results in increased efficiency of the heat pump.
- Potential to improve efficiency to up to 2X conventional ground source heat pump



7 AFFORDABLE AND CLEAN ENERGY

ILLUSTRATIVE CASE:

Overcoming road blocks to scaling roof-top solar



PROJECT SUN SOLAR ENERGY

-innovative model for future roof top solar projects

PROPERTY SUMMARY

Fund **LPF**
Investment year **2019**
6.9 MW grid connected solar PV systems on roof areas of 5 logistics properties in Denmark
Installation **2019 / 2020**

In 2019, NREP started the construction of Denmark's first grid connected commercial rooftop solar system on five of its logistics properties

BACKGROUND

- Misalignment of the allocation of benefits, risks and investment burden among key stakeholders is a major hurdle preventing scaling up grid-connected roof top solar on commercial buildings in Denmark
- NREP was looking for ways to use more roof surfaces for solar generation and thus set out to collaborate with other stakeholders to identify solutions to the problem, eventually structuring an innovative SPV ownership structure that can pave the way for future projects where real estate landlords can lease roof areas to solar developers

PROJECT PROFILE

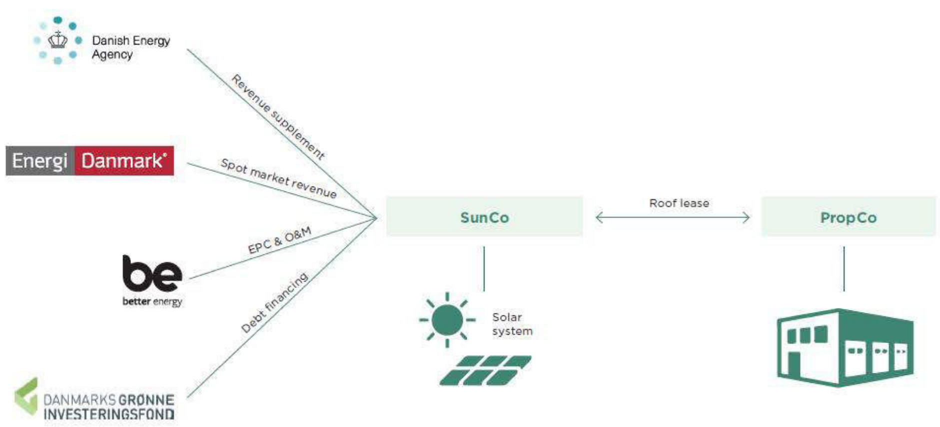
- Denmark's first grid connected rooftop solar system
- 6.9 MW grid connected solar PV systems on roof areas of 5 logistics properties in Denmark
- Tier 1 panels and well proven industry standard components
- Installed on fixed price turn-key contract with leading Danish supplier, Better Energy
- Expected asset life of 20-30 years
- Warranted production of 5.9 GWh per year
- Revenue supplement of 149 DKK/MWh for 20 years from The Danish Energy Agency
- 5 year fixed price operations agreement with performance guarantee and product guarantees with Better Energy
- CO2 emissions reduction of >2.000 tons per year

Project Sun
New ways to partner

Misalignment of incentives, benefits, risks and investment burden is a key hurdle preventing scaling up grid-connected roof top solar on commercial buildings in Denmark.

One solution to address the misalignment is to separate the ownership, investment burden and risks of the solar energy assets from the ownership of the real estate asset, where solar developer lease roof areas. The innovative solutions to the incentives and ownership structure that NREP, energy industry partners and public entities crafted can serve as a model that paves the way for future scaling up.

- SunCo signs long term roof leases with relevant properties "PropCo's"
- SunCo sells power in the wholesale market (NordPool) via a broker
- SunCo is financed by the Danish Green Investment Fund



ILLUSTRATIVE CASE:

Local deep geothermal zero emissions heating

KOSKELONKUJA DEEP GEOTHERMAL

- Logistics development with pioneering zero emission heating

PROPERTY SUMMARY

Fund **NSF3**
1 deep geothermal well
Heat capacity for **20,000 SQM** building+extensions
Transaction year **2019**
Construction year **2019**
Total investment **€500 000**
Upfront government subsidy of **50%**
Annual savings **€65,- 75,000**
Pay-back **7-8 years**

In 2019, NREP completed a pioneering medium deep geothermal (2000m) zero emissions heating system at its Koskelonkuja logistics property

FOCUS TOPIC - DEEP GEOTHERMAL FOR AFFORDABLE AND EMISSION FREE HEAT

- Medium deep geothermal heat production enables near zero-emission heating and cooling for larger multi-family or commercial real estate projects in places where it is otherwise not possible to achieve low-emission power generation, such as in dense urban areas
- In Finland, deep geothermal offers the potential to achieve a 95% reduction in CO2 emissions and a 20% reduction in energy cost compared to typical district heating
- Advances in drilling technology and heat extraction method makes it possible to utilize 2km wells with sufficient high temperature to meet the water temperature needs of end-user infrastructure, i.e. 40 °C
- Collector pipe is Vacuum Insulated Tubing, allowing close to zero heat loss
- Local geothermal systems only need to provide heat at end-user system temperatures of around 40 °C, in contrast to the very high temperatures required by district heating systems, and as such it is enough to drill to only 2000 meters depth to reach sufficient temperatures
- Industrial size and efficient heat pump system close to end user makes waste heat recovery economical and practical

ILLUSTRATIVE EXAMPLES:

Logistics Property Environmental Sustainability Opportunities

Behavioral change: We advise our customers to make them aware of opportunities and help them achieve their specific environmental goals. Our properties are linked to the energy measurement system Mestro, that enables the tenant to track the hourly energy consumption and optimize its operations

Case deep dive:

Upcycling

SUSTAINABILITY

UPCYCLE STUDIOS & THE RESOURCE ROWS

SEPTEMBER 2020

NREP

LENDAGER GROUP

MOE

EXECUTIVE SUMMARY

LCA AND LCC ON UPCYCLE STUDIOS AND THE RESOURCE ROWS

SUSTAINABLE BUILDINGS

In 2015 NREP embarked on two significant sustainable housing projects in Copenhagen with a particular focus on resource optimization and reduction of embodied CO_2 through the use of upcycled building materials within a conventional budget for new constructions: Upcycle Studios and the Resource Rows.

This report presents a summary of the post-completion LCA and LCC analysis of the upcycle materials and the overall building projects. The analyses were conducted as part of the efforts to understand to what extent the specific upcycling solution employed achieved the intended outcomes compared to comparable new materials and to capture the learnings from these projects for the benefit of future projects.

LCA RESULTS

Despite significant first-time production challenges and project-specific limiting preconditions, the LCA demonstrated significant savings largely in line with expectations based on prior projects and testing. At product level the CO_2 savings ranged between 5-8% for concrete, 38% for brick walls, 44-88% for wood products and 87% for windows. At building level the LCA indicated reduction of embodied carbon of 32% for Upcycle Studios and 12% for Resource Rows. At building level the learnings are less clear because several confounding factors and unrelated design decisions impact the aggregate building level CO_2 footprint.

LCC RESULTS

The upcycle products in general were higher priced than benchmark and due to the more complex first-time process there were additional indirect costs. However, while not being directly competitive on cost in the first production line (based on expenses for development), the results from the latter phases of the projects and the learnings for how to readily optimize processes and design in future projects indicate that upcycled windows, wood products and brick walls should be able to compete directly on market prices already in the next iterations.

LOOKING TO THE FUTURE

To identify what solutions that should be developed further and carried forward to future projects with the potential to scale, the analysis needs to look at applicability in other contexts and consider a broader set of factors. The LCA/LCC complemented with evaluation of additional factors indicate varying degrees of impact, complexity, scalability and cost competitiveness for the different upcycling products that were employed. Overall the results indicate that upcycling solutions indeed have potential and should be explored further by the real estate industry as one of the tools to improve its resource efficiency and CO_2 footprint.

Upcycle product or material	kg CO_2-eq/unit	% CO_2 saved	Total waste saved
Upcycle Brick Wall	49 kg CO_2-eq/m^2	38%	459 tonnes
Upcycle Windows	380 kg CO_2-eq/m^2	87%	7 tonnes
Upcycle Window Panes**	17 kg CO_2-eq/m^2	32%	-
Upcycle Concrete	28 kg CO_2-eq/m^3*	5-8 %	904 tonnes
Upcycle Concrete Aggregate**	9 kg CO_2-eq/m^3	84%	-
All Wood Products	127 kg CO_2-eq/m^3****	44-88%	7 tonnes

*Best case

** Upcycle material

*** Compared to new bricks

**** Average saving of all wood products

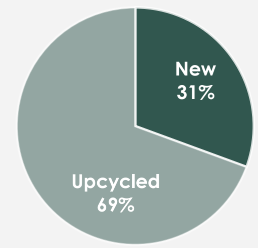
UPCYCLE STUDIOS

Embodied carbon: 32 % saving
Full lifetime: 45 % saving
8.08 kg CO_2 -eq/m² per year

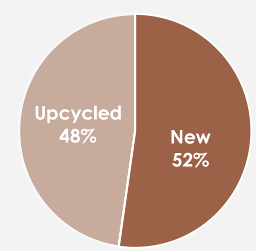
914 tonnes waste in total

Building operation per year:
72% saving
1.3 kg CO_2 -eq/m² per year

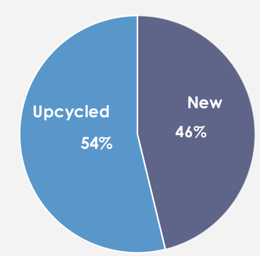
Material distribution by weight



CO2-eq distribution



Cost distribution



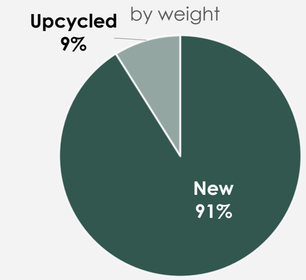
RESOURCE ROWS

Embodied carbon: 12 %
Full lifetime: 29 % saving
6.64 kg CO_2 -eq/m² per year

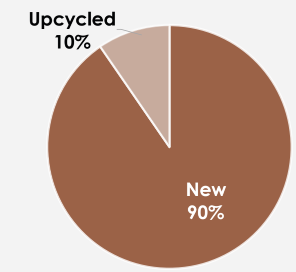
463 tonnes waste in total

Building operation per year:
48% saving
2.1 kg CO_2 -eq/m² per year

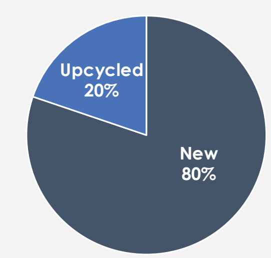
Material distribution by weight



CO2-eq distribution



Cost distribution



KEY LEARNINGS

TAKE AWAYS FOR FUTURE SUSTAINABLE PROJECTS

NEXT STEPS: UPCYCLE MATERIALS

We have achieved a positive environmental impact across upcycle materials in Upcycle Studios and Resource Rows already in first iteration, but the central question now is how we can build on existing learnings to improve environmental impact, decrease prices and scale upcycle solutions to achieve material impact.

Results from Upcycle Studios and Resource Rows demonstrate positive environmental impact across the upcycle materials employed in spite of first-production challenges. To increase future impact the central question is how we can build on these projects' learnings to create a path towards a future where improved upcycling solutions are adopted at scale and thus truly make a material difference.

- Sustainable value: CO_2 and waste optimization.
- Scalability: Potential for scaling solutions across projects
- Economy: Cost competitiveness (incl. maintenance).
- Risk: Sourcing of upcycle materials and performance of products
- Identity: Visualising the sustainable changes in projects to inspire others for change.

Based on the five evaluation parameters we find that the upcycle window and wood solutions employed have strong performance as is, while the brick and concrete solutions should be developed further to improve economy, risks and scalability.

NEXT STEPS: SUSTAINABLE BUILDINGS

The results from the LCA and LCC analyses show several impact categories across the lifetime of the building from the construction process to operations.

Looking at materials, we have a 32 % CO_2 reduction in Upcycle Studios and 12 % reduction in Resource Rows. Looking at both embodied CO_2 and CO_2 from operations across a 50 year lifetime we reach a 45 % CO_2 reduction in Upcycle Studios and 29 % in Resource Rows.

These numbers show clear gains from having a high focus on sustainability early in the design and construction process, but also a potential for increasing the impact further if we would have worked with specific impact measurements throughout the construction process.

For future projects we recommend repeating the use of upcycle materials to further reduce embodied CO_2 and waste creation while further minimizing CO_2 emissions through heat pumps, choosing sustainable materials, designing to minimize materials usage, working with raw materials to crate healthier indoor environments while easing future circulation potentials.

Find a none exhausted list of recommendations to increase sustainability in coming construction projects to the right.

	PARAMETERS OF IMPACT	Sustainable value 1 = Low & 5 = High	Scalability 1 = Low & 5 = High	Economy 1 = Low & 5 = High	Risk 1 = Low & 5 = High	Identity 1 = Low & 5 = High	Total score
MATERIALS	**BRICK**						
	Brick - As built	5	4	1	3	3	16
	Brick - New mounting	5	5	2	3	3	18
	WINDOW						
	Window - As built	5	5	4	4	4	22
	Window - Residential adaptation	5	5	3	4	4	21
	CONCRETE						
	Concrete	5	5	2	3	3	18
	WOOD						
	Wood indoor	5	5	4	5	5	24
	Wood outdoor	5	5	4	5	5	24

RECOMMENDATIONS FOR EFFORTS IN FUTURE SUSTAINABILITY BUILDING PROJECTS

BRICKS:

- Further develop upcycle brick solution as more traditional front brick wall based on cut out elements to improve process and results financially and environmentally.

CONCRETE:

- Optimize cement quantity for higher impact.
- Increase quantity in production to increased economic competitiveness.
- Use in hybrid constructions as core, floor separation, foundations, terrain deck etc.
- Source upcycle aggregate as close to construction project as possible from either infrastructure projects or demolitions.

WINDOWS:

- Increase amount of upcycle glazing (from 50% to a potential 81 %) to further improve impact and price.
- Scale upcycle window for commercial projects as replacement of traditional curtain walls.
- Develop format for residential projects achieving a 45 % CO_2 reduction compared to a wood/alu energy window.

WOOD:

- Facades and wood floors should be scaled.
- Wooden walls should be developed and implemented for healthier indoor climate, CO2 savings and CO2 storage.
- Replace concrete with wood where it makes sense (hybrid).
- Focus on minimizing wood treatment (heat treated / linseed oil).

- **Repeat:** Learnings from existing upcycle projects will lead to better impact and price, hereby raising the standard for sustainable construction and resource consumption going forward.
- **Increased focus on materials:** Optimise material usage by choosing the right sustainable materials for the right purposes.
- **Clear goals:** Be clear about the sustainable goals and use LCA and LCC throughout the process to achieve goals.
- **CO2 and material bank:** See constructions as a carbon bank postponing CO_2 emissions and waste production with up to100 years.
- **Strategic alignment:** Ensure upfront that your stakeholders and necessary actors are aligned with the vision and committed to a process that supports the sourcing and use of upcycling materials.
- **Active developer:** As the investor/owner the developer has the highest interest to succeed and needs to be active and involved throughout the process.
- **Identify and manage barriers up-front**: Regulations, site specific limitations or perceptions by key stakeholders.
- **Necessary scale:** The project specific nature of sourcing and production means that projects need to be of a certain size to achieve economies of scale and efficiency - the bigger the better (financially and environmentally).
- **Material access**: Gain continuous access to waste resource to ensure steady supply and scale is key.
- **Regulations:** Challenge the habits of the authorities, which far from always supports the sustainable choice.
- **Structures:** Use concrete where it makes the most sense, and replace with wood where possible. Optimize concrete constructions as much as possible by better design and choice of cement.
- **Minimize energy consumption:** to minimize biomass! Alternatively, be self-sufficient on electricity with e.g. heat pumps.
- **Minimize treatment:** Treat materials as little as possible to achieve a healthier indoor climate, less CO2 impact and easier circulation.
- **Certification:** Set requirements for certified construction, and set higher requirements for selected, important criteria.

TABLE OF CONTENT

CHAPTER 1
INTRODUCTION

PURPOSE

PURPOSE OF THIS REPORT

40 % OF THE WORLD'S CO_2 EMISSIONS & RAW MATERIALS CONSUMPTION
Currently, real estate is responsible for approximately 40 % of the global raw material consumption and 40 % of the worlds CO_2 emissions. Of new buildings, an average of approximately 50% of the life cycle CO_2 emissions is embodied carbon. Our raw materials consumption is not sustainable and if we are to reach the "below 2 degrees" goal of the Paris agreement and the Danish government's ambition of 70% reduction of CO_2 emissions by 2030, this has to change.

Addressing these complex challenges will require the industry to employ a broad range of solutions. Complementing other measures, one of the potential solutions is to increase the upcycling of existing waste materials that would otherwise have been discarded.

While the amount of existing and future waste material that could be upcycled into new construction is immense, upcycling practices will not scale until pioneering projects have tested and proven their economic and environmental merits. Upcycle Studios and the Resource Rows set out to employ a specific set of upcycled solutions for concrete, brick façades, wood façades, wood floorings and windows. These materials and construction elements make up the majority of the embodied CO_2 of current construction projects and they will continue to be used at large scale also in the future. Hence, even solutions with marginal improvements are worthwhile pursuing if they can be scaled.

Upcycle Studios and Resource Rows have already demonstrated large savings by only changing parts of the building components. Imagine the savings if we increase the number of upcycled materials per building - or the savings if the industry used upcycle materials in all new construction projects.

While we have much to further develop and improve, we want to share our imperfect journey and the findings from these two projects so that we can learn from others and others can learn from us as we jointly progress the agenda for a more sustainable future.

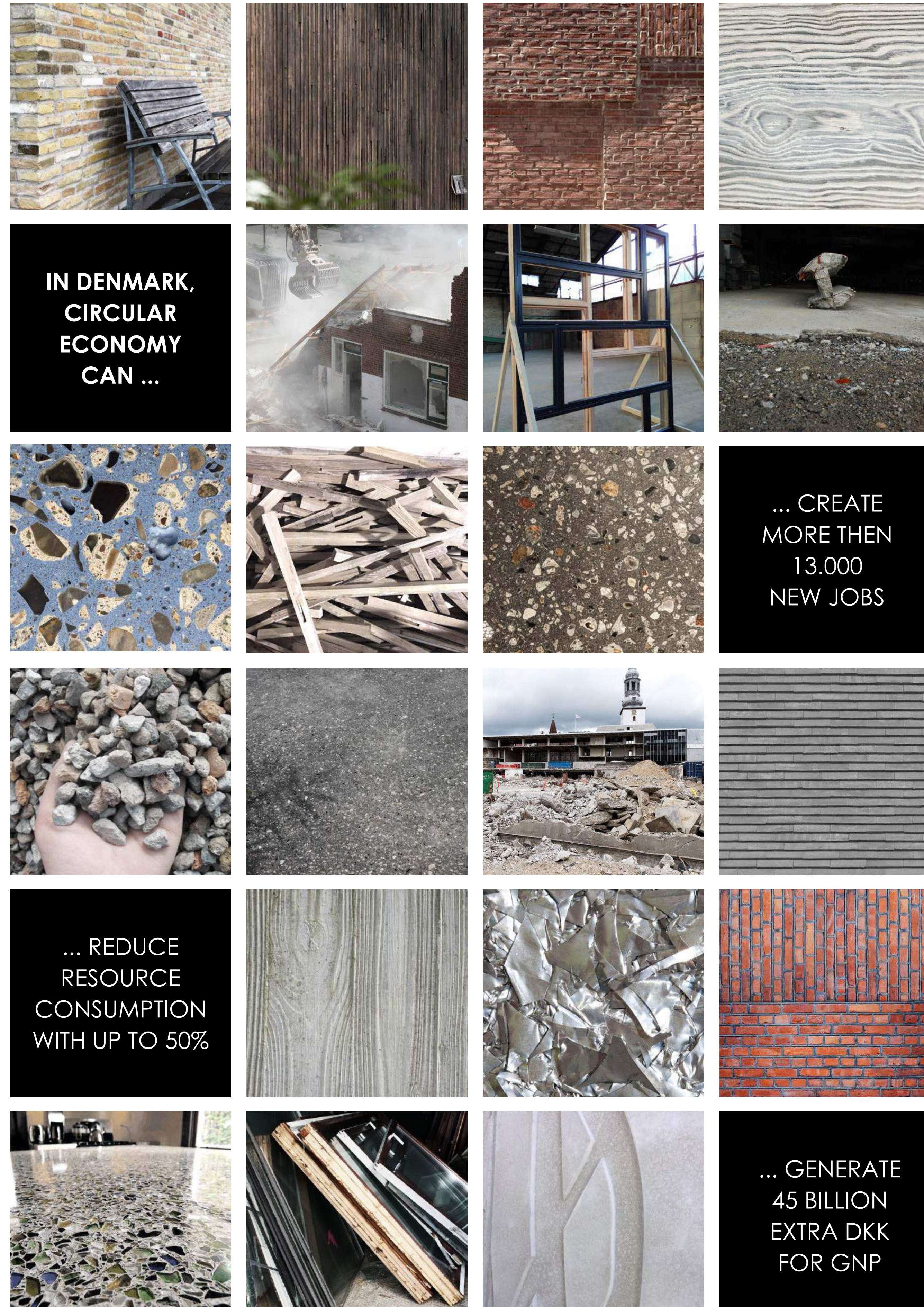
READING GUIDE
The report is structured as follows:

- **Chapter 1:** Clarifying how LCA and LCC calculations are conducted.
- **Chapter 2:** Reviewing impact on material and product level across LCA and LCC.
- **Chapter 3:** Reviewing impact on building level across LCA, LCC and energy efforts.
- **Chapter 4:** Concluding on the achieved impact.

PARTNERS
The report is based on calculations done by Lendager Group verified by LCA expert Morten Birkved, SDU, and quality checked by MOE A/S.

MATERIALS
For the two building projects we focused on circulation of the following materials:

BRICKS | WINDOWS | CONCRETE | WOOD



WHY CIRCULATE MATERIALS?

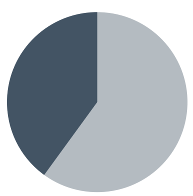
NATIONAL CHALLENGES

4.2
Earths

"IF EVERYONE LIVED LIKE DANES WE WOULD NEED **4.2 GLOBES.**"

Reference: WWF "I dag er jordens ressourcer opbrugt for 2018"

40%
of the resource consumption



"WITH ITS 4,3 MILLION TONNES, THE BUILDING AND CONSTRUCTION WASTE CONSTITUDED OVER ONE THIRDS OF DENMARK'S TOTAL WASTE IN 2016."

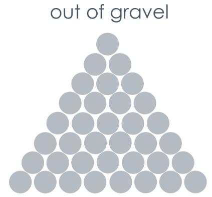
Reference: Miljøstyrelse "Affaldsstatistikken 2016"

4.3
million ton waste

"40 % OF THE RESOURCE CONSUMPTION IN DENMARK IS ACCOUNTED FOR BY THE CONSTRUCTION INDUSTRY."

Reference: "Dansk Byggeri: Håndværkere skal gribe den digitale værktøjskasse"

In 2056
Denmark runs out of gravel



"DENMARK RUNS OUT OF GRAVEL IN THE YEAR 2056, PROVIDING A BURNING PLATFORM TO RESOURCE SCARCITY ON CONCRETE GRAVEL."

Reference: "Danmark er ved at løbe tør for grus: 'Et af de vigtigste råstoffer, verden har'"

CONCRETE, BRICKS, WINDOWS AND WOOD

One thing is circular construction, but why concrete, windows, bricks and wood? Below you find facts on why we need to rethink the way we utilise our current building materials.

BRICKS

- In Denmark, 199,000 tonnes of bricks are wasted annually.
- For each brick, 0.5 kg of CO_2 is emitted. This corresponds to 1 tonne CO_2 per 2,000 bricks.
- Growing urbanization is creating an increasing number of empty buildings outside the cities - many with bricks left with no value.
- Bricks with cement mortar cannot be reused directly since the mortar is stronger than the brick itself. Therefore, this type of masonry is only circulated via crushing.

WINDOWS

- In Denmark, approx. 32,000 tons of flat glass is wasted yearly. The majority is estimated to come from energy renovations.
- The global demand is expected to double from 2008 to 2023.
- We are running out of sand which is the most important resource in glass production.
- Flat glass waste is mostly circulated through downcycling to, for example, jars and bottles. If it cannot be melted, it will be crushed and used for glass wool.

CONCRETE

- More than 1 million tonnes of concrete waste is produced annually in Denmark (about 430,000 m^3).
- Cement production accounts for 8 % of the world's total CO_2 emissions - a figure that is expected to increase with urbanization.
- By 2056, all Danish municipalities will run out of gravel for concrete production.
- Today, concrete is mainly circulated via downcycling to roadfill.

WOOD

- 181,000 tonnes of wood are burned every year in Denmark leading to high CO_2 emissions.
- 130,000 tonnes of new wood is used in the Danish construction industry yearly.
- When circulating wood you prolong the lifespan of wood avoiding emissions of the embedded CO_2.
- Often, high quality wood is discarded due to minor flaws leading to unnecessary waste of highly usable materials.

LCA - LIFE CYCLE ASSESSMENT

METHOD - MATERIAL AND PRODUCT LEVEL

THE WHAT AND HOW OF LCA

Upcycling of materials and circular economy is driven by the potential of reducing the use of virgin materials, hereby reducing the environmental impact when producing new materials. Life Cycle Assessment, LCA, is an acknowledged method for quantifying the environmental impact of a given material, product, and building. An LCA covers the entire life cycle from cradle to grave/cradle to cradle divided into phases shown in the figure to the right. Within each of these life cycle phases, an LCA is divided into sub-phases covering all processes within each phase.

CONSISTENCY AND TRANSPARENCY

When performing LCA, various tools are available. Each tool is built upon a database with data for both production and disposal of materials. Here, GaBi and Ecoinvent are the two most acknowledged databases on the market today - especially due to their level of detail. Some programs are suitable for making LCAs on a detailed product level where others are more suitable for generic and overall LCAs on building level. Working with DGNB, LCAbyg with Ökobau database is often used to conduct LCAs on building level.

The multiple assessment methods underline the importance of consistency across different LCAs in order to make them comparable. Additionally, since LCAs are based on many assumptions, transparency is crucial in order to understand the results of the LCA. On the following pages we introduce the methods and tools used for conducting the LCAs in this report.

MATERIAL AND PRODUCT LEVEL ASSESSMENTS

In this report we will present LCAs on three different levels; 1) material, 2) product and 3) building. Product level is needed to conduct an LCA on building level. We further present LCAs on material level to clarify the impact of the separate materials circulated not taking any added virgin materials into account. The LCAs on material and product level are conducted as following:

Collection of data: Data has been collected from the manufacturers of each developed upcycle product in order to obtain accurate data. All used materials, energy, water, transport and waste during the production have been considered.

LCA modelling: The LCA has been conducted using the database Ecoinvent 3.4 in the open software OpenLCA version 1.8. Furthermore, the cut-off inventory system model has been used as a typical LCA assessment method on product level.

Included LCA phases: A1-A3 have been included for all materials and products. For concrete, A4 is also included since impact of the upcycle aggregate is found within that phase due to resource scarcity of local gravel.

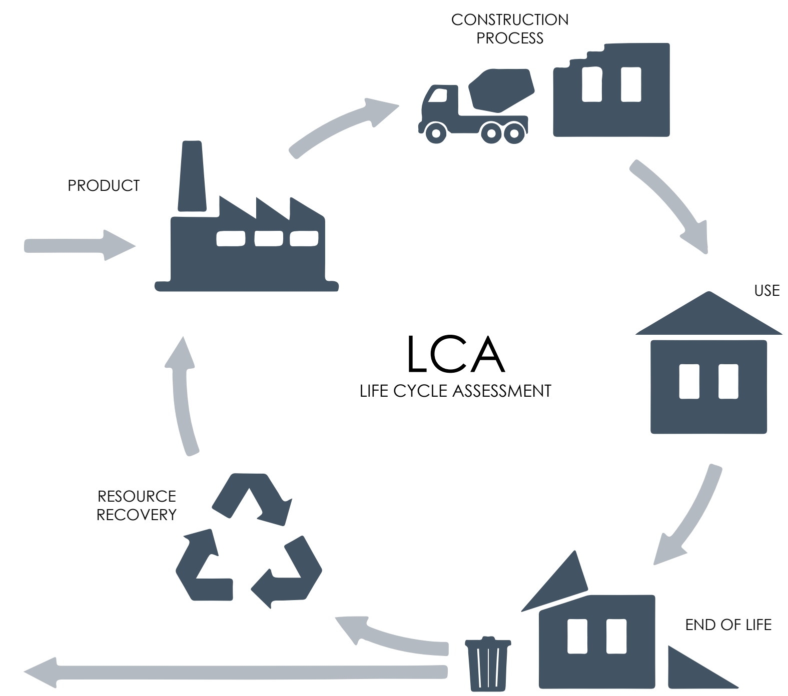
Biogenic carbon: When trees are growing, they absorb atmospheric carbon dioxide which is fixed in the wood as biogenic carbon. Performing LCA on wooden products includes taking the biogenic carbon into account. According to standards, the biogenic carbon should only be included when looking at the entire life cycle. Since the LCAs at product level only are looking at phase A1-A3, biogenic carbon has not been accounted for. However, this still means that there is biogenic carbon embedded within the upcycle wood products, leaving a potential for an even greater impact when reusing wood as you hereby continue the storage of the carbon absorbed in the wood.

LCIA method: CML 2 Baseline 2000. Since we only have EPD and LCAbyg data available for wood products, these will be investigated with the CML-IA baseline method corresponding to the data in LCAbyg and EPDs.

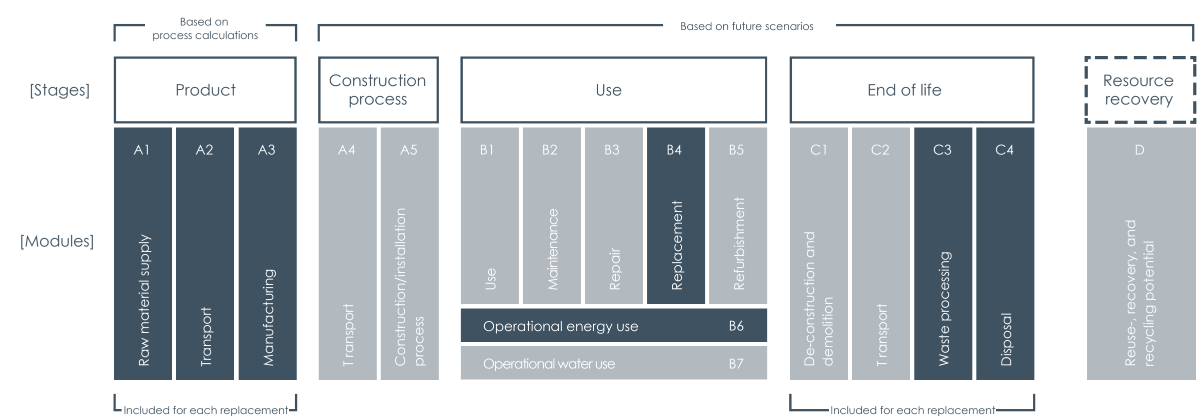
Benchmark: The benchmark of each product corresponds to how the given product would be built in a conventional way providing a similar architecture. Benchmark data has been provided by MOE A/S.

Optimised scenario: Product LCAs are supplemented by LCA calculations of optimized scenarios. These calculations are based on identified potentials for improvements in as-built upcycle products. Improvements include increase of upcycle materials, improvement of production methods, increase of volume, improvement of product design and decrease of virgin materials. Each optimized scenario is explained in material sections in chapter 2.

Verification: The product specific LCAs on upcycle bricks, windows, and concrete have been verified by LCA expert Morten Birkved, SDU.



The life cycle of products and buildings (adapted from Dialogværktøj - Circularity City, VIA University College & SBi)



LCA phases and subphases (adapted from Bygningens livscyklus, SBi)

LCA - LIFE CYCLE ASSESSMENT

METHOD - BUILDING LEVEL

BUILDING LEVEL PROCESS

The modelling of LCAs on building level complies with the DGNB standards in accordance with the DGNB manual (DGNB System Denmark, Kategori: Ejendomme og rækkehuse v. 2016). The LCAs on building level are conducted based on the following:

Unit focus: For the LCA on building level we focus on one row house from Upcycle Studios and Resource Rows respectively.

Collection of data: The data has been collected by extracting amounts on all materials from the Revit model of the specific building. The level of detail is in accordance with the DGNB manual.

LCA modelling: The LCA has been conducted using the software LCAbyg version 3.2.0.4. When lacking products in the given database, these have been built as in LCAbyg version 4.0 BETA. The upcycle products have been implemented as EPD data for each product for phase A1-A3. In order to obtain product specific data in the right format, the data has been extracted from OpenLCA by using the LCIA method CML-IA Baseline and Cumulative Energy Demand. End of life phase C3-C4 for the upcycle products are modelled with the standard data for a similar product in LCAbyg.

Included phases: The analysis A1-A3, B4, B6, and C3-C4 (the ones marked in figure on the previous page).

Biogenic carbon: The biogenic carbon of wood products is calculated in accordance with the Danish standard; DS/EN 16449:2014.

Life span: 50 years including use of the building.

Benchmark: The benchmark building is made by replacing all the upcycle products with their corresponding benchmark product from product level. Hereby, a 1:1 benchmark is obtained which provides a picture of how the environmental impact of the buildings would have been without the upcycle products while reaching the same level of architectural expression. Furthermore the final LCA results of Resource Rows and Upcycle Studios will be benchmarked to 12 LCA calculations of row houses conducted by SBi as well as expectations for level of CO_2 emissions in the new Danish "frivillige bæredygtighedsorden".

Verification: The modelling of each building and benchmark building have been quality checked by MOE A/S.

IMPACT CATEGORIES

When assessing the environmental impact through an LCA, multiple impact categories are analysed. Impact categories vary across different LCA methods. The categories shown in the figure to the right are among the most common. The figure also applies a description of why each category is relevant for the environment.

Today, Global Warming Potential is the most used impact category which is why this category also will be highlighted in this report.

Category **GWP** Global Warming Potential
Unit CO_2 equivalents
Relevance When the amount of greenhouse gasses increases, the air temperature around the earth increases resulting in climate change.

Category **ODP** Ozon layer depletion
Unit R11 equivalents
Relevance Degradation of the stratospheric ozone layer that protects flora and fauna from the sun's harmful UV-A and UV-B rays.

Category **POCP** Photochemical oxidation
Unit C_2H_4 equivalents
Relevance Contributes in connection with UV rays to the formation of ozone near the earth (summer smog) which e.g. is harmful to our respiratory system.

Category **AP** Acidification
Unit SO_2 equivalents
Relevance Reacts with water and falls as "acid rain" which e.g. contributes to breaking down root systems and leaching plant nutrients.

Category **EP** Eutrophication
Unit PO_4^{3-} equivalents
Relevance Excessive nutrient supply promotes undesirable plant growth in fragile ecosystems, e.g. algae growth resulting in fish death.

Category **PEtot** Primary energy consumption
Unit MJ or kWh
Relevance High consumption of primary energy resources (before conversion) from fossil and renewable sources can contribute to resource scarcity.

Impact categories (adapted from Bygningens livscyklus, SBi)

LCC - LIFE CYCLE COSTS

METHOD - PRODUCT AND BUILDING LEVEL

THE HOW AND WHAT OF LCC

The purpose of LCC is to compare the Net Present Values (NPV) of different building solutions serving the same purpose/function; that is, to account for all costs arisen in different points in time, and express them in the present value of money; thus making them comparable. The scope of LCC can be either at product level, where NPVs are estimated per unit, or at building level, where NPV are totals.

Upcycle products involve completely new processes at all levels, also financially. In this context, the need for accounting arises; firstly, gaining insights into financial costs help spot improvement areas, secondly, it allows to benchmark against market alternatives.

The LCC analysis is carried out using two programs; LCCbyg and Microsoft Office Excel.

LCCBYG

The software used is LCCbyg version 2.2.52. The guidelines to estimate Life Cycle Costs are laid out in the DGNB manual (DGNB System Denmark, Kategori: Ejendomme og rækkehuse v. 2016). The assumptions used are as follows:

Calculation period:	50 years (DGNB standard).
Calculation principle:	Nominal interest rate and current prices.
Calculation rent:	Discount rate 5 % from year 0-71.

The software accounts for the building cost categories showed in the figure below.

LCCbyg is an NPV estimation tool applied to the building sector. Once the assumptions are defined, and the cost categories are selected, it is only a matter of introducing the data collected for the analysis. This takes us to the necessary estimation of unitary costs.

EVOLUTION OF PRICES

• General price development	2 %
• Drinking water price development	4 %
• Sewage water price development	7 %
• Energy price development	4 %
• District heating price development	3 %
• Natural gas price development	1,5 %
• Liquid fuel price development	4 %
• Solid fuel price development	3 %
• Electricity price development	3,5 %
• Taxes and tariffs price development	2 %
• Insurance price development	5 %
• Administration price development	2 %

Plot, Consultancy & Client Costs	Site and Structure	Furniture & eq.	Management	Supply	Cleaning
Site	*Substructure*	*Furniture & eq.*	*Taxes & tariffs*	*Water*	*Site*
Consultancy fees	*Primary Elements*		*Insurance*	*Heating*	*Buildings, externc*
Client Costs	*Completions*		*Administration*	*Electricity*	*Buildings, internal*
	Applied Finishes			*Other*	
	Sanitation & HVAC				
	Electrical services				

PRODUCT LEVEL PROCESS

Following we provide a description of the process and hypotheses made when conducting the LCC analysis on product level.

Cost structure analysis: Every expense registered for the development of the specific project is collected across material, supplementary material, production, production equipment, transport, storage, R&D, travel expenditures and management costs. Expenses are grouped into the following categories: Material, labour and other.

Benchmark: Based on function of upcycle products, the characteristics and properties of the benchmark product are defined in order to find a suitable alternative to compare against.

Comparative analysis of products: The upcycle solutions are compared to benchmark on an overall level. The results are expressed in the relevant units (DKK/m^2, m^3 or others). Benchmark data is based on Molio database.

R&D: The first-time nature of materials productions means that there was know-how developed both before and during the production process. R&D costs are not included in the unit cost.

Project management costs: Project management costs reflecting hours spent by internal architects, engineers and consultants is calculated at 10 % pr. product.

Future scenarios: All upcycle products presented here are based on first and second productions leaving room for future optimisations of amount of circulated resources and more efficient processes. For this reason we have included optimised scenarios to visualise the potentials.

LCC: The expense data is introduced in LCCbyg, which estimates the maintenance costs and generates a report with the alternatives presented.

BUILDING LEVEL PROCESS

The following provides a description of the process when conducting LCC on building level.

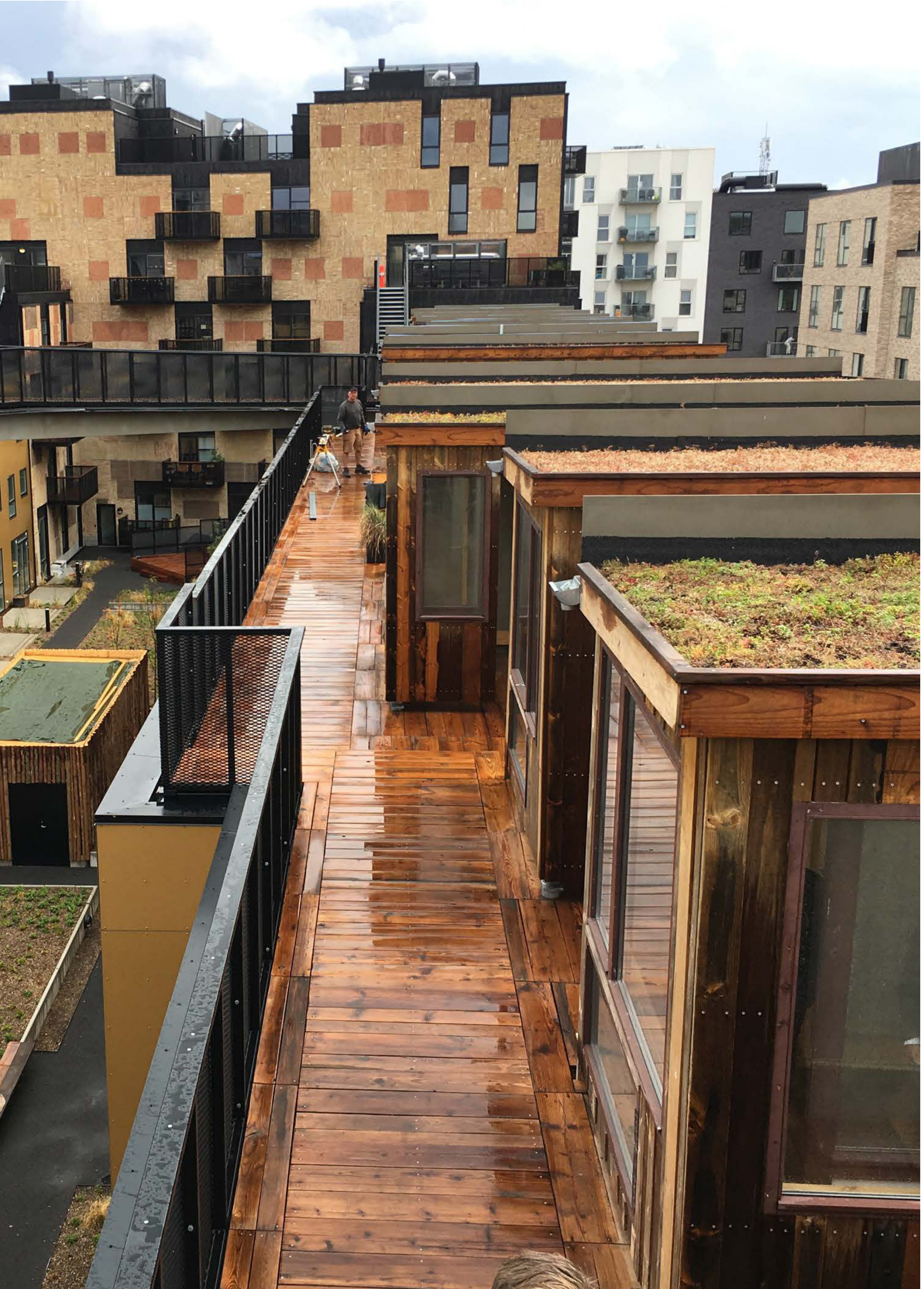
Collection of data: As upcycle materials only take up a part of the two building projects we have collected data on expenses for other materials through the developer, AG Gruppen, forming the basis of the building LCC calculations.

Benchmark: All benchmarks across product and building level match benchmarks from LCA to ensure baseline for comparison. The basis for the calculation of the benchmark building consists in estimating the LCC, if we were to replace those elements with market alternatives. In short, this means that the benchmark prices found for the product level are used, if lacking, primary source has been Molio price database.

EXPENSES VS. SELLING PRICE

It is important to clarify and underline that LCC on product level and building level are based on two different sets of data. LCC on product level is conducted on the basis of the material suppliers' expenses in development, production, transportation etc. while the data for LCC on building level is based on the actual selling price. The selling price is also visualised in the graphs on LCC product level to create transparency on potential differences.

CHAPTER 2
CIRCULAR BUILDING MATERIALS



UPCYCLE MATERIALS AND PRODUCTS

LCA AND LCC

IMPACT ON PRODUCT LEVEL

In the following chapter we will introduce the environmental and economic impacts of upcycle products across Upcycle Studios and Resource Rows. The environmental impacts are presented across a focus on CO_2 and waste minimisation.

Product level: LCAs are presented across all upcycle products used in Upcycle Studios and the Resource Rows as this was needed for the LCA calculation on building level.

Many products include both upcycle and conventional materials, why the first three LCAs on product level are supplemented by an LCA calculation on material level showing the embedded CO_2 in the specific material.

Furthermore, we have supplemented the LCA calculations with data on the amount of waste that has been eliminated through upcycling of wood, concrete, bricks and windows. This is done to visualize the impact across CO_2 and resource optimisation.

LCC calculations in building level are based on data from AG-Gruppen. Therefore, it has not been needed to conduct detailed LCC calculations on product level as is the case for LCA. That being said, we have included LCC results on selected products where LCC analysis was available from other projects. This provides an insight in not only the selling price, but as interesting the expenses held in developing these new building materials.

All products are presented through a benchmark comparison. When assessing the results, it is important to keep in mind what we benchmark against. Here, the aim has been to create a benchmark scenario having the same architectural quality while using conventional available products on the market. Choosing another benchmark will, of course, provide a different result. Benchmarks have been chosen and developed in close collaboration with MOE A/S for third party validation.

Product LCAs are supplemented by LCA calculations of optimized scenarios. These calculations are based on identified potentials for improvements in as-built upcycle products. Improvements include increase of upcycle materials, improvement of production methods, increase of volume, improvement of product design and decrease of virgin materials. We have online included improvement realistic for implementation in next iteration of products. Each optimized scenario is explained in material sections below.

Impact of waste mitigation of wooden products is presented as total numbers across upcycled wooden products.

Upcycle bricks:
- LCA on material level and product level
- LCC on product level

Upcycle windows:
- LCA on material level and product level
- LCC on product level

Upcycle concrete:
- LCA on material level and product level
- LCC on product level

Offcut douglas facade:
- LCA on product level

Offcut douglas wall cladding:
- LCA on product level

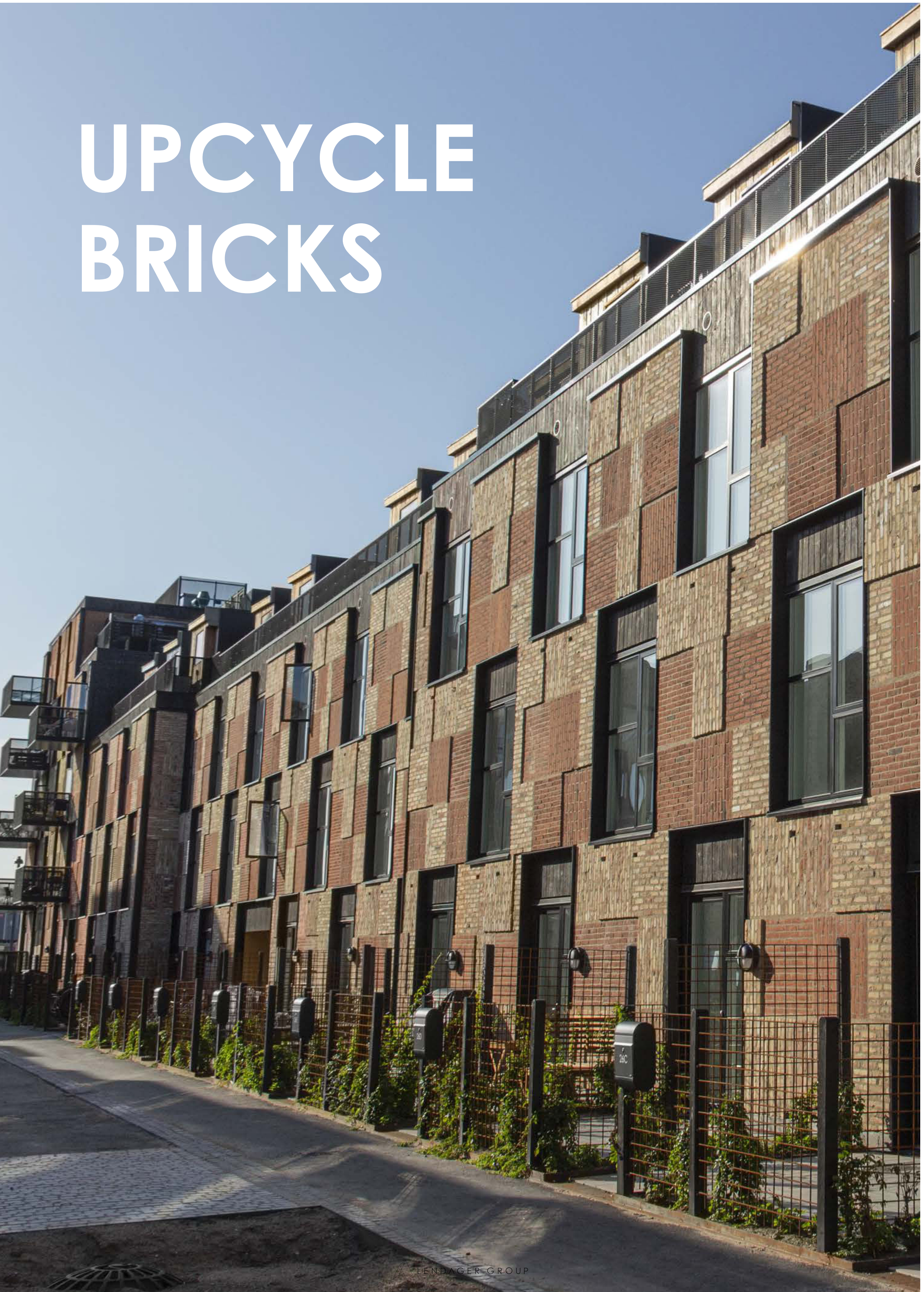
Offcut douglas floor:
- LCA on product level

Offcut oak floor:
- LCA on product level

Upcycled terrace:
- LCA on product level

Upcycle burned facade:
- LCA on product level

Upcycle roof top houses:
- LCA on product level



UPCYCLE BRICKS

INTRODUCTION

IMPACT OF UPCYCLE BRICK

On the following pages we will present the impact of upcycle brick for the facades in Resource Rows. This wil be presented across an analysis of;

1. LCA on material level
2. LCA on product level
3. LCC on product level
4. Waste minimisation

But before we dive into the impact parameters, here is a descripton of the product and performance:

PRODUCT DESCRIPTION

The upcycle brick wall is an exterior wall construction with a brick facade consisting of 100 % reused bricks. The reused bricks are a mix of cut brick elements from buildings ready for demolition and reused bricks, all casted together on a concrete back plate in a pattern creating a unique aesthetic expression.

Type and use: The brick wall for the row houses consists of a prefabricated front wall with reused bricks and concrete mounted with steel brackets on a wood construction. The load of the prefabricated front wall is carried by itself.

Material source: The cut brick elements originate from large unbroken facades in two former brewing houses in Carlsberg-byen (Stødpuden and the Matrix Building) and two schools in Aarhus. Here, a completely new technique for harvesting bricks in cement mortar has been developed, allowing bricks from the 1960's that could not be used again because the mortar is stronger than the bricks why it is difficult out separate out the bricks without breaking them, to now be circulated. In combination with the cut brick elements, recycled bricks and waste from Gamle Mursten is used.

Quantity: 2,914 m^2 brick facade have been erected in the Resource Rows. Here, approximately half of them are placed at the row house facades facing the street.

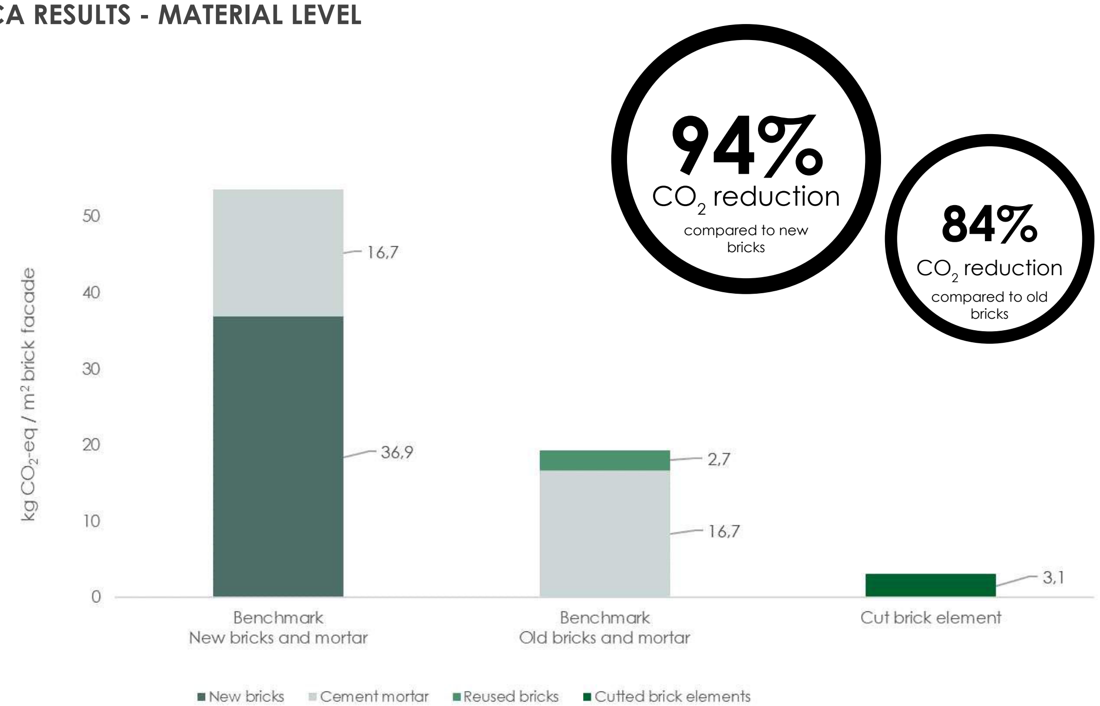
Performance: 50-100 years of lifetime expectancy.

Size: The final prefabricated front walls varies in size from 2.3–15 m^2.

Design: The combination of different brick colors due to available sources carries the story of an upcycle brick wall. The brick front wall consists of brick elements placed in a pattern with recesses in which the elements are rotated with both horizontal and vertical brick patterns creating a unique architectural expression that can be adapted to specific design wishes.

UPCYCLE BRICK WALL

LCA RESULTS - MATERIAL LEVEL



BRICKS
Bricks are one of the most widely used construction materials in Denmark and have strongly impacted architectural design and history. Sociological trends are shifting populations towards cities, leaving behind empty buildings in less dense areas. Since the 1960's, cement mortar being stronger than the bricks have been used making it impossible to disassemble the bricks and mortar. The availability of this waste material allows for new ways of expression while preserving historical and aesthetical values.

Declared unit: 1 m² outer wall with brick facade.

Included processes: The processes included are the production of new materials as well as preparation and handling of reused materials.

Benchmark: Here, two benchmarks are presented when comparing cut brick elements with alternatives. The benchmarks are 1) new bricks and cement mortar and 2) reused old bricks from Gamle Mursten and cements mortar.

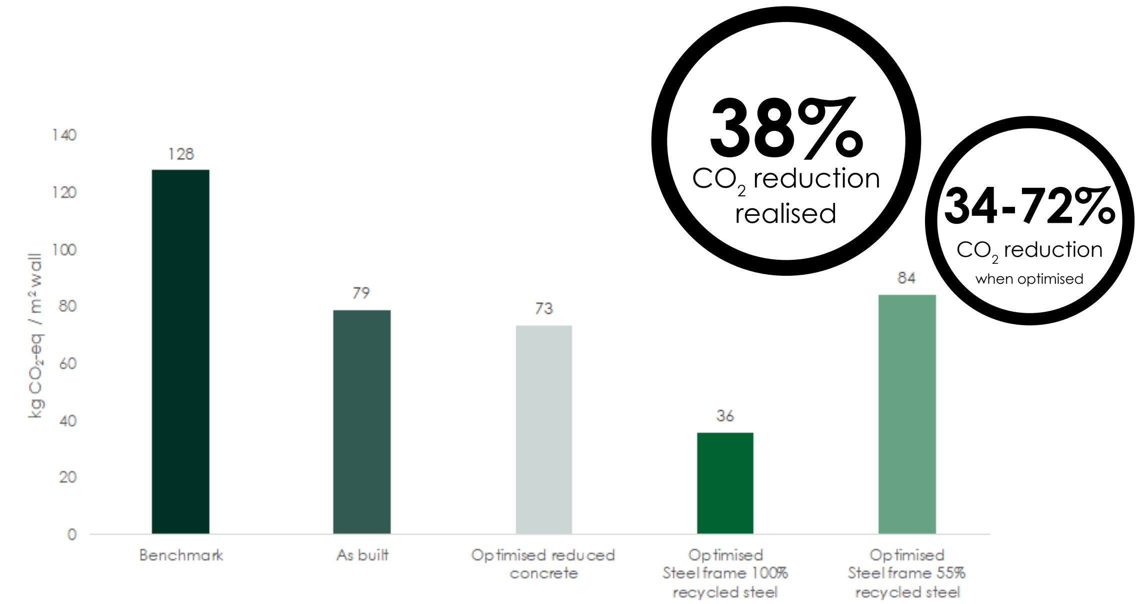
RESULT: 84-94 % CO_2 reduction: When comparing the production of cut brick elements with the benchmarks, we obtain different levels of CO_2 savings. Having only cut brick elements instead of the conventional benchmark with virgin materials, we save 94 % CO_2 whereas we save 84 % when comparing with recycled bricks and new mortar. The two benchmarks include the use of virgin mortar while the upcycle brick elements do not. The principle for doing so is that the cut elements are not placed element by element on top of each other but instead casted directly into a loadbearing concrete plate. Assessing the results, it is seen how the CO_2 emissions of producing/processing both new and reused bricks are extremely high compared to cutting brick elements. This proves the necessity of further upcycling with the newly developed method.

Optimised scenario: The optimised scenario will be to only use cut brick elements for the brick facade instead of mixing cut brick elements with materials from Gamle Mursten.

The potential is even higher: In 2019 SBi published a report showing the CO_2 emissions of conventional brick walls being 66.36 kg CO_2-eq /m², which exceeds the benchmark used for this analysis. This was not included in the analysis as the report is based on another LCA methodology and therefore cannot be directly compared, yet it shows an even higher potentail saving for upcycling bricks.

UPCYCLE BRICK WALL

LCA RESULTS - PRODUCT LEVEL



UPCYCLE BRICK WALL
The upcycle brick wall for the row houses at the Resource Rows consists of a facade made of reused bricks casted in concrete and mounted with steel brackets on a standard wood construction. The reused bricks consist of 55 % cut brick elements from demolition mature buildings, 22.5 % waste from Gamle Mursten, and 22.5 % reused bricks from Gamle Mursten.

Declared unit: 1 m² of upcycle brick wall.

Included processes: The processes included are the production of all new materials, potential transport of materials to manufacturer of the brick facade, water and energy consumption for manufacturing the brick facade, cutting and transporting the brick elements with pallet lifter and truck. Furthermore, the LCA also accounts for the production of the aggregate handling the cut elements and special made pallets for transporting the cut elements. The concrete used is modelled according to the concrete recipe from TCT including waste during manufacturing. A flowchart showing the included processes more specific can be found in appendix 3.

Benchmark: The benchmark is a conventional shell wall with new bricks, insulation and a loadbearing concrete back wall with lower transportation.

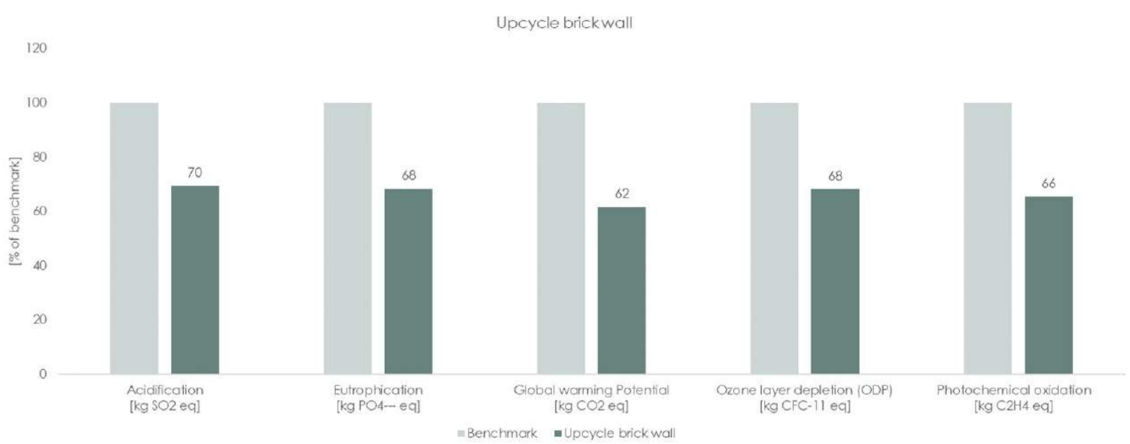
RESULT: 38 % CO_2 reduction: Comparing the upcycle brick wall with benchmark, a CO_2 saving of 38 % has been obtained.

Optimised scenario: Three optimised scenarios are included due to investigation of other structural possibilities. In all three scenarios, 100 % cut brick elements are used. Scenario 1) has a 7 % reduction of the concrete behind the cut brick elements, 2) and 3) has substituded the concrete behind the cut brick elements by a steel frame holding the cut brick elements where scenario 2) has a 100 % recycled steel frame and 3) has a 55 % recycled steel frame (market average). Scenario 1), 2), and 3) has a potential CO_2 saving of 43 %, 72 %, and 34 %, respectively, when comparing with benchmark.

Bricks, concrete, and steel: Recycling bricks as a cut brick element has a positive impact when looking at CO_2 and resource consumption. However, the way these elements are further handled and mounted is crucial to the final CO_2 potential of the upcycled product. A steel frame is only preferable over concrete when having a high recycling percentage of the steel. Aiming for a recycled steel frame behind the bricks, an optimised upcycle brick wall has the potential of lowering the CO_2 emissions with 72 % compared to benchmark. A fourth option could also be to change the wall design so that the windows are not in checkered pattern but rather in columns eliminating the need for extra steel structure (not part of calculations presented above).

UPCYCLE BRICK WALL

ACROSS IMPACT CATEGORIES + WASTE



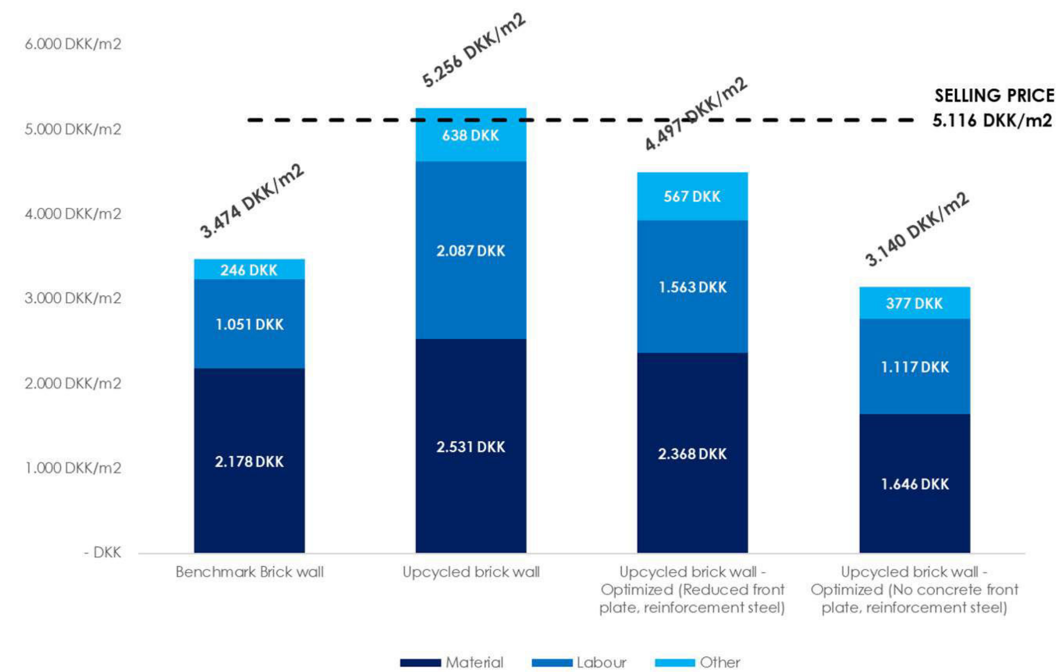
Impact category	Product	
	Benchmark	Upcycle brick wall
Acidification [kg SO_2 eq]	0,372	0,258
Eutrophication [kg PO_4--- eq]	0,127	0,087
Global warming Potential [kg CO_2 eq]	127,767	78,799
Ozone layer depletion (ODP) [kg CFC-11 eq]	6,61E-06	4,52E-06
Photochemical oxidation [kg C_2H_4 eq]	0,030	0,019

ACROSS IMPACT CATEGORIES

The table and graphic above show the environmental impacts that occur in the production of 1 m² upcycle brick wall at the Resource Rows and 1 m² corresponding to conventional shell-walled outer wall. From this it can be seen that the upcycle brick wall perform significantly better in all impact categories.

UPCYCLE BRICK WALL

LCC RESULTS - PRODUCT LEVEL



LCC UPCYCLE BRICK

The graph above expresses the cost structure of upcycle brick, two optimised scenarios, and benchmark. The bars reflect the split in the following expence catagories: material, labour and other costs. Costs include installation, given that the benchmark and upcycle processes are different from each other.

Benchmark: The benchmark consists of a concrete back wall, a layer of insulation and a front layer of bricks, as defined in the LCA analysis. The brick price is based on "Blødstrøgen" by Randerstegl, with same thickness and similar aesthetics as the upcycle brick wall. The prices used for the insulation and concrete are the same as for the upcycle brick wall. Considering that these elements are not upcycled nor produced by Lendager, they already serve as a benchmark.

Upcycle Brick Wall: The present cost structure of upcycle brick wall reflects all production costs, excluding R&D and 90% of project management costs, as seen before for other products.

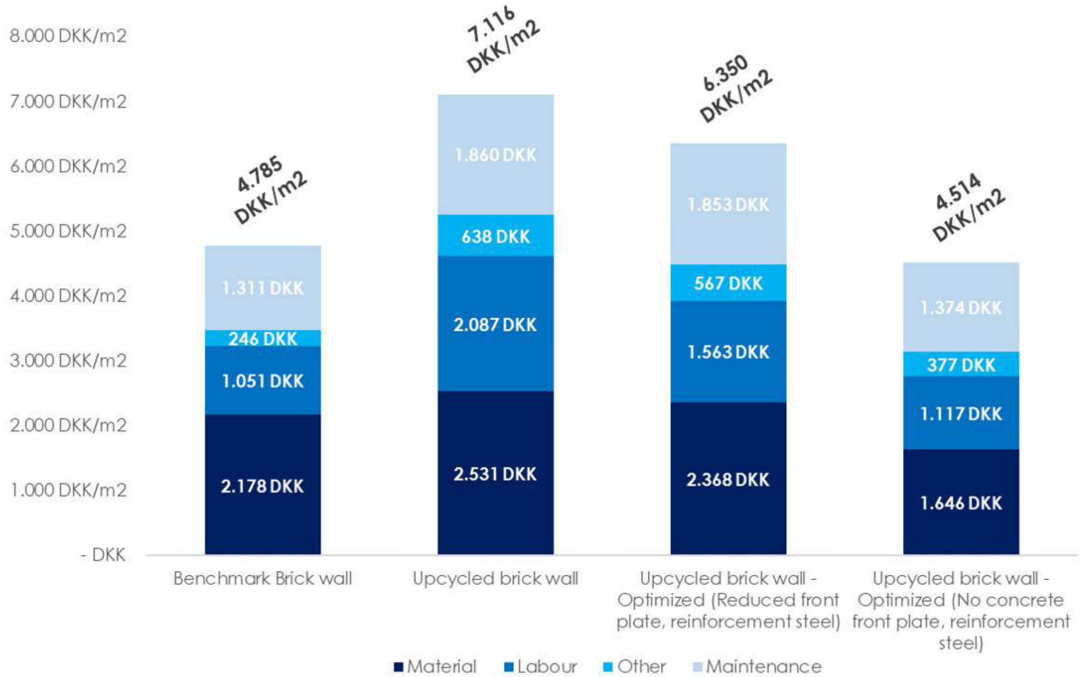
The wall consists of cut brick elements as well as loose bricks casted on a concrete plate and supported by a wooden layer containing insulation.

Optimised scenario: There are two future scenarios forecasted, the first is based on the premises that the average thickness of the concrete layer can be reduced by 7%, and second, the optimised wall will not use loose bricks. The second scenario, goes further and assumes that there will be no need to cast the cut elements on a concrete plate. These improvements in the process can make the upcycle solution competitive with market alternatives.

Result: The technical differences between the benchmark and the upcycle brick wall make the latter appear expensive. This is largely because the upcycle wall has a wide range of additional elements, such as reinforcement steel, brackets and further use of concrete, adding to the cost per m².

UPCYCLE BRICK WALL

LCC RESULTS - PRODUCT LEVEL



Furthermore, the value of the upcycle brick wall is also significantly higher due to the unique design and impact justifying the higher cost. That being said the optimised scenarios show a potential for significant changes should the product be directly competitive on price.

Selling price: Looking at the selling price it is marginally lower than expenses for the production and mounting of the elements. Improvements in the optimised scenarios can allow a close to direct benchmark with conventional brick wall.

It is important to state that the expenses in delivered upcycle brick wall and optimised scenario do not include any kinds of margins for the supplier. These numbers are only based on costs.

Cost structure: The costs between benchmark and upcycle brick wall are very similar on material level, while expenses almost double on labour costs due to a high level of manual labour on cutting out bricks. In the optimised scenarios the manual labour is improved through more efficient processes and higher level of experience speeding up the work across cutting and producing element.

Maintenance: Maintenance and replacement costs are dependent on the type of material and the price of the product. In the case of upcycle brick wall the difference in maintenance reflects difference in materials in the back wall (construction). Benchmark and upcycled brick wall optimised (no concrete) both have a concrete back wall needing lower maintenance than upcycled brick wall and upcycle brick wall optimised (steel) that are based on a wooden construction. Hence, the maintenance costs for the upcycled brick frontwall are the same across all four scenarios.

UPCYCLE BRICK WALL

SUMMARY OF IMPACT

RESOURCE OPTIMISATION

With the amount of upcycle brick wall erected in the Resource Rows, the environment has saved 459 tonnes of waste - only by circulating the brick. Waste that would otherwise end up crushed or deposited in the wild. In addition, the tonnes of saved waste is a clear indicator of the amount of virgin resources saved alone in this project.

UPCYCLE BRICK WALL
RESULTS FOR RESOURCE ROWS

	AS BUILD	POTENTIAL IF BUILD PER OPTIMISED SCENARIOS*
CO_2	3 tonnes CO_2 -eq /rowhouse 38 % saving	5 tonnes CO_2 -eq/rowhouse 72 % saving
$	-101,574 DKK/rowhouse 51 % more expensive	19,038 DKK/rowhouse 10 % saving
	459 tonnes waste in total	459 tonnes waste in total

* Best case

UPCYCLE WINDOWS

INTRODUCTION

IMPACT OF UPCYCLE WINDOW
On the following pages we will present the impact of upcycle windows for the construction of Upcycle Studios. This will be presented across an analysis of;

1. LCA on material level
2. LCA on product level
3. LCC on product level
4. Waste minimisation

Before we dive into the impact parameters, here is a description of the product and performance:

PRODUCT DESCRIPTION
Upcycle window is a completely new window element based on a two layered framing each with recycled double glazing from building renovations and demolitions supplemented with new double glazing and safety glazing. When the two layers of double glazing are gathered as one layer, an air tight room between the glazings gathers heat and contributes to a high performance. In this way, old windows can be reused and still meet the 2020 requirements.

Type and use: The upcycle window is a double frame window with up to 50 % recycled double layered windowpanes in the current best case scenario. The frame is made of pine and treated with linseed oil. When a door is included in the window element, it is made of new triple layered glazing. Reusing two layered windowpanes in a double frame allows the use of two layered virgin windows as supplement hereby saving one layer of glazing in the virgin windowpanes, while still meeting the 2020 requirements.

Material source: The windowpanes are double glazed and originate from a general housing association in Aalborg.

Quantity: 870 m^2 upcycle windows have been delivered for Upcycle Studios distributed in a total of 57 window sections.

Performance: The lifespan expectancy of a window is normally 25 years. The remaining lifespan of the reused glazing is tested by the Danish Technological Institute to be 24-36 years from now, hereby meeting the expected lifespan of new glazing. This indicates that windows normally are changed before their actual end of life. The upcycle windows are DVV-labelled meaning that they as a minimum comply with the standards for products and production defined in the Window Industry's Technical Regulations for Danish Window Verification.

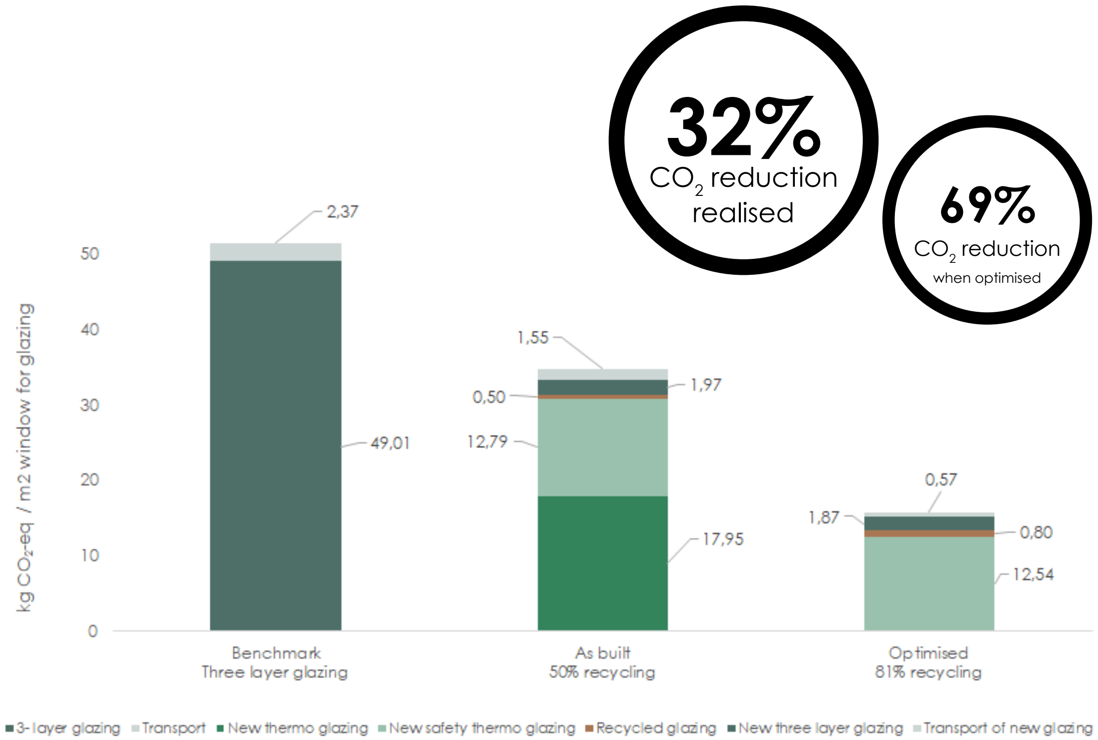
- **U-value:** 0.69 W/m^{2}K (area weighted average)
- **G-value:** 0.49
- **Energy efficiency:** The windows meet the official guarantee for window's energy efficiency from DS / EN 10077-1.

Size: A window section at Upcycle Studios differs between 4-30 m^2. The size can be adapted to the specific building and the recycling rate can be increased by designing the window based on accessible resources for circulation.

Design: The upcycle windows express the upcycle story by letting the two layers of panes go past each other - highlighted by the interior frame being unstained and the exterior painted black.

UPCYCLE WINDOWPANES

LCA RESULTS - MATERIAL LEVEL



WINDOWPANES

Windowpanes are currently being replaced across Denmark in order to live up to 2020 energy requirements and are therefore often discarded before their functional end of life. Alongside this, the world's resources of sand is running dry[1] which is the most important resource in glass production. As the demand for windows is expected to double in 2023 relative to 2008 levels[2], we need to improve the use of the glass that is already in use.

Declared unit: Window glazing for 1 m² window. The glazing represents how the windows are as built in Upcycle Studios best case scenario consisting of 50 % recycled panes, alongside new safety, thermo and three layered glazing.

Included processes: The processes included for the upcycle glazing is transport and cleaning of reused glazing as well as manufacturing and transport to Krone Vinduer of the new glazing.

Benchmark: The windowpanes are benchmarked with a tripple layered glazing transported from the manufacturer to Krone Vinduer.

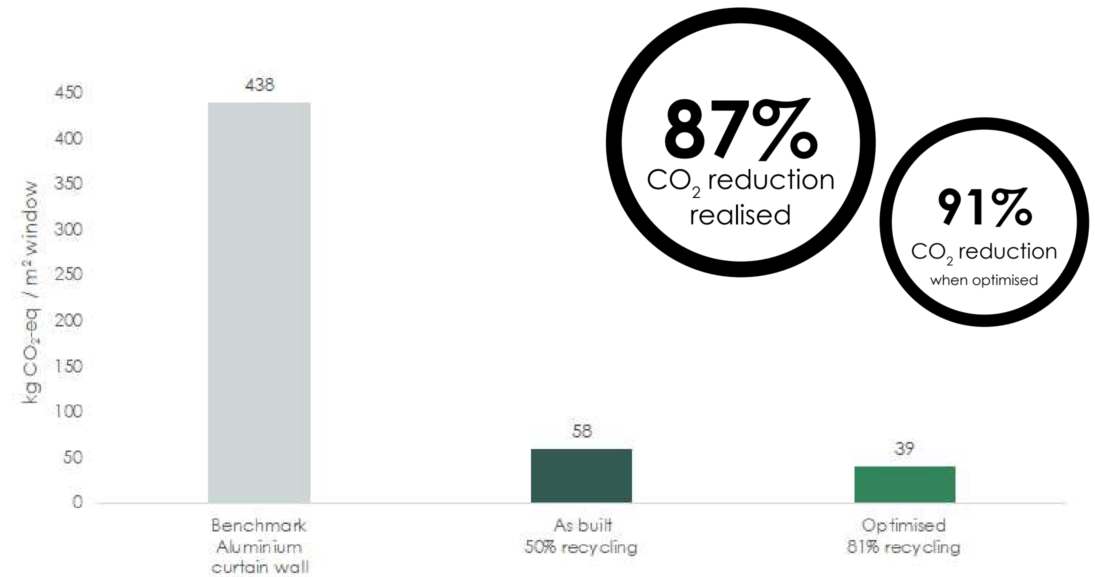
Result: 32 % CO_2 reduction: Comparing the CO_2 emissions of virgin windowpanes with using 50 % upcycle windowpanes shows a reduction of 32 %. Looking at the graph above it becomes very clear that the actual production of new three layer glazing is a very CO_2 heavy process making up for most of the benchmark impact. This is also clearly shown in the upcycle windowpane analysis showing a quite high impact from the use of new glazing compared to the recycled glazing that has close to no negative impact.

Optimised scenario: An optimisation of the as build glazing for the upcycle window will be to add more reused glazing. Here, a recycling percentage of 81 % glazing will be realistic still having new safety glazing and new tripple glazing as a door. This gives a CO_2 saving of 69 % compared to the benchmark windowpane.

1 https://www.dr.dk/nyheder/verden-er-ved-loebe-toer-sand
2 https://www.statista.com/topics/4108/glass/

UPCYCLE WINDOWS

LCA RESULTS - PRODUCT LEVEL



UPCYCLE WINDOW

For Upcycle Studios, upcycle windows in double frames are delivered in various sizes. In this report, the focus is on the large window section of 27 m² which achieves a recycling factor of 50 % at its best case scenario.

Declared unit: 1 m² of a 27 m² window section that meets the 2020 requirements for windows.

Included processes: The processes included are production of new materials, preparing and cleaning the recycled panes, transport to Krone Vinduer, and energy and nails for manufacturing of the final window section. Additionally, the steel brackets for wind support are included as well as waste at Krone Vinduer. A flowchart showing the included processes more in detail can be found in appendix 2.

Benchmark: The benchmark is a conventional curtain wall with three layered glazing window in aluminium frames from Schüco. Due to wind pressure and load on the large window, some aluminium frames are reinforced with steel. This benchmark obtains a similar structural strength and architectural expression as the upcycle window in Upcycle Studios.

RESULT: 87% CO_2 reduction: Comparing 1 m² of the upcycle window of 50 % reused glazing with the benchmark window, a saving of 380 kg CO_2-eq is obtained corresponding to a saving of 87 %. This result is very significant - especially as it is based on a first-time-production.

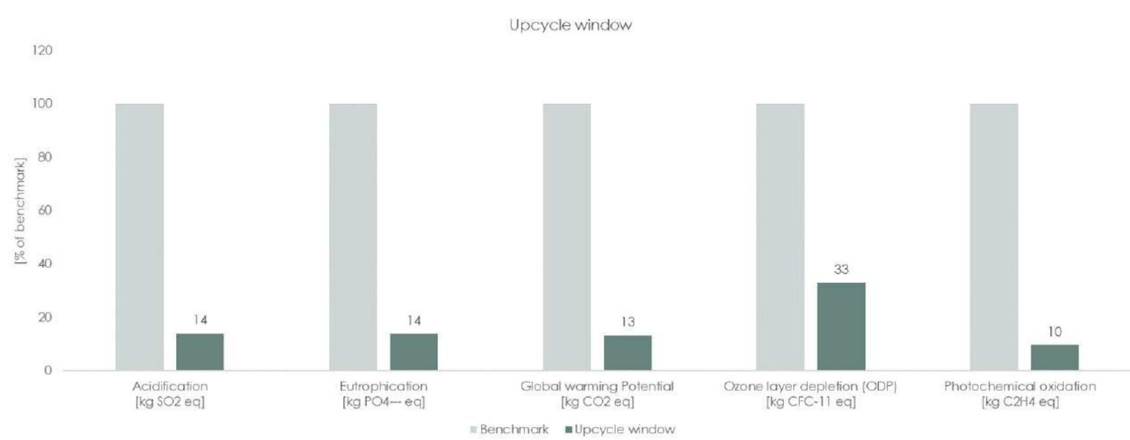
Optimised scenario: As described under material level, an optimised upcycle window can achieve a 81 % recycling rate for the windowpanes due to experience and optimisation opportunities using a newly developed design tool. Implementing these future optimisations and keeping the wooden double frame, it can enable a saving of 91 % in CO_2 emissions.

Reused glazing and wood frame: The analysis shows that the largest CO_2 savings come from 1) using reused glazing supplemented with new double glazing instead of new triple glazing and 2) using wood frames instead of aluminium. The need for aluminium is lowered in the upcycle window due to the strengths of the double layered framing allowing wood to be used instead.

The remaining lifetime of the reused glazing indicates that panes generally are changed before they reach their end of life. This proves the need to keep circulating well functioning glazing and keep improving on the innovation of upcycle windows as it is extremely important in order to reach full utilization of the earth's resources.

UPCYCLE WINDOWS

ACROSS IMPACT CATEGORIES



Impact category	Product	
	Benchmark	Upcycle window
Acidification [kg SO2 eq]	2,491	0,349
Eutrophication [kg PO4--- eq]	0,652	0,091
Global warming Potential [kg CO2 eq]	438,091	58,145
Ozone layer depletion (ODP) [kg CFC-11 eq]	1,80E-05	5,94E-06
Photochemical oxidation [kg C2H4 eq]	0,164	0,016

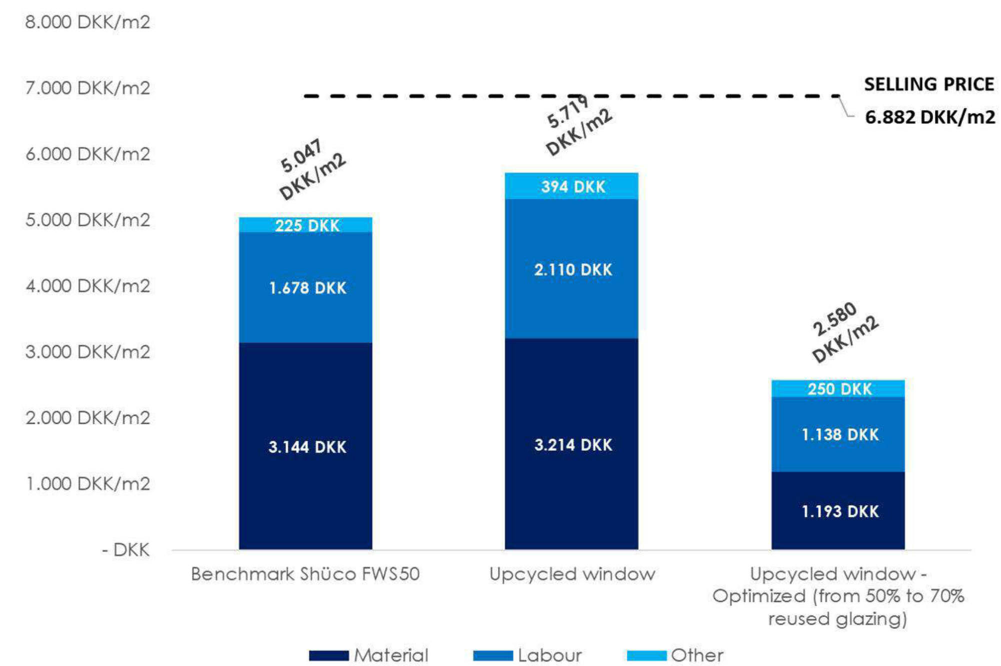
ACROSS IMPACT CATEGORIES
The diagram and table above show the environmental impacts that occur in the production of 1 m^2 upcycle window for Upcycle Studios benchmarked with a corresponding 1m^2 curtain wall (benchmark). This shows that upcycle window outperforms benchmark on all parameters.

AMOUNT OF UPCYCLE GLAZING
The LCA on product level is based on a 50 % share of recycled glazing, while the optimized scenario has an 81% recycling rate. The expectation of increase in recycling rate in future inventions is due to:

1. Increase in energy renovations leads to an increase of relatively young window glazing for recycling,
2. Positive results on tests of remaining lifetime indicating a longer lifetime of the glazing of windows than normally expected, leading to an increase of the pool of materials for upcycling
3. Due to first time production, we were restricted by a precautionary principle limiting the amount of recycled glazing to 50 %. Due to quality and performance of upcycle windows precautionary principles are expected change in future interventions.

UPCYCLE WINDOWS

LCC RESULTS - PRODUCT LEVEL



LCC UPCYCLE WINDOWS
The graph above expresses the cost structure of upcycle window, optimised upcycle window and benchmark. The bars reflect the split in the following expense categories: material, labour and other costs. As opposed to the concrete estimations, costs include installation, given that the two processes are different from each other.

Benchmark: The chosen benchmark is the facade solution offered by Schüco, the FWS50 curtain wall in aluminium frame. While the size of upcycle windows range from 4-30 m2, both LCA and LCC is focused on the windows installed in the south face of Upcycle Studios, that is 27 m^2. For this reason, and due to its' size, the benchmark necessarily needs to be a curtain wall capable of bearing the weight of a facade. Furthermore, the benchmark accounts for the additional costs of having three operational windows and one door.

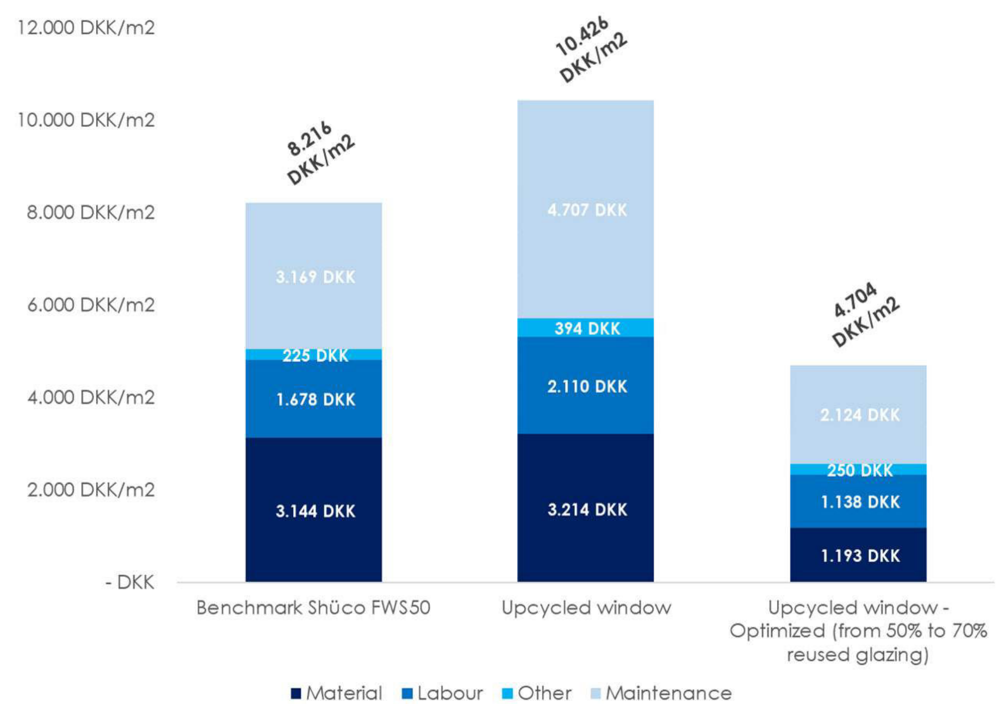
Upcycle window: The present cost structure of upcycle windows reflect all production costs, excluding R&D and 90% of project management costs, as proceeded with upcycle concrete. They have a 50/50% distribution between reused and new glazing.

Optimised scenario: The optimised cost structure is based on the assumption that the mounting of the glazing in the frame will be done in the factory, not on site, heavily reducing labour costs. Furthermore, the share of reused glazing will be increased from 50% to 70%, reducing a big share of the total expenses per m^2.

Result: The expenses on upcycle window ends up being close to DKK 700,- more expensive per. m^2 compared to benchmark. Though this is an increase it is not significant as upcycle windows expenses are based on a first-time-production while benchmark is based on a strong and known industry player. Looking at the expenses for producing the optimised scenario the product becomes very competitive strengthening the potential for scaling the solution.

UPCYCLE WINDOWS

LCC RESULTS - PRODUCT LEVEL



Selling price: Looking at the selling price it is higher than benchmark reflecting the higher value of a specially design and newly developed window. That being said, improvements in the optimised scenarios will allow to heavily outperform the benchmark product.

It is important to state that the expenses in delivered upcycle window and optimised scenario do not include any kinds of margins for the supplier. These figures are only based on costs.

Cost structure: The cost structures between benchmark and upcycle window are very similar leaving a bit higher expenses for materials, labour and others in the delivered upcycle window. This is due to fairly high acquisition costs of windows for circulation as timing did not allow a market search for other sources with same amount and quality as sourced for this project. Furthermore, the expenses for virgin two-layered glazing was significant why there is both an environmental and economic incentive for further optimisation.

Maintenance: Maintenance and replacement costs are dependent on the type of material. In short, it is the net present value of two cash flows: on the one hand, the yearly maintenance costs, estimated as a percentage of the acquisition price; on the other hand, replacement costs, estimated at 125% of the acquisition costs that are to be paid at the end of the products life cycle. In the case of windows, the life span of frames and glazing are <50 years, thus, maintenance costs are higher than acquisition as they account for 1 replacement plus yearly maintenance

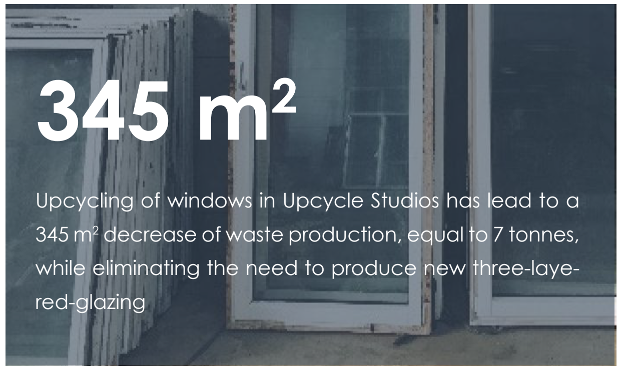
While similar to the benchmark in acquisition costs (material, labour and other), the maintenance costs are higher. This is due to the fact that aluminium frames (benchmark) in general have smaller maintenance costs than wooden frames (upcycle window).

UPCYCLE WINDOWS

SUMMARY OF IMPACT

RESOURCE OPTIMISATION

In addition to the CO_2 savings achieved by upcycling the window panes, a saving of resources has also been achieved. The upcycling of window panes has resulted in a saving of 7 tonnes of waste that has been upcycled instead of being downcycled, incinerated or landfilled. This minimises the need to produce new, virgine panes that pose a significant environmental impact.



UPCYCLE WINDOW
RESULTS FOR UPCYCLE STUDIOS

	AS BUILD	POTENTIAL IF BUILD PER OPTIMISED SCENARIOS
CO_2	16 tonnes CO_2 -eq/rowhouse 87 % saving	17 tonnes CO_2 -eq/rowhouse 91 % saving
$	-29,232 DKK/rowhouse 13 % more expensive	107,315 DKK/rowhouse 49 % saving
	345 m² waste in total	559 m² waste in total

UPCYCLE CONCRETE

INTRODUCTION

IMPACT OF UPCYCLE CONCRETE

On the following pages we will present the impact of upcycle concrete for the construction of Upcycle Studios. This will be presented across an analysis of;

1. LCA on material level
2. LCA on product level
3. LCC on product level
4. Waste minimisation

But before we dive into the impact parameters, here is a description of the product and performance:

PRODUCT DESCRIPTION

Upcycle Concrete is construction concrete developed for load-bearing constructions. 100 % of the coarse aggregate is recycled giving the final concrete a recycling percentage of 45 %.

Type and use: The structural concrete is included in the class SCC meaning passive C25/30 CC2 and is designed for use as interior walls, floor slabs and terrain deck. Upcycle concrete is mixed on site and in situ casted.

Material source: The recycled aggregate is crushed concrete. The concrete used as aggregate originates from the subway construction in Copenhagen.

Quantity: 837 m^3 upcycle concrete has been delivered for the construction of Upcycle Studios.

Performance: The contractor required for two types of upcycle concrete for floor slabs and interior walls, respectively. Both in passive environmental class with the strength C25/30 certified in accordance with DS / EN 206-1: 2000 and DS 2426: 2011.

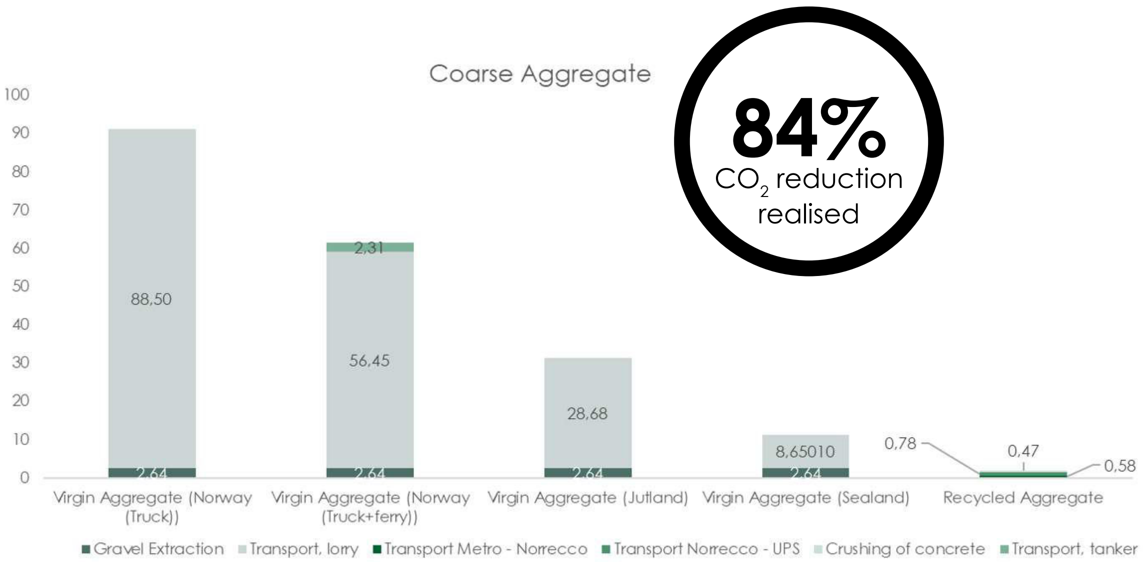
Strength requirements: In Upcycle Studios, the characteristic compressive strength after 28 curing days ranged from 35.7-46.9 MPa which is why the concrete meets the same requirements as virgin concrete in the same strength class with a characteristic compressive strength of minimum 31 MPa. Actually, the strength in the same class is higher for the upcycle concrete due to restrictions on a first time production.

Coarse aggregate: The crushed concrete meets the general requirements for aggregates in DS 2426 as well as additional specifications, cf. DS/EN 12620.

Air content and E-module: The air content is measured in the range of 5.7–8.7 % which corresponds to the air content of virgin concrete that is around 6-7 %. The E-module is 28 GPa after 28 days which matches what can be expected of a traditional concrete of a similar strength.

UPCYCLE CONCRETE AGGREGATE

LCA RESULTS - MATERIAL LEVEL



CONCRETE AGGREGATE

Concrete is the most used material in the world after water. According to Niras' projections, Region Hovedstaden will run out of gravel in 2027, Sealand in 2032 and Denmark in 2056[1]. Therefore, we need to find alternative materials to be used as aggregates for concrete which is why Lendager Group has developed a new type of coarse aggregate made of crushed old concrete from demolitions and left over productions.

Declared unit: 1 tonne of coarse aggregate ready to be used on the construction site.

Included processes: The processes for the upcycle concrete aggregate include the transport from the sourcing site Norrecco, the electricity used for crushing it into the desired size and the transportation to the construction site of Upcycle Studios.

Benchmark: As aggregate makes up 45 % of concrete products, it is an essential ingredient concerning volume. Today we can source aggregate locally, but as we are running out locally, the need of transport will grow.

In the graph above we have included four potential benchmarks based on aggregate sourced from respectively Norway (by truck or by truck and ferry), Jutland (Aalborg), Sealand, and Copenhagen (recycled aggregate). With the various benchmarks we truly see the importance of minimising transport and sourcing locally. All benchmarks include new coarse aggregate; extraction of virgin gravel from a gravel plant and transportation to the construction site.

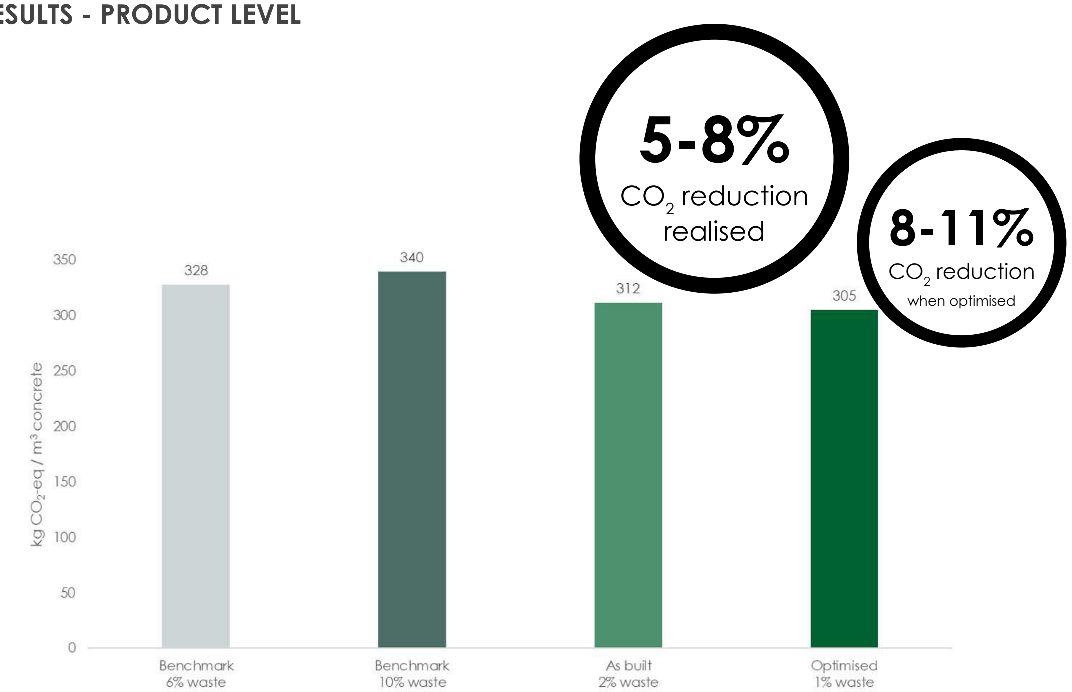
Result: 84 % CO_2 reduction: Comparing the CO_2 emissions from extracting virgin gravel from Sealand with using upcycle aggregate, a reduction of 84 % is seen. Only looking at the CO_2 emissions from the extraction of the gravel exceeds the full production of upcycle aggregate. This is partly due to the sourcing of upcycle aggregate very close to the construction site which circular economy allows. Furthermore, we see a minimal amount of energy used to crush the concrete into the finished, usable aggregate. See graph above.

Based on a combination of the predicted future lack of virgin gravel combined with the high achieved CO_2 saving on material level it is clear that there is a growing important impact on using recycled concrete as aggregate.

1 https://www.dr.dk/nyheder/indland/danmark-er-ved-loebe-toer-grus-et-af-de-vigtigste-raastoffer-verden-har

UPCYCLE CONCRETE

LCA RESULTS - PRODUCT LEVEL



UPCYCLE ON-SITE CONCRETE

An upcycle construction concrete was used in Upcycle Studio produced from a mobile mixing plant on site.

Declared unit: 1 m³ ready-mixed concrete in strength class 25 MPa, passive environmental class (passiv miljøklasse) ready for use on the construction site including waste. A waste percentage of 2 % for upcycle concrete and 6-10 % for conventional concrete has been used due to difference in amount of waste in industrial and on site production.[1]

Included processes: The processes included are production of all materials, transport from manufacturer to construction site and energy consumption for mixing as well as for light and heat during the winter season. A flowchart showing the included processes more specific can be found in appendix 1.

Benchmark: The benchmark is a conventional factory concrete with virgin aggregate mixed at a factory with a lower electricity consumption compared to that of the upcycle concrete. The concrete recipe for the benchmark concrete is equal to the one used for the upcycle concrete to achieve a comparable result.

RESULT: 5-8 % CO_2 reduction: Comparing the upcycle concrete as built with benchmark of conventional concrete, a saving of around 20 kg CO_2-eq has been achieved corresponding to a saving of 5-8 %. This represents a relatively small change per m³, but looking at the amount of concrete used in buildings it can make a huge difference. Savings stem mainly from reduction of waste and corresponds to results from a lifecycle assesment of circular solutions done by SBi.

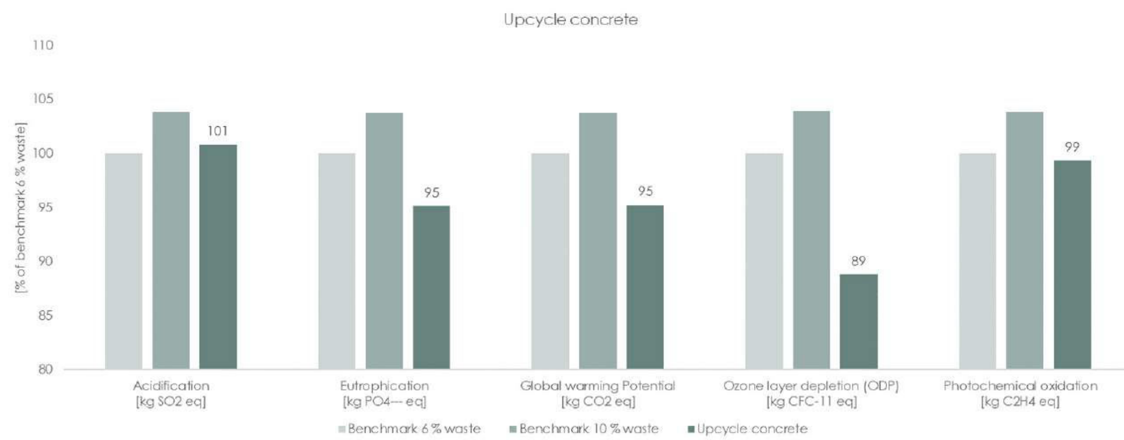
Optimised scenario: The optimised scenario of upcycle concrete is based on 1) the mobile mixing plant no longer using diesel generator but being powered through the Danish electricity grid and 2) a reduced waste percentage due to increased experience. These optimisations enable a CO_2 reduction of 8-11 % compared to benchmark.

Cement and waste: The analysis shows that the cement content by far has the highest impact in the production of concrete corresponding to 89 % of the CO_2 emissions of the upcycle concrete. To really reduce the environmental impact of concrete it is imperative to consider adoption of cement innovations that reduce the CO_2 of the cement component of the concrete. However, we are also facing a need for new solutions for concrete aggregate combined with a big existing waste problem which is why the upcycled concrete aggregate is an important step towards improving the impact of concrete production.

1 Ellen Macarthur Foundation, 2015
"Potential for Denmark as a circular economy" from Ellen MacArthur Foundation, 2015, it is estimated that 10-15 % of new building materials are wasted. This estimate is based on conducted interviews.

UPCYCLE CONCRETE

LCA - ACROSS IMPACT CATEGORIES



Impact category	Product		
	Benchmark 6 % waste	Benchmark 10 % waste	Upcycle concrete
Acidification [kg SO2 eq]	0,65	0,68	0,66
Eutrophication [kg PO4--- eq]	0,18	0,19	0,17
Global warming Potential [kg CO2 eq]	327,48	339,93	311,94
Ozone layer depletion (ODP) [kg CFC-11 eq]	1,52E-05	1,58E-05	1,35E-05
Photochemical oxidation [kg C2H4 eq]	0,027	0,028	0,027

ACROSS IMPACT CATEGORIES

The diagram and table above show the environmental impacts that occur in the production of 1 m³ upcycle concrete from mobile mixing plants and at 1 m³ equivalent conventional concrete with respectively 6-10 % waste (upcycled has 2 % due to local casting).

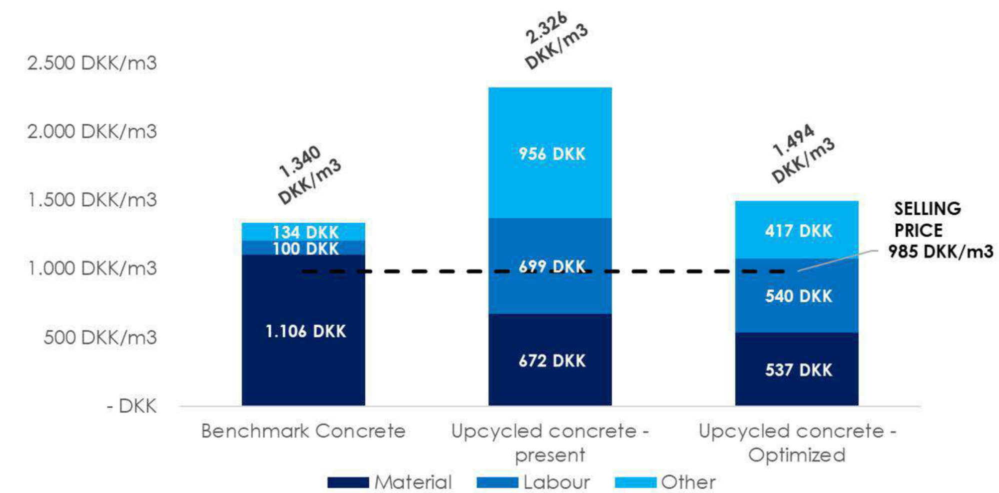
From this it can be seen that upcycle concrete performs better than conventional concrete in all impact categories.

DIRECT AND DERIVATIVE IMPACTS

In the LCA of concrete we find both direct and derivative impacts. The direct impact from upcycling stems from the savings in replacing virgin aggregate with upcycled materials, though this impact is low in amount of CO_2 relative to the high negative impact of using cement.

The derivative effect comes from minimizing waste due to on site production as industrial production was not possible at the time. This derivative impact comes out mainly positive due to reduction of waste, though we also find that using a diesel generator in the production (as it was not posible to use the Danish electricity grid) should not be repeated if possible.

LCC RESULTS - PRODUCT LEVEL



LCC UPCYCLE CONCRETE

The graph above shows the expenses for producing concrete across benchmark, upcycle concrete and optimised concrete. The results shown express the cost structure of the different alternatives across the following parameters: material, labour and other costs. The benchmark is the same as presented in the LCA of upcycle concrete.

Benchmark: The benchmark chosen is from the supplier UNICON CEMENTIR, the functional concrete UNI-WALL® (DMAX 16 MM, SLUMPFLOW 620 MM) compressive strength of C35. The prices reflected are based on MOE experience price in m³ and do not include pumping costs as this process does not differ from upcycle concrete; by excluding them, the LCC results unbiasedly show the differences in the two production processes. In addition, a waste percentage of 10% has been added to the unit price in order to make the analysis aligned with LCA.

Upcycle concrete: The present cost structure of upcycle concrete reflects all production costs, excluding R&D and 90% of project management costs; they are considered to be investment in innovation, and thus ought not to be part of the analysis. Furthermore, pumping costs have been excluded following the same rationale described in the previous paragraph.

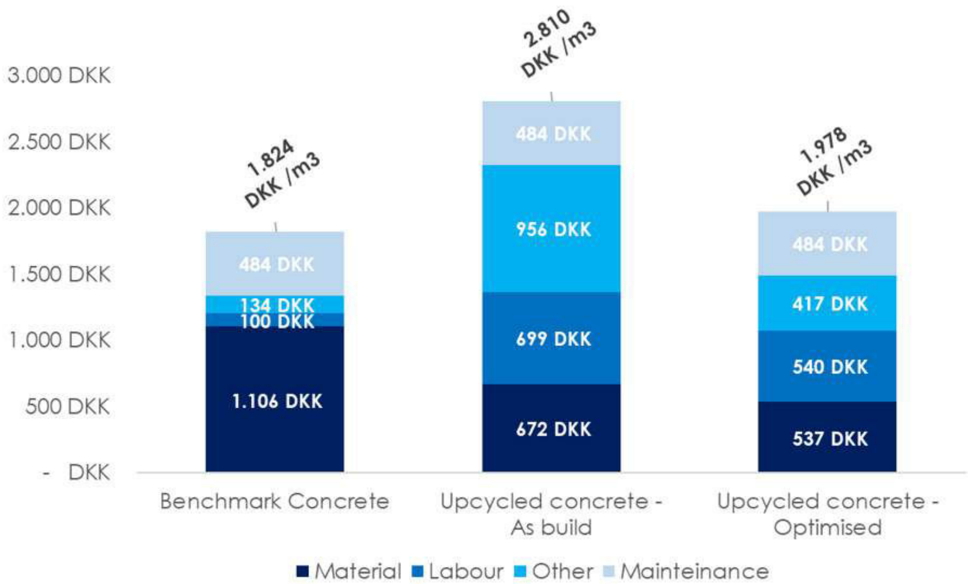
Finally, an additional 2% of waste has been added to the unit price in order to make the results aligned with the LCA analysis.

Optimised scenario: The future cost structure is forecasted on the assumptions of a larger production (2000 m3), reduced idle time and a better planning of fixed cost, primarily rentals. In short, these are the benefits of economies of scale. If these premises hold, upcycle concrete is more competitive to benchmark's selling price.

Result: The benchmark concrete outperforms the present upcycle concrete. This is largely due to the low amount of concrete delivered in this project directly competing with big concrete factories with the advantage of streamlined production processes and economies of scale. In concrete products there is a very high level of fixed costs why amount has a big impact on the price per unit. This is shown in the optimised upcycle concrete where the biggest change lies in the amount produced (from 837 to 2000 m³). Furthermore, expenses for upcycle concrete are based on a first-time-production leaving room for many smaller optimisations in production processes.

UPCYCLE CONCRETE

LCC RESULTS - PRODUCT LEVEL



Selling price: Looking at the result compared to the selling price on the former page there is a clear difference. Here it is important to state that the selling price was based on an agreement of delivering 2000 m³ concrete, which in the development process was scaled down to 837m³ concrete delivered. Due to this change an extra payment was made later in the process evening out the difference.

Cost structure analysis: The cost structure notably differs between the benchmark, the upcycled concrete as-build and the optimised upcycle concrete. In benchmark we find a very heavy expense to the purchase of materials while benchmark is more efficient on labour and other costs. On the other hand, circular production of concrete has a large share of "other costs", mostly reflecting costs for the rental of equipment.

As the expenses for upcycle concrete are based on first-time-production there is a clear potential in optimizing the expenses for labour costs and thus become more competitive on price. Among others, this is a big difference between the upcycling concrete delivered and the optimised upcycle concrete.

The differences in expenses do not only show interesting potentials for optimisation. They also reflect a more sustainable business model spending less on the acquisition of natural resources and more on labour, hereby investing in people instead of materials.

Maintenance: In the graph above is presented the total costs of a product including maintenance. Maintenance and replacement costs are dependent on the type of material. In short, it is the net present value of the yearly maintenance costs, estimated as a percentage of the acquisition price. Replacement costs are not included, as the calculation period is shorter than the concrete's life span.

As the materials are exactly the same across benchmark and upcycle concrete the maintenance is also forecasted to be the same.

UPCYCLE CONCRETE

SUMMARY OF IMPACT

RESOURCE OPTIMISATION

In addition to the CO_2 and financial effect, the use of recycling aggregate contributes to saving 904 tonnes of waste from downcycling and / or landfill - just for this project at Upcycle Studios. This also means that the same amount of virgine gravel has been saved as aggregate, which is a key resource impact, knowing that we will run out of access to gravel in Denmark by 2056.

UPCYCLE CONCRETE
RESULTS FOR UPCYCLE STUDIOS

	AS BUILD	POTENTIAL IF BUILD PER OPTIMISED SCENARIOS*
CO_2	25 tonnes CO_2-eq/rowhouse 8 % saving	31 tonnes CO_2-eq/rowhouse 11 % saving
$	-86,239 DKK/rowhouse 74 % more expensive	-13,469 DKK/rowhouse 12 % saving
	904 tonnes waste in total	904 tonnes waste in total

* Best case

PRODUCT DESCRIPTION

The offcut douglas facade consists of upcycle wood that as been treated with linseed oil in order to protect the wood and provide the desired aesthetics. Linseed oil protects the wood from the sun's radiation and its fungicide protects the wood from rot and fungus. The linseed oil penetrates the wood and, after curing, creates a strong thermoplastic membrane that minimises the absorption of moisture.

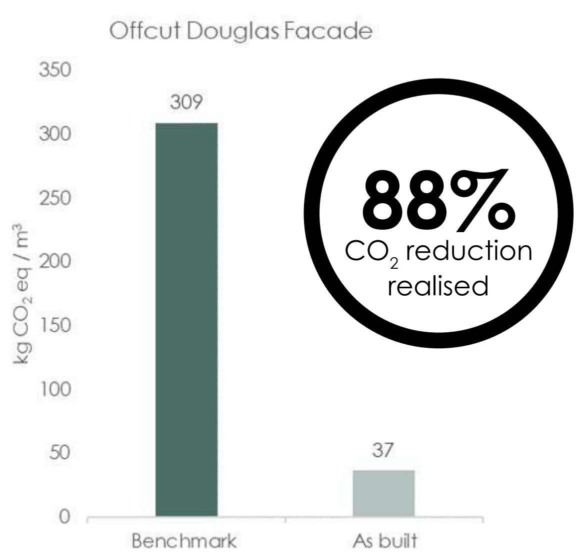
Material source: The wood is discarded wood from Dinesen Floors high quality production.

Declared unit: 1 m³ weather resistant wood facade.

Included processes: The processes included are the handling, profiling, and surface treatment of the wood as well as production waste.

Benchmark: The benchmark is thermotreated spruce and pine (from Moelven EPD) with a surface treatment of paint.

Result: 88 % CO_2 reduction: When comparing the upcycle offcut wood facade with benchmark, a CO_2 saving of 88 % is found. This is mainly due to the fact that a waste wood material, that is used in the upcycle product, does not contribute with negative environmental impacts in the beginning phases concerning processing of the wood from full life trees to wooden materials.

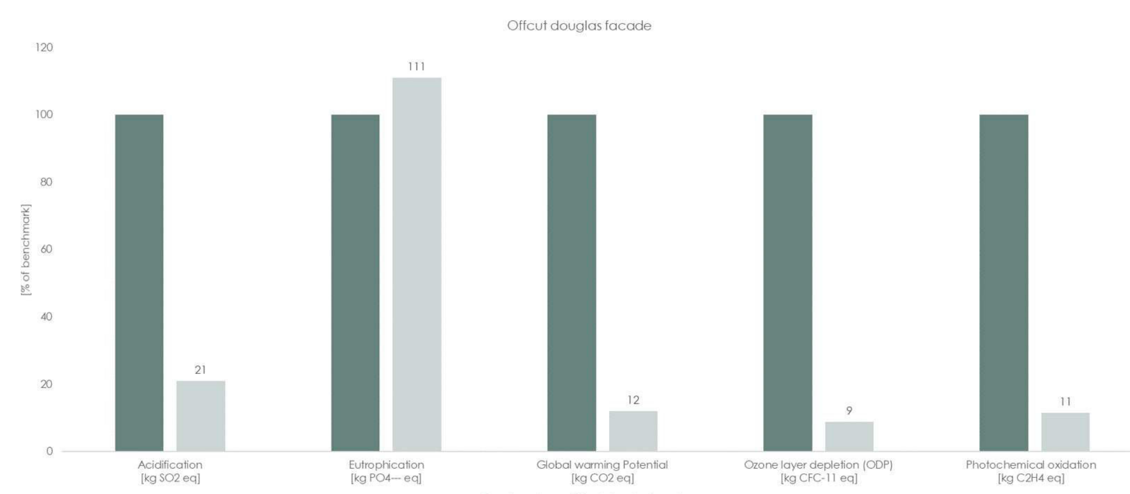


OFFCUT DOUGLAS FACADE

ACROSS IMPACT CATEGORIES

The table and graphic below show the environmental impacts that occur in the production of 1 m² offcut douglas facade in Upcycle Studio and 1 m² corresponding wooden facade. From this it can be seen that the offcut douglas facade performs better across most impact categories - and most heavily in Global Warming Potential as it is not necessary to produce new wood for the upcycle product.

Impact category	Product	
	Benchmark	Offcut douglas facade
Acidification [kg SO2 eq]	1,47	0,31
Eutrophication [kg PO4--- eq]	0,19	0,21
Global warming Potential [kg CO2 eq]	309,06	37,00
Ozone layer depletion (ODP) [kg CFC-11 eq]	4,55E-05	3,99E-06
Photochemical oxidation [kg C2H4 eq]	0,13	0,02



PRODUCT DESCRIPTION

The offcut douglas wall cladding is upcycle flooring wood used as interior wall cladding. The wood is painted with linseed oil in order to obtain the desired aesthetic expression. Douglas is a soft species of wood that is recognizable for its distinct annual growth rings as well as the tree's heartwood which differs in color from the sapwood.

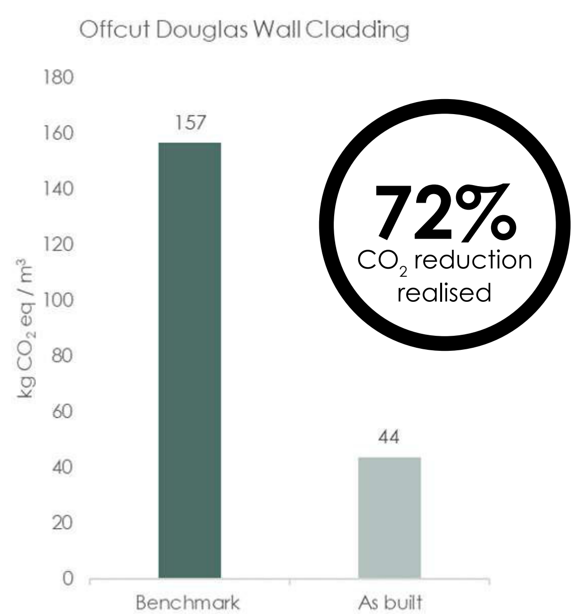
Material source: The wood is discarded wood from Dinesen Floors high quality production.

Declared unit: 1 m³ surface treated soft wood wall cladding.

Included processes: The processes included are the handling, profiling, and surface treatment of the wood as well as production waste.

Benchmark: The benchmark is solid pine wood panel for internal use, surface treated with wood paint (from Moelven EPD).

Result: 72 % CO_2 reduction: When comparing the offcut douglas wall cladding with benchmark, a CO_2 reduction of 72% is found. This is mainly due to the fact that a waste wood material, that is used in the upcycle product, does not contribute with negative environmental impacts in the beginning phases concerning processing of the wood from full life trees to wooden materials.

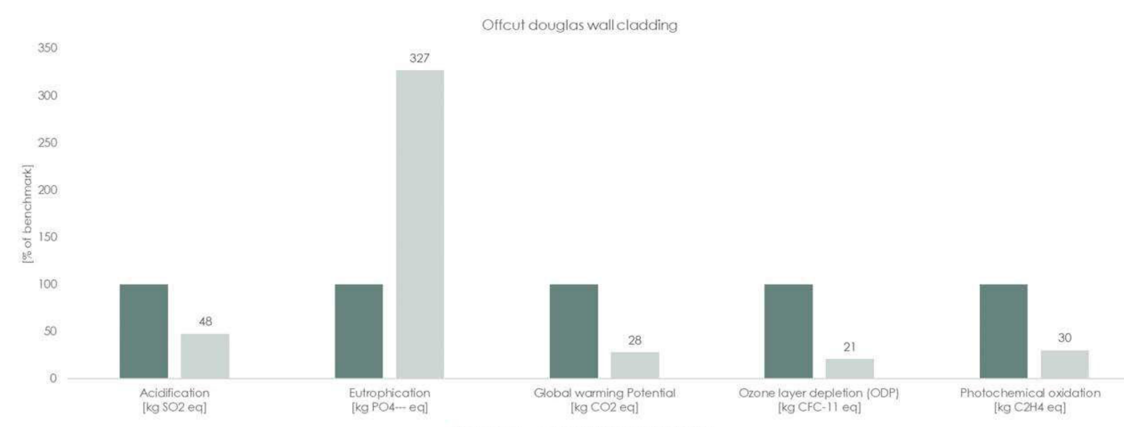


OFFCUT DOUGLAS WALL CLADDING

ACROSS IMPACT CATEGORIES

The table and graphic below show the environmental impacts that occur in the production of 1 m² offcut douglas wall cladding in Upcycle Studio and 1 m² corresponding wooden wall cladding. From this it can be seen that the offcut douglas wall cladding performs better in all impact categories apart from eutrophication compared to benchmark.

Impact category	Product	
	Benchmark	Offcut douglas wall cladding
Acidification [kg SO2 eq]	0,82	0,39
Eutrophication [kg PO4--- eq]	0,09	0,28
Global warming Potential [kg CO2 eq]	156,92	44,00
Ozone layer depletion (ODP) [kg CFC-11 eq]	1,93E-05	4,01E-06
Photochemical oxidation [kg C2H4 eq]	0,06	0,02



OFFCUT DOUGLAS FLOOR

PRODUCT DESCRIPTION

The offcut douglas floor is upcycle wood planks used for interior flooring. The wood is painted with linseed oil in order to obtain the desired aesthetic expression. Douglas is a soft species of wood that is recognisable for its distinct annual growth rings as well as the tree's heartwood which differs in color from the sapwood.

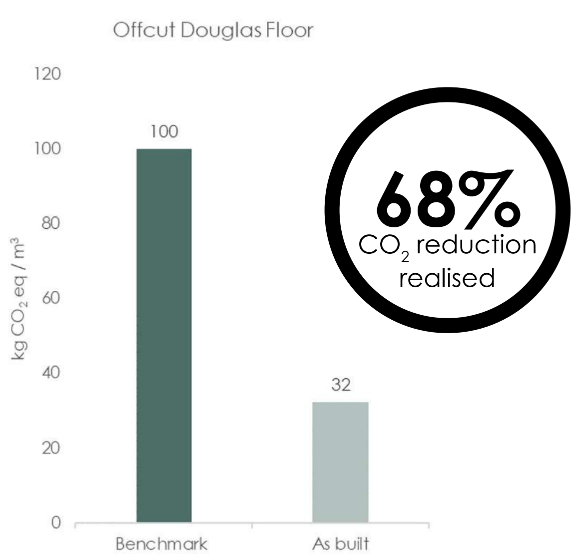
Material source: The wood is discarded wood from Dinesen Floors high quality production.

Declared unit: 1 m³ surface treated soft wood floor.

Included processes: The processes included are the handling, profiling, and surface treatment of the wood as well as production waste.

Benchmark: The benchmark is solid pine flooring surface treated with hard wax oil (from Moelven EPD).

RESULT: 68 % CO_2 reduction: When comparing the offcut douglas floor with benchmark, a CO_2 reduction of 68% is found. This is mainly due to the fact that a waste wood material, that is used in the upcycle product, does not contribute with negative environmental impacts in the beginning phases concerning processing of the wood from full life trees to wooden materials.



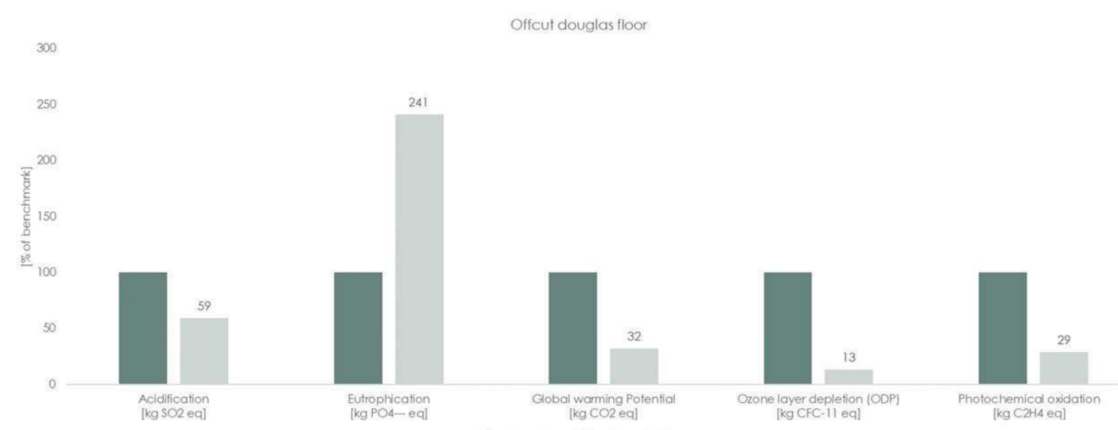
LENDAGER GROUP

OFFCUT DOUGLAS FLOOR

ACROSS IMPACT CATEGORIES

The table and graphic below show the environmental impacts that occur in the production of 1 m² offcut douglas floor in Upcycle Studio and 1 m² corresponding wooden product. From this it can be seen that the offcut douglas floor perform better than benchmark in all impact categories apart from eutrophication.

Impact category	Product	
	Benchmark	Offcut douglas floor
Acidification [kg SO2 eq]	0,54	0,32
Eutrophication [kg PO4--- eq]	0,10	0,23
Global warming Potential [kg CO2 eq]	100,00	32,00
Ozone layer depletion (ODP) [kg CFC-11 eq]	1,63E-05	2,16E-06
Photochemical oxidation [kg C2H4 eq]	0,05	0,02



LENDAGER GROUP

PRODUCT DESCRIPTION

The offcut oak floor is upcycle wood planks used interior flooring. The wood is painted with linseed oil in order to obtain the desired aesthetic expression. Oak is a hard species of wood that is recognizable for its limited color variation, creating an aesthetically simple look.

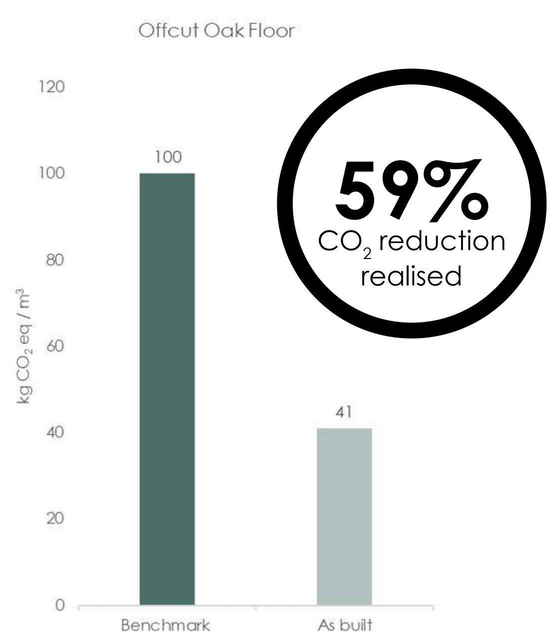
Material source: The wood is discarded wood from Dinesen Floors high quality production.

Declared unit: 1 m³ surface treated hard wood floor.

Included processes: The processes included are the handling, profiling, and surface treatment of the wood as well as production waste.

Benchmark: The benchmark is solid pine flooring surface treated with hard wax oil (from Moelven EPD).

RESULT: 59% CO_2 reduction: When comparing the offcut oak floor with benchmark, a 59% CO_2 reduction is found. This is due to the fact that the upcycled wood is a waste material thereby not giving an impact for the growing, harvesting and production of the virgin wood material.

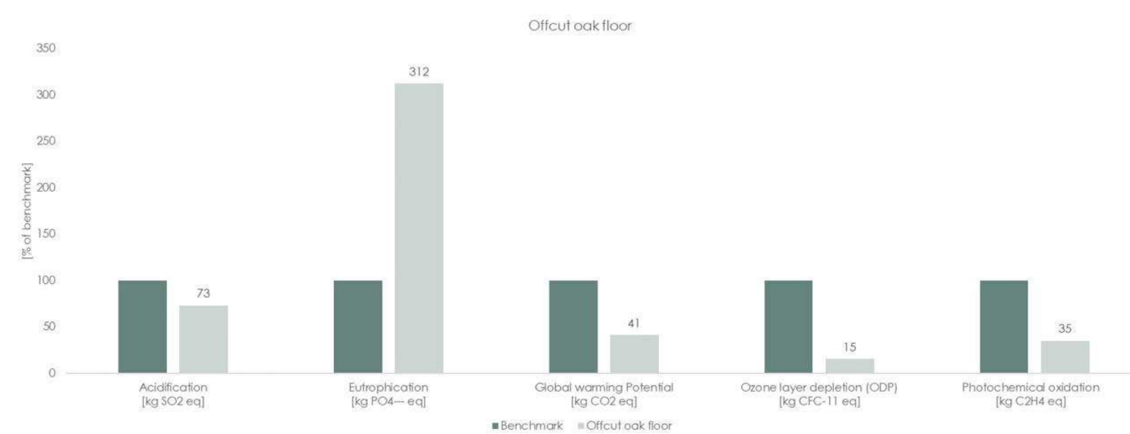


OFFCUT OAK FLOOR

ACROSS IMPACT CATEGORIES

The table and graphic below show the environmental impacts that occur in the production of 1 m² offcut oak floor in Resource Rows and 1 m² corresponding wooden product. From this it can be seen that the offcut oak floor performs better than benchmark in every impact category apart from eutrophication.

Impact category	Product	
	Benchmark	Offcut oak floor
Acidification [kg SO2 eq]	0,54	0,39
Eutrophication [kg PO4--- eq]	0,10	0,30
Global warming Potential [kg CO2 eq]	100,00	41,00
Ozone layer depletion (ODP) [kg CFC-11 eq]	1,63E-05	2,47E-06
Photochemical oxidation [kg C2H4 eq]	0,05	0,02



UPCYCLE TERRACE

PRODUCT DESCRIPTION

The upcycle terrace consists of upcycle wood that has been cut into new planks and impregnated with linseed oil. Impregnating with linseed oil protects the wood from the sun's radiation and its fungicide protects the wood from rot and fungus. The linseed oil penetrates the wood and, after curing, creates a strong thermoplastic membrane that minimises the absorption of moisture.

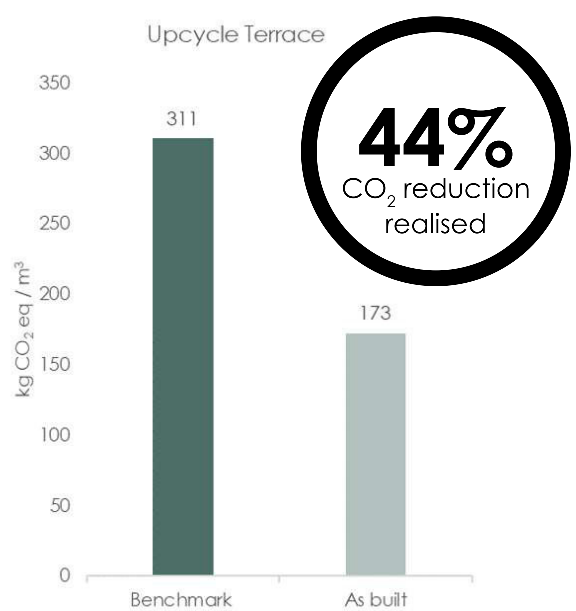
Material source: The wood used for the Resource Rows are discarded wooden sleepers from the Copenhagen Metro.

Declared unit: 1 m³ weather resistant terrace wood.

Included processes: The processes included are handling, cutting, and impregnating the wood planks as well as waste.

Benchmark: The benchmark is thermotreated spruce and pine (from Moelven EPD) with a surface treatment.

Result: 44% CO_2 reduction: When comparing the upcycled terrace with benchmark, a CO_2 reduction of 44% is realised. This is mainly due to the fact that a waste wood material, that is used in the upcycle product, does not contribute with negative environmental impacts in the beginning phases concerning processing of the wood from full life trees to wooden materials.

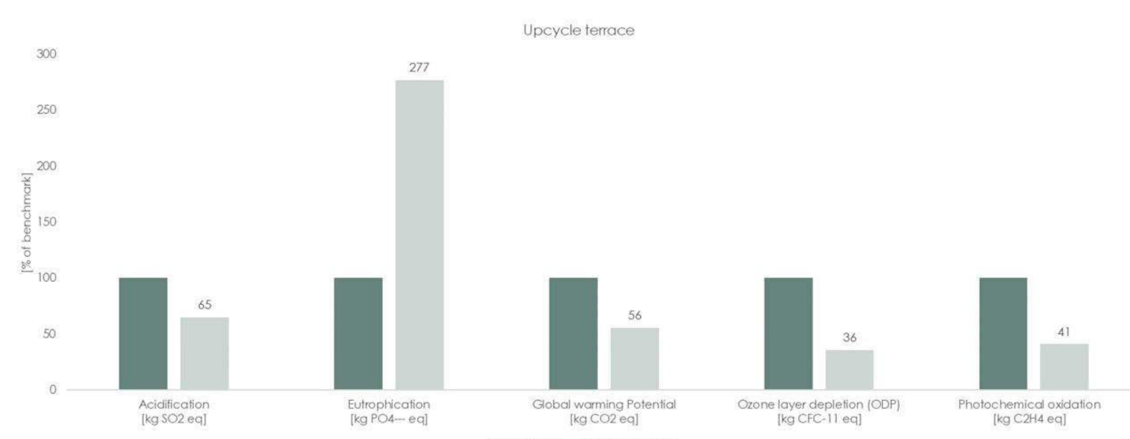


UPCYCLE TERRACE

ACROSS IMPACT CATEGORIES

The table and graphic below show the environmental impacts that occur in the production of 1 m² upcycle terrace facade in Upcycle Studio and 1 m² corresponding wooden facade. From this it can be seen that the upcycle terrace performs better across all impact categories apart from eutrophication.

Impact category	Product	
	Benchmark	Upcycle terrace
Acidification [kg SO2 eq]	1,48	0,96
Eutrophication [kg PO4--- eq]	0,19	0,53
Global warming Potential [kg CO2 eq]	310,63	173,00
Ozone layer depletion (ODP) [kg CFC-11 eq]	4,55E-05	1,63E-05
Photochemical oxidation [kg C2H4 eq]	0,13	0,06



PRODUCT DESCRIPTION

The upcycle burned wood facade consists of reused wood. Instead of impregnating the wood, the surface has been burned and treated with linseed oil. By burning the upper millimeters of the wood, the sugar inside the tree will also be burned meaning that harmful microorganisms cannot live in the wood. Additionally, water evaporates from the wood and the surfaces closes so that no water can enter. This is a sustainable method making the wood highly weather resistant and providing a beautiful surface.

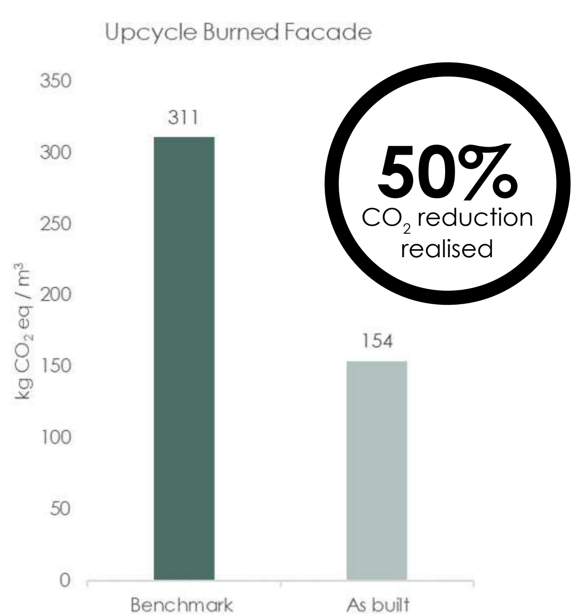
Material source: The wood used for the Resource Rows are discarded wooden sleepers from the Copenhagen Metro.

Declared unit: 1 m^3 surface treated wood facade.

Included processes: The processes included are handling, cutting, burning, surface treating the planks, and waste. Gas for and emissions from burning the planks are also included.

Benchmark: The benchmark is thermotreated spruce and pine (from Moelven EPD) surface treated with wood paint.

Result: 50% CO_2 reduction: When comparing the burned facade of upcycled wood with virgin thermotreated wood, the CO_2 emissions are lowered by 50%. This is mainly due to the fact that a waste wood material, that is used in the upcycle product, does not contribute with negative environmental impacts in the beginning phases concerning processing of the wood from full life trees to wooden materials.

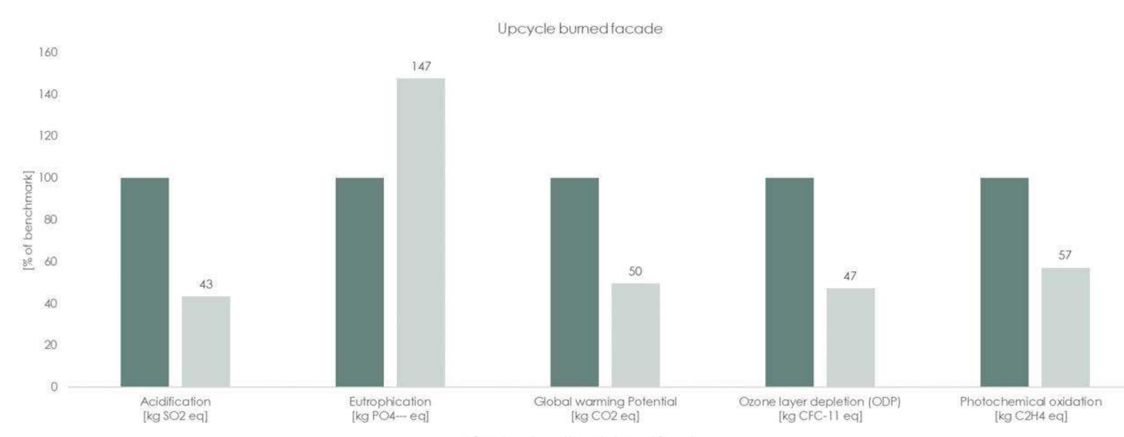


UPCYCLE BURNED FACADE

ACROSS IMPACT CATEGORIES

The table and graphic below show the environmental impacts that occur in the production of 1 m^2 upcycle burned wood facade in Resource Rows and 1 m^2 corresponding wooden facade. From this it can be seen that the upcycle burned wood facade performs better across all impact categories (apart from eutrophication) - and most heavy in Global Warming Potential.

Impact category	Product	
	Benchmark	Upcycle burned facade
Acidification [kg SO2 eq]	1,48	0,64
Eutrophication [kg PO4--- eq]	0,19	0,28
Global warming Potential [kg CO2 eq]	310,63	154,00
Ozone layer depletion (ODP) [kg CFC-11 eq]	4,55E-05	2,14E-05
Photochemical oxidation [kg C2H4 eq]	0,13	0,08



UPCYCLE ROOF TOP HOUSE

PRODUCT DESCRIPTION
The upcycle roof top house at the Resource Rows are made of different types of reused wood as well as reused glazing. The roof top house has only facade materials on three sides as it is placed against a fire resistant wall on one side it is mounted. Furthermore, there is no flooring.

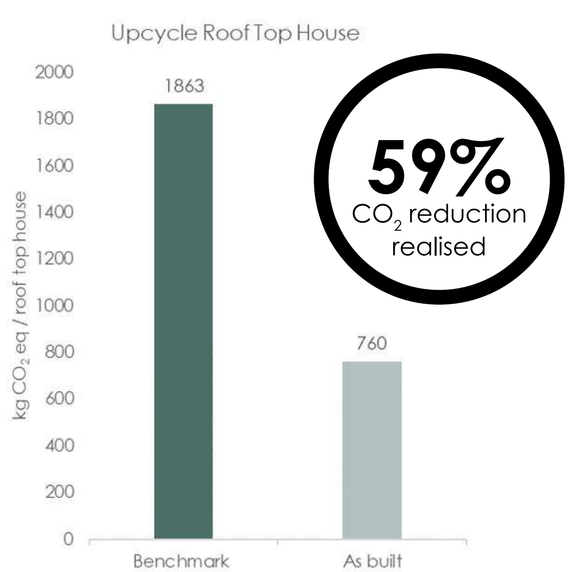
Material source: Discarded wood from the Danish gluelam factory Vinderup Træindustri and the Norwegian modified wood producer, Kebony, as well as double glazing from an energy renovation of a building in Copenhagen.

Declared unit: 1 roof top house of 10 m² with windows, access through a door, and no floor. Waste of wood and roofing membrane is also included.

Included processes: The processes included are transport and preparation of reused materials, production of all virgin materials, and manufacturing of the roof top house.

Benchmark: A 1:1 roof top house made of comparable virgin wood. Both wood products have been replaced with thermotreated spruce and pine. The windows are made of one layered glazing and wood frame.

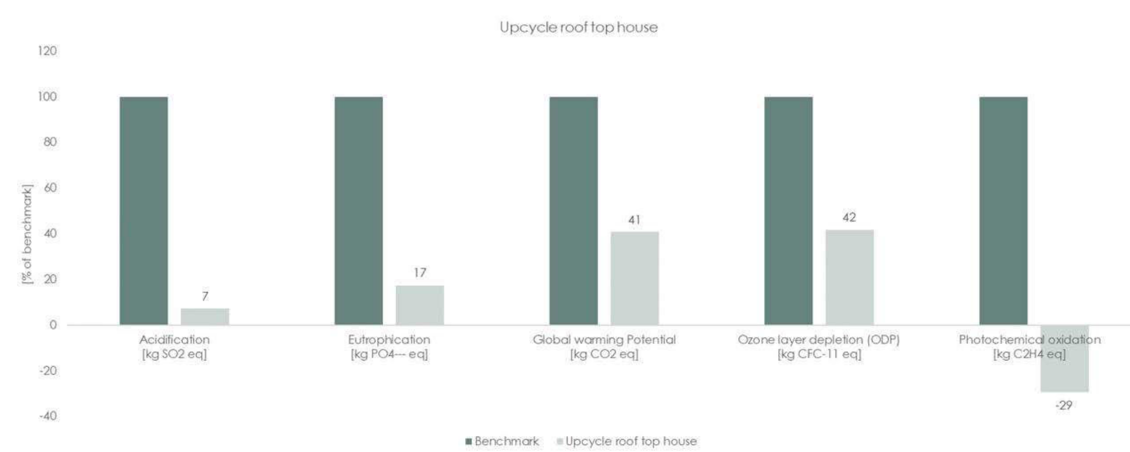
59% CO_2 reduction: When comparing the upcycle roof top house with benchmark, 59% CO_2 reduction is obtained. This is mainly due to the fact that a waste wood material, that is used in the upcycle product, does not contribute with negative environmental impacts in the beginning phases concerning processing of the wood from full life trees to wooden materials.



UPCYCLE ROOF TOP HOUSE

ACROSS IMPACT CATEGORIES
The table and graphic below show the environmental impacts that occur in the production of 1 m² upcycle roof top house at Resource Rows and 1 m² corresponding wooden product. From this it can be seen that the upcycle roof top houses perform better in all impact catagories.

Impact category	Product	
	Benchmark	Upcycle roof top house
Acidification [kg SO2 eq]	12,019	0,871
Eutrophication [kg PO4--- eq]	1,484	0,258
Global warming Potential [kg CO2 eq]	1863,349	760,000
Ozone layer depletion (ODP) [kg CFC-11 eq]	2,06E-04	8,60E-05
Photochemical oxidation [kg C2H4 eq]	-0,177	0,052

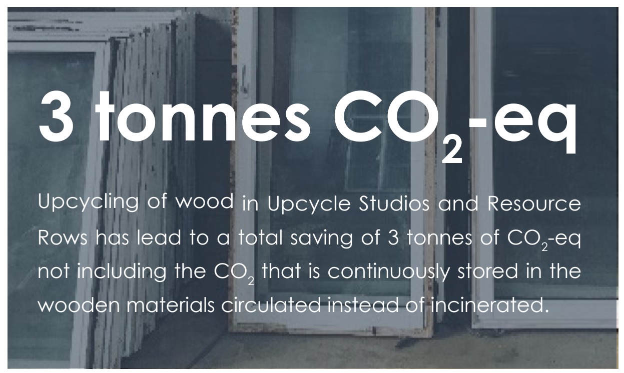


UPCYCLE WOOD

SUMMARY OF IMPACT

RESOURCE OPTIMISATION

In addition to the CO_2 savings achieved by upcycling the window panes, a saving of resources has also been achieved. The upcycling of wooden products have resulted in a saving of 7 tonnes of waste that has been upcycled instead of being downcycled, incinerated or landfilled. This minimises the need to produce new, virgine panes that pose a significant environmental impact.



3 tonnes CO_2-eq

Upcycling of wood in Upcycle Studios and Resource Rows has lead to a total saving of 3 tonnes of CO_2-eq not including the CO_2 that is continuously stored in the wooden materials circulated instead of incinerated.

UPCYCLED WOOD
FOR UPCYCLE STUDIOS & RESOURCE ROWS

AS BUILD*

CO_2 3 tonnes CO_2-eq

7 tonnes waste

* Includes interior and exterior wood products

REFLECTION

HOW DOES CIRCULAR BUILDING MATERIALS PERFORM?

UPCYCLING MATTERS
Across the analysed materials, it is seen that upcycling matters. It does make a difference to use upcycle materials instead of virgin materials! This is both in regards to climate change, resource scarcity, and partly financials having potentials to be directly competitive in optimised scenarios.

Based on an assessment of the four upcycle materials; concrete, windows, bricks and wood, we can conclude that significant environmental value has been created in all four material categories. Despite that it is the first time windows and bricks have been circulated with this method and the first time that concrete is based on 100% recycled aggregate, we have now demonstrated clear positive effect of upcycle materials across resource consumption and CO_2 emissions.

The products included in Upcycle Studios and the Resource Rows are all first time productions. This means, that we have obtained an impressive impact based on little former experience.

WASTE MINIMISING
There is also a significant positive environmental impact in the minimisation of waste and the saving of virgin resources. In the development of the four products we have saved 2,223 tonnes of waste from the two case builds alone. A saving that will be rising in a scenario of scaling.

THE POSITIVE ADD-ON'S OF UPCYCLING
Clarifying that circulation of materials has a positive CO_2 effect is positive, but not surprising. What is also interesting in these analyses is how we have several positive impacts that are not directly embedded in the specific circulated materials, but related to the processes and consequences of the circulation. These include:

- Being able to use wooden frames instead of aluminium frames for the windows due to the double-layered framing strengthening the upcycle window.
- The opportunity to source concrete aggregate locally instead of transporting it long distances.
- The treatment of the wood material where there has been made very sustainable choices due to the focus on circular economy and clean materials.

PRICES WITH POTENTIAL
In the LCC analysis we have found that though products were more expensive than benchmark they all have the potential for direct competitive optimised versions which will not only lead to better prices, but also to an even higher impact across waste and CO_2 emissions (as the price optimisation partly is achieved through an increase in recycled materials).

Reasons for the relatively higher product prices include:

- Precautionary principles taken to ensure the quality and performance of the upcycle materials due to first-time-production. This includes increased strength requirements for concrete, thickness of concrete back wall in brick element and retrofitting of recycle glazing in windows.
- Lack of economies of scale, thus relatively high fixed costs, imply a high cost per unit.
- Due to the first production line for windows and bricks, and second production line for concrete, it will be possible to increase efficiency that can reduce costs for development, harvesting, transport, production and assembly costs.

All reasons that can be handled in future productions making the upcycle products more price competitive with high performance on design and aesthetics, while further improving the environmental impact.

PRODUCTS ACROSS CO_2, WASTE AND PRICE
For a review of impact across parameters, see next page.

BRICK
Looking at the brick analysis, the percentage potential of lowering environmental impacts is larger at material level than at product level. This difference is caused by the need of adding either steel or concrete behind the cut brick elements in order to reuse them as a facade. The brick facade is not directly competitive on price and will only be so if harvest and production methods are very optimised. That being said, the brick facade brings a completely new aesthetic providing a branding and aesthetic value to the final building project.

CONCRETE
Though the impact of upcycle concrete is lower than on eg. upcycle bricks looking at the percentage of CO_2 savings per m³, the impact in large scale is still bigger. In construction today concrete is still the most used material meaning that an improvement of 5-8 % of CO_2 per m³ can and will be a significant impact if the solution is scaled across construction sites. This also enables a more profitable business case, as the fixed costs of concrete production are very high, and we therefore need volume to make it a scalabe solution. Future scenarios, where the aggregate cannot be sourced locally, will lead to a further increase in CO_2-savings.

Window
The upcycle windows have the largest percentage improvement of CO_2 across the four materials. Here CO_2 savings of 380 kg CO_2 eq / m² have been achieved. That's a total CO_2 saving of 87% compared to benchmark - a saving that can be made even better in optimised scenarios with a higher recycling rate. Windows are also the material performing best on price with +13 % in comparison to a standard curtain wall benchmark and a potential to reach 40-50 % improvement on price in the optimised scenario.

WOOD
The upcycle wooden products include everything from interior such as wall cladding and flooring as well as exterior products including terrasse flooring, roof top houses and wooden facade materials. Across LCA analyses of wooden products, we see a positive performance of upcycle materials with 44-82 % reduced CO_2 savings compared to benchmarks. These savings have been reached due to eliminating the need of the production phases as you have when using virgin wooden materials. LCC calculations have not been conducted on wooden products ,why we cannot say how they performed in terms of price.

CHAPTER 3
SUSTAINABLE BUILDINGS

SUSTAINABLE BUILDINGS

INTRODUCTION

LCA, LCC AND ENERGY

Building on the prior chapter's review of the impact of the specific upcycle materials and products, this chapter will seek to elaborate on how the impact of upcycle solutions is reflected in the overall construction of an average row house in Upcycle Studios and Resource Rows respectively.

The impact analysis is conducted based on the following parameters:

- LCA on building level
- LCC on building level
- 12 different benchmarks
- Energy optimisations

All impact parameters are analysed across the two buildings Upcycle Studios and the Resource Rows. LCA and LCC on building level is conducted on a single, average row house of Upcycle Studios og Resource Rows respectively.

In the different analyses we will dive into the overall effect of different sustainability efforts supplemented by a deep dive into the effect of upcycle efforts across parameters of CO_2, financials and waste.

12 DIFFERENT BENCHMARKS

In the LCA and LCC analyses the results are benchmarked to the same row house in Upcycle Studios og Resource Rows - but without upcycling products.

To understand how Upcycle Studios and Resource Rows perform compared to other row house products, we have included a comparative analysis with 12 LCA calculations of row houses conducted by SBi (see p 98).

UPCYCLE STUDIOS

UPCYCLE STUDIOS - BUILDING LEVEL

LCA AND LCC

THE CONCEPT

Upcycle Studios was the first fully circular residential development, using upcycled solutions ranging from the concrete structure to the upcycle floors, wall cladding, facade, and windows.

In the design of Upcycle Studios there was a great emphasis on upcycling, resource efficiency, and minimizing carbon footprint. At the same time, Upcycle Studios facilitates sharing economy through an embodied basic idea of access instead of ownership creating a shared community between residents.

The building is designed for a high degree of flexibility to ensure the best possible use of the homes at all hours of the day and in different phases of life. The units can be used as a combined housing and workshop for creative freelancers or self-employed entrepreneurs, but also as one dwelling for large families or divided into two separate apartments.

UPCYCLE STUDIOS

Adress:
Robert Jacobsens Vej,
2300 København S
Construction year: 2015-2018
Size: 3340 m^2
Housing: 20 row houses
Project partners:

- Developer: NREP A/S
- Contractor: Arkitektgruppen
- Architect: Lendager ARC
- Upcycle material supplier: Lendager UP
- Consulting engineer: MOE

Total cost: EUR 13.9 millon

The project was economically constructed as a conventional row house project, where sustainability actions could not increase the total budget for the development. This general budgetary constraint has lead to many iterative processes with suppliers and partners that initially had different views and constraints with regards to material upcycling and sustainability.

THE IMPACT

The following chapter will show the overall impact of Upcycle Studios on a building level across carbon footprint and financials. An overview of how many products that are upcycled as well as how the buildings perform across LCA and LCC will be presented here. The LCA will be a deep dive on CO_2 and an overview on how the building performs across all impact categories, while the LCC will investigate the spilt in costs across building elements and between conventional and upcycle products.

Focus on sustainability includes:

MATERIALS

Building waste today represent a huge untapped resource which was exploited in the construction of Upcycle Studios. This was done through upcycling of windows, wood, and concrete.

ENERGY

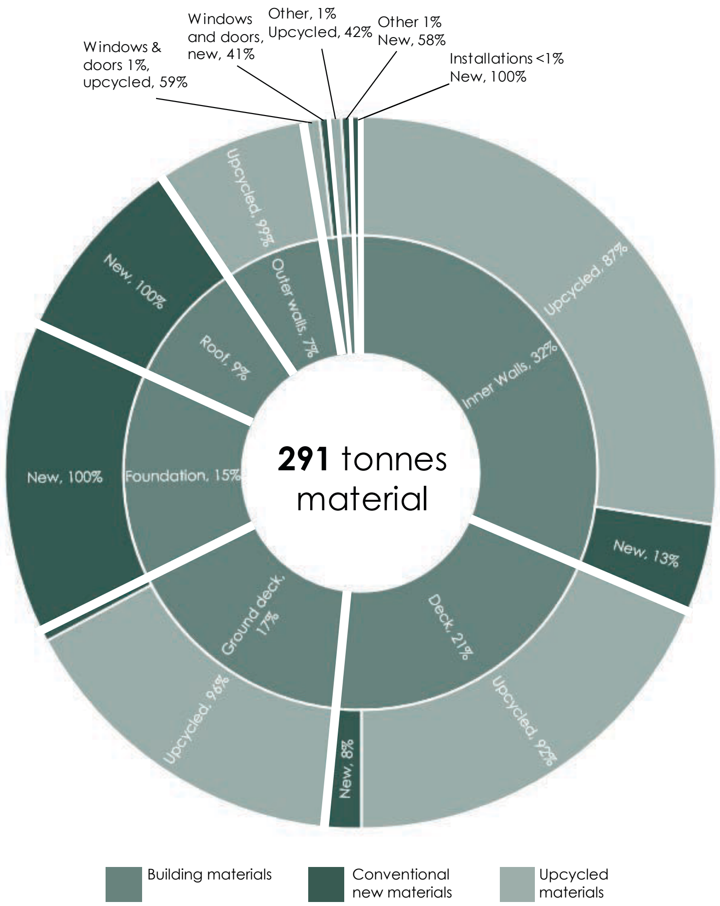
Through the design of the building envelope and use of efficient ventilation, heat recycling, and solar technologies, it is possible to lower the energy consumption for the operation of each home as well as saving CO_2 when using the buildings.

SOCIAL

Communities are developed around the concept of sharing resources providing economic and social benefits for all parties.

UPCYCLE STUDIOS - BUILDING LEVEL

LCA - MATERIAL AMOUNT



DISTRIBUTION BETWEEN UPCYCLE AND NEW MATERIALS

Our current relation to the world's resources is paradoxical. We are continuously exploiting new resources from the Earth, while discarding large amounts of materials that could be reused. Fortunately, we can change the way we do things.

The graph above illustrates the distribution of materials in the building - 291 tonnes representing the total weight of one average row house in Upcycle Studios. The inner annulus shows the distribution across building parts and components, and the outer annulus shows the distribution between new and upcycle materials for each of the building parts.

Out of the 291 tonnes of materials, approximately 202 tonnes or 69% represent upcycle materials, most of which are visible materials. This is a very significant amount considering that all types of materials including foundation, insulation and installations are included here. Not only does it mean that we have eliminated 202 tonnes of waste in the construction of Upcycle Studios. It also means that we have avoided the extraction, production and transportation of the same amount of virgin materials.

The graph reflects the conscious choice of focusing upcycle materials where they are visible in the outer walls, inner walls, and windows. Though upcycle materials also take up a significant part of ground deck and decks, future projects might consider a further effort in using upcycle materials in the more invisible parts and components as e.g. insulation. In the graph above it seems like windows do not take up a big part of upcycle materials. This is only due to window's low density compared to other materials. Had the graph reflected a distribution in m² the picture would have been a bit different.

BUILDING PARTS AND COMPONENTS

Foundation:
- Foundation

Ground slab:
- Ground slab

Outer walls:
- Upcycled windowpanel
- Basement outerwall
- Stern capsule
- Upcycled brick
- Street row house
- Murkrone row house

Inner walls:
- Glass shielding
- Residential wall
- Bath wall
- Apartment boundary walls

Deck:
- Concrete Deck
- Suspended ceiling
- Wooden floor on joists
- Concrete hollow deck

Roof:
- Roof
- Upcycled terrasse
- Upcycled roof greenhouse

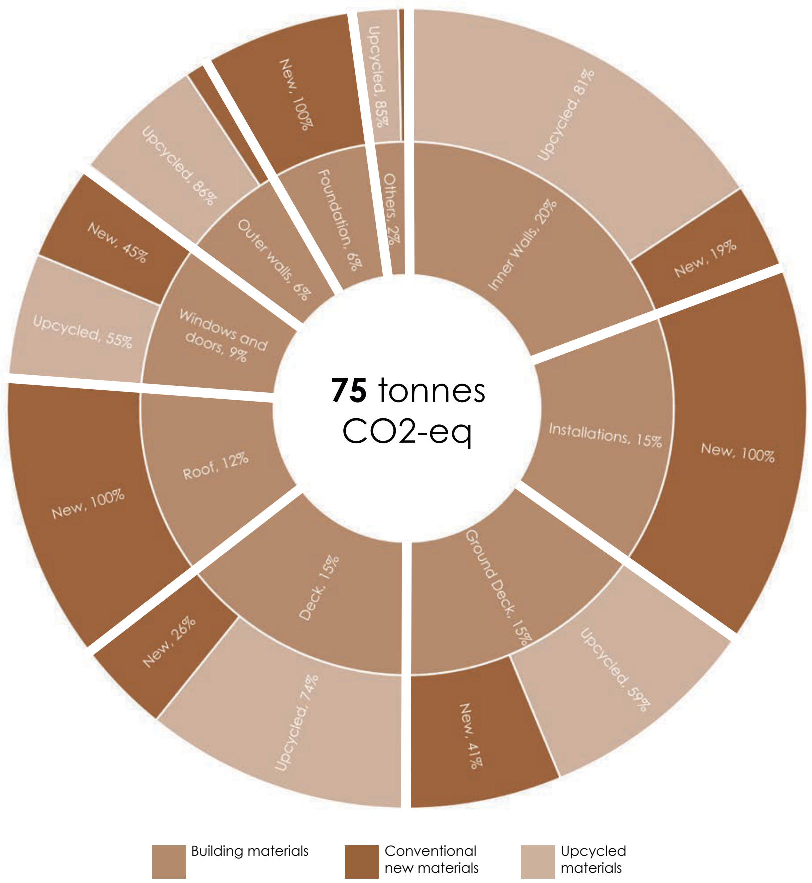
Windows and doors

Installations:
- Sanitation
- Heat
- Ventilation
- Electricity

Others:
- Stairs
- Pillars

UPCYCLE STUDIOS - BUILDING LEVEL

LCA - EMISSIONS OF CO_2-EQ



DISTRIBUTION OF CO_2-EQ

The built environment is one of the most polluting industries due to the high resource consumption and large CO_2 footprint. The built environment is responsible for 40% of the global CO_2 emission. By circulating the materials in the existing buildings, we can reduce CO_2 emissions, minimise the amount of waste generated and decrease the use of virgin materials.

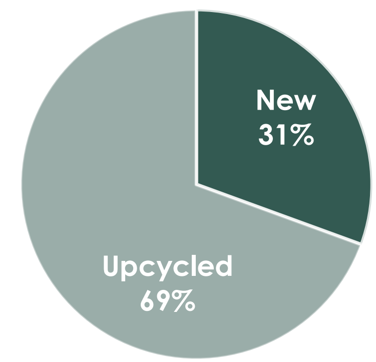
There are considerable differences in the amount of CO_2 embedded in different construction materials. Classical sinners include concrete, windows and bricks as they are CO_2 heavy in the production phase.

The graph above shows the distribution of CO_2-eq from new and upcycle materials - 75 tonnes CO_2-eq representing the total amount of CO2 emitted from one average row house in Upcycle Studios. The inner annulus shows the distribution across the building parts and components, and the outer annulus shows the distribution between new and upcycle materials for each of the building part. A total of 35 tonnes CO_2-eq, or 48% is from upcycle materials, while the main amount of CO_2 emissions stems from conventional materials (52 %). This shows that even though we have a bigger amount of upcycle materials, still the highest amount of CO_2 emission comes from conventional materials speaking the case for circulation.

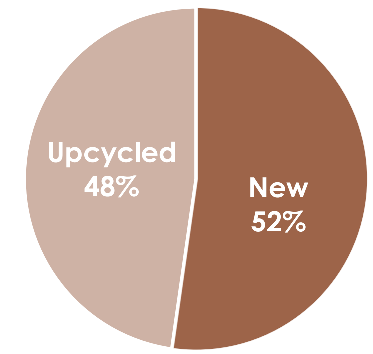
Going a layer deeper we see how the amount of CO_2 emitted from upcycle products mostly come from the concrete elements. This is partly due to the fact that concrete elements "only" has a upcycle percentage of 45 % with several CO_2 heavy virgin materials, including cement. Furthermore, the relatively high level of CO_2 from the concrete is also based on several precautionary principles in the production demanding a higher strength than actually needed. These precautionary principles have been taken to ensure that the upcycle materials live up to safety standards. This is done even if the materials have been tested, and are perform according to standard. As circular construction becomes more common, this will change in the future.

LIFE CYCLE ASSESMENT

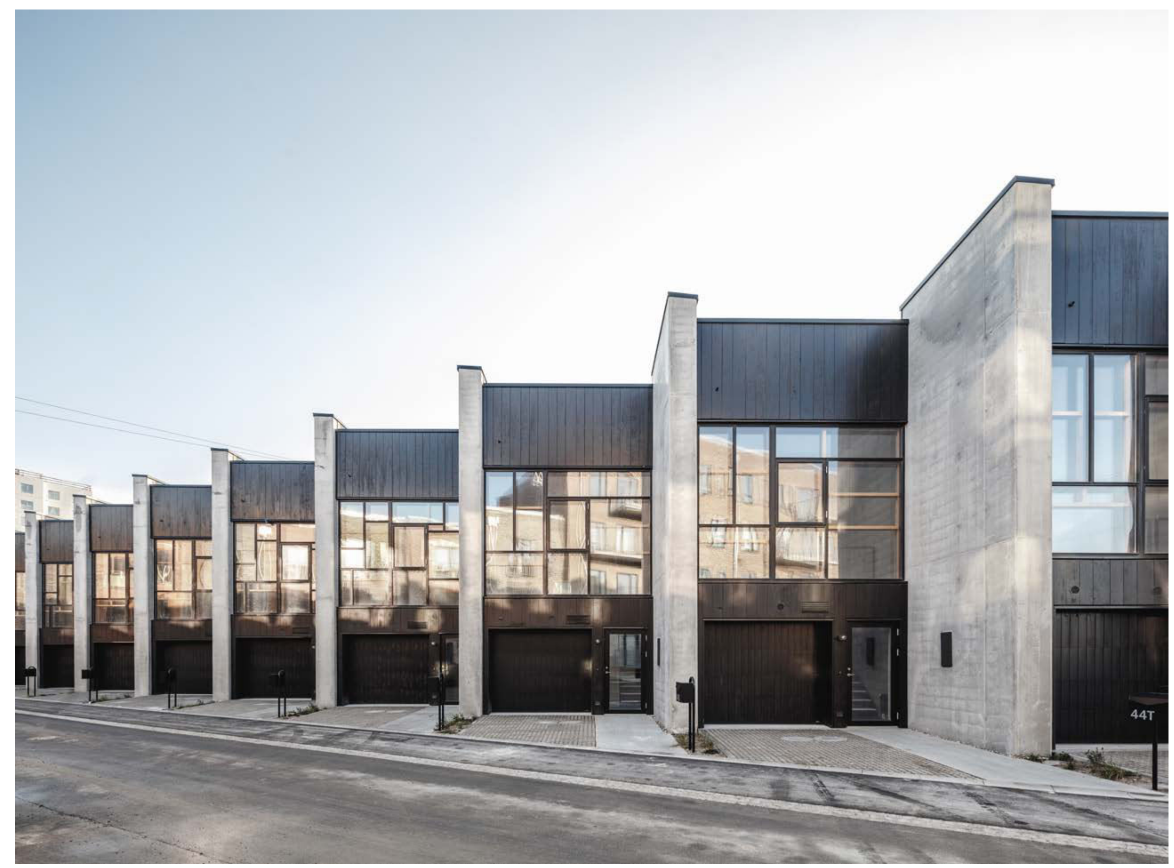
Material distribution by weight



CO2-eq distribution

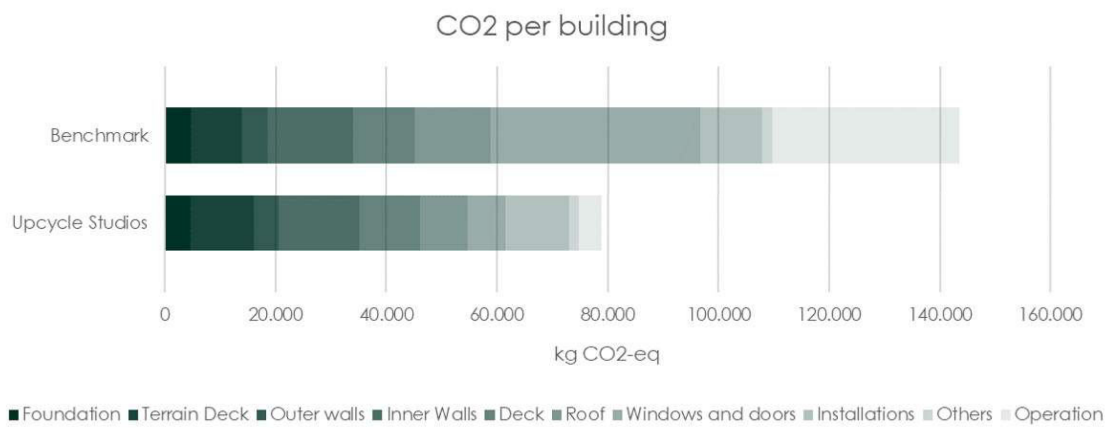


CO2-eq distribution



UPCYCLE STUDIOS - BUILDING LEVEL

LCA- BENCHMARK ANALYSIS



COMPARING UPCYCLE STUDIOS TO BENCHMARK

Life Cycle Assessment (LCA) considers both the embodied CO_2 as well as the CO_2-impact of operations across the life of the building. When comparing the amount of CO_2-eq for Upcycle Studios to the benchmark the results shows that Upcycle Studios has saved in total 65 tonnes of CO2-eq. The graph above illustrates how we move from over 140,000 kg CO_2-eq in benchmark to just beneath 80,000 kg CO_2-eq in Upcycle Studios.

This leads to a 32 % reduction in materials and a total saving of 45 % including operations.

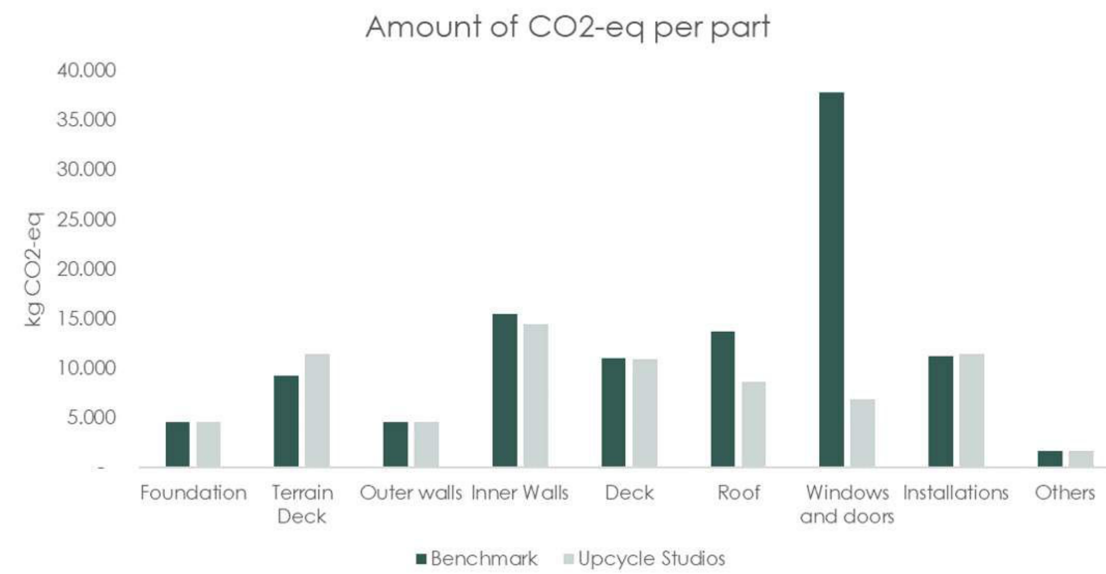
In the top graph on the next page it is shown where the CO_2 emissions come from across building parts, components and operations compared to benchmark.

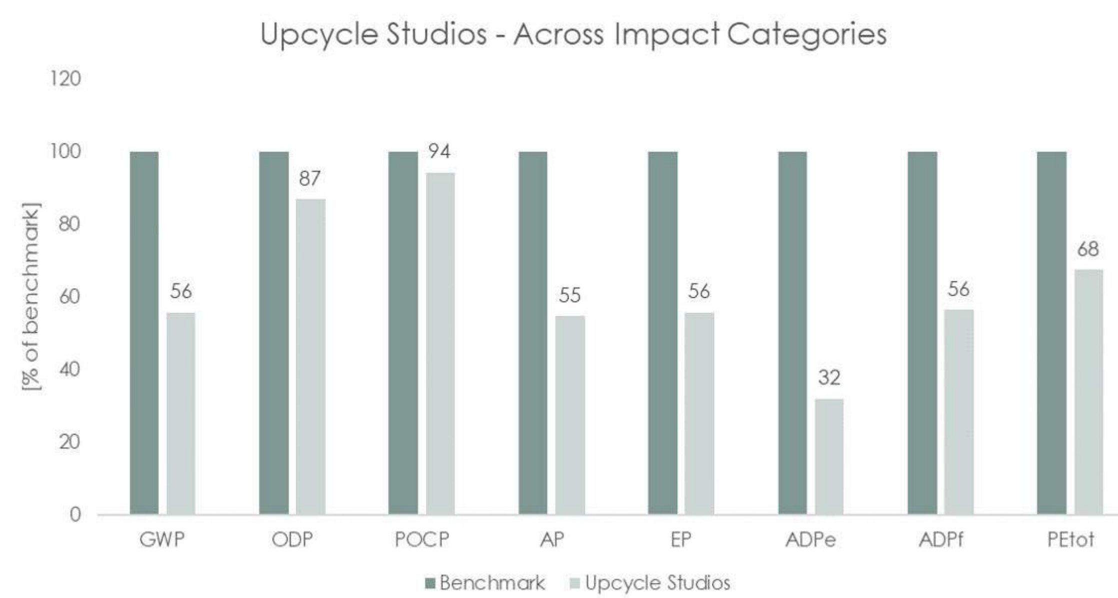
Here we find two central impact categories including operations and windows. You will find a deep dive of operations in section below. The high positive impact within the category of windows and doors stems from upcycle windows as we have reached a 87 % CO2 saving here compared to a curtain wall. If we choose to compare the windows to regular alu/wood windows we see a smaller, but still high impact of 45 %

The central impact categories are supplemented by several other smaller improvements across outer walls, decks and inner walls.

ACROSS IMPACT CATEGORIES

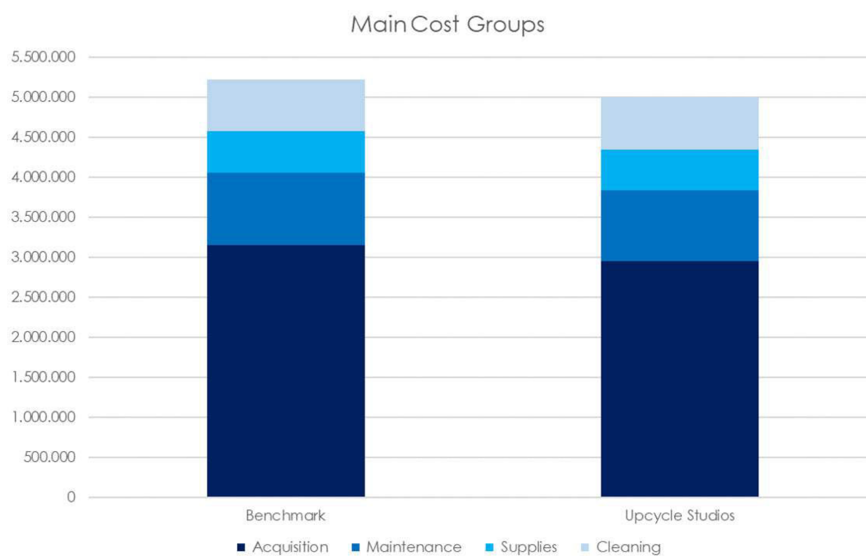
When comparing Upcycle Studios to the benchmark Upcycle Studios has a lower impact across all impact categories. See bottom graph on next page.

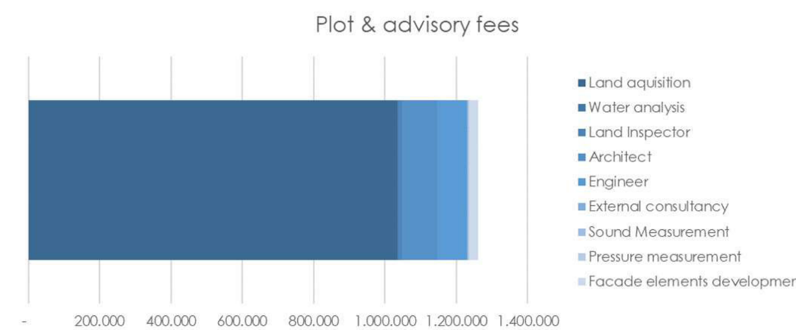




UPCYCLE STUDIOS - BUILDING LEVEL

LCC- OVERALL COST DISTRIBUTION





LCC ON BUILDING LEVEL

To be able to scale an impactful solution, it needs to be able to compete on price or at least fit into an overall budget for construction and maintenance. On the following pages we will dive into an analysis of life cycle costings on building level to clarify the competitiveness of one average Upcycle Studios row house.

DIVISION OF COSTS

The bar chart above reflects all life cycle costs for one Upcycle Studios row house and its benchmark. It gathers all cost categories, ranging from acquisition (construction/materials), maintenance, supply of water and electricity, as well as cleaning costs.

The largest differences arise in the acquisition and maintenance groups. This is due to the price difference in the materials, adding to DKK 203,000, as well as the different maintenance needs given the specifics of the products, adding an additional DKK 22,137. Supply and maintenance are assumed to be the same.

PLOT AND ADVISORY COSTS

In the green diagram the distribution of expenses for advisory is visualised.

KEY FIGURES

Upcycle Studios:

- Acquisition per building costs: DKK 2,956,167
- Net present value of total life cycle costs (including maintenance, supply and cleaning): DKK 5,001,500
- Net present value/m²/year: DKK 1,405 / m² / year is achieved for Upcycle Studios

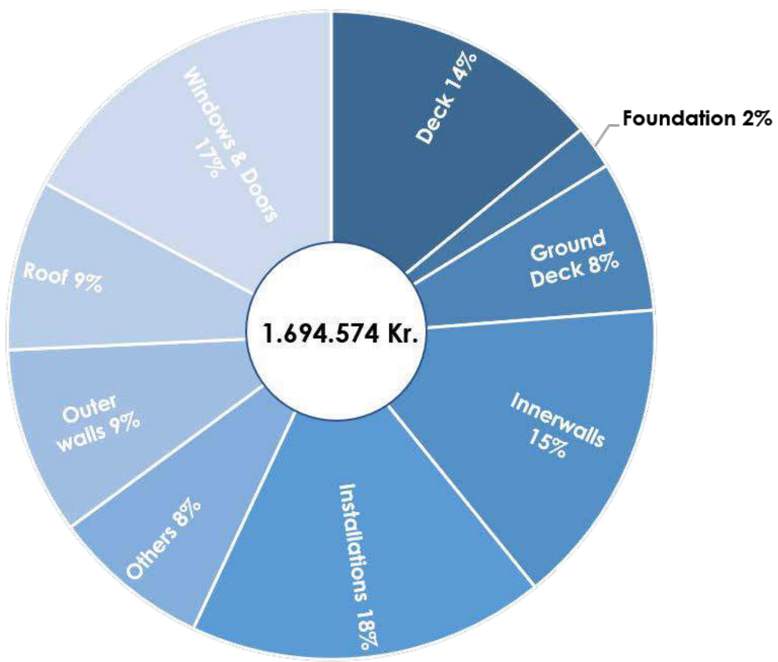
Benchmark:

- Acquisition per building costs: DKK 3,159,167
- Net present value of total life cycle costs (including maintenance, supply and cleaning): DKK 5,226,637
- Net present value per m² per year: DKK 1,467 / m² / year is achieved for benchmark

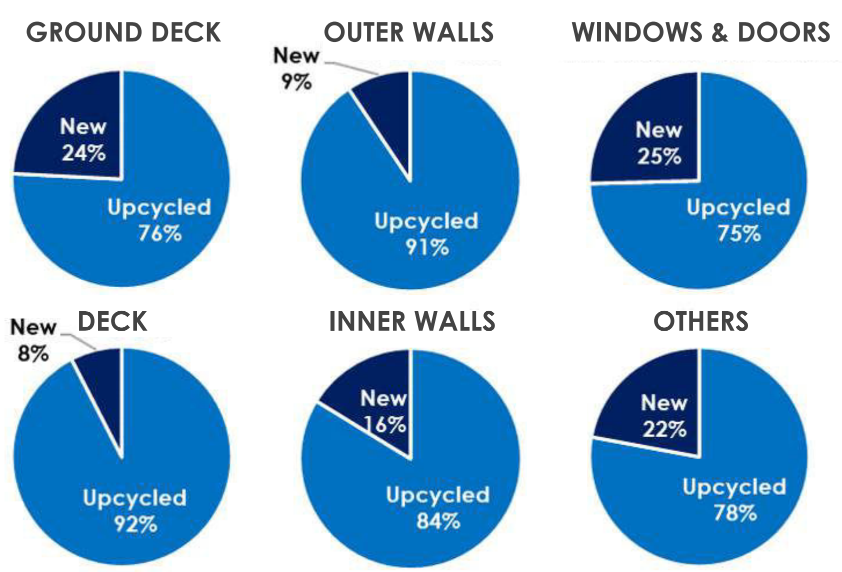
	Benchmark		Upcycle Studios	
	DKK	%	DKK	%
Acquisition	**3.158.586**	**60%**	**2.956.167**	**57%**
Land & advisory	1.261.593	24%	1.261.593	24%
Building basis	182.435	3%	164.531	3%
Primary building parts	941.687	18%	770.109	15%
Complementary building parts	325.991	6%	329.639	6%
Surface building parts	142.590	3%	127.941	2%
Installations	168.453	3%	168.453	3%
Electrical & mechanical systems	135.837	3%	133.901	3%
Maintenance	**901.599**	**17%**	**879.614**	**17%**
Building basis	23.734	0%	21.405	0%
Primary building parts	254.631	5%	205.389	4%
Complementary building parts	189.853	4%	229.096	4%
Surface building parts	98.777	2%	90.638	2%
Installations	260.732	5%	260.732	5%
Electrical & mechanical systems	73.872	1%	72.354	1%
Supplies	**514.453**	**10%**	**514.453**	**10%**
Water	436.266	8%	436.266	8%
Electricity	78.187	1%	78.187	1%
Cleaning	**651.266**	**12%**	**651.266**	**12%**
Terrain	3.724	0%	3.724	0%
Buildings, exterior	79.620	2%	79.620	2%
Indoor areas and spaces	567.922	11%	567.922	11%

UPCYCLE STUDIOS - BUILDING LEVEL

LCC - DIVISION OF COSTS



Material cost distribution



GROUND DECK AND FOUNDATION:
- Upcycle concrete ground deck
- Upcycle foundation

OUTER WALLS:
- Concrete outer walls
- Upcycle wooden staircase (roof)
- Mineral wool insulation
- Concrete fence-walls

INNER WALLS:
- Upcycle concrete partition walls
- Upcycle wooden wall
- Upcycle inner wall wooden surface (Dinesen)
- Concrete shaft walls
- Concrete blocks

DECK:
- Upcycle concrete floor slab
- Mineral wool insulation
- Upcycle Dinesen wooden floor

ROOF:
- Skylights
- Concrete roof
- Mineral wool insulation
- Alu and plywood cover
- Concrete tiles
- Roofing boards

WINDOWS AND DOORS:
- Upcycle windows
- Upcycle wooden door
- Wooden door

INSTALLATIONS:
- Sanitation
- Heat
- Ventilation
- Electic

OTHERS:
- Upcycle wooden staircase (interior)
- Supporting structures (concrete and steel columns)
- Steel handrails
- Wood railings

DISTRIBUTION OF MATERIAL COSTS

The overall figures for Upcycle Studios show that the construction is competitive on price on an overall level. In the following we dive deeper into how the costs are distributed across virgin and upcyle materials to better understand the size of investment related to the size of impact.

The big piechart to the top left shows the distribution of costs across all material categories registered in Upcycle Studios.

Upcycle Studios has been built primarily with concrete, and this becomes evident when we add all concrete elements together: Deck, foundation, ground deck, outer walls, and a part of inner walls, adding up to 58% of total material expenditure. It must be stated, that some other than concrete are included in them. The other building material that has been widely used is glass. Windows and doors amount to 17% of material expense, the largest cost category after installations.

Diving into the costs across upcycle and conventional materials the small piecharts to the left show the split across building parts and components where at least 75 % of each category is upcycled. This shows a relative high investment in upcycle materials in the six categories presented. The other categories in the big piechart do not include expenses for upcycling, why these are not highlighted. Across categories 54 % of all costs have been spent on upcycle products and 46 % on other types of expenses. As 69 % of the total weight of materials and only 44 % of the CO_2 emissions is based on upcycle products the relation between material amount, CO_2 performance/value and price is reasonable.

UPCYCLE STUDIOS - BUILDING LEVEL

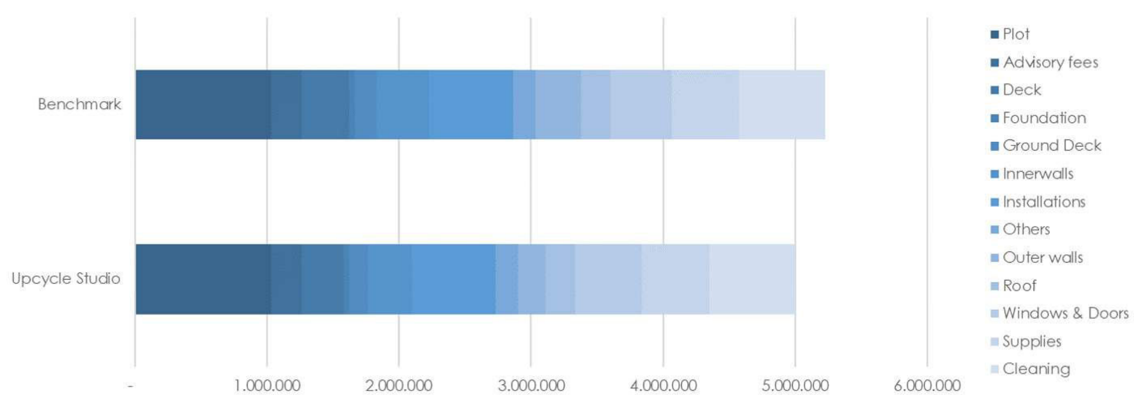
LCC - BENCHMARK ANALYSIS

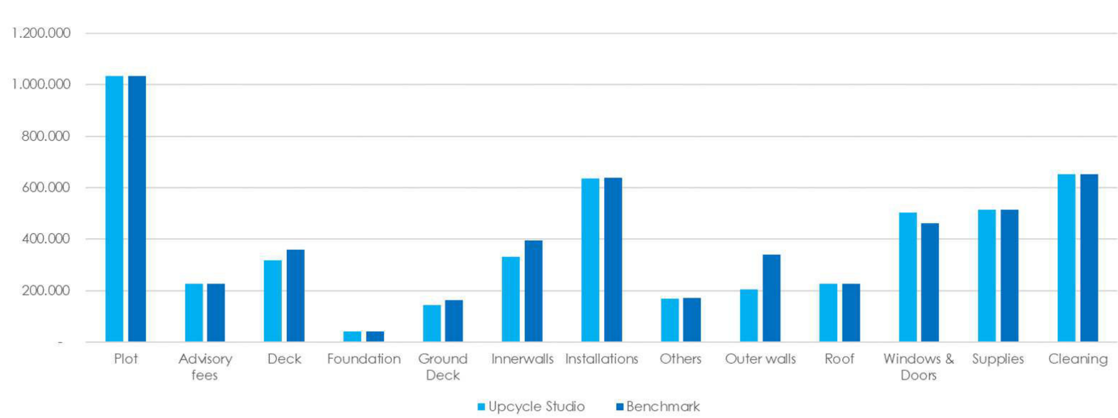
BENCHMARK ANALYSIS

One thing is how the costs are distributed in one project. Another thing is how it performs compared to benchmark. As in LCA, here the benchmark is Upcycle Studios, but without the use of upcycle products.

Differing from the LCC on product level it is very important to notice that the prices on upcycle products included here are based on selling price - and therefore do not necessarily reflect the upcycle products' financial reality as shows in LCC on product level (concrete, windows and bricks). This choice is partially due to that we do not have LCC on product level for all upcycle products and that the purpose of the building level LCC is to reflect the costs to the developer.

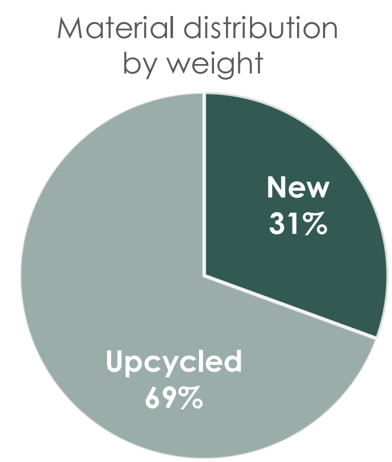
In the bottom bar-chart you see how building level LCC of all categories with upcycle products compare to benchmark. The categories that are exactly the same as benchmark do not include any costs for upcycle products.

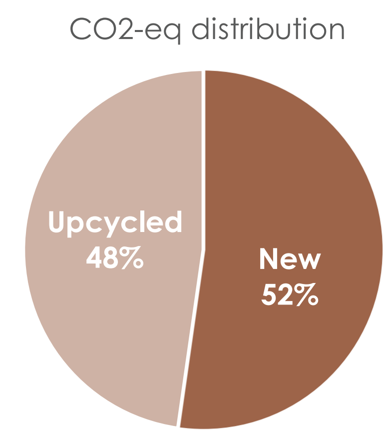


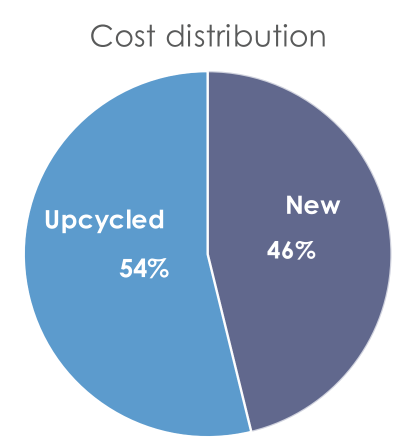


UPCYCLE STUDIOS - BUILDING LEVEL

RESULTS ACROSS CO_2, WASTE AND PRICE







UPCYCLE STUDIOS

65 tonnes CO_2 -eq
45 % saving

914 tonnes waste in total

488 kg CO_2 -eq per year
53 % saving

THE RESOURCE ROWS - BUILDING LEVEL

INTRODUCTION

THE CONCEPT

With the Resource Rows project, NREP strived to challenge and investigate what a thorough understanding of resources can bring about in terms of value and quality for new constructions.

Resource Rows is a residential project comprising 29 row houses and 63 apartments in Ørestaden. Resource efficiency and optimisation formed the underlying concept of the project.

The project was underwritten based on a conventional row house and apartment project meaning that all sustainability efforts had to fit in a conventional budget frame in order to be implemented in the final project.

THE IMPACT

The following chapter will show the overall impact of a row house in The Resource Rows across carbon footprint and financials. An overview of how many products are upcycled as well as how the buildings perform across LCA and LCC will be presented here. The LCA will be a deep dive on CO_2 and an overview on how the building performs across all impact categories.

The Resource Rows focuses on the following impacts:

THE RESOURCE ROWS

Adress:
Else Alfelts Vej,
2300 København S
Construction year: 2017-2019
Size: 9148 m²
Housing:

- 63 apartments
- 29 row houses

Project partners:

- Developer: NREP A/S
- Contractor: Arkitektgruppen
- Architect: Lendager ARC
- Upcycle material supplier: Lendager UP
- Consulting engineer: MOE

Total cost: EUR 38.3 millions

SOCIAL

The sharing economy proves that it is practical to allow resources that are otherwise used only occasionally to be shared by people other than the owner. This provides an economic incentive to all parties involved and it brings neighbours together.

BIO

The integration of green infrastructure acts as a common thread throughout the settlement, with large biodiversity green areas.

WATER

Reuse of water is an important part of the Resource Rows' identity. For non-portable uses, outdoor waster is replaced with rainwater that is collected from solar cells and other unused surfaces.

ENERGY

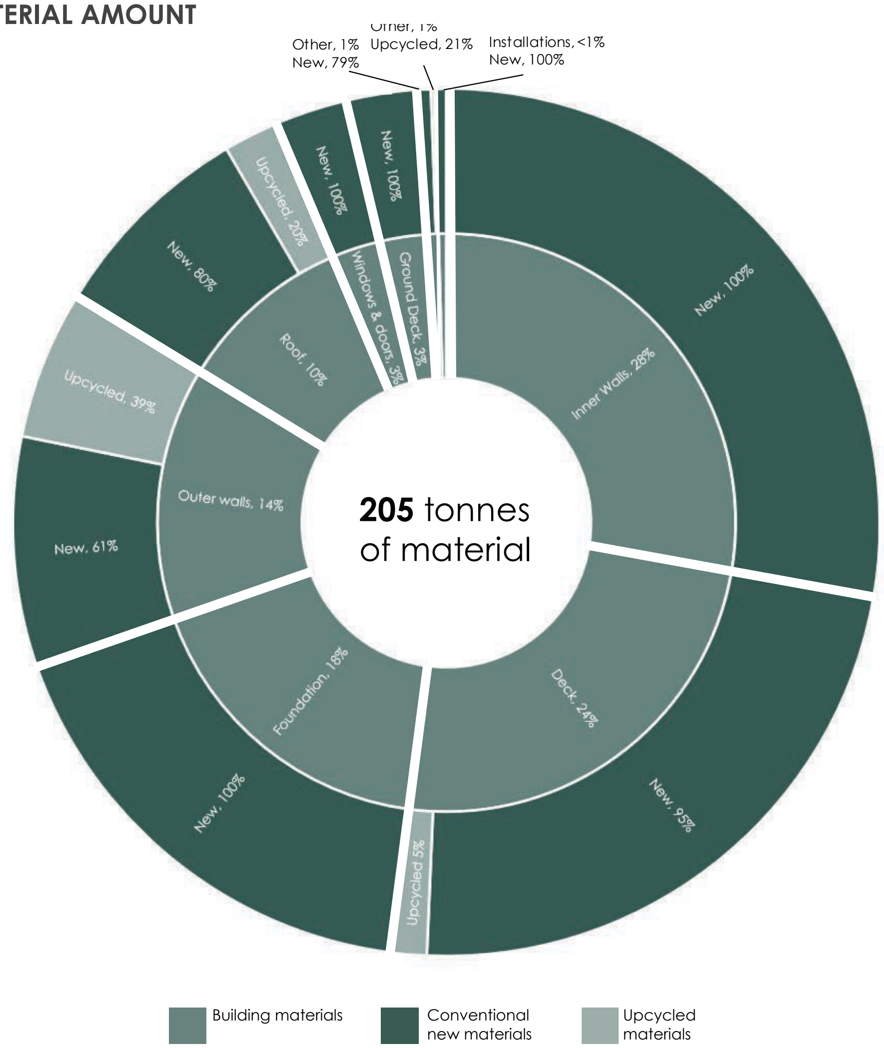
Design of the building envelope and use of efficient ventilation, heat recycling, and solar cells. This resulting in economic savings on utility costs for the residents as well as CO_2 savings on the building use.

MATERIALS

Building waste today represents a huge untapped resource, which was exploited in the construction of the Resource Rows. By reusing the walls from abandoned dwellings as new facadeelements, CO_2 and use of virgin materials was minimised while getting a new building with history and character from day one.

THE RESOURCE ROWS - BUILDING LEVEL

LCA - MATERIAL AMOUNT



DISTRIBUTION BETWEEN UPCYCLE AND NEW MATERIALS

The Resource Rows is built from a combination of new and up-cycled materials. The graph above illustrates the distribution of materials in the building - 205 tonnes representing the total weight of one average row house in Resource Rows. The inner annulus shows the distribution across the building parts and components, and the outer annulus shows the distribution between new and upcycle material for each of the building parts.

In the Resource Rows there has been a focus on using visible upcycle materials such as the upcycle brick facade, the offcut wooden facades, offcut wooden floors, offcut wooden terrace, upcycle roof top houses and more wooden products listed in chapter 2. Ensuring the visibility of upcycle products is done to inform about circular economy and show that it is not only possible to do, but also aesthetically pleasing.

Out of the 205 tonnes of materials, approximately 18 tonnes or 9% are upcycled materials. The volume of upcycle materials seem much lower than in Upcycle Studios due to the amounts calculated in tonnes which makes the many upcycle wooden materials disappear in more dense conventional materials such as concrete, that is not upcycled in Resource Rows.

The design of Resource Rows has focused on more natural materials speaking to the softer side of community building - especially on the roof, where there has been made great efforts in using upcycle wooden materials along with a directly reused bridge connecting different parts of the city block.

BUILDING PARTS AND COMPONENTS

Foundation:
- Slab foundation

Ground deck:
- Ground deck basement

Outer walls:
- Upcycled windowpanel
- Basement outerwall
- Stern capsule
- Upcycled brick
- Street row house
- Murkrone row house

Inner walls:
- Glass shielding
- Residential wall
- Bath wall
- Apartment boundary walls

Deck:
- Concrete Deck
- Suspended ceiling
- Wooden floor on joists
- Concrete hollow deck

Roof:
- Roof
- Upcycled terrasse

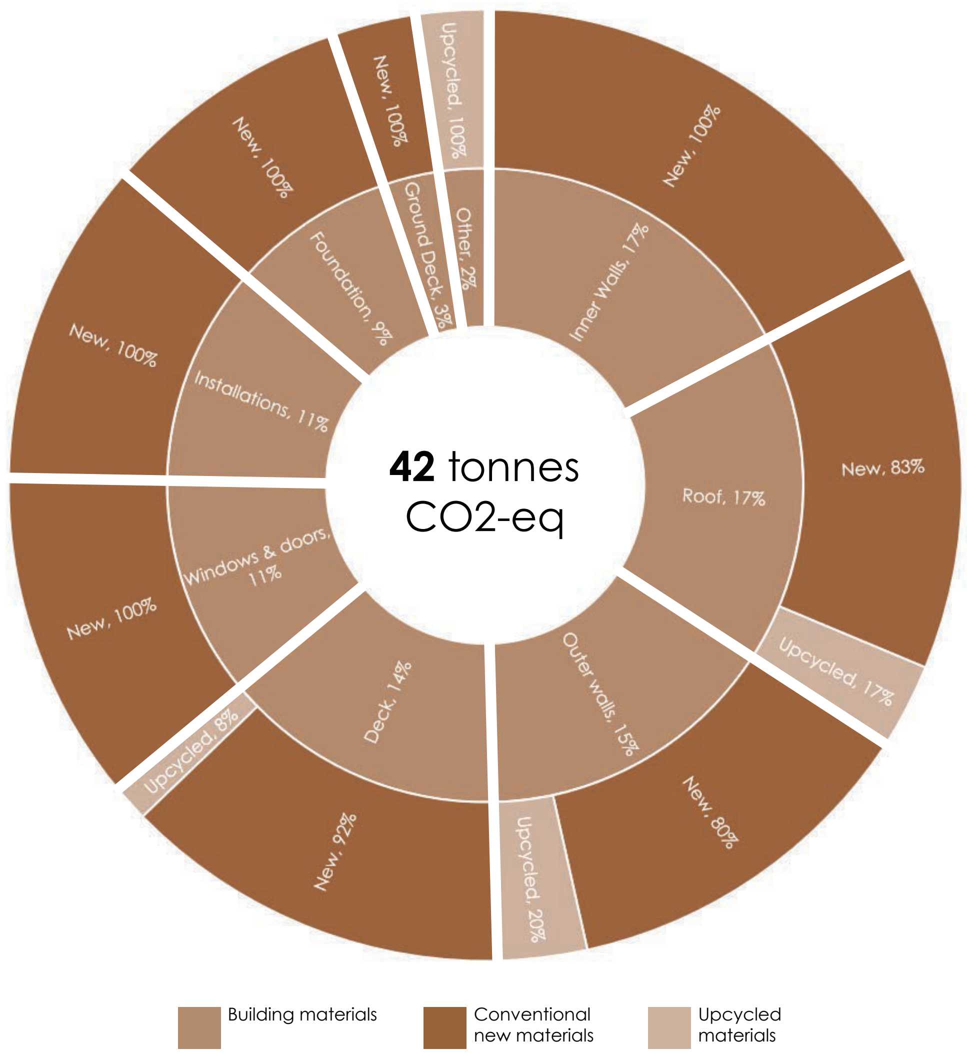
Windows and doors

Installations:
- Sanitation
- Heat
- Ventilation
- Electricity

Others:
- Stairs
- Upcycle roof top house

THE RESOURCE ROWS - BUILDING LEVEL

LCA - CO_2-EQ EMISSIONS



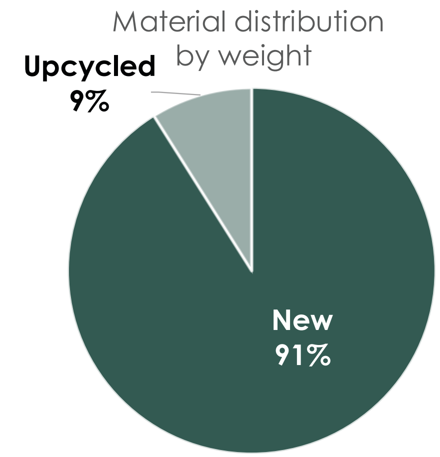
DISTRIBUTION OF CO_2-EQ

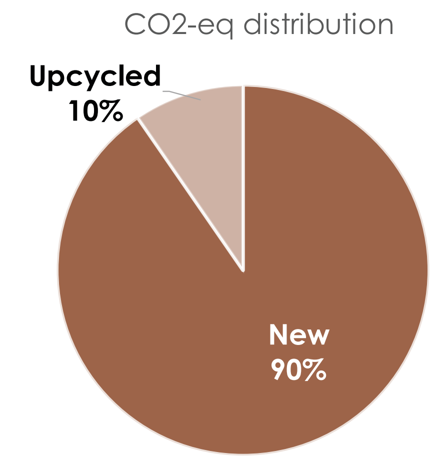
The graph above shows the distribution of CO_2-eq from new and upcycle materials - 42 tonnes CO_2-eq representing the total amount of CO_2 emitted from one average row house in Resource Rows. The inner annulus shows the distribution across the building parts and components, and the outer annulus shows the distribution between new and upcycle material for each of the building parts.

The outer walls consists of 39% upcycle materials, while only contributing with 20% of the CO_2-eq for the outer walls. This is an example of how circulating materials makes it possible to lower the amount of CO_2 emissions from construction projects.

The ratio between the amount of material and CO_2-eq for the roof indicates that the upcycle materials in the roof contribute more. This could be due to precautionary principles when a larger amount of material is used, to ensure that the upcycle materials live up to safety standards. This is done even if the materials have been tested, and are seemingly strong enough. As circular construction becomes more common, this will change in the future.

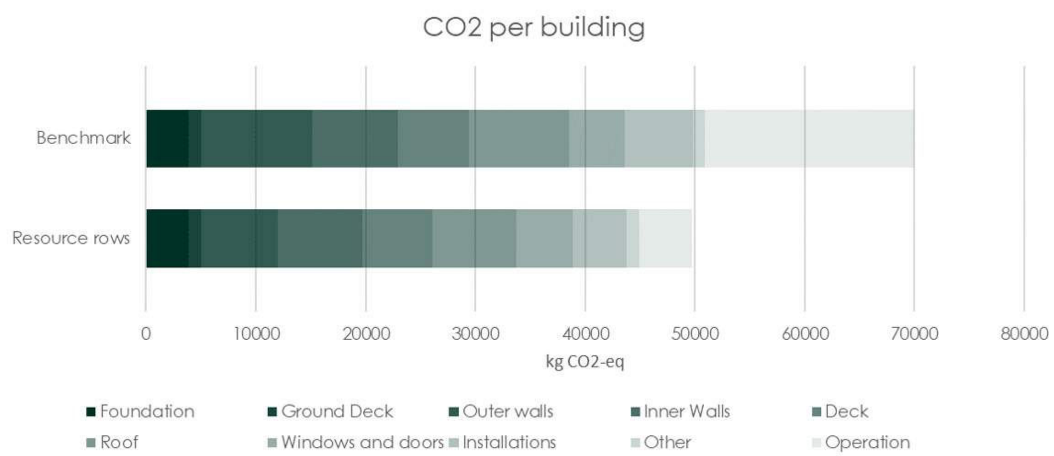
LCA - TOTAL RESULTS ON MATERIALS





THE RESOURCE ROWS - BUILDING LEVEL

LCA - BENCHMARK ANALYSIS



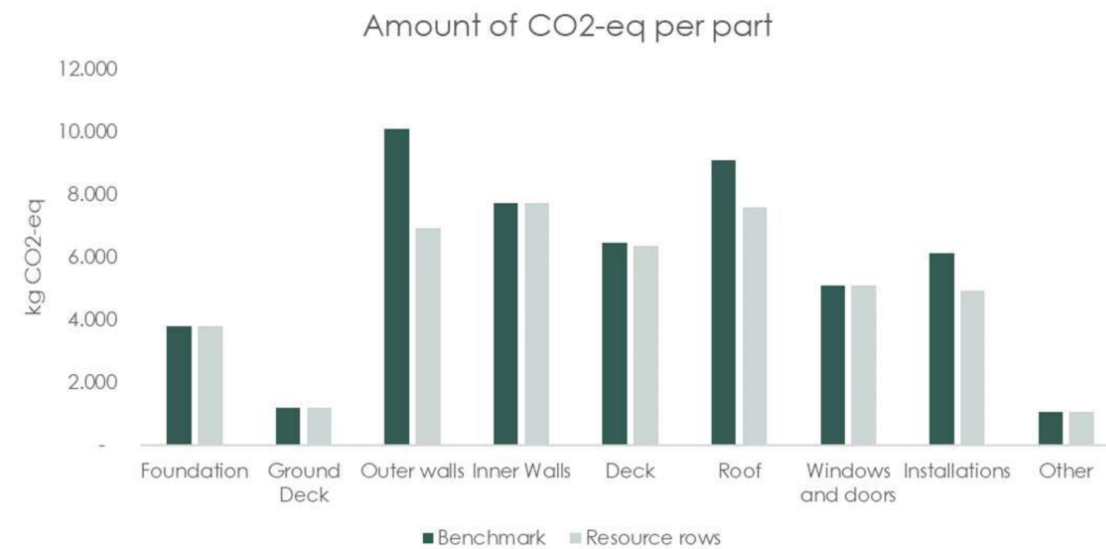
LCA BENCHMARK ANALYSIS

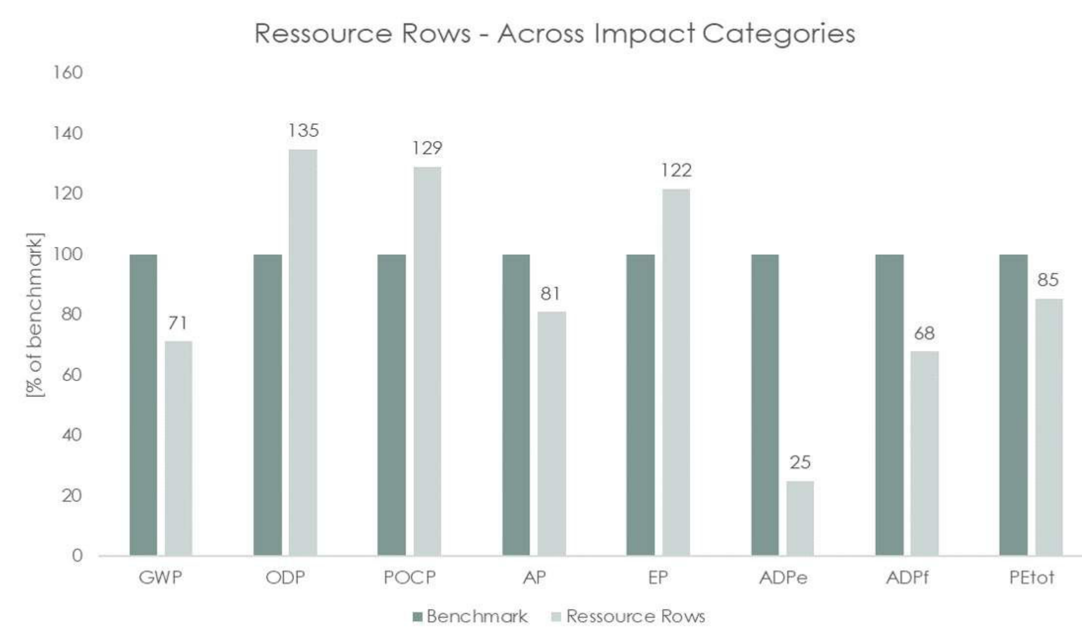
Life Cycle Assessment (LCA) considers both the embodied CO_2 as well as the CO_2 impact of operations across the life of the building. Compared to benchmark, Resource Rows has saved in total 20 tonnes CO_{2eq}, or 29%. The graph above illustrates how we move from a 12 % reduction in materials to a total saving of 29 % including operations.

The upper graph on the next page illustrate where the savings occur, indicating that we have achieved savings across the categories of outer walls, roof and installations supplemented by a small impact on decks (the wooden indoor floors).

ACROSS IMPACT CATEGORIES

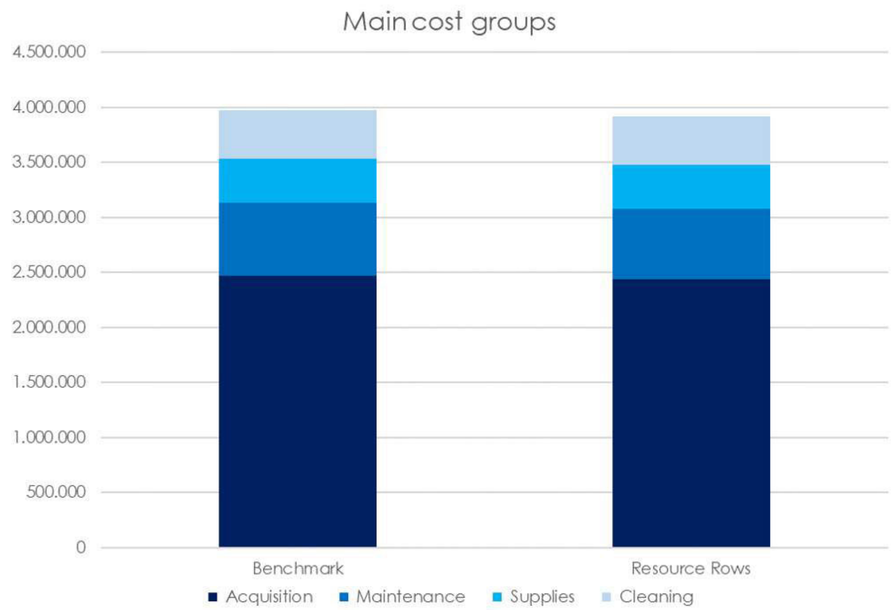
When comparing the Resource Rows to benchmark, the Resource Rows have lower impacts in most categories compared to the benchmark, except in ODP, POCP and EP.





RESOURCE ROWS - BUILDING LEVEL

LCC - OVERALL COST DISTRIBUTION



LCC ON BUILDING LEVEL

To be able to scale an impactful solution, it needs to be able to compete on price or at least fit into an overall budget for construction and maintenance. On the following pages we will dive into an analysis of life cycle costings on building level to clarify the competitiveness of one average Resource Rows row house.

DIVISION OF COSTS

The bar chart above reflects all life cycle costs for one Resource Rows row house and its benchmark. It gathers all cost categories, ranging from acquisition (construction/materials), maintenance, supply of water and electricity, as well as cleaning costs.

The largest differences arise in the acquisition and maintenance groups. This is due to the price difference in the materials, adding to DKK 36,162, as well as the different maintenance, adding an additional DKK 19,687. The difference in maintenance is particularly high due to the choice of a benchmark for the upcycle brick walls. Supply and maintenance are assumed to be the same.

PLOT AND ADVISORY COSTS

In the green diagram the distribution of expenses for advisory is visualised.

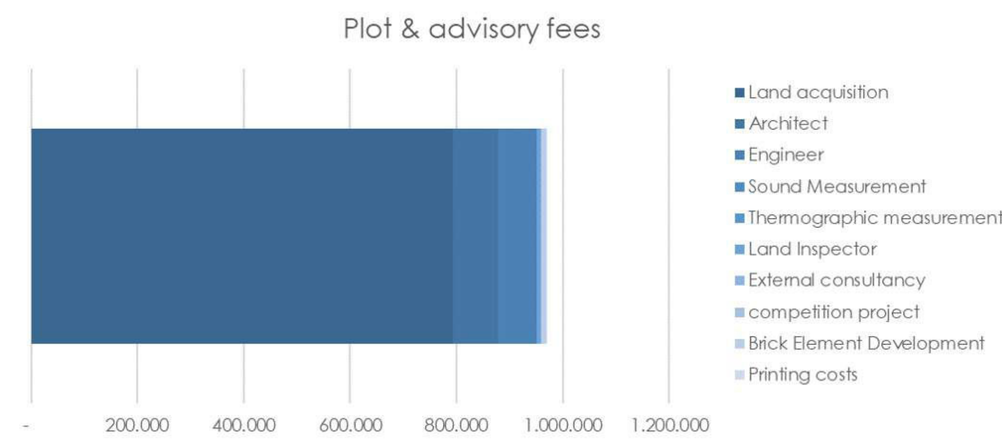
KEY FIGURES

Resource Rows:

- Acquisition costs per row house: DKK 2,435,954.
- Net present value of total life cycle costs (including maintenance, supply and cleaning): DKK 3,921,784.
- Net present value/m²/year: DKK 1,432 / m² / year is achieved for Resource Rows.

Benchmark:

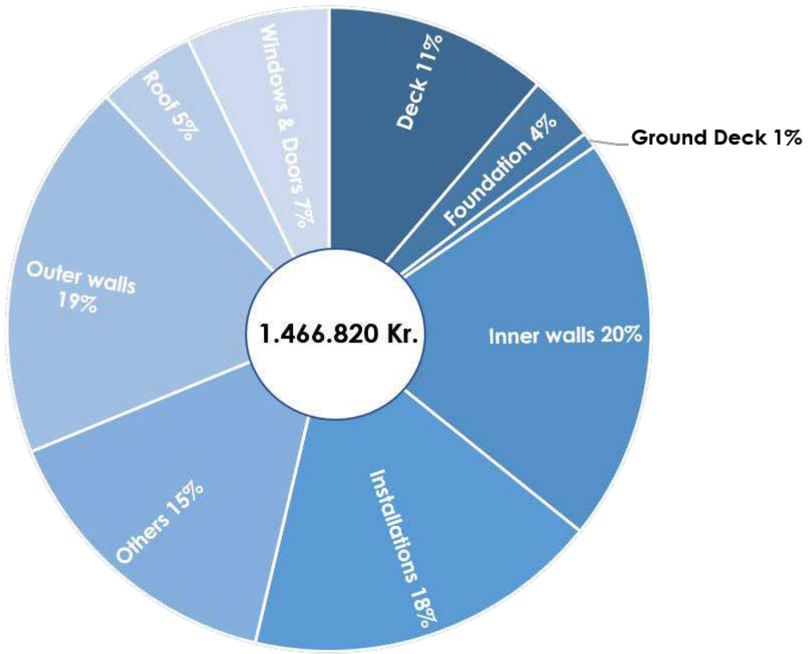
- Acquisition costs per row house: DKK 2,472,116.
- Net present value of total life cycle costs (including maintenance, supply and cleaning): DKK 3,977,633.
- Net present value per m² per year: DKK 1,453 / m² / year is achieved for Resource Row's Benchmark.



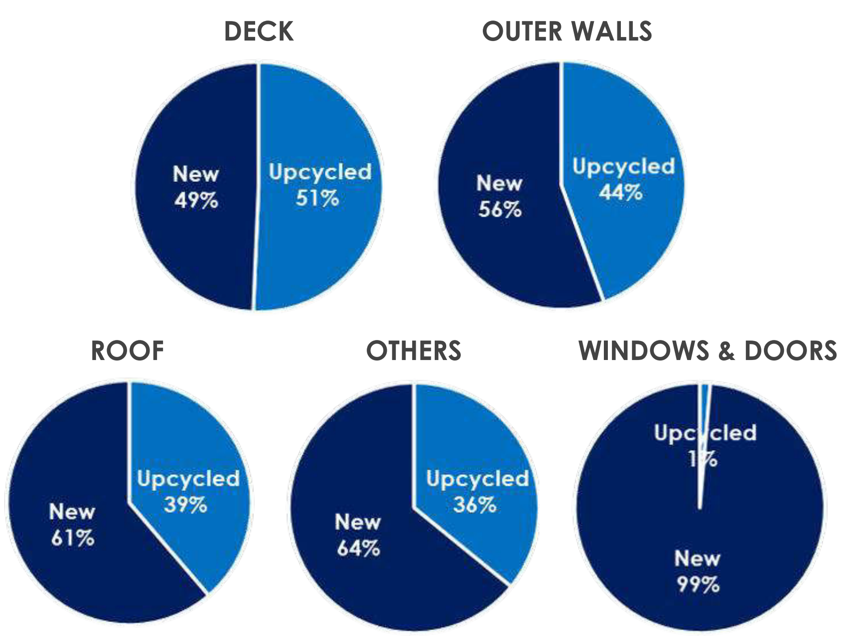
	Benchmark		Resource Rows	
	DKK	%	DKK	%
Acquisition	**2.472.116**	**62%**	**2.435.954**	**62%**
Land & advisory	969.134	24%	969.134	25%
Building basis	61.260	2%	61.260	2%
Primary building parts	652.188	16%	707.832	18%
Complementary building parts	280.659	7%	218.850	6%
Surface building parts	238.442	6%	216.189	6%
Installations	155.470	4%	155.470	4%
Electrical & mechanical systems	114.963	3%	107.219	3%
Maintenance	**661.123**	**17%**	**641.436**	**16%**
Building basis	8.269	0%	8.269	0%
Primary building parts	185.921	5%	199.185	5%
Complementary building parts	115.602	3%	94.513	2%
Surface building parts	161.254	4%	155.464	4%
Installations	146.634	4%	146.634	4%
Electrical & mechanical systems	43.442	1%	37.370	1%
Supplies	**404.074**	**10%**	**404.074**	**10%**
Water	325.010	8%	325.010	8%
Electricity	79.064	2%	79.064	2%
Cleaning	**440.320**	**11%**	**440.320**	**11%**
Terrain	6.765	0%	6.765	0%
Buildings, exterior	41.621	1%	41.621	1%
Indoor areas and spaces	391.934	10%	391.934	10%

THE RESOURCE ROWS - BUILDING LEVEL

LCC- DIVISION OF COSTS



Material cost distribution



FOUNDATION:
- Concrete slab foundation

GROUND DECK:
- Concrete ground deck
- Insulation

OUTER WALLS:
- Upcycle brick wall elements
- Concrete retaining walls
- Aluminium wall elements
- Paint products

INNER WALLS:
- Various concrete wall types
- Paint products

DECK:
- Upcycle wooden floor
- Concrete floor slab
- Paint products

ROOF:
- Upcycle wooden roof boards
- Roof insulation
- Plaster ceiling surfaces
- Roofing felt

WINDOWS AND DOORS:
- Upcycle facade wood elements
- Doors (alu, messing and wood)
- Windows (alu and meesing)

INSTALLATIONS:
- Sanitation
- Heat
- Ventilation
- Electric

OTHERS:
- Upcycle Roof top house
- Steel staircase

DISTRIBUTION OF MATERIAL COSTS

The overall figures for Upcycle Studios show that the construction is competitive on price on an overall level. In the following we dive deeper into how the costs are distributed across virgin and upcycle materials to better understand the size of investment related to the size of impact.

The big pie-chart on the prior page shows the distribution of costs across all material categories registered in the Resource Rows.

Outer walls is the largest cost group with upcycle materials, accounting for the upcycle brick elements. Furthermore, we find a lot of wooden products in the rest of the cost groups. Their overall economic impact is lesser compared to other more financially demanding material categories.

Diving into the costs across upcycle and conventional materials the small pie-charts to the bottom left shows the split across building parts and components visualising a higher level of expenses related to conventional materials than upcycle materials. This is positive based on the amount of materials upcycle stated above. The other categories in the big pie-chart do not include expenses for upcycling, why these are not highlighted. Across categories 20 % of all costs have been spent on upcycle products and 80 % on other types of expenses. As 9 % of the total weight of materials and 10 % of the CO_2 emissions is based on upcycle products the relation between material amount, CO_2 performance/value and price seems reasonable, though a bit higher than for Upcycle Studios. This can be reasoned in the high focus on upcycle wood in Resource Rows that are not as CO_2 heavy as e.g. winows.

THE RESOURCE ROWS - BUILDING LEVEL

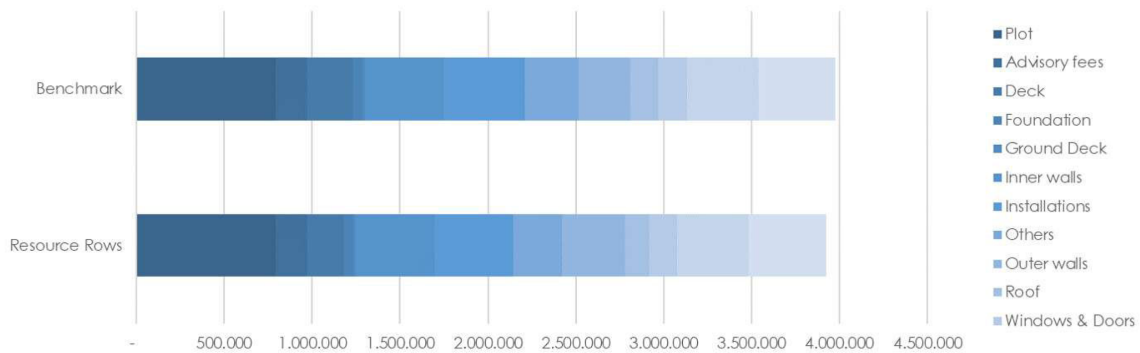
LCC- BENCHMARK ANALYSIS

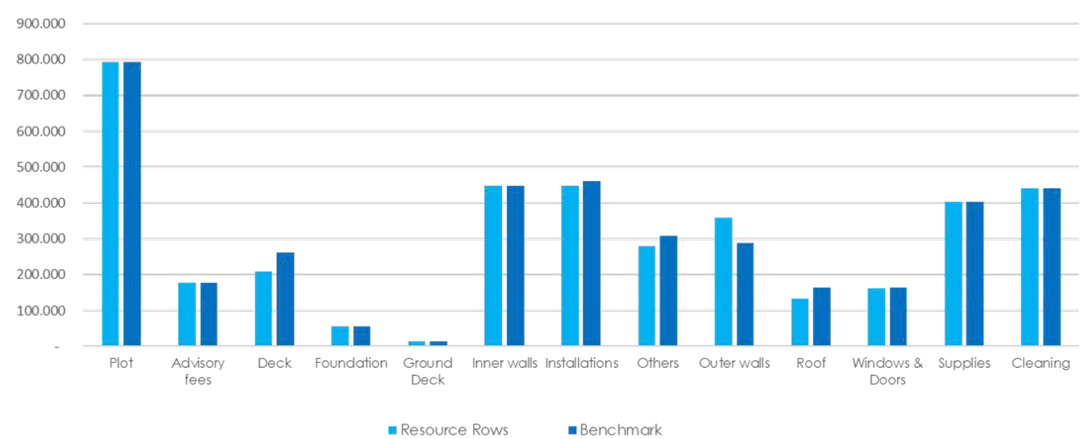
BENCHMARK ANALYSIS

One thing is how the costs are distribution in one project. Another thing is how it performs compared to benchmark. As in LCA, here the benchmark is a Resource Rows row house, but without the use of upcycle products.

Differing from the LCC on product level it is very important to notice that the prices on upcycle products included here are based on selling price - and therefore do not necessarily reflect the upcycle products' financial reality as shown in LCC on product level (concrete, windows and bricks). This choice is partially based on the need as we do not have LCC on product level for all upcycle products. At the same time the purpose of LCC on building level is to reflect the costs held by the developer, why expenses for delivering the upcycle products are not relevant here - though interesting of cause to see and understand the potential differences.

The two diagrams below show a result very close to benchmark both at an overall level (upper diagram) and across expense categories (lower diagram). In the bottom bar-chart you see how all categories with upcycle products include less costs compared to benchmark except windows, doors and outer walls (due to the choice of benchmark). The categories that are exactly the same as benchmark do not include any costs for upcycle products.

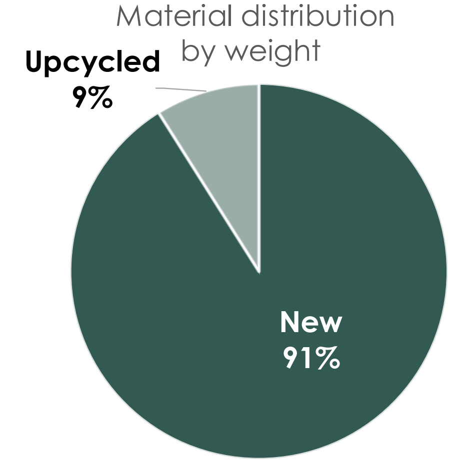


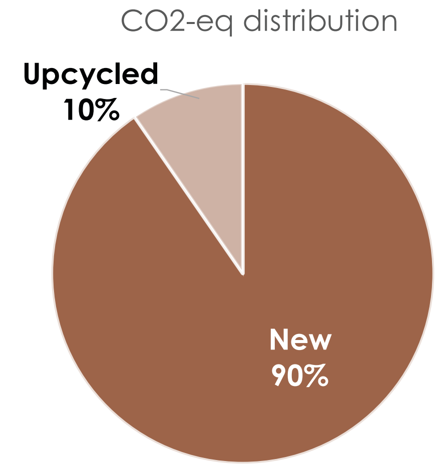


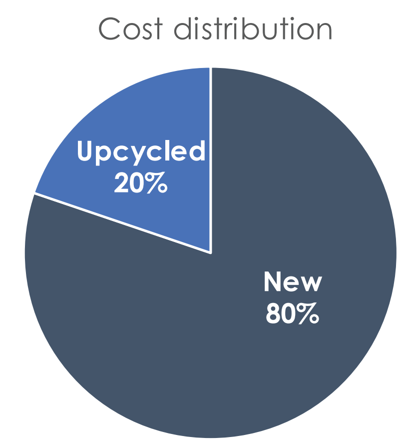
LENDAGER GROUP

THE RESOURCE ROWS - BUILDING LEVEL

RESULTS ACROSS CO_2, WASTE AND PRICE







RESOURCE ROWS

CO_2 20 tonnes CO_2 -eq
29 % saving

463 tonnes waste in total

270 kg CO_2 -eq per year
39 % saving

LENDAGER GROUP

12 DIFFERENT BENCHMARKS

VOLUNTARY SUSTAINABILITY VALUATION

BUILDING LEVEL

A NEW SUSTAINABILITY CLASS FOR BUILDINGS

The Danish Government has presented a new standard for sustainability valuation in the construction sector based on recommendations from the Climate Partnership in the build & construction sector. Amongst others, it is suggested that Carbon Footprint assessments are made mandatory for the voluntary sustainability classification and build regulation. This classification will continuously be sharpened as the market develops. In the Climate Partnership recommendations they included recommendations for making it mandatory for all buildings to have a maximum total GWP of 12 kg CO_2-eq /m²/year and a voluntary sustainability standard to perform below a GWP of 8.5 kg CO_2-eq /m²/year.

Recently, SBi has conducted life cycle assessments of 60 sustainable houses of which 12 row houses are included. To get a more varied result and a broader perspective on the sustainable impacts of the Resource Rows and Upcycle Studios these buildings are benchmarked towards the 12 row houses, which can be seen in the table below.

BUILDINGS AHEAD OF THEIR TIME

The table below shows that Upcycle Studios and the Resource Rows are placed in top three performing row houses compared to the 12 row house calculations published by SBi.

Furthermore, it shows how both Upcycle Studios and the Resource Rows perform better than the potential coming voluntary sustainability standard of 8.5 kg CO_2-eq/m²/year.

Both building projects were planned and initiated long before standards were published and despite not deliberately working towards these standards both buildings are meeting the requirement.

Rowhouse Number	GWP total kg CO_2-eq/m²/year	GWP materials kg CO_2-eq/m²/year	GWP operation kg CO_2-eq/m²/year	Ranking
R06	6.58	4.42	2.16	1
RES	**6.64**	**5.99**	**0.65**	**2**
UPS	**8.08**	**7.67**	**0.41**	**3**
R01	8.39	8.17	0.22	4
R10	8.5	5.9	2.6	5
R07	8.57	5.8	2.77	6
R09	8.67	6.13	2.55	7
R11	9.63	6.85	2.78	8
R08	9.99	7.39	2.6	9
R02	10.2	7.44	2.78	10
R12	10.5	5.87	4.58	11
R03	10.6	8.11	2.48	12
R04	14.2	10.8	3.36	13
R05	14.5	10.8	3.7	14

ENERGY IMPROVING INITIATIVES

BACKGROUND DATA

ENERGY IMPROVING INITIATIVES

In the following, we will map the impact of energy improving initiatives in connection to Upcycle Studio and the Resource Rows. The significance is investigated by comparing energy calculations of current buildings and if they were built as "standard" buildings. This section is written by MOE and based on their calculations.

Three scenarios are examined for each of the two buildings:

1. "As-built": The actual construction as it is built today
2. "As-built: The actual construction where solar cells are adapted to comply with BK2020 requirements only" BK2020
3. "Reference": The building adapted so that building components conform to the "standard / common" practice for compliance with BK2020 requirements.

PREREQUISITES

To map the significance of incorporated energy measures in respectively Upcycle Studios and The Resource Rows, the two energy calculations have been adapted to match how one would build a traditional town house. In the case of building parts/components where common practice has been applied in UPC or RES, the same values are used in the two calculations. Only the row houses for The Resource Rows were included in the analysis.

The diagrams below show the changes made in the respective energy frames. Calculations have been conducted in accordance with Building Regulations 2015 incl. associated energy calculation program Be15.

Upcycle Studios		As-built	Referencebyggeri
Klimaskærm	Vinduer, alm.	Gns. 0,76 W/m²K Upcycle vinduer 2+2 lag	Gns. 0,85 W/m²K Standard vinduer 3 lags
	Vinduer, dobbelthøje	Gns. 0,71 W/m²K Upcycle vinduer 2+2 lag	Gns. 1,20 W/m²K Curtain wall (alu)
	Ydervægge, inkl. kuldebroer og linjetab	Gns. 0,16 W/m²K	Gns. 0,18 W/m²K
Varmeanlæg	Forsyning	Varmepumper med buffertanke	Varmeveksler, indirekte fjernvarme
	Frem- og returløbstemperatur [°C]	45/35	60/30
	Varmefordelingsanlæg, ublandet vand, længde	0 m	180 m
Varmekapacitet		140 Wh/K m² Tung bygning, flere tunge dele fx blottede betonvægge	100 Wh/K m² Middel let bygning, Enkelte tunge dele fx porebetonvægge
Tæthed ved trykprøvning på 50 Pa		Ekstra tæt: 0,5 l/s m²	Alm. tæthed: 1,0 l/s m²

Ressourcerækkerne		As-built	Referencebyggeri
Klimaskærm	Vinduer, alm.	Gns. 0,82 W/m²K Standard vinduer 3 lags (projektspecifik)	Gns. 0,85 W/m²K Standard vinduer 3 lags
	Ydervægge inkl. kuldebroer og linjetab	Gns. 0,15 W/m²K	Gns. 0,18 W/m²K
Varmeanlæg	Forsyning	Varmepumper med buffertanke	Varmeveksler, indirekte fjernvarme
	Frem- og returløbstemperatur [°C]	45/35	60/30
	Varmefordelingsanlæg, ublandet vand, længde	0 m	120 m
Tæthed ved trykprøvning på 50 Pa		Ekstra tæt: 0,55 l/s m²	Alm. tæthed: 1,00 l/s m²

ENERGY IMPROVING INITIATIVES

ENERGY RESULTS

ENERGY CALCULATION

The top table on next page shows the energy requirements for the customized standard buildings, as well as the importance of the individual energy measures. The calculated energy demand is stated as primary energy i.e. a primary energy factor of 0.6 for district heating and a primary energy factor of 1.8 for electricity (cf. BR15, BK2020).

The graphs below show the construction scenario's energy frame result (primary energy demand) as well as the proportion covered by electricity produced by solar cells.

Both Upcycle Studio and The Resource Rows (row houses) are listed to comply with the BK2020, which was necessary to introduce heat pumps into the row houses.

The graphs show that the required solar cell area to comply with BK2020 for Upcycle Studio has been reduced from 14 m² per housing unit in standard construction to 7 m2 per housing unit with the energy measures used. That is, the need for solar cells has halved.

For the Resource Rows it is seen that there is a need for 5 m² of solar cells per housing unit in standard construction, while it is possible to comply with BK2020 requirements with only 0.5 m² per housing unit with the energy measures used.

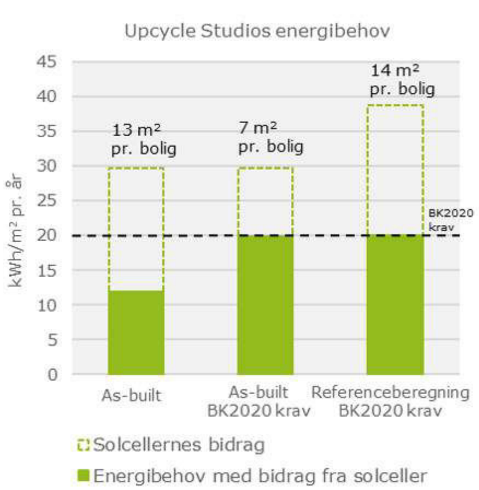
NETTO ENERGY CONSUMPTION

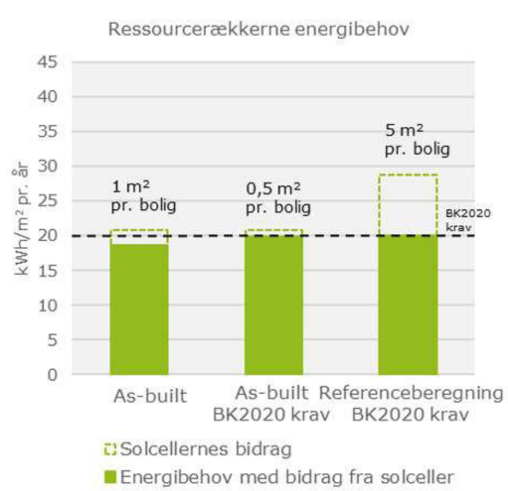
The bottom table on next page shows the buildings' contribution to energy needs without primary energy factors (ie net energy consumption = the theoretical real consumption in the house). In BR15, BK2020, the energy factors used are 0.6 for district heating and 1.8 for electricity. That is, the primary energy consumption in Upcycle Studio from the previous section is converted to a theoretical measure of energy consumption in operation by 11.9 / 1.8 = 6.6 kWh / m² per year.

Both Upcycle Studio and the Resource Rows are made with heat pumps (which produce heat via electricity), which is why only energy consumption for electricity is stated here.

Net electricity consumption is electricity for building operations minus electricity produced by solar cells. For the reference buildings, more electricity is produced with solar cells than is in-cluded in the energy calculation in order to comply with the energy frame requirement, which explains the negative contribution from this.

It should be noted that the enlightened energy for building operation, i.e. energy for pumps, ventilation systems, heat, etc., in fact also include an energy consumption for, for example, lighting and electrical appliances.





		Upcycle Studios kWh/m² pr. år	Ressourcerækkerne
Referencebyggeri energibehov (uden solceller)		38,7	28,8
Tiltag:			
Klimaskærm	Vinduer alm.	-0,7	-0,2
	Vinduer dobbelthøje	-3,1	N/A
	Ydervægge	-0,5	-1,2
Varmeanlæg		-3,1	-5,9
Varmekapacitet		-0,3	N/A
Tæthed		-1,3	-0,7
As-built energibehov (uden solceller)		**29,7**	**20,8**
Reduktion i Energibehov ift. reference		-9	-8
BK2020 krav jf. BR15 [kWh/m² år]		20,0	20,0
As-built energibehov (inkl. solceller)		**11,9** (13 m² solceller pr. bolig)	**18,6** (1 m² solceller pr. bolig)
Reduktion i Energibehov ift. reference		-26,8	-10,2

Upcycle Studios	**As-built**	**As-built BK2020 krav**	**Referencebygning**
El til bygningsdrift [kWh/m² pr. år]	16,5	16,5	3,7
El produceret af solceller [kWh/m² pr. år]	9,9	5,4	10,0
Netto El forbrug, (bygningsdrift minus produceret) [kWh/m² pr. år]	6,6	11,1	-6,3
Varme [kWh/m² pr. år]	0	0	53,5

Ressourcerækkerne	**As-built**	**As-built BK2020 krav**	**Referencebygning**
El til bygningsdrift [kWh/m² pr. år]	11,6	11,6	3,9
El produceret af solceller [kWh/m² pr. år]	1,2	0,5	4,9
Netto El forbrug, (bygningsdrift – produceret) [kWh/m² pr. år]	10,4	11,1	-1,0
Varme [kWh/m² pr. år]	0	0	36,2

ENERGY IMPROVING INITIATIVES

ENERGY RESULTS

CO_2 EMISSION FROM BUILDING OPERATION

Based on calculated net energy consumption, the buildings' CO_2 emissions from construction operations are determined for the three scenarios. The calculations are based on LCA emission factors for the year 2020 from LCAbyg:

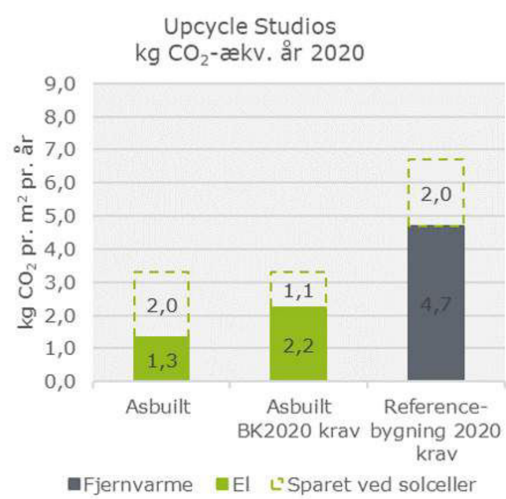
- Electricity: 0.201 kg CO_2 eq / kWh
- District heating: 0.112 kg CO_2 eq / kWh

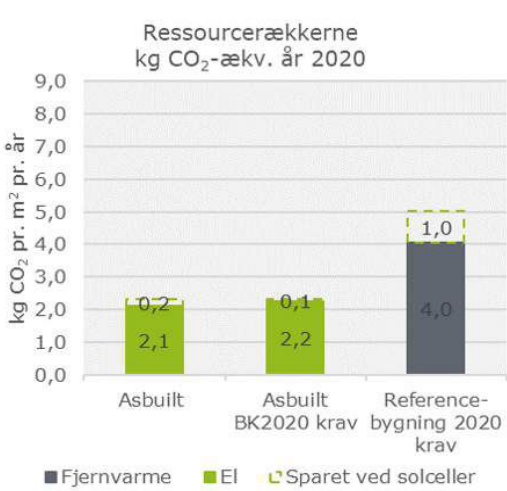
The results are summarized in the diagrams here.

For Upcycle Studio, CO_2 emissions from building operations are seen to be 4.7 kg CO_2 eq pr. m² pr. year for the reference building. By incorporating the previously listed energy measures (improved climate display, heat pump, density, etc.), the CO_2 emissions during building operation are seen to be 2.2 kg CO_2 eq pr. m² per year. This is a 53 % reduction.

For Upcycle Studio, more solar cells have been established than necessary for compliance with the BR15 BK2020. When this solar cell production is offset, the emission is again seen to halve. That means, in the year 2020, Upcycle Studios will emit 72 % less CO_2 than a similar reference building.

For Resource Rows, it is seen that the CO_2 emissions during building operation are 4.0 kg CO_2 eq/ m² per years for the reference building. By incorporating the previously listed energy measures (improved climate display, heat pump, density, etc.), the CO_2 emissions during building operation are 2.2 kg CO_2 eq/m² per year. This represents a reduction of 39 %.





RESULTS

This section has presented the results of multiple energy calculations for Upcycle Studios and the Resource Rows with and without the implementation of energy-enhancing initiatives. To understand the significance of the initiatives, a benchmark building using only "standard" building methods was used as benchmark for both cases.

The analysis clarifies that implementing energy-enhancing initiatives both reduces the primary energy need and the need of using solar cells to obey the energy demand for low energy buildings stated in the building regulations. In both cases, the use of windows with a low U-value, high building airtightness, heat pumps with buffer tanks and a low temperature heating system, is compared to normal windows, normal airtightness and traditional district heating. Furthermore, the analysis investigates the effect of applying heavy and exposed structures for Upcycle Studios versus lighter building structures.

For Upcycle Studios the need of primary energy was reduced from 38.7 to 29.7 kWh/m2/year by implementing the energy-enhancing initiatives. This reduced the area of necessary solar cells from 14 to 7 m2 per dwelling.

For the Resource Rows the need of primary energy was a bit lower for the benchmark building, but it was still possible to reduce the energy consumption from 28.8 to 20.8 kWh/m²/year by implementing the energy-enhancing initiatives. The area of necessary solar cells was reduced from 5 to 0.5 m² per dwelling. However, to reduce the energy consumption for building operation even more, a total of respectively 13 m² and 1 m² solar cells were implemented at Upcycle Studios and the Resource Rows. The need of primary energy hereby ended at 11.9 kWh/m² year for Upcycle Studios and 18.6 kWh/m² year for the Resource Rows.

The reduction in need of primary energy not only has a positive effect on the operational cost, but also on the environment. By implementing the energy-enhancing initiatives, the total CO_2 emission from the two buildings was also reduced. For Upcycle Studios the CO_2 emission at building operation was reduced 72 % from 4.7 to 1.3 kg CO_2eq/m² per year and for the Resource Rows the CO_2 emission at building operation was reduced 48 % from 4.0 to 2.1 kg CO_2eq/m² per year.

CHAPTER 4
CONCLUSION

CONCLUSION

MAIN FINDINGS

Summarizing the analysis presented in prior chapters of this report, it can be concluded that in spite of first-time production challenges and only replacing parts of the building components, the upcycling initiatives achieved significant environmental impacts. The project learnings indicate that the solutions could be expected to achieve even stronger results in a next iteration of projects.

EMBODIED CO_2
In Upcycle Studios, upcycling 69 % of the building mass made it possible to realise a CO_2 reduction of 32% taking only materials into account.

For the Resource Rows, 9 % of the building mass was upcycled leading to a CO_2 reduction of 12 %, again taking only materials into account. On top of the realised CO_2 reductions at Upcycle Studios and the Resource Rows, this study shows that there is potential for even higher CO_2 reductions when optimising the developed products.

ENERGY EFFICIENCY
Besides upcycling materials, effective energy initiatives have also contributed to a large reduction of CO_2 from operations. For Upcycle Studios the reduction of CO_2 from building operations was 72 % compared to benchmark, achieving 1.3 kg $CO_{2\text{-eq}}/m^2$ per year compared to 4.7 kg. For the Resource Rows the CO_2 emissions from building operations was reduced 48 % from 4.0 kg to 2.1 kg $CO_{2\text{-eq}}/m^2$ per year.

WASTE MINIMISATION
Putting waste material to use, thus optimising resource efficiency and minimising the projects' upcycling initiatives decreased the need for virgin materials. Across Upcycle Studios and the Resource Rows no less than 1,377 tonnes of waste was put into use giving the materials new life while adding value to the building projects.

THE IMPACT OF BENCHMARK
As with all other LCA and LCC calculations the choice of benchmark highly impacts the final results. For this reason we have chosen to include several benchmarks on product and building level creating transparency and insight into potential savings in future sustainable building projects.

On building level we compare Resource Rows and Upcycle Studios to 12 other life cycle analyses on row houses. Here we find a performance of 6.64 kg CO_2/m^2/year in Resource Rows and 8.08 kg CO_2/m^2/year in Upcycle Studios ranking no. 2 and 3 out of the 12 benchmarks conducted by SBi.

ECONOMIC IMPACT
While LCCs at building level were favourable compared to benchmark, looking at product level of upcycled products it is clear that some upcycling products were economically competitive in spite of first-time production challenges while others will need to be further developed or implemented with larger scale in order to achieve cost competitiveness.

Due to experience gained across the value chain, the costs for delivering optimised upcycle products can and will lower in next productions based on;

1. Less precautionary principles in terms of quality and performance,
2. Higher level of quantity lowering the effects of high fixed costs on product/m$^{2/3}$ and
3. Higher efficiency based on optimised processes cutting costs on harvesting, production and mounting.

All optimisations are based on gaining experience not only for the material supplier, but as important for the developer, contractor and advising engineer - making it easier to obtain and increase positive impacts across the value chain and in new building projects.

	UPCYCLE STUDIOS	RESOURCE ROWS	TOTAL
CO_2	65 tonnes CO_2 -eq 45 % saving	20 tonnes CO_2 -eq 29 % saving	85 tonnes CO_2 -eq
Waste	914 tonnes waste in total	463 tonnes waste in total	1377 tonnes waste in total
Energy	488 kg CO_2 -eq per year 53 % saving	270 kg CO_2 -eq per year 39 % saving	758 kg CO_2 -eq per year

Upcycle product or material	kg CO_2-eq/unit	% CO_2 saved	Total waste saved
Upcycle Brick Wall	49 kg CO_2-eq/m^2	38%	459 tonnes
Upcycle Windows	380 kg CO_2-eq/m^2	87%	7 tonnes
Upcycle Window Panes**	17 kg CO_2-eq/m^2	32%	-
Upcycle Concrete	28 kg CO_2-eq/m^3*	5-8 %	904 tonnes
Upcycle Concrete Aggregate**	9 kg CO_2-eq/m^3	84%	-
All Wood Products	127 kg CO_2-eq/m^3****	44-88%	7 tonnes

*Best case
** Upcycle material
*** Compared to new bricks
**** Average saving of all wood products

MORTEN BIRKVED

REFLECTION ON LCA

MORTEN BIRKVED
Professor MSO
SDU Livscykluscenter
Institut for Kemi-, Bio- og Miljøteknologi, SDU

Overall challenges of environmental assessment of circular building materials.

Building materials developed for a future circular economy should inherently be assessed in a way where the environmental assessment considers the economic model (i.e. circular economic oriented) that these materials are intended to fit into.

Unfortunately, the situation is that building materials are evaluated using data and modeling approaches intended for a linear economic model which e.g. is reflected by the data typically used in LCAs of buildings. Building LCAs are most often based on an inventory system model called "cut-off" (i.e. when data from the Swiss database Ecoinvent are used, which is the case here). One of the main assumptions in the "cut-off" model is that used materials/components that are recycled are available environmentally "free" when recycled. This obviously means that the first user of the produced material/component bears the entire burden and, therefore, all subsequent uses are "environmentally impact free"/burden free. This basic assumption reflects, of course, a subjective angle induced in the data/system model by the data provider.

The cut-off system model is probably intended to motivate for recycling by giving materials based on recycled products an environmental advantage as well as facilitating the use of these data (as making the production system models needed for the assessments much simpler). Whether a simplified system like the cut-off model reflects the actual conditions and all relevant aspects on circular economic models for building components/materials is questionable as there probably are several other relevant perspectives on how the burden of the primary use of a material should be distributed down in the circular value chain (i.e. one could imagine that the second and perhaps third user must also carry a part of the environmental impact from the original production together with the first user).

In the assessments presented in this report, Lendager UP has used the "cut-off" inventory system model which follows current/typical practice for building related LCAs. This also makes it possible to compare the results on the environmental impacts of the building components with other assessments of building products/components/materials.

The system models for concrete, windows, and bricks presented in this report, are all set up in OpenLCA which, in contrast to e.g. LCAbyg offered by the Danish Building Research Institute (SBi), allows the assessor to create complete product system models themselves and thereby assess new/alternative building materials/components. In LCAbyg, the user has a very limited opportunity to model and introduce new materials and components. LCAbyg was therefore opted less usable as product system modeling software in this project when modelling product systems for upcycled building products.

In addition, OpenLCA makes it possible to use several different system boundary models and, in contrast to LCAbyg, it hence allows for exploring other ways of distributing the environmental burden from the original production over several use cycles.

An alternative distribution (compared to the current cut-off system model) of the environmental burden from the original production has not been investigated in this project. However, it seems relevant to reevaluate which system models can catalyze the Danish construction industry's transition into circular economy by providing the most fair and accurate decision support on the environmental performance of building materials, building components and entire buildings.

Sustainability governance framework

As part of NREP's corporate 2025 strategy, formulated in 2018, NREP started a gradual development of its general organizational set-up to more effectively manage and leverage its growing organization and business activities. As part of the strategy, the approach to governing and strengthening our management of sustainability risks and opportunities was also updated and will continue to evolve over the coming years.

NREP's business line and product teams are closest to the properties and our stakeholders, and accordingly have the ownership for identifying, managing and acting on property level sustainability risks and opportunities.

The corporate Sustainability Function holds the responsibility for providing and developing the strategy, tools and systems required to enable the business lines to act. The Finance & IT Department is supporting the Sustainability Function in the continuous development of the necessary IT and data systems platforms, and is responsible for the ongoing sustainability data management and reporting.

The Sustainability Function operationally reports to the COO and indirectly to the CEO, who is ultimately responsible for direction, execution and operational oversight. The CEO is informed and involved on an ongoing and as-needed basis.

The CIO and Investment Committee (IC) provides quality assurance and oversight of sustainability risks and initiatives of new investments, developments and portfolio. The investment approval process and portfolio monitoring process provides coherent management and monitoring of sustainability from lead to exit. Head of Sustainability is invited to all ICs and sustainability is a mandatory part of all ICs.

The Risk & Compliance Committee receives sustainability risk reporting as an integrated part of the quarterly and annual risk monitoring and management process. The overall responsibility for oversight and direction of sustainability management ultimately resides with the Board of Directors.

Corporate and business line sustainability plans are an integrated part of the general corporate strategy processes, which are reviewed and approved by the Executive Management Team and the Board. At a minimum on an annual basis a sustainability progress report, strategy update and sustainability plan for the coming period are shared with the Executive Management Team and Board to support oversight on strategic priorities, business needs, and key issues.

NREP's policy framework relating to ESG consists of a set of internal policies and other governance documents, which in turn refer to external frameworks, including national legislations, regulations and building codes, international references based on EU or UN frameworks; and industry body frameworks.

SUSTAINABILITY ORGANISATIONAL GOVERNANCE FRAMEWORK

OVERSIGHT

Board
- Ultimately responsible for oversight and approval of direction
- Informed on quarterly and annual basis

Risk and Compliance Committee
- Corporate wide monitoring informed on quarterly and annual basis

EXECUTIVE MANAGEMENT

CEO
- Ultimately responsible for direction, execution and operational oversight

EXECUTIVE MANAGEMENT TEAM
- Adoption of corporate sustainability strategy
- Ongoing and quarterly risk management

CIO & INVESTMENT COMMITTEE
- Evaluation and assessment of investment and portfolio ESG opportunities/risks/budgets
- Quality assurance

OPERATIONS

Sustainability Function
- Responsible for providing the strategy, tools, systems and expertise required to enable the business lines to act
- Corporate center of competency
- Reviews ESG data and reports

Corporate Impact Coordination Team:
- Cross-functional, cross-business-lines, cross-geography working group to leverage and improve the ESHS operational strategy/systems

Business lines:
- Responsible for identifying and acting on ESHS risks and opportunities as part of acquisition assessments, developments and portfolio property management
- Responsible for monitoring and data capture

Finance and IT Department:
Responsible for data/reporting and monitoring
- Owns and manages ESG data systems
- Responsible for risk and compliance reporting on quarterly and annual basis

SUSTAINABILITY POLICY GOVERNANCE FRAMEWORK

IMPACT AREA	INTERNAL GOVERNANCE REFERENCE
Social and environmental	• NREP ESG policies • NREP Impact Strategy • NREP sustainability acquisition, develpoment and operations program
Safety	• NREP Corporate Manual • NREP Health & Safety Policy
Employee relations	• NREP Corporate Manual and Employee Handbook • NREP Diversity and Inclusion Policy • NREP Work Environment Policy

IMPACT AREA	INTERNAL GOVERNANCE REFERENCE
Inclusion and diversity	• NREP Inclusion and Diversity Policy
Human rights	• NREP ESG policies • NREP Anti-trafficking and slavery policy
Anti-corruption	• NREP Anti-bribery and Corruption Policy
Anti-money laundering	• NREP AML Policy'
Responsible procurement	• NREP Supplier Code of Conduct • NREP Corporate Manual

Alignment of NREP's goals with the UN SDGs

We have assessed which issues that are of greatest significance taking consideration of a broad set of key stakeholders and our business. Our 2018 materiality assessment was updated also based on the United Nation's 17 Global Goals for Sustainable Development (the "SDGs"), which provide a common reference for identifying and assessing opportunities for impact across a broad spectrum of major local and global challenges. We have identified which of the 169 sub-targets underpinning the SDG-framework that NREP will focus on.

Our primary impact goals relate to sub-targets of SDGs 11, 3, 12, 15 and 7. Going forward, NREP will seek to increase its positive impact by engaging more to influence supply chains and industry practices beyond our direct impacts, and as such SDG '17 Partnerships for the Goals' sub-targets 17.16 and 17.17 will become a larger focus for our business.

NREP finds that real estate in the Nordics can contribute to the spirit of many of the SDGs, but that for other than the below highlighted SDGs the materiality is lower or NREP's contributions are more indirect.

UN17 Village Copenhagen

Engaging multiple stakeholders, the UN17 Village is an ambitious interpretation of livability and sustainability, using the spirit and intention of each of the UN 17 Global Goals as a starting point and design tool

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Goals

Address underserved needs with affordable customer-centric and community centric products
(SDG 11.3, 11.6, 11.7)

Build environments that support physical, social and mental health
(SDG 3.4)

Innovate and optimize building design and materials
(SDG 12.2, 12.5, 12.8, 15.5, 15.A)

Ensure energy efficiency and increase renewables
(SDG 7.2, 7.3, 7.A)

SDG Alignment

11 SUSTAINABLE CITIES AND COMMUNITIES

Make cities and human settlements inclusive, safe, resilient and sustainable

11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries

11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

11.7 By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities

3 GOOD HEALTH AND WELL-BEING

Ensure healthy lives and promote well-being for all at all ages

3.4 By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being.

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

Ensure sustainable consumption and production patterns

12.2 By 2030, achieve the sustainable management and efficient use of natural resources

12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse

12.8 By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature

15 LIFE ON LAND

Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species

15.A Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems

7 AFFORDABLE AND CLEAN ENERGY

Ensure access to affordable, reliable, sustainable and modern energy for all

7.2 By 2030, increase substantially the share of renewable energy in the global energy mix

7.3 By 2030, double the global rate of improvement in energy efficiency

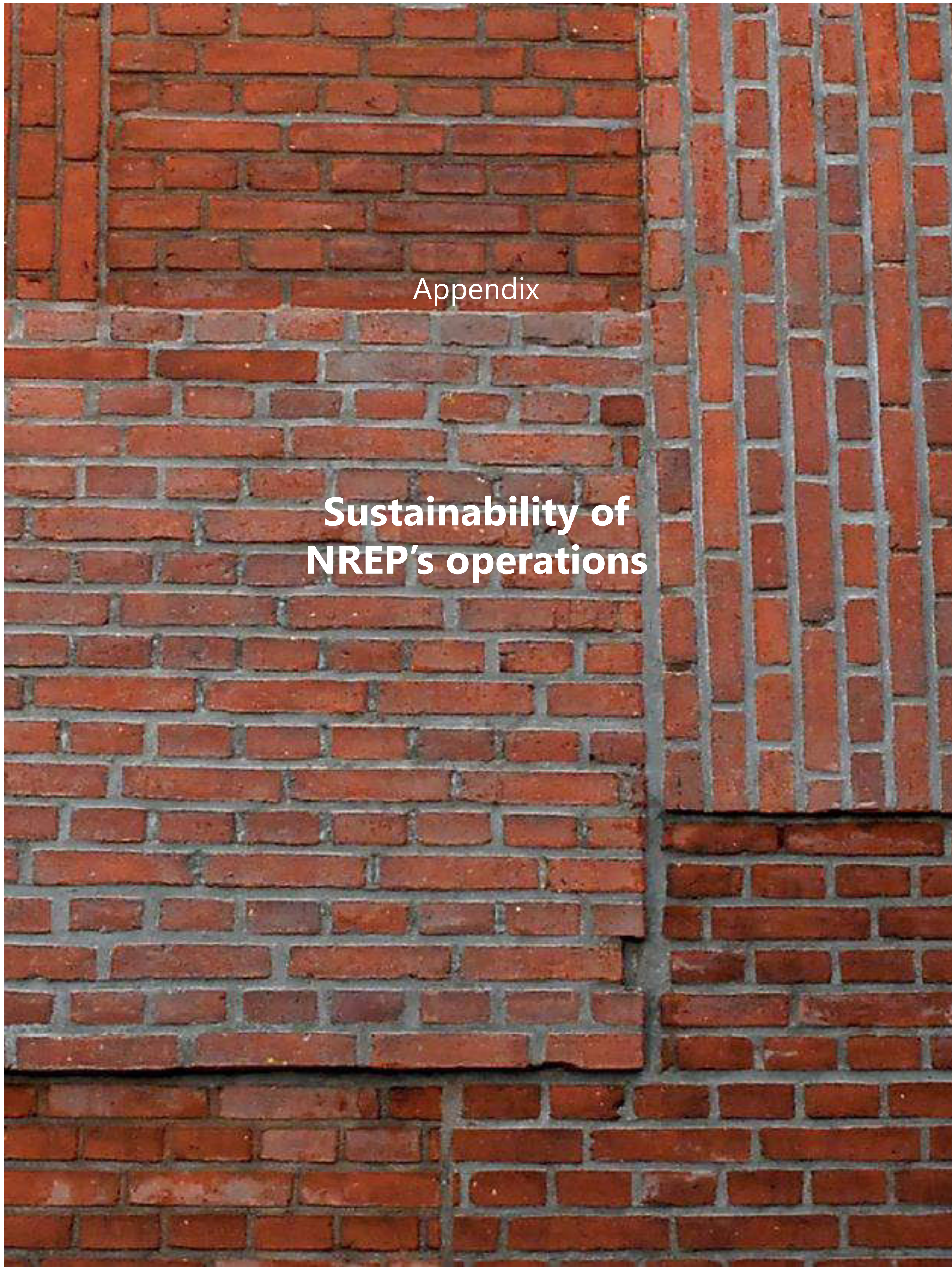
7.A By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology

17 PARTNERSHIPS FOR THE GOALS

Strengthen the means of implementation and revitalize the global partnership for sustainable development

17.16 Enhance the global partnership for sustainable development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology and financial resources, to support the achievement of the sustainable development goals in all countries, in particular developing countries

17.17 Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships



Our people

NREP's ability to attract, retain and unleash the power of a multi-disciplinary team of specialists is the foundation of our success.

Professional growth and recognition
We are committed to help all people at NREP unleash their full potential and continuously grow their careers. We invest in development programs with HR staff dedicated to professional development, training and coaching. We engage external consultants to provide skills, team management and personal management training.

We also seek to build deeper connections between staff both within offices and between offices.

Culture of diversity and inclusion
Motto: SHARING VALUES, VALUING DIFFERENCES

As a team we want to be the best at what we do and we work hard to achieve our goals, but we want to do so in a collaborative and caring culture, and we want to make a positive difference while doing it. NREP is a place where people truly work together as a team, valuing each other's differences and the importance of each and every team member. Together we dare to innovate and challenge status quo, which has been a key to our success as a firm and our ability to have a positive impact.

Our HR and senior management works actively to create an environment that values different backgrounds, perspectives and contributions. We are committed to our belief that an open, diverse, inclusive and safe work environment is key to enable our staff to be happy, unleash their potential and be truly effective. We work systematically with promoting a best in class inclusive safe culture and actively support, increase and retain the representation of diverse employees.

Health and Wellbeing
Health and wellbeing is of key importance to support that staff are happy and productive. The approach and components differs between countries, but includes mental, physical and financial wellbeing initiatives. All offices are located close to public transportation and allows the possibility for a large proportion of staff to commute to work by bike, providing facilities for bike parking and changing rooms.

To promote life balance for people in different life situations, NREP promotes flexible work arrangements in all offices.

Physical exercise is encouraged and NREP makes specific efforts that contribute towards physical exercise during everyday work as well as outside, including participation in running, biking, paddel, soccer and schemes benefiting sports memberships.

HR connects with staff to understand physical and mental health at work through interviews and weekly surveys. HR also sets annual goals for physical and mental well being, including:

a) Zero work injuries (2019: 0)
b) Less than 1% of staff on leave due to stress (2019: Less than 1%)
c) All offices promote employees to incorporate bicycling or walking as part of their daily commutes (2019: Yes)

HR monitors implementation of corporate health and wellbeing programs on an annual basis.

Safety and ergonomic suitability of workstations are performed on an as-needed basis or in connection with office relations. All offices to establish indoor climate monitoring

Charity and community initiatives
NREP's N-Power foundation and charity engagement initiative was formalized in 2014, enabling staff to nominate causes to fund and to personally take paid work-time to directly support charity or community work.

Risk assessment
On an annual basis, NREP HR performs a review and risk assessment of diversity, workers rights, executive compensation and safety of all offices.

Our environmental footprint

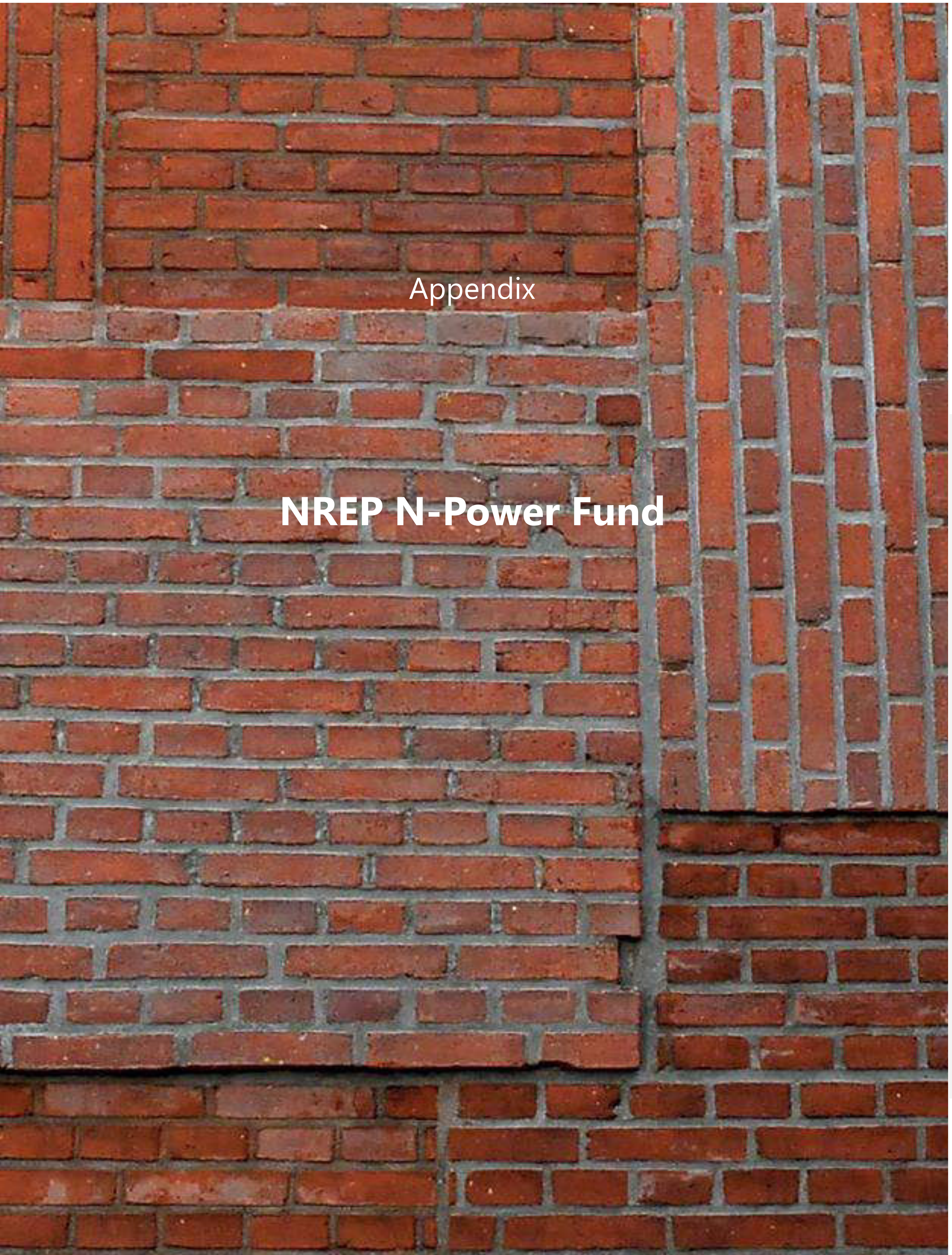
NREP's operations consist mainly of impacts related to the activities by staff in our offices, travel to external meetings or engagements, sourcing of office supplies and the operations of our office premises. NREP is committed to systematically lowering our individual carbon footprint

Reduce travel-related carbon emissions
- All NREP offices have polycom meeting rooms as a first choice for your meetings, especially for internal meetings
- Corporate car-sharing (and other low-carbon mobility vehicles) for local in-town meetings and commute to/from airport (6 month pilot in Copenhagen, and then roll out to other offices as relevant)

Reduce commute-related carbon emissions
- All offices are located close to public transportation and allows the possibility for a large proportion of staff to commute to work by bike, providing facilities for bike parking and changing rooms.

Reduce food-related carbon emission
- Internally provided food is operating a 80/20-type buffet[2] (80% plant-based / 20% animal), with emphasis on local seasonal, healthy and organic food, and produced with directions to Reduce food-waste – cooking right amounts and reusing

Reduce carbon footprint from our offices
- NREP is working towards all its offices procuring green electricity, with a target to reach 100% green electricity by the end of 2021



Appendix

NREP N-Power Fund

Human Practice Foundation

In 2014, NREP's N-Power Fund co-founded the innovative charity Human Practice Foundation, which is currently one of the main focus areas of the Fund. The Human Practice Foundation primarily supports projects aimed at elevating the living standards in developing countries using a business and investment approach with local anchoring. To date HPF has founded 59 schools helping 27 000 children.

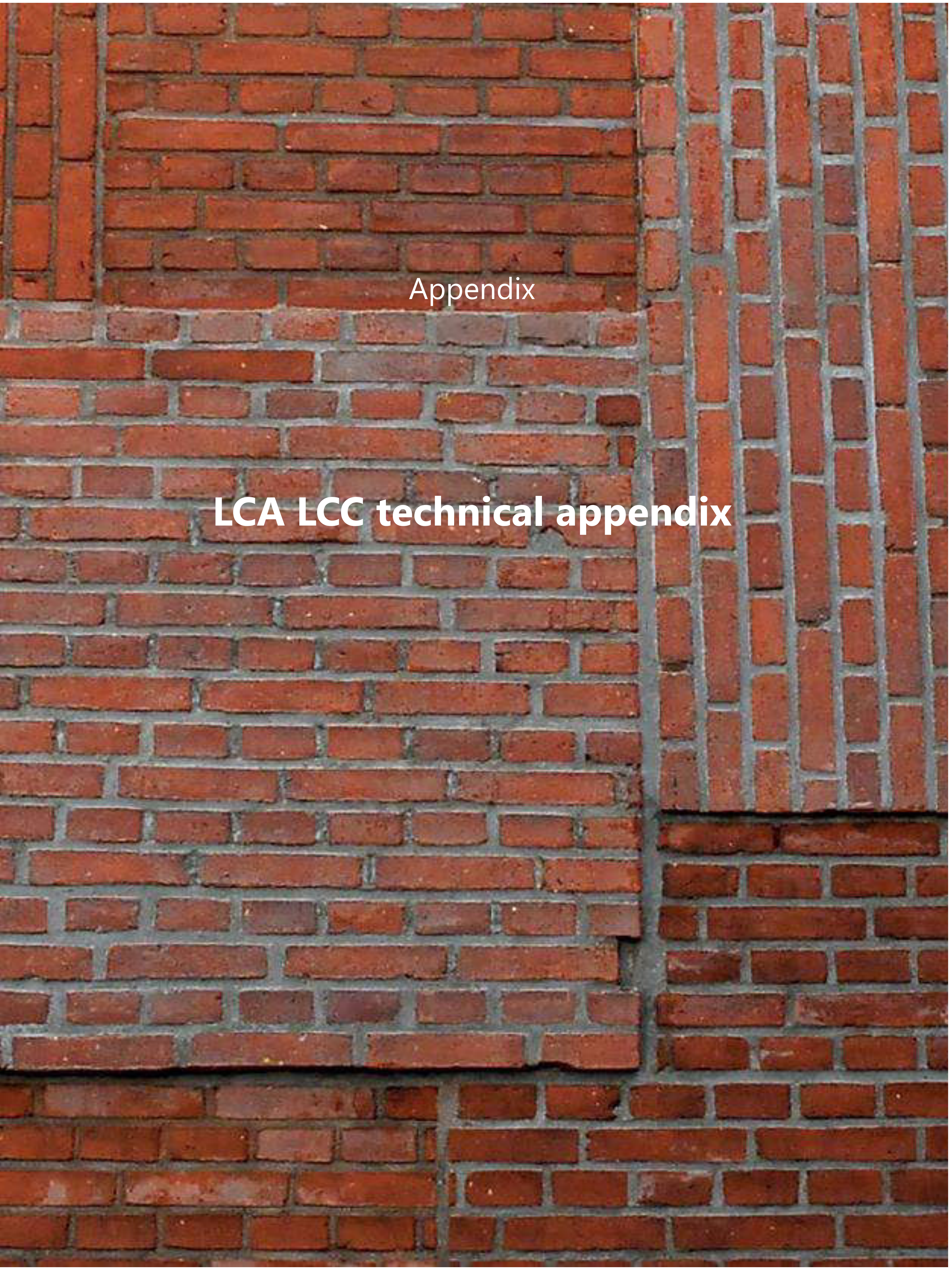
The activities of the Human Practice Foundation are in line with NREP's ambition to support projects that build long term economic empowerment. In addition to being the single largest financial donor, NREP has been providing offices, staff time and other support for the Human Practice Foundation. In 2019, NREP continued using its allocation of 10% of profits to support the Human Practice Foundation.

Impact where needed most

10%

Of our profit goes to charity

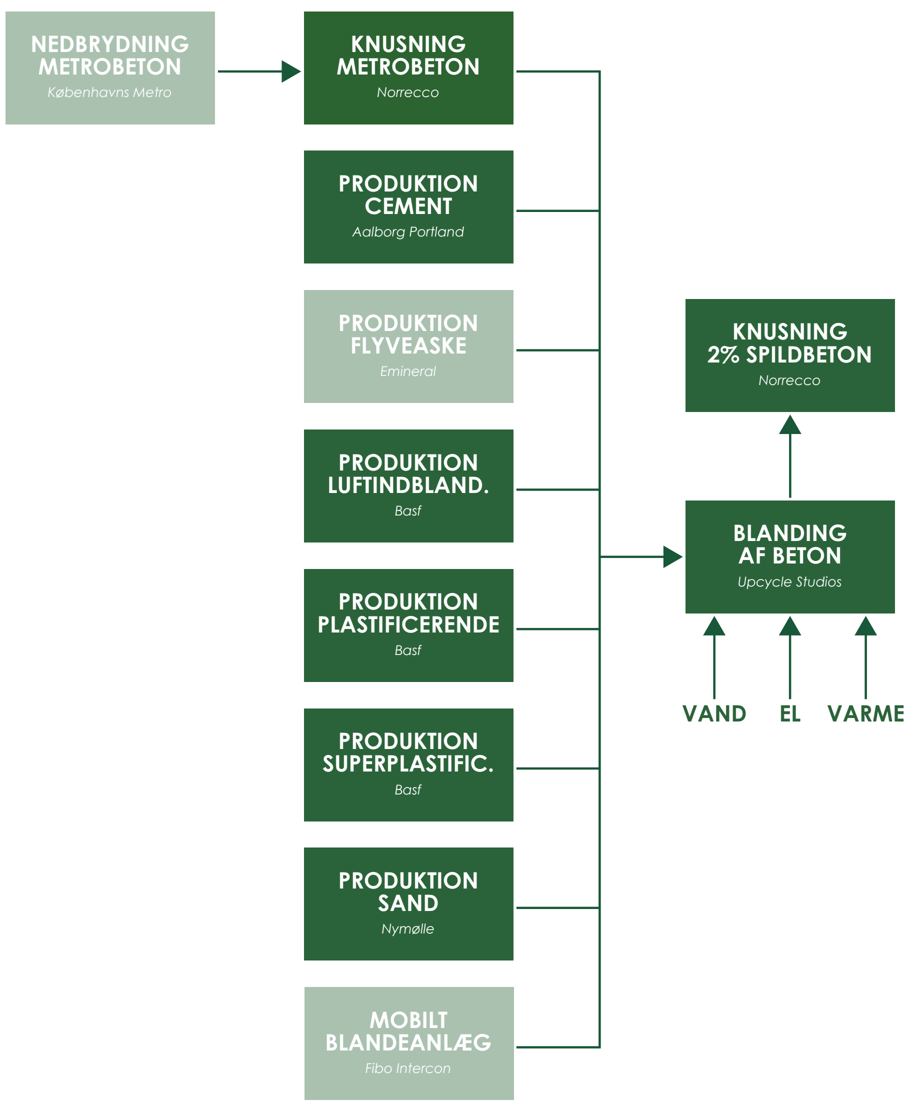
POWER



APPENDIX INDEX

APPENDIX I

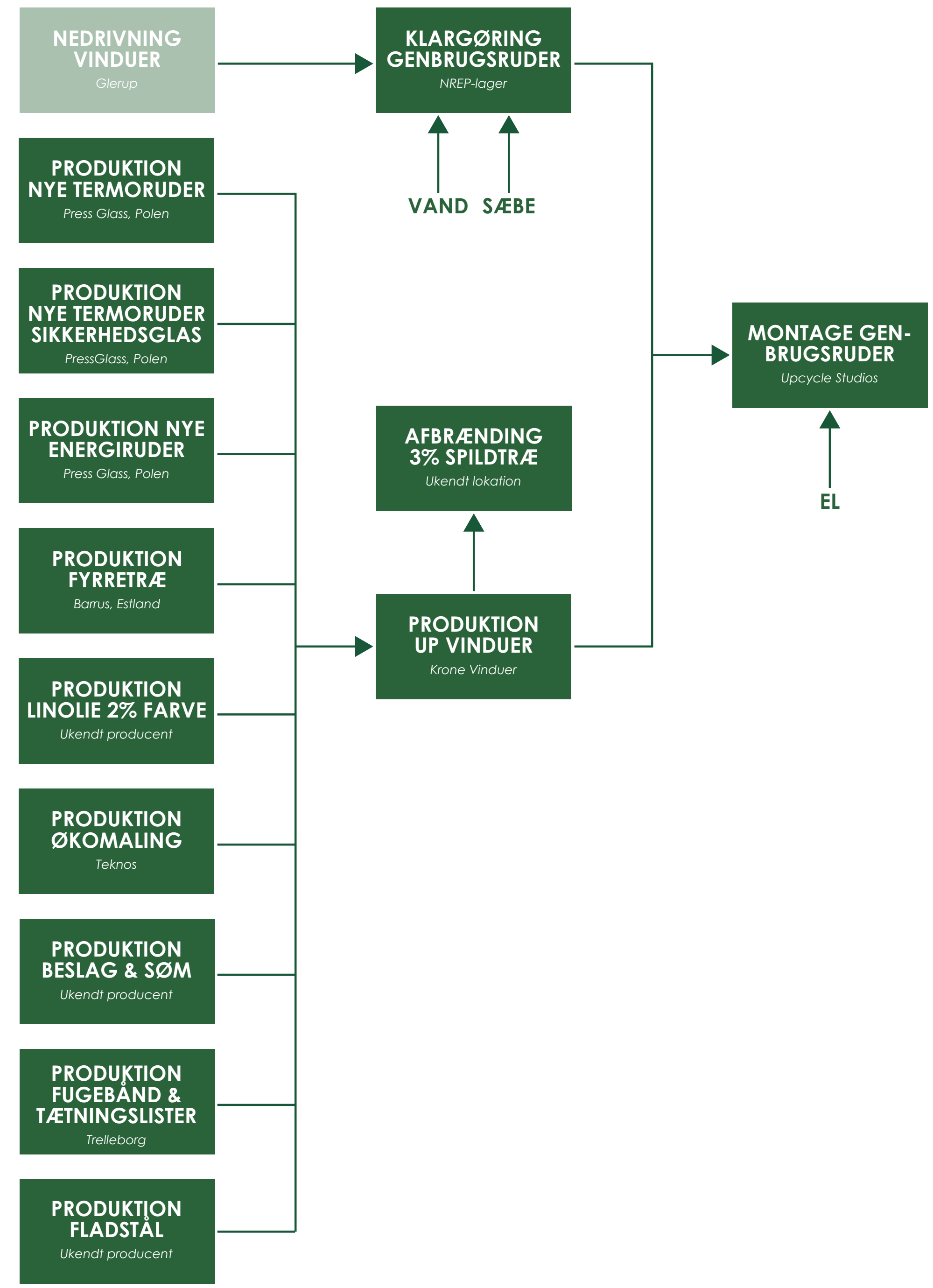
FLOW CHART OF THE INCLUDED PROCESSES IN THE LCA OF UPCYCLE CONCRETE



PROCES
PROCES EJ INKLUDERET
INPUTFLOW INKL. TRANSPORT

APPENDIX II

FLOW CHART OF THE INCLUDED PROCESSES IN THE LCA OF UPCYCLE WINDOWS



PROCES
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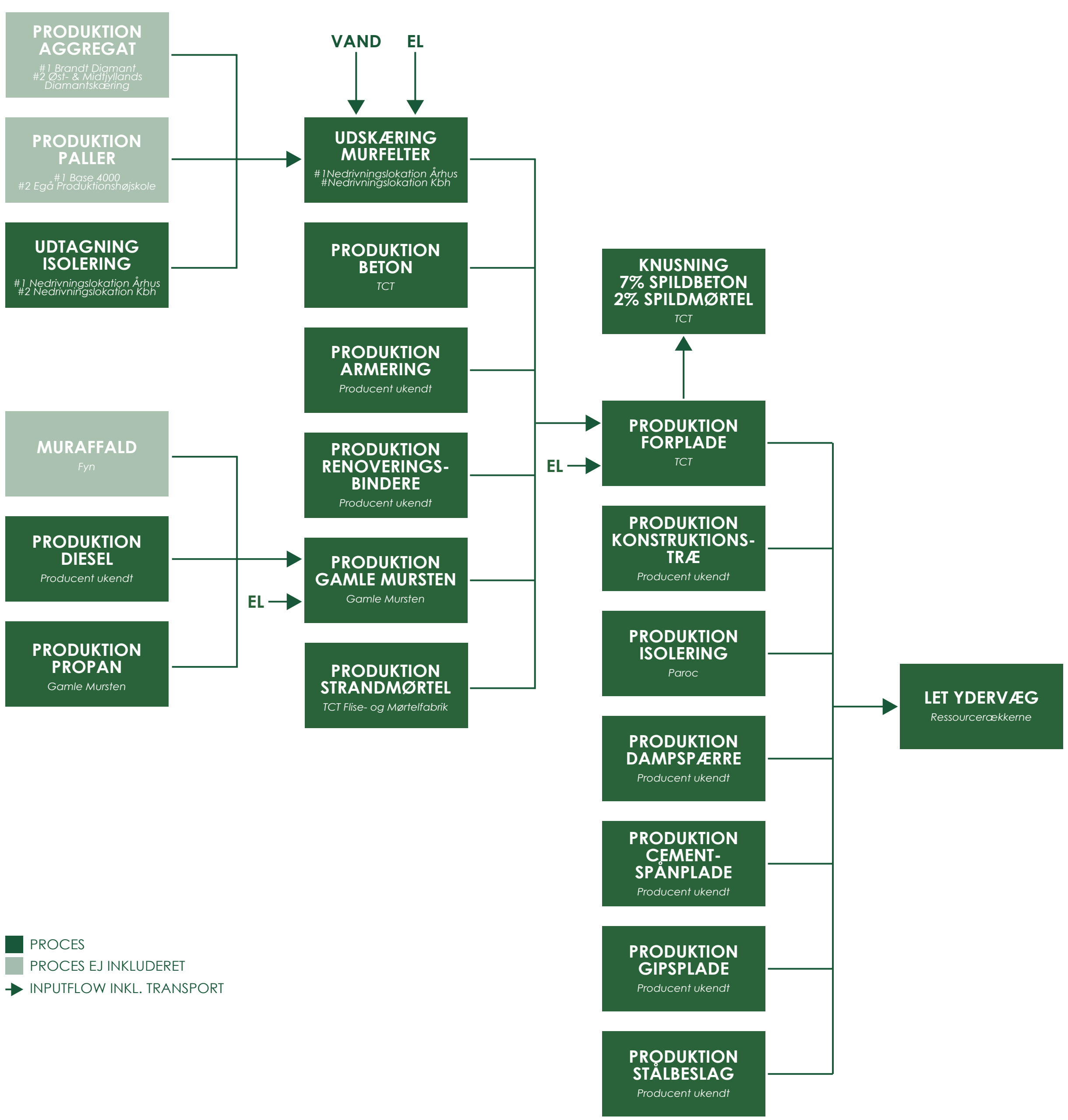
APPENDIX III

FLOW CHART OF THE INCLUDED PROCESSES IN THE LCA OF UPCYLCE BRICK WALL



APPENDIX IV

LCC BUILD REPORT OF UPCYCLE STUDIOS

Upcycle Studios

Denne rapport er udfærdiget i LCCbyg 2.2.52

LCC af et rækkehus i Upcycle Studios

Alternativer

Upcycle Studios	Upcycle Studios, ét rækkehus

Antagelser

Generelle beregningsforudsætninger	50 år
Kalkulationsrente	fra og med år 1: 5,00 % fra og med år 36: 5,00 % fra og med år 71: 5,00 %
Prisudvikling generelt	2,00 %
Prisudvikling for drikkevand	4,00 %
Prisudvikling for spildevand	7,00 %
Prisudvikling for energi generelt	4,00 %
Prisudvikling for fjernvarme	3,00 %
Prisudvikling for gas	1,50 %
Prisudvikling for flydende brændsel	4,00 %
Prisudvikling for fast brændsel	3,00 %
Prisudvikling for el	3,50 %
Prisudvikling for skatter og afgifter	2,00 %
Prisudvikling for forsikring	5,00 %
Prisudvikling for administration	2,00 %

Konklusion

Nøgletallene for analysen er opgjort nedenfor. Nøgletallene for analysen viser, at:

- De laveste anskaffelsesomkostninger er på ***2.956.167*** kr. for ***Upcycle Studios***
- Den laveste nutidsværdi er på ***5.001.500*** kr. for ***Upcycle Studios***
- Den laveste årlige omkostning per kvadratmeter på ***1.405*** kr/m2/år opnås for ***Upcycle Studios***
- Det foretrukne alternativ er ***Ikke valgt***.

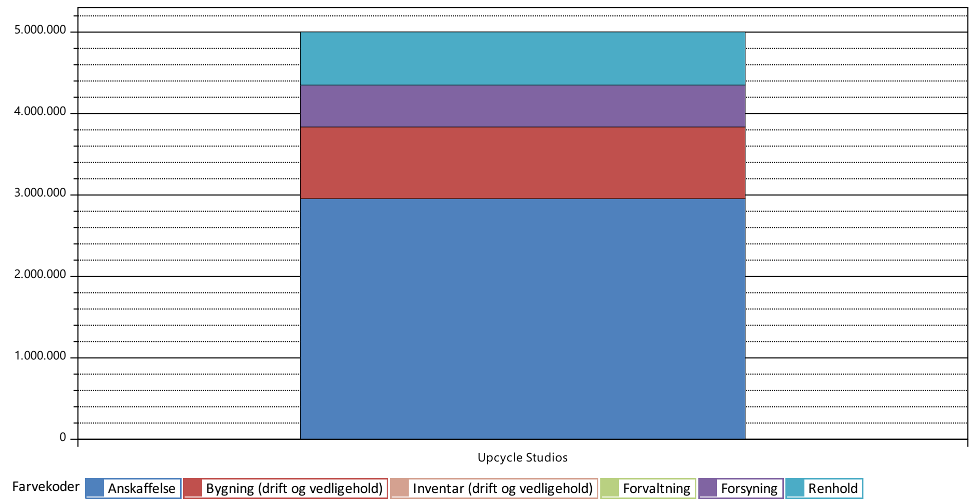
Nutidsværdi

	Upcycle Studios	%
Anskaffelse	2.956.167	59
Bygning (drift og vedligehold)	879.614	18
Inventar (drift og vedligehold)	0	0
Forvaltning	0	0
Forsyning	514.453	10
Renhold	651.266	13
Nutidsværdi	**5.001.500**	
Nutidsværdi per m2	**25.649**	
Årsomkostning (kr/m2/år)	**1.405**	

LCC BUILD REPORT OF UPCYCLE STUDIOS

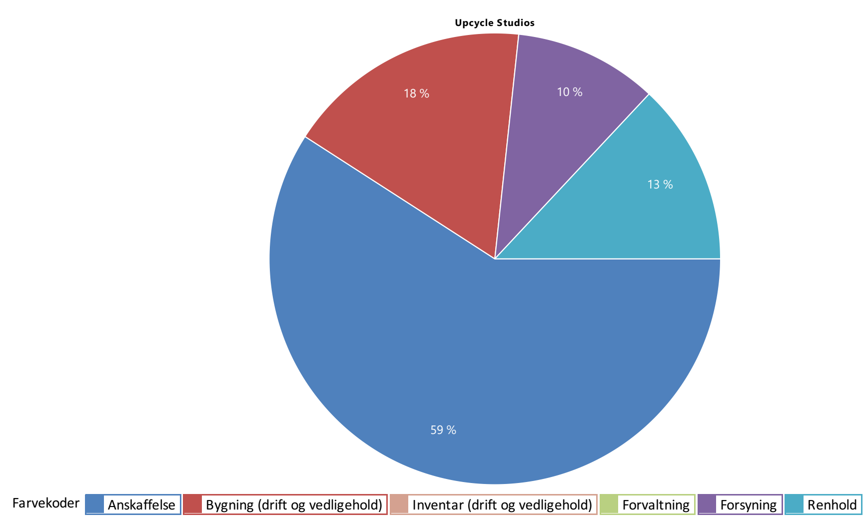
Hovedomkostningsgrupper

Stavdiagram med alternativers hovedomkostninger



Hovedomkostningsgrupper

Figurerne nedenfor viser, hvordan nutidsværdien for det eller de valgte alternativer fordeler sig på hovedomkostningsgrupper.
Cirkeldiagrammerne viser ikke eventuelle indtægter.



LCC BUILD REPORT OF UPCYCLE STUDIOS

Hovedomkostningsgrupper i tal

	Upcycle Studios	%
Anskaffelse	**2.956.167**	**59**
Grund, rådgivning og bygherre	1.261.593	25,22
Bygningsbasis	164.531	3,29
Primære bygningsdele	770.109	15,40
Kompletterende bygningsdele	329.639	6,59
Overfladebygningsdele	127.941	2,56
VVS-anlæg	168.453	3,37
El- og mekaniske anlæg	133.901	2,68
Inventar og udstyr	0	0,00
Bygning (drift og vedligehold)	**879.614**	**18**
Bygningsbasis	21.405	0,43
Primære bygningsdele	205.389	4,11
Kompletterende bygningsdele	229.096	4,58
Overfladebygningsdele	90.638	1,81
VVS-anlæg	260.732	5,21
El- og mekaniske anlæg	72.354	1,45
Inventar (drift og vedligehold)	**0**	**0**
Inventar og udstyr	0	0,00
Forvaltning	**0**	**0**
Forvaltning	0	0,00
Forsyning	**514.453**	**10**
Forsyning	514.453	10,29
Renhold	**651.266**	**13**
Terræn	3.724	0,07
Bygninger, udvendigt	79.620	1,59
Indendørsarealer og rum	567.922	11,36

Hovedomkostningsgrupper i tal med undergrupper

	Upcycle Studios	%
Anskaffelse	**2.956.167**	**59**
Grund, rådgivning og bygherre	1.261.593	25,22
Byggegrund	1.048.299	20,96
Rådgiverhonorarer	213.294	4,26
Bygherreomkostninger	0	0,00
Bygningsbasis	164.531	3,29
Bygningsbasis, terræn	0	0,00
Fundamenter	36.764	0,74
Terrændæk	127.767	2,55
Primære bygningsdele	770.109	15,40
Terræn	1.296	0,03
Ydervægge	157.459	3,15
Indervægge	255.354	5,11
Dæk	170.760	3,41
Trapper og ramper	104.400	2,09
Bærende konstruktioner	12.800	0,26
Altaner og altangange	0	0,00
Tage	68.040	1,36
Øvrige primære bygningsdele, bygning	0	0,00
Kompletterende bygningsdele	329.639	6,59
Terræn, komplettering	0	0,00
Ydervægge, komplettering	264.472	5,29
Indervægge, komplettering	27.500	0,55
Dæk, komplettering	0	0,00
Trapper og ramper, komplettering	0	0,00
Lofter, komplettering	0	0,00
Altaner, komplettering	16.785	0,34
Tage, komplettering	20.882	0,42
Kompletterende bygningsdele bygning, øvrige	0	0,00
Overfladebygningsdele	127.941	2,56
Belægninger, terræn	39.358	0,79

LCC BUILD REPORT OF UPCYCLE STUDIOS

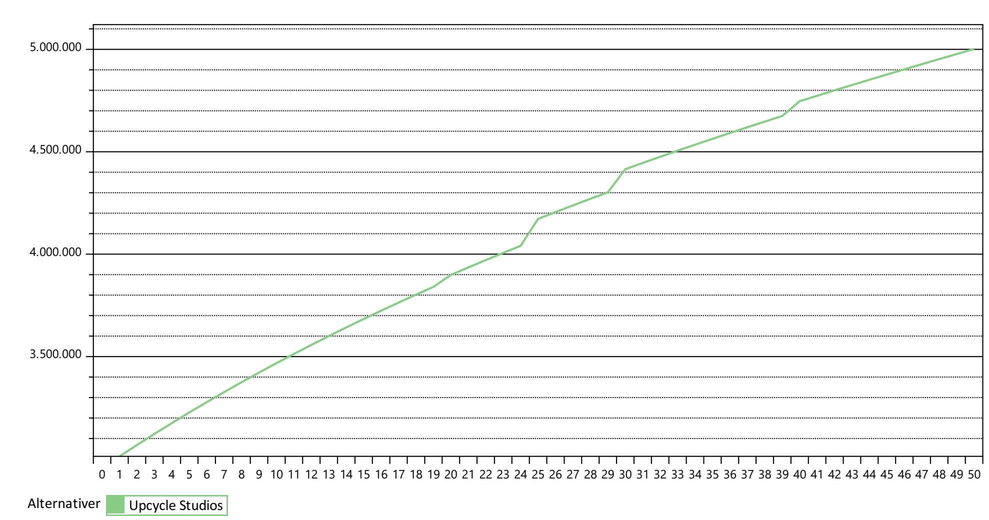
Udvendige vægoverflader	0	0,00
Indvendige vægoverflader	5.640	0,11
Dæk og gulve, overflader	67.311	1,35
Trapper og ramper, overflader	0	0,00
Lofter, overflader	0	0,00
Altaner, overflader	0	0,00
Tage, overflader	15.633	0,31
Øvrige overflader, bygning	0	0,00
VVS-anlæg	168.453	3,37
VVS-anlæg, terræn	3.722	0,07
Affald	0	0,00
Afløb og sanitet	27.039	0,54
Vand (koldt/varmt vand, behandlet vand)	5.238	0,10
Luftarter (gas, trykluft, vakuum, damp)	0	0,00
Køling	0	0,00
Varme (vand, damp, kondens, hedtolie)	81.370	1,63
Ventilationsanlæg	49.135	0,98
VVS-anlæg, bygning, øvrige	1.949	0,04
El- og mekaniske anlæg	133.901	2,68
El- og mekaniske anlæg, terræn	4.322	0,09
Højspændingsanlæg	25.168	0,50
Lavspændingsanlæg	94.185	1,88
Elektronik og svagstrøm	2.374	0,05
Transportanlæg	0	0,00
Mekaniske anlæg, øvrige	0	0,00
Elektriske anlæg, øvrige	7.852	0,16
Inventar og udstyr	0	0,00
Inventar og udstyr	0	0,00
Bygning (drift og vedligehold)	**879.614**	**18**
Bygningsbasis	21.405	0,43
Bygningsbasis, terræn	0	0,00
Fundamenter	4.783	0,10
Terrændæk	16.622	0,33
Primære bygningsdele	205.389	4,11
Terræn	337	0,01
Ydervægge	45.979	0,92
Indervægge	66.442	1,33
Dæk	44.431	0,89
Trapper og ramper	27.165	0,54
Bærende konstruktioner	3.331	0,07
Altaner og altangange	0	0,00
Tage	17.704	0,35
Øvrige primære bygningsdele, bygning	0	0,00
Kompletterende bygningsdele	229.096	4,58
Terræn, komplettering	0	0,00
Ydervægge, komplettering	203.992	4,08
Indervægge, komplettering	7.155	0,14
Dæk, komplettering	0	0,00
Trapper og ramper, komplettering	0	0,00
Lofter, komplettering	0	0,00
Altaner, komplettering	4.367	0,09
Tage, komplettering	13.581	0,27
Kompletterende bygningsdele bygning, øvrige	0	0,00
Overfladebygningsdele	90.638	1,81
Belægninger, terræn	30.792	0,62
Udvendige vægoverflader	0	0,00
Indvendige vægoverflader	3.678	0,07
Dæk og gulve, overflader	35.028	0,70
Trapper og ramper, overflader	0	0,00
Lofter, overflader	0	0,00
Altaner, overflader	0	0,00
Tage, overflader	21.140	0,42
Øvrige overflader, bygning	0	0,00
VVS-anlæg	260.732	5,21

LCC BUILD REPORT OF UPCYCLE STUDIOS

VVS-anlæg, terræn	484	0,01
Affald	0	0,00
Afløb og sanitet	29.398	0,59
Vand (koldt/varmt vand, behandlet vand)	4.259	0,09
Luftarter (gas, trykluft, vakuum, damp)	0	0,00
Køling	0	0,00
Varme (vand, damp, kondens, hedtolie)	139.130	2,78
Ventilationsanlæg	87.460	1,75
VVS-anlæg, bygning, øvrige	0	0,00
El- og mekaniske anlæg	72.354	1,45
El- og mekaniske anlæg, terræn	2.819	0,06
Højspændingsanlæg	19.734	0,39
Lavspændingsanlæg	45.643	0,91
Elektronik og svagstrøm	3.210	0,06
Transportanlæg	0	0,00
Mekaniske anlæg, øvrige	0	0,00
Elektriske anlæg, øvrige	948	0,02
Inventar (drift og vedligehold)	**0**	**0**
Inventar og udstyr	0	0,00
Inventar og udstyr	0	0,00
Forvaltning	**0**	**0**
Forvaltning	0	0,00
Skatter	0	0,00
Forsikringer	0	0,00
Administration	0	0,00
Forsyning	**514.453**	**10**
Forsyning	514.453	10,29
Vand	436.266	8,72
Varme	0	0,00
Electricitet	78.187	1,56
Renhold	**651.266**	**13**
Terræn	3.724	0,07
Udeareal	3.724	0,07
Bygninger, udvendigt	79.620	1,59
Klimaskærm	79.620	1,59
Indendørsarealer og rum	567.922	11,36
Rum	567.922	11,36

Hovedomkostningsgrupper

Figurerne nedenfor viser, hvordan nutidsværdien for det eller de valgte alternativer fordeler sig på hovedomkostningsgrupper.



APPENDIX V

LCC BUILD REPORT OF UPCYCLE STUDIOS BENCHMARK

Upcycle Studios

Denne rapport er udfærdiget i LCCbyg 2.2.52

LCC af et rækkehus i Upcycle Studios

Alternativer

Upcycle Studios	Upcycle Studios, ét rækkehus

Antagelser

Generelle beregningsforudsætninger	50 år
Kalkulationsrente	fra og med år 1: 5,00 % fra og med år 36: 5,00 % fra og med år 71: 5,00 %
Prisudvikling generelt	2,00 %
Prisudvikling for drikkevand	4,00 %
Prisudvikling for spildevand	7,00 %
Prisudvikling for energi generelt	4,00 %
Prisudvikling for fjernvarme	3,00 %
Prisudvikling for gas	1,50 %
Prisudvikling for flydende brændsel	4,00 %
Prisudvikling for fast brændsel	3,00 %
Prisudvikling for el	3,50 %
Prisudvikling for skatter og afgifter	2,00 %
Prisudvikling for forsikring	5,00 %
Prisudvikling for administration	2,00 %

Konklusion

Nøgletallene for analysen er opgjort nedenfor. Nøgletallene for analysen viser, at:

- De laveste anskaffelsesomkostninger er på ***3.159.167*** kr. for ***Upcycle Studios***
- Den laveste nutidsværdi er på ***5.226.637*** kr. for ***Upcycle Studios***
- Den laveste årlige omkostning per kvadratmeter på ***1.467*** kr/m2/år opnås for ***Upcycle Studios***
- Det foretrukne alternativ er ***Ikke valgt***.

Nutidsværdi

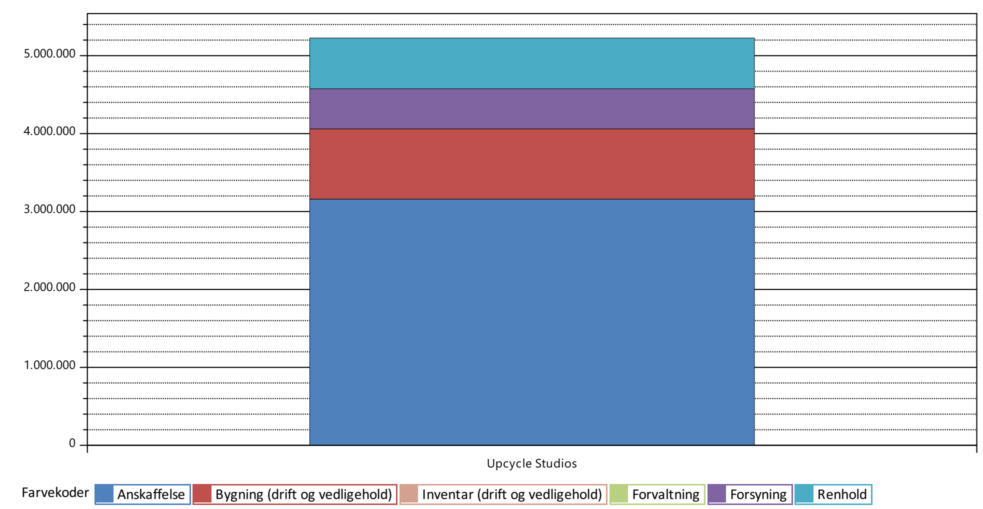
	Upcycle Studios	%
Anskaffelse	3.159.167	60
Bygning (drift og vedligehold)	901.750	17
Inventar (drift og vedligehold)	0	0
Forvaltning	0	0
Forsyning	514.453	10
Renhold	651.266	12
Nutidsværdi	**5.226.637**	
Nutidsværdi per m2	**26.787**	
Årsomkostning (kr/m2/år)	**1.467**	

side 1/5

LCC BUILD REPORT OF UPCYCLE STUDIOS BENCHMARK

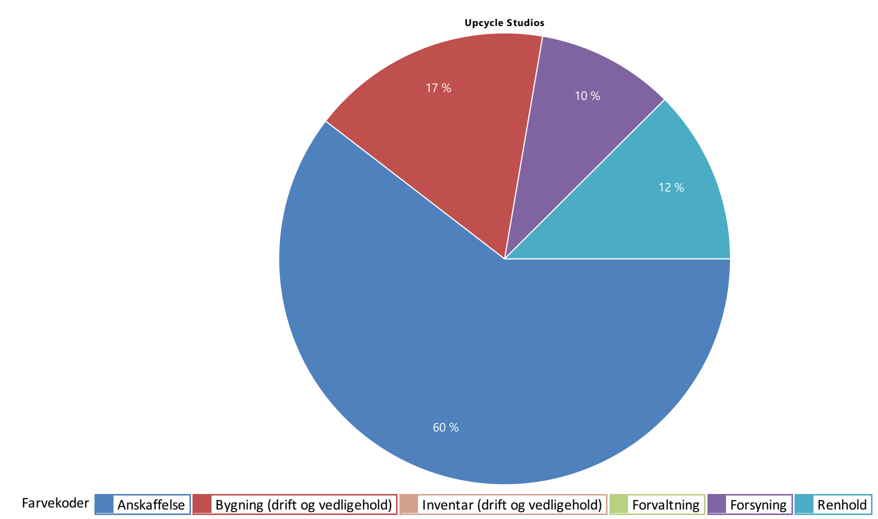
Hovedomkostningsgrupper

Stavdiagram med alternativers hovedomkostninger



Hovedomkostningsgrupper

Figurerne nedenfor viser, hvordan nutidsværdien for det eller de valgte alternativer fordeler sig på hovedomkostningsgrupper. Cirkeldiagrammerne viser ikke eventuelle indtægter.



side 2/5

LCC BUILD REPORT OF UPCYCLE STUDIOS BENCHMARK

Hovedomkostningsgrupper i tal

	Upcycle Studios	%
Anskaffelse	**3.159.167**	**60**
Grund, rådgivning og bygherre	1.261.593	24,14
Bygningsbasis	182.435	3,49
Primære bygningsdele	941.687	18,02
Kompletterende bygningsdele	326.572	6,25
Overfladebygningsdele	142.590	2,73
VVS-anlæg	168.453	3,22
El- og mekaniske anlæg	135.837	2,60
Inventar og udstyr	0	0,00
Bygning (drift og vedligehold)	**901.750**	**17**
Bygningsbasis	23.734	0,45
Primære bygningsdele	254.631	4,87
Kompletterende bygningsdele	190.004	3,64
Overfladebygningsdele	98.777	1,89
VVS-anlæg	260.732	4,99
El- og mekaniske anlæg	73.872	1,41
Inventar (drift og vedligehold)	**0**	**0**
Inventar og udstyr	0	0,00
Forvaltning	**0**	**0**
Forvaltning	0	0,00
Forsyning	**514.453**	**10**
Forsyning	514.453	9,84
Renhold	**651.266**	**12**
Terræn	3.724	0,07
Bygninger, udvendigt	79.620	1,52
Indendørsarealer og rum	567.922	10,87

Hovedomkostningsgrupper i tal med undergrupper

	Upcycle Studios	%
Anskaffelse	**3.159.167**	**60**
Grund, rådgivning og bygherre	1.261.593	24,14
Byggegrund	1.048.300	20,06
Rådgiverhonorarer	213.293	4,08
Bygherreomkostninger	0	0,00
Bygningsbasis	182.435	3,49
Bygningsbasis, terræn	0	0,00
Fundamenter	36.764	0,70
Terrændæk	145.671	2,79
Primære bygningsdele	941.687	18,02
Terræn	1.296	0,02
Ydervægge	260.585	4,99
Indervægge	300.734	5,75
Dæk	191.882	3,67
Trapper og ramper	106.350	2,03
Bærende konstruktioner	12.800	0,24
Altaner og altangange	0	0,00
Tage	68.040	1,30
Øvrige primære bygningsdele, bygning	0	0,00
Kompletterende bygningsdele	326.572	6,25
Terræn, komplettering	0	0,00
Ydervægge, komplettering	261.405	5,00
Indervægge, komplettering	27.500	0,53
Dæk, komplettering	0	0,00
Trapper og ramper, komplettering	0	0,00
Lofter, komplettering	0	0,00
Altaner, komplettering	16.785	0,32
Tage, komplettering	20.882	0,40
Kompletterende bygningsdele bygning, øvrige	0	0,00
Overfladebygningsdele	142.590	2,73
Belægninger, terræn	39.358	0,75

side 3/5

LENDAGER GROUP

LCC BUILD REPORT OF UPCYCLE STUDIOS BENCHMARK

Udvendige vægoverflader	0	0,00
Indvendige vægoverflader	9.552	0,18
Dæk og gulve, overflader	78.048	1,49
Trapper og ramper, overflader	0	0,00
Lofter, overflader	0	0,00
Altaner, overflader	0	0,00
Tage, overflader	15.633	0,30
Øvrige overflader, bygning	0	0,00
VVS-anlæg	168.453	3,22
VVS-anlæg, terræn	3.722	0,07
Affald	0	0,00
Afløb og sanitet	27.039	0,52
Vand (koldt/varmt vand, behandlet vand)	5.238	0,10
Luftarter (gas, trykluft, vakuum, damp)	0	0,00
Køling	0	0,00
Varme (vand, damp, kondens, hedtolie)	81.370	1,56
Ventilationsanlæg	49.135	0,94
VVS-anlæg, bygning, øvrige	1.949	0,04
El- og mekaniske anlæg	135.837	2,60
El- og mekaniske anlæg, terræn	4.322	0,08
Højspændingsanlæg	27.104	0,52
Lavspændingsanlæg	94.185	1,80
Elektronik og svagstrøm	2.374	0,05
Transportanlæg	0	0,00
Mekaniske anlæg, øvrige	0	0,00
Elektriske anlæg, øvrige	7.852	0,15
Inventar og udstyr	0	0,00
Inventar og udstyr	0	0,00
Bygning (drift og vedligehold)	**901.750**	**17**
Bygningsbasis	23.734	0,45
Bygningsbasis, terræn	0	0,00
Fundamenter	4.783	0,09
Terrændæk	18.952	0,36
Primære bygningsdele	254.631	4,87
Terræn	337	0,01
Ydervægge	77.411	1,48
Indervægge	78.250	1,50
Dæk	49.927	0,96
Trapper og ramper	27.672	0,53
Bærende konstruktioner	3.331	0,06
Altaner og altangange	0	0,00
Tage	17.704	0,34
Øvrige primære bygningsdele, bygning	0	0,00
Kompletterende bygningsdele	190.004	3,64
Terræn, komplettering	0	0,00
Ydervægge, komplettering	164.900	3,16
Indervægge, komplettering	7.155	0,14
Dæk, komplettering	0	0,00
Trapper og ramper, komplettering	0	0,00
Lofter, komplettering	0	0,00
Altaner, komplettering	4.367	0,08
Tage, komplettering	13.581	0,26
Kompletterende bygningsdele bygning, øvrige	0	0,00
Overfladebygningsdele	98.777	1,89
Belægninger, terræn	30.792	0,59
Udvendige vægoverflader	0	0,00
Indvendige vægoverflader	6.231	0,12
Dæk og gulve, overflader	40.615	0,78
Trapper og ramper, overflader	0	0,00
Lofter, overflader	0	0,00
Altaner, overflader	0	0,00
Tage, overflader	21.140	0,40
Øvrige overflader, bygning	0	0,00
VVS-anlæg	260.732	4,99

side 4/5

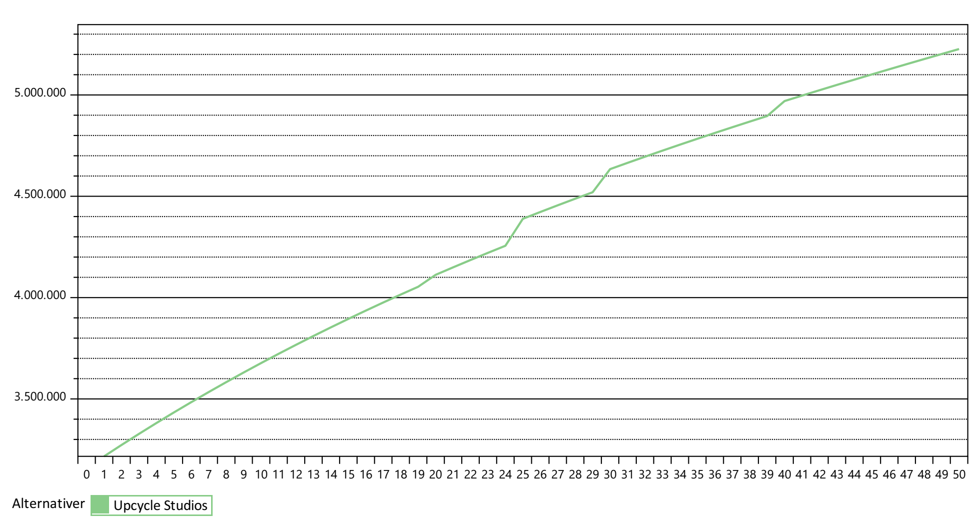
LENDAGER GROUP

LCC BUILD REPORT OF UPCYCLE STUDIOS BENCHMARK

VVS-anlæg, terræn	484	0,01
Affald	0	0,00
Afløb og sanitet	29.398	0,56
Vand (koldt/varmt vand, behandlet vand)	4.259	0,08
Luftarter (gas, trykluft, vakuum, damp)	0	0,00
Køling	0	0,00
Varme (vand, damp, kondens, hedtolie)	139.130	2,66
Ventilationsanlæg	87.460	1,67
VVS-anlæg, bygning, øvrige	0	0,00
El- og mekaniske anlæg	73.872	1,41
El- og mekaniske anlæg, terræn	2.819	0,05
Højspændingsanlæg	21.252	0,41
Lavspændingsanlæg	45.643	0,87
Elektronik og svagstrøm	3.210	0,06
Transportanlæg	0	0,00
Mekaniske anlæg, øvrige	0	0,00
Elektriske anlæg, øvrige	948	0,02
Inventar (drift og vedligehold)	**0**	**0**
Inventar og udstyr	0	0,00
Inventar og udstyr	0	0,00
Forvaltning	**0**	**0**
Forvaltning	0	0,00
Skatter	0	0,00
Forsikringer	0	0,00
Administration	0	0,00
Forsyning	**514.453**	**10**
Forsyning	514.453	9,84
Vand	436.266	8,35
Varme	0	0,00
Electricitet	78.187	1,50
Renhold	**651.266**	**12**
Terræn	3.724	0,07
Udeareal	3.724	0,07
Bygninger, udvendigt	79.620	1,52
Klimaskærm	79.620	1,52
Indendørsarealer og rum	567.922	10,87
Rum	567.922	10,87

Hovedomkostningsgrupper

Figurerne nedenfor viser, hvordan nutidsværdien for det eller de valgte alternativer fordeler sig på hovedomkostningsgrupper.



side 5/5

APPENDIX VI

LCC BUILD REPORT OF THE RESOURCE ROWS

LLC Ressource Rækkerne

Denne rapport er udfærdiget i LCCbyg 2.2.52

Livscyklus-omkostninger resultater af et ressource Rækkerne.

Resultaterne, der udtrykkes, henviser til udgifterne til 1 hus på 150 m2.

Omkostningerne er opdelt i tre kategorier:

- Materialer

- Installationer (såsom elektricitet, maling og ventilation).

- Rådgivnings- og konsulentgebyrer.

For de to sidste kategorier har vi de samlede omkostninger til Resource House-projektet; vi har estimeret forholdet for 1 hus.

Alternativer

Ressource Rows	Building Life Cycle Costs

Antagelser

Generelle beregningsforudsætninger	50 år
Kalkulationsrente	fra og med år 1: 5,00 % fra og med år 36: 5,00 % fra og med år 71: 5,00 %
Prisudvikling generelt	2,00 %
Prisudvikling for drikkevand	4,00 %
Prisudvikling for spildevand	7,00 %
Prisudvikling for energi generelt	4,00 %
Prisudvikling for fjernvarme	3,00 %
Prisudvikling for gas	1,50 %
Prisudvikling for flydende brændsel	4,00 %
Prisudvikling for fast brændsel	3,00 %
Prisudvikling for el	3,50 %
Prisudvikling for skatter og afgifter	2,00 %
Prisudvikling for forsikring	5,00 %
Prisudvikling for administration	2,00 %

Konklusion

Nøgletallene for analysen er opgjort nedenfor. Nøgletallene for analysen viser, at:

- De laveste anskaffelsesomkostninger er på ***2.435.954*** kr. for ***Ressource Rows***
- Den laveste nutidsværdi er på ***3.921.784*** kr. for ***Ressource Rows***
- Den laveste årlige omkostning per kvadratmeter på ***1.432*** kr/m2/år opnås for ***Ressource Rows***
- Det foretrukne alternativ er ***Ikke valgt***.

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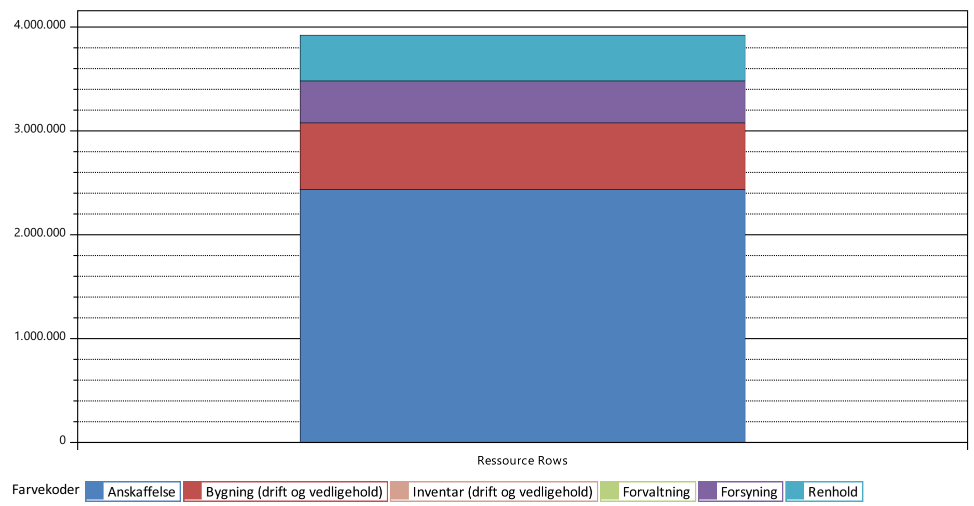
LCC BUILD REPORT OF THE RESOURCE ROWS

Nutidsværdi

	Ressource Rows	%
Anskaffelse	2.435.954	62
Bygning (drift og vedligehold)	641.436	16
Inventar (drift og vedligehold)	0	0
Forvaltning	0	0
Forsyning	404.074	10
Renhold	440.320	11
Nutidsværdi	**3.921.784**	
Nutidsværdi per m2	**26.145**	
Årsomkostning (kr/m2/år)	**1.432**	

Hovedomkostningsgrupper

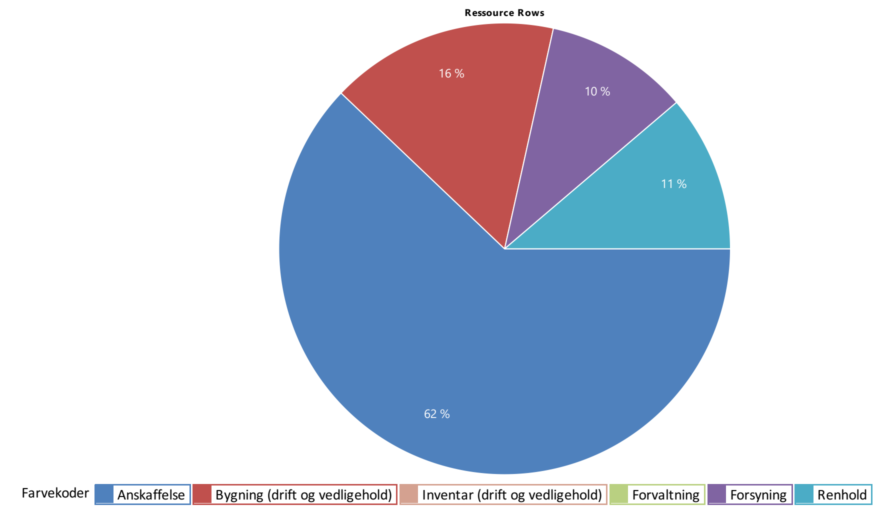
Stavdiagram med alternativers hovedomkostninger



LCC BUILD REPORT OF THE RESOURCE ROWS

Hovedomkostningsgrupper

Figurerne nedenfor viser, hvordan nutidsværdien for det eller de valgte alternativer fordeler sig på hovedomkostningsgrupper. Cirkeldiagrammerne viser ikke eventuelle indtægter.



Hovedomkostningsgrupper i tal

	Ressource Rows	%
Anskaffelse	**2.435.954**	**62**
Grund, rådgivning og bygherre	969.134	24,71
Bygningsbasis	61.260	1,56
Primære bygningsdele	707.832	18,05
Kompletterende bygningsdele	218.850	5,58
Overfladebygningsdele	216.189	5,51
VVS-anlæg	155.470	3,96
El- og mekaniske anlæg	107.219	2,73
Inventar og udstyr	0	0,00
Bygning (drift og vedligehold)	**641.436**	**16**
Bygningsbasis	8.269	0,21
Primære bygningsdele	199.185	5,08
Kompletterende bygningsdele	94.513	2,41
Overfladebygningsdele	155.464	3,96
VVS-anlæg	146.634	3,74
El- og mekaniske anlæg	37.370	0,95
Inventar (drift og vedligehold)	**0**	**0**
Inventar og udstyr	0	0,00
Forvaltning	**0**	**0**
Forvaltning	0	0,00
Forsyning	**404.074**	**10**
Forsyning	404.074	10,30
Renhold	**440.320**	**11**
Terræn	6.765	0,17
Bygninger, udvendigt	41.621	1,06
Indendørsarealer og rum	391.934	9,99

Hovedomkostningsgrupper i tal med undergrupper

	Ressource Rows	%
Anskaffelse	**2.435.954**	**62**
Grund, rådgivning og bygherre	969.134	24,71
Byggegrund	792.436	20,21

LCC BUILD REPORT OF THE RESOURCE ROWS

Rådgiverhonorarer	176.698	4,51
Bygherreomkostninger	0	0,00
Bygningsbasis	61.260	1,56
Bygningsbasis, terræn	0	0,00
Fundamenter	49.760	1,27
Terrændæk	11.500	0,29
Primære bygningsdele	707.832	18,05
Terræn	29.400	0,75
Ydervægge	182.402	4,65
Indervægge	256.040	6,53
Dæk	80.620	2,06
Trapper og ramper	142.200	3,63
Bærende konstruktioner	0	0,00
Altaner og altangange	0	0,00
Tage	17.170	0,44
Øvrige primære bygningsdele, bygning	0	0,00
Kompletterende bygningsdele	218.850	5,58
Terræn, komplettering	0	0,00
Ydervægge, komplettering	70.764	1,80
Indervægge, komplettering	33.716	0,86
Dæk, komplettering	83.420	2,13
Trapper og ramper, komplettering	0	0,00
Lofter, komplettering	2.900	0,07
Altaner, komplettering	0	0,00
Tage, komplettering	28.050	0,72
Kompletterende bygningsdele bygning, øvrige	0	0,00
Overfladebygningsdele	216.189	5,51
Belægninger, terræn	0	0,00
Udvendige vægoverflader	68.925	1,76
Indvendige vægoverflader	42.885	1,09
Dæk og gulve, overflader	551	0,01
Trapper og ramper, overflader	0	0,00
Lofter, overflader	13.751	0,35
Altaner, overflader	0	0,00
Tage, overflader	10.560	0,27
Øvrige overflader, bygning	79.517	2,03
VVS-anlæg	155.470	3,96
VVS-anlæg, terræn	574	0,01
Affald	0	0,00
Afløb og sanitet	9.297	0,24
Vand (koldt/varmt vand, behandlet vand)	28.580	0,73
Luftarter (gas, trykluft, vakuum, damp)	0	0,00
Køling	0	0,00
Varme (vand, damp, kondens, hedtolie)	55.094	1,40
Ventilationsanlæg	61.925	1,58
VVS-anlæg, bygning, øvrige	0	0,00
El- og mekaniske anlæg	107.219	2,73
El- og mekaniske anlæg, terræn	1.455	0,04
Højspændingsanlæg	1.936	0,05
Lavspændingsanlæg	72.681	1,85
Elektronik og svagstrøm	6.270	0,16
Transportanlæg	0	0,00
Mekaniske anlæg, øvrige	0	0,00
Elektriske anlæg, øvrige	24.877	0,63
Inventar og udstyr	0	0,00
Inventar og udstyr	0	0,00
Bygning (drift og vedligehold)	**641.436**	**16**
Bygningsbasis	8.269	0,21
Bygningsbasis, terræn	0	0,00
Fundamenter	6.474	0,17
Terrændæk	1.795	0,05
Primære bygningsdele	199.185	5,08
Terræn	11.884	0,30
Ydervægge	58.235	1,48

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LCC BUILD REPORT OF THE RESOURCE ROWS

Indervægge	66.621	1,70
Dæk	20.977	0,53
Trapper og ramper	37.000	0,94
Bærende konstruktioner	0	0,00
Altaner og altangange	0	0,00
Tage	4.468	0,11
Øvrige primære bygningsdele, bygning	0	0,00
Kompletterende bygningsdele	94.513	2,41
Terræn, komplettering	0	0,00
Ydervægge, komplettering	46.862	1,19
Indervægge, komplettering	8.773	0,22
Dæk, komplettering	21.706	0,55
Trapper og ramper, komplettering	0	0,00
Lofter, komplettering	2.576	0,07
Altaner, komplettering	0	0,00
Tage, komplettering	14.597	0,37
Kompletterende bygningsdele bygning, øvrige	0	0,00
Overfladebygningsdele	155.464	3,96
Belægninger, terræn	0	0,00
Udvendige vægoverflader	10.375	0,26
Indvendige vægoverflader	82.874	2,11
Dæk og gulve, overflader	1.549	0,04
Trapper og ramper, overflader	0	0,00
Lofter, overflader	25.695	0,66
Altaner, overflader	0	0,00
Tage, overflader	14.280	0,36
Øvrige overflader, bygning	20.690	0,53
VVS-anlæg	146.634	3,74
VVS-anlæg, terræn	75	0,00
Affald	0	0,00
Afløb og sanitet	3.950	0,10
Vand (koldt/varmt vand, behandlet vand)	23.152	0,59
Luftarter (gas, trykluft, vakuum, damp)	0	0,00
Køling	0	0,00
Varme (vand, damp, kondens, hedtolie)	57.910	1,48
Ventilationsanlæg	61.548	1,57
VVS-anlæg, bygning, øvrige	0	0,00
El- og mekaniske anlæg	37.370	0,95
El- og mekaniske anlæg, terræn	949	0,02
Højspændingsanlæg	1.518	0,04
Lavspændingsanlæg	24.938	0,64
Elektronik og svagstrøm	8.479	0,22
Transportanlæg	0	0,00
Mekaniske anlæg, øvrige	0	0,00
Elektriske anlæg, øvrige	1.487	0,04
Inventar (drift og vedligehold)	**0**	**0**
Inventar og udstyr	0	0,00
Inventar og udstyr	0	0,00
Forvaltning	**0**	**0**
Forvaltning	0	0,00
Skatter	0	0,00
Forsikringer	0	0,00
Administration	0	0,00
Forsyning	**404.074**	**10**
Forsyning	404.074	10,30
Vand	325.010	8,29
Varme	0	0,00
Electricitet	79.064	2,02
Renhold	**440.320**	**11**
Terræn	6.765	0,17
Udeareal	6.765	0,17
Bygninger, udvendigt	41.621	1,06
Klimaskærm	41.621	1,06
Indendørsarealer og rum	391.934	9,99

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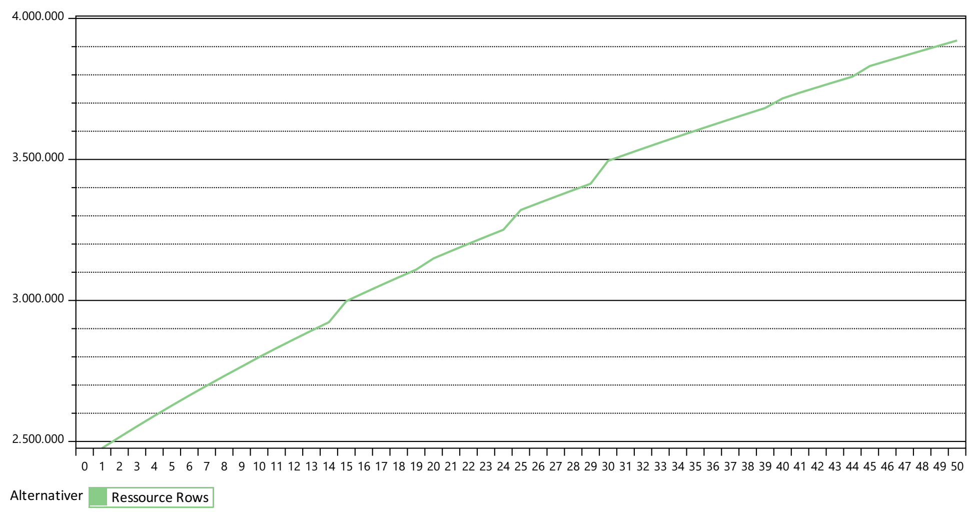
LCC BUILD REPORT OF THE RESOURCE ROWS

Rum	391.934	9,99

Hovedomkostningsgrupper

Figurerne nedenfor viser, hvordan nutidsværdien for det eller de valgte alternativer fordeler sig på hovedomkostningsgrupper.



APPENDIX VII

LCC BUILD REPORT OF THE RESOURCE ROWS BENCHMARK

LLC Ressource Rækkerne

Denne rapport er udfærdiget i LCCbyg 2.2.52

Livscyklus-omkostninger resultater af et ressource Rækkerne.

Resultaterne, der udtrykkes, henviser til udgifterne til 1 hus på 150 m2.

Omkostningerne er opdelt i tre kategorier:

- Materialer

- Installationer (såsom elektricitet, maling og ventilation).

- Rådgivnings- og konsulentgebyrer.

For de to sidste kategorier har vi de samlede omkostninger til Resource House-projektet; vi har estimeret forholdet for 1 hus.

Alternativer

Ressource Rows Benchmark	Building Life Cycle Costs for one benchmark building

Antagelser

Generelle beregningsforudsætninger	50 år
Kalkulationsrente	fra og med år 1: 5,00 % fra og med år 36: 5,00 % fra og med år 71: 5,00 %
Prisudvikling generelt	2,00 %
Prisudvikling for drikkevand	4,00 %
Prisudvikling for spildevand	7,00 %
Prisudvikling for energi generelt	4,00 %
Prisudvikling for fjernvarme	3,00 %
Prisudvikling for gas	1,50 %
Prisudvikling for flydende brændsel	4,00 %
Prisudvikling for fast brændsel	3,00 %
Prisudvikling for el	3,50 %
Prisudvikling for skatter og afgifter	2,00 %
Prisudvikling for forsikring	5,00 %
Prisudvikling for administration	2,00 %

Konklusion

Nøgletallene for analysen er opgjort nedenfor. Nøgletallene for analysen viser, at:

- De laveste anskaffelsesomkostninger er på ***2.472.116*** kr. for ***Ressource Rows Benchmark***
- Den laveste nutidsværdi er på ***3.977.633*** kr. for ***Ressource Rows Benchmark***
- Den laveste årlige omkostning per kvadratmeter på ***1.453*** kr/m2/år opnås for ***Ressource Rows Benchmark***
- Det foretrukne alternativ er ***Ikke valgt***.

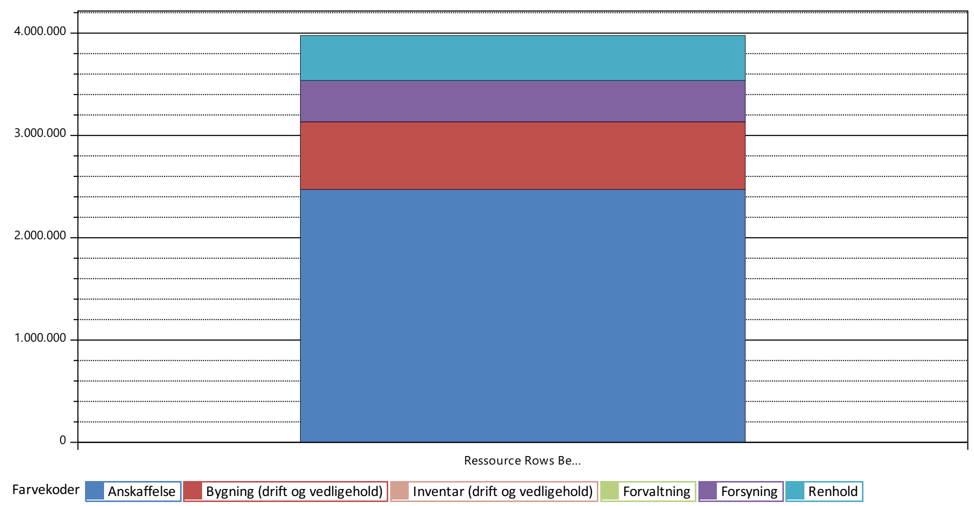
LCC BUILD REPORT OF THE RESOURCE ROWS BENCHMARK

Nutidsværdi

	Ressource Rows Benchmark	%
Anskaffelse	2.472.116	62
Bygning (drift og vedligehold)	661.123	17
Inventar (drift og vedligehold)	0	0
Forvaltning	0	0
Forsyning	404.074	10
Renhold	440.320	11
Nutidsværdi	**3.977.633**	
Nutidsværdi per m2	**26.518**	
Årsomkostning (kr/m2/år)	**1.453**	

Hovedomkostningsgrupper

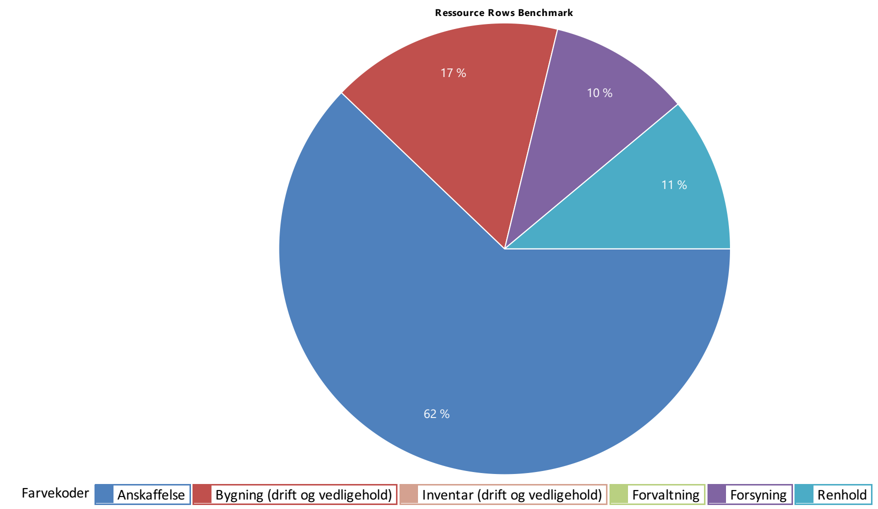
Stavdiagram med alternativers hovedomkostninger



LCC BUILD REPORT OF THE RESOURCE ROWS BENCHMARK

Hovedomkostningsgrupper

Figurerne nedenfor viser, hvordan nutidsværdien for det eller de valgte alternativer fordeler sig på hovedomkostningsgrupper.
Cirkeldiagrammerne viser ikke eventuelle indtægter.



Hovedomkostningsgrupper i tal

	Ressource Rows Benchmark	%
Anskaffelse	**2.472.116**	**62**
Grund, rådgivning og bygherre	969.134	24,36
Bygningsbasis	61.260	1,54
Primære bygningsdele	652.188	16,40
Kompletterende bygningsdele	280.659	7,06
Overfladebygningsdele	238.442	5,99
VVS-anlæg	155.470	3,91
El- og mekaniske anlæg	114.963	2,89
Inventar og udstyr	0	0,00
Bygning (drift og vedligehold)	**661.123**	**17**
Bygningsbasis	8.269	0,21
Primære bygningsdele	185.921	4,67
Kompletterende bygningsdele	115.602	2,91
Overfladebygningsdele	161.254	4,05
VVS-anlæg	146.634	3,69
El- og mekaniske anlæg	43.442	1,09
Inventar (drift og vedligehold)	**0**	**0**
Inventar og udstyr	0	0,00
Forvaltning	**0**	**0**
Forvaltning	0	0,00
Forsyning	**404.074**	**10**
Forsyning	404.074	10,16
Renhold	**440.320**	**11**
Terræn	6.765	0,17
Bygninger, udvendigt	41.621	1,05
Indendørsarealer og rum	391.934	9,85

Hovedomkostningsgrupper i tal med undergrupper

	Ressource Rows Benchmark	%
Anskaffelse	**2.472.116**	**62**
Grund, rådgivning og bygherre	969.134	24,36

LCC BUILD REPORT OF THE RESOURCE ROWS BENCHMARK

Byggegrund	792.436	19,92
Rådgiverhonorarer	176.698	4,44
Bygherreomkostninger	0	0,00
Bygningsbasis	61.260	1,54
Bygningsbasis, terræn	0	0,00
Fundamenter	49.760	1,25
Terrændæk	11.500	0,29
Primære bygningsdele	652.188	16,40
Terræn	29.400	0,74
Ydervægge	126.758	3,19
Indervægge	256.040	6,44
Dæk	80.620	2,03
Trapper og ramper	142.200	3,57
Bærende konstruktioner	0	0,00
Altaner og altangange	0	0,00
Tage	17.170	0,43
Øvrige primære bygningsdele, bygning	0	0,00
Kompletterende bygningsdele	280.659	7,06
Terræn, komplettering	0	0,00
Ydervægge, komplettering	70.764	1,78
Indervægge, komplettering	33.716	0,85
Dæk, komplettering	125.990	3,17
Trapper og ramper, komplettering	0	0,00
Lofter, komplettering	2.900	0,07
Altaner, komplettering	0	0,00
Tage, komplettering	47.289	1,19
Kompletterende bygningsdele bygning, øvrige	0	0,00
Overfladebygningsdele	238.442	5,99
Belægninger, terræn	0	0,00
Udvendige vægoverflader	68.925	1,73
Indvendige vægoverflader	42.885	1,08
Dæk og gulve, overflader	551	0,01
Trapper og ramper, overflader	0	0,00
Lofter, overflader	13.751	0,35
Altaner, overflader	0	0,00
Tage, overflader	10.560	0,27
Øvrige overflader, bygning	101.770	2,56
VVS-anlæg	155.470	3,91
VVS-anlæg, terræn	574	0,01
Affald	0	0,00
Afløb og sanitet	9.297	0,23
Vand (koldt/varmt vand, behandlet vand)	28.580	0,72
Luftarter (gas, trykluft, vakuum, damp)	0	0,00
Køling	0	0,00
Varme (vand, damp, kondens, hedtolie)	55.094	1,39
Ventilationsanlæg	61.925	1,56
VVS-anlæg, bygning, øvrige	0	0,00
El- og mekaniske anlæg	114.963	2,89
El- og mekaniske anlæg, terræn	1.455	0,04
Højspændingsanlæg	9.680	0,24
Lavspændingsanlæg	72.681	1,83
Elektronik og svagstrøm	6.270	0,16
Transportanlæg	0	0,00
Mekaniske anlæg, øvrige	0	0,00
Elektriske anlæg, øvrige	24.877	0,63
Inventar og udstyr	0	0,00
Inventar og udstyr	0	0,00
Bygning (drift og vedligehold)	**661.123**	**17**
Bygningsbasis	8.269	0,21
Bygningsbasis, terræn	0	0,00
Fundamenter	6.474	0,16
Terrændæk	1.795	0,05
Primære bygningsdele	185.921	4,67
Terræn	11.884	0,30

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LCC BUILD REPORT OF THE RESOURCE ROWS BENCHMARK

Ydervægge	44.972	1,13
Indervægge	66.621	1,67
Dæk	20.977	0,53
Trapper og ramper	37.000	0,93
Bærende konstruktioner	0	0,00
Altaner og altangange	0	0,00
Tage	4.468	0,11
Øvrige primære bygningsdele, bygning	0	0,00
Kompletterende bygningsdele	115.602	2,91
Terræn, komplettering	0	0,00
Ydervægge, komplettering	46.862	1,18
Indervægge, komplettering	8.773	0,22
Dæk, komplettering	32.782	0,82
Trapper og ramper, komplettering	0	0,00
Lofter, komplettering	2.576	0,06
Altaner, komplettering	0	0,00
Tage, komplettering	24.609	0,62
Kompletterende bygningsdele bygning, øvrige	0	0,00
Overfladebygningsdele	161.254	4,05
Belægninger, terræn	0	0,00
Udvendige vægoverflader	10.375	0,26
Indvendige vægoverflader	82.874	2,08
Dæk og gulve, overflader	1.549	0,04
Trapper og ramper, overflader	0	0,00
Lofter, overflader	25.695	0,65
Altaner, overflader	0	0,00
Tage, overflader	14.280	0,36
Øvrige overflader, bygning	26.480	0,67
VVS-anlæg	146.634	3,69
VVS-anlæg, terræn	75	0,00
Affald	0	0,00
Afløb og sanitet	3.950	0,10
Vand (koldt/varmt vand, behandlet vand)	23.152	0,58
Luftarter (gas, trykluft, vakuum, damp)	0	0,00
Køling	0	0,00
Varme (vand, damp, kondens, hedtolie)	57.910	1,46
Ventilationsanlæg	61.548	1,55
VVS-anlæg, bygning, øvrige	0	0,00
El- og mekaniske anlæg	43.442	1,09
El- og mekaniske anlæg, terræn	949	0,02
Højspændingsanlæg	7.590	0,19
Lavspændingsanlæg	24.938	0,63
Elektronik og svagstrøm	8.479	0,21
Transportanlæg	0	0,00
Mekaniske anlæg, øvrige	0	0,00
Elektriske anlæg, øvrige	1.487	0,04
Inventar (drift og vedligehold)	**0**	**0**
Inventar og udstyr	0	0,00
Inventar og udstyr	0	0,00
Forvaltning	**0**	**0**
Forvaltning	0	0,00
Skatter	0	0,00
Forsikringer	0	0,00
Administration	0	0,00
Forsyning	**404.074**	**10**
Forsyning	404.074	10,16
Vand	325.010	8,17
Varme	0	0,00
Electricitet	79.064	1,99
Renhold	**440.320**	**11**
Terræn	6.765	0,17
Udeareal	6.765	0,17
Bygninger, udvendigt	41.621	1,05
Klimaskærm	41.621	1,05

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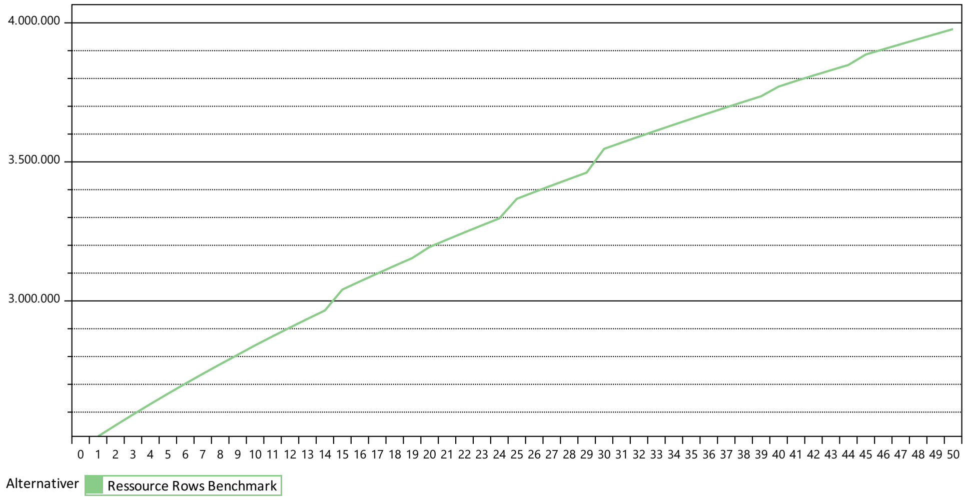
LCC BUILD REPORT OF THE RESOURCE ROWS BENCHMARK

Indendørsarealer og rum	391.934	9,85
Rum	391.934	9,85

Hovedomkostningsgrupper

Figurerne nedenfor viser, hvordan nutidsværdien for det eller de valgte alternativer fordeler sig på hovedomkostningsgrupper.



Sustainability - Upcycle Studios & The Resource Rows

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