THE CIRCULARITY GAP REPORT

Built Environment, the Netherlands

Closing the Circularity Gap in the Dutch Built Environment

June 2022

CIRCLE ECONOMY

METABOLIC

Metabolic adviseert overheden, bedrijven en NGO's over hoe ze zich kunnen aanpassen aan de snel veranderende wereldwijde context, met disruptieve oplossingen die grote verschuivingen in de economie teweeg kunnen brengen. Metabolic analyseert data, komt met strategieën en hulpmiddelen, werkt aan pilots en begint nieuwe initiatieven die helpen met het ontwikkelen van schaalbare oplossingen voor kritieke problemen.

creators

Het doel van C-creators is de transitie naar de circulaire economie versnellen en opschalen. Binnen de Metropoolregio Amsterdam (MRA) treedt C-creators op als een onafhankelijke organisatie die de transitie naar een circulaire economie promoot. De MRA-regio heeft de schaal om als voorbeeld te dienen op het gebied van groei richting een circulaire economie, wat exportkansen met zich meebrengt.

BEHIND THE COVER

Aerial shot of the typical Dutch houses showing the lines of homes and street.

CIRCLE ECONOMY

Circle Economy is een impactorganisatie met een internationaal team van gepassioneerde experts, gevestigd in Amsterdam. Ze ondersteunen bedrijven, gemeenten en nationale overheden met praktische en schaalbare oplossingen om de circulaire transitie te versnellen. Hun visie is een economisch systeem waarin gestreefd wordt naar algemene welvaart binnen de grenzen van de planeet. Om verdere klimaatafbraak tegen te gaan, is het doel om de wereldwijde circulariteit in 2032 te verdubbelen.

GOLDSCHMEDING FOUNDATION
MENS • WERK • ECONOMIE

De Goldschmeding Foundation is een filantropisch fonds dat is opgericht door Frits Goldschmeding, tevens de oprichter van de Randstad Groep. De foundation zet zich in om de manier waarop mensen werken én samenwerken blijvend te veranderen. Met meer oog voor het belang van anderen en met ruimte voor iedereen die met werk aan onze samenleving wil bijdragen. Met kennis, eigen geld en haar netwerk ondersteunt de Goldschmeding Foundation kansrijke initiatieven van 'realistische idealisten', die met aantoonbaar resultaat laten zien hoe het anders kan. Samen zetten zij zich in voor een inclusieve arbeidsmarkt, duurzaam werk en een menswaardige economie.

DEHOGEDENNENCAPITAL

De Hoge Dennen Capital is een Nederlands familiefonds. Naast een aantal vastgoed investeringen zijn ze actief in de Nederlandse private equity en filantropie. De investeringsfilosofie van De Hoge Dennen kenmerkt zich door ondernemerschap, flexibiliteit, samenwerking en lange termijn relaties. De Hoge Dennen is partner van Circle Economy.

IN SUPPORT OF *THE CIRCULARITY GAP REPORT: BUILT ENVIRONMENT, THE NETHERLANDS*

VIVIANNE HEIJNEN
Secretary of State at Ministry of Infrastructure and Water Management

'A just transition to a circular economy will require us to consider how we use non-replenishable, carbon-intensive materials. Exploring ways to move away from emissions-intensive resources towards regenerative materials and circularity is absolutely crucial to ensure we achieve the goals of the Paris Agreement. As the Government, we need to continue to incentivise industry, especially in harder-to-abate sectors, to progress towards climate neutrality. Reports like this provide guidance on how best we can achieve this.'

ANNEMARIE VAN DOORN
CEO at Dutch Green Building Council

'Circularity is one of the most important things we can scale up in the Dutch construction sector. Material flows often remain out of sight—and insights are therefore crucial. Only in this way can we transition to a climate neutral and circular built environment. Thank you Circle Economy for providing these insights!'

OTTO DE BONT
CEO at Renewi

‘Successfully confronting the climate crisis will require significant policy changes that transform the Dutch building sector. This report shows that currently, only a small portion of the materials used come from secondary sources. To accelerate a circular building sector, I urge governments to introduce legislation that requires secondary material use—recycled sand and gravel for cement and asphalt production, for example—and facilitates the process of obtaining end-of-life materials for reuse.'

ELLEN HOEIJENBOS
Trade Union Official EU Affairs at FNV Construction and Housing Sector

'While a circular economy can boost the social market economy in the Netherlands, a clear focus on decent and sustainable jobs is a prerequisite to boost circularity in the built environment. These are actually two sides of the same coin. *The Circularity Gap Report: Built Environment, the Netherlands* makes this absolutely clear.'

EXECUTIVE **SUMMARY**

Only 8% of the Dutch built environment's material use comes from secondary sources. This means that the vast majority of materials the construction sector uses to carry out business as usual come from virgin sources. In the Netherlands, half of all resource use is funnelled into the built environment—and as a result, the sector generates one-third of the country's emissions and 40% of its waste.[1] This impact isn't expected to decrease any time soon: in response to a serious housing crisis, the government has set the target of building 75,000 new homes annually until 2025, on top of infrastructure development, public spaces and commercial buildings. In a time where we need to use and consume substantially less, the built environment is demanding more. But circular strategies that tackle material use, minimise waste, ensure high-value cycling at end-of-life and develop human capital can help the Netherlands reach key environmental targets while meeting the needs of its residents and society as a whole. Reaching the government's ambitious target—halved material consumption by 2030 and full circularity by 2050—will require all hands on deck across sectors, with targeted effort from the construction sector in particular.

The Dutch built environment is characterised by a mammoth material footprint. This report analyses how various materials are used to meet the Netherlands' need for residential and commercial buildings. The sector is characterised by mammoth material consumption: 20.6 million tonnes per year, 19 million tonnes of which stems from virgin sources. The vast majority—nearly 90%—is emissions-intensive concrete, with sand and steel contributing lesser proportions. Regenerative, bio-based materials—such as wood—represent only 1% of the sector's material use: this will need to be scaled substantially to meaningfully reduce the material and carbon footprint, the analysis finds.

Focusing attention on jobs and skills will be crucial to the sector's circular transition and resilience. In the Netherlands, the building sector employs 685,000 people, from construction workers and contractors to architects, engineers and material manufacturers.[2] While it employs a significant proportion of the population, it's also faced with a number of challenges: labour shortages, an ageing workforce, and an insufficient influx of new workers to make up for those leaving the sector. Its labour force is also not equipped with the skills needed to go circular, and may be hesitant to switch gears if the circular transition is not coupled with efforts to ascertain job security.[3] The analysis shows that the transition to a circular built environment in the Netherlands will transform the sector and the labour market: redistributing jobs, and changing the occupations and skills demanded by the sector. An equitable transition will therefore require the mobilisation of human capital, supported by upskilling and reskilling, a culture of lifelong learning, and the creation of fairly-paid, more appealing and decent jobs. This report highlights the importance of finding the mutual benefits of circularity and long-term human capital strategies that can alleviate current labour shortages while realising climate and circularity ambitions.

Measuring circularity in the sector is complex. While Circle Economy's *Circularity Gap Reports* have traditionally centred on one Metric—a quantification of cycled materials in an economy—this report has captured the complexity of quantifying built environment indicators in the Netherlands into three Metrics. These quantify the proportion of secondary resources as a share of the total (8%); the proportion of renewable resources as a share of the total (4%); and a measure of the materials reused and recycled—without distinction between levels of value and complexity—as a share of total waste generation (88%).

The built environment in the Netherlands is a massive motor for downcycling. On paper, the Dutch built environment is a circular champion: as we've seen, 88% of construction and demolition waste is cycled, with less than 10% ending up landfilled or incinerated. However, low-value cycling—where valuable and complex materials are crushed and used as aggregate for backfilling, for example, roads—is prevalent: while nearly 90% of the sector's waste is 'cycled', only 8% of construction materials for buildings stem from secondary sources. Boosting circularity isn't just

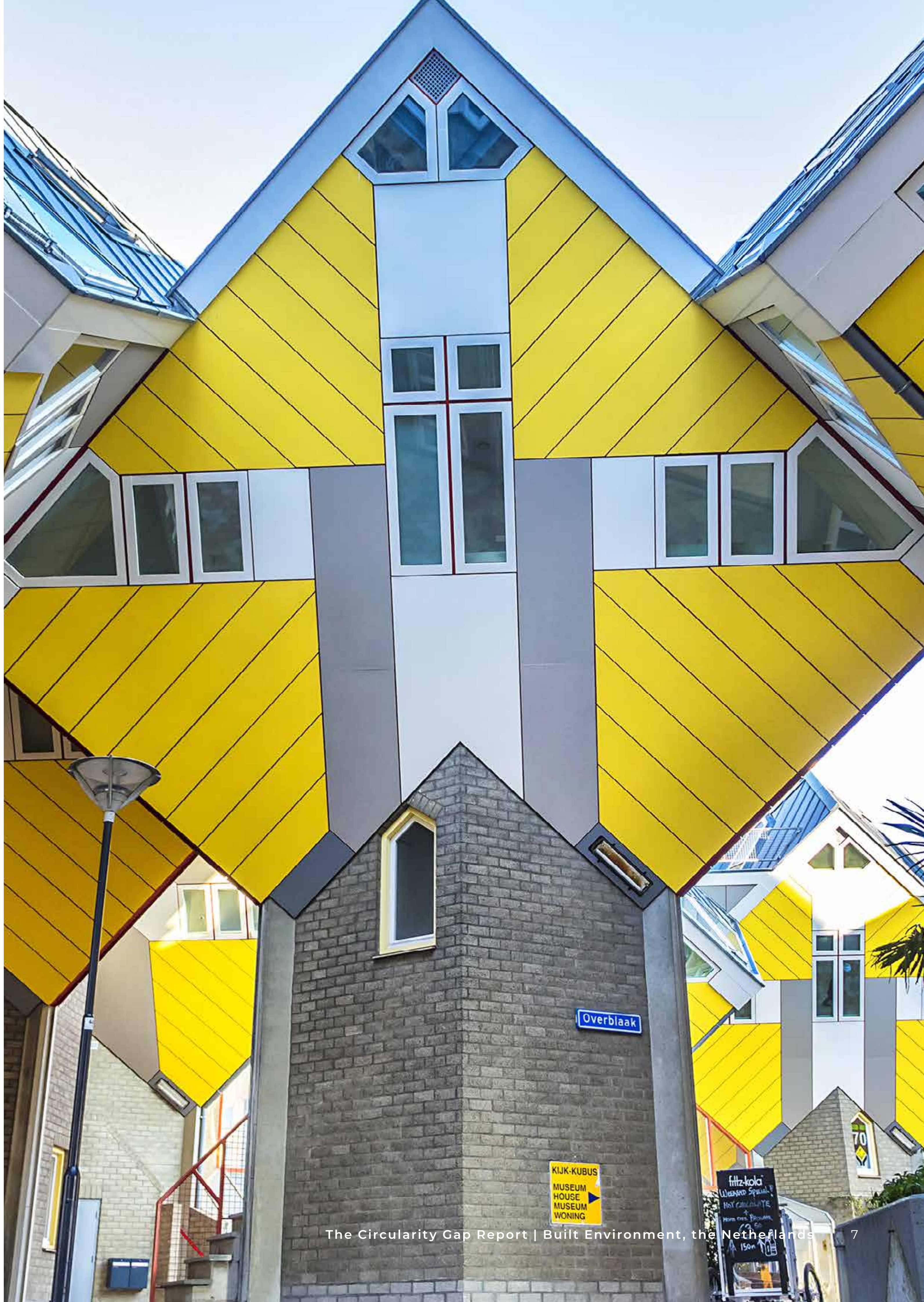
about cycling, but also preserving materials' value and complexity to the highest extent possible. This should be a key focus of the Dutch construction sector in building a more circular future.

Key strategies can drive progress toward a circular built environment in the Netherlands. To achieve a circular built environment for the Netherlands, this report explores four 'what-if' scenarios that apply strategies to boost circularity, cut material use and greenhouse gas emissions and provide decent jobs. This paper's guidelines for circularity journeys along the value chain, exploring strategies for material sourcing, design, buildings' use phase and finally end-of-life. The four scenarios are:

1. Summarise insights on how the Netherlands can achieve a circular built environment, and shed light on the human capital required to do so.
2. Outline the circular strategies to be prioritised, given their potential environmental benefits and impact on the Netherlands' Circularity Gap.
3. Examine the labour market effects of scaling circular economy activities in the Dutch built environment, painting a picture of the jobs needed to support and realise a circular built environment.
4. Support policymakers, industry associations, trade unions and urban planners alike in understanding their role and the actions they need to take to achieve a human capital agenda and circular, fossil-free built environment in the Netherlands.

Each scenario is expected to strongly impact the traditional structures and dynamics of the labour market, redistributing, or changing the number or nature of the jobs available across the sector. It will also demand new skills, particularly knowledge of new digital technologies. It is critical that the Dutch labour market be well-prepared—and well supported—to shift away from linear norms in construction and embrace circularity.

A means to an end: achieving circularity will do more than cut material use. Current measures for the built environment centre on increasing energy efficiency, and while this should remain a top priority, circular strategies must be considered as a means to achieve this. It also carries the potential to address the embodied emissions—and associated impacts—connected to building materials. While achieving a circular built environment is key to reaching the Dutch government's circular ambitions—but it will also, crucially, serve to slash carbon and nitrogen emissions, safeguard biodiversity and help achieve a number of Sustainable Development Goals, such as decent work. As a means to an end, the circular economy could help the Netherlands achieve the end goal of a world—and nation—that meets its citizens' needs without surpassing the planet's ecological limits.



CONTENTS

1. INTRODUCTION

Within the last few years, we have reached a sobering milestone: the materials flowing through the global economy have exceeded a staggering 100 billion tonnes. Of all the materials we use across the globe—for sectors from food, to manufacturing and mobility—just 8.6% come from secondary sources. More than one-third of this material use—38.8 billion tonnes—is funnelled into meeting our societal need for housing.[4] Yet, the built environment—referred to in this report as residential, industrial and commercial buildings[5]—can also be a key lever for change. At 24.5% circular, the Netherlands currently far surpasses the global average. Circle Economy's *Circularity Gap Report, the Netherlands* in 2020 revealed how the nation could increase its circularity to 70%—becoming a true frontrunner in the world's race to shift to a circular economy, supporting people and the planet. With a mass of 28.9 million tonnes and value of €95.6 billion, the construction sector is the most material-intensive sector in the Netherlands,[6] accounting for half of all material consumption in the country.[7] Employing about 685,000 people, the creation of the Dutch built environment involves jobs and activities that extend beyond the construction sector, including professional services and manufacturing.

> The construction sector accounts for half of all material consumption in the Netherlands, and employs 685.000 people.

WHAT IS THE CIRCULAR ECONOMY—AND WHY DO WE NEED IT?

We are living in the anthropocene: the activities of humans have altered nearly every ecosystem on earth. While industrialisation has allowed some people, particularly in the global north, to flourish, our current extractive, linear economy has caused great damage. The most recent report from the Intergovernmental Panel on Climate Change (IPCC) rang an unmistakable alarm bell: we are running out of time to limit catastrophic climate breakdown.[8]

The circular economy can be a powerful solution: the *Circularity Gap Report 2021* found that strategies that prioritise regenerative materials, slow product lifetimes, focus on using materials more efficiently and use waste as a resource could get the world on a 1.5-degree pathway within the next decade.[9] And emissions aren't the only focus: wider ecological breakdown—compounded by endless resource extraction and use, and avalanches of waste—is also a key target of circularity. As a means to an end, the circular economy can also help meet a range of sustainable development goals, provide decent jobs—boosting social outcomes—and bolster savings and profits for businesses.

The built environment represents a small fraction of global land use: only 1% of the earth can be considered 'built up', meaning it is covered with cities, villages, towns or infrastructure.[10] The Netherlands is a densely populated country that significantly exceeds the global average land use: 15% of its land is covered by the built environment[11]—and huge volumes of materials are needed to maintain and expand this, supplying housing and infrastructure for the growing population. Despite covering a small fraction of the planet, the global industry for the built environment places immense stress on several planetary boundaries: from biodiversity loss, resource depletion and freshwater use to its emissions and pollution of aquatic and terrestrial ecosystems.[12] At the same time, however, it is critical for maintaining societal well-being; providing shelter, safety, mobility and a place for communities to live and come together.

Growth of the built environment will not slow down: the global population is growing exponentially, met by rapid urbanisation—by 2050, 68% of the world's population is expected to live in cities.[13] In the Netherlands, the population is expected to continue growing, reaching 20.6 million by 2070—largely owing to migration and increasing lifespans.[14] The need to build won't go away—but if the way we build does not change, it will continue to be a prime driver of environmental harm. We need a systemic solution: one that addresses the negative impacts of the built environment head-on, ensuring that it continues to provide the conditions for a thriving society and a decent, people-centric construction sector while using and wasting less. The circular economy can address this challenge head on. Circular strategies can equip the construction sector with the knowledge, tools and personnel needed to slash its impact and achieve resilience by taking a different approach to design, reuse and material choice. The circular economy is also already highly compatible with existing forms of action from smart cities and nature-based solutions to digitisation.

A CIRCULAR BUILT ENVIRONMENT FOR THE NETHERLANDS BRINGS CHALLENGES AND OPPORTUNITIES

The Netherlands is facing a severe housing mismatch: the number of people living in a dwelling is shrinking—meaning that single people are often living in large homes that could house a few. It is estimated that substantial stock expansion will be needed to address the crisis, as well as to accommodate the need for decent housing for migrant labourers working in the Netherlands, with the government aiming to build 75,000 new homes each year until 2025.[15] And it's not just houses that are needed, but the infrastructure to service them—from roads and utility connections to public spaces, shopping centres and offices. The energy transition also demands that the majority of the Dutch housing stock improves its energy performance via renovation and renewable energy. These factors all represent a significant opportunity for the country to fulfil its climate pledges by switching to circular practices in the built environment, such as designing for reuse rather than demolition. Changes to the Dutch construction sector will be crucial to meet climate targets and the goals of the Paris Agreement, limiting carbon and nitrogen emissions, protecting biodiversity and overcoming challenges in the labour market—contributing to various Sustainable Development Goals in the process.

PROGRESS TOWARDS A CIRCULAR CONSTRUCTION SECTOR FOR THE NETHERLANDS

The Netherlands has put forward the ambitious goal of a fully circular economy by 2050, with an intermediary target of halving virgin material consumption by 2030.[16] Transforming the built environment represents a significant opportunity to move towards this goal. The Dutch built environment accounts for half of the country's resource use, 40% of its energy and 30% of its water. As a result it produces more than one-third of its emissions and 40% of its waste.[17]
While some of the sector's achievements look good on paper—material efficiency has increased in recent years, and 88% of construction and demolition waste is recycled—our analysis shows that just around 8% of all construction materials for residential and commercial buildings consist of secondary materials. A clear circular roadmap that includes a human capital agenda and that works towards a sustainable construction sector for personnel is also lacking. While the amount of cycled waste sounds impressive, it is marred by the proportion of waste used for low-grade applications: infrastructure backfilling is the main use, which locks away a potentially valuable resource and downcycles its value, and incineration is still present.

SCOPING THE DUTCH BUILT ENVIRONMENT: BUILDINGS AND INFRASTRUCTURE

Residential, commercial and institutional buildings are what immediately come to mind when considering the built environment, and the construction of these assets represents around half of the construction sector's activities. This doesn't take into account the vast infrastructure that stitches together the fabric of the built environment. The Netherlands has around 168,000 bridges, viaducts, and culverts, over 2,000 kilometres of quays, not to mention roads, cycle paths, and other forms of infrastructure.[18] Unlike buildings, the primary material flows in infrastructure involve soil, sand, concrete, asphalt and metals. Earth, asphalt and concrete are represented in huge volumes, yet around 60% are often supplied from sources of construction and demolition waste.[19]
Despite the massive share of materials represented in infrastructure, these assets have long lifespans of 80 to 100 years, and the majority of the impact from infrastructure is caused by the use of construction equipment, electricity consumption, cement, asphalt, road surfacing and metals. It is estimated that the total CO_2 emissions from infrastructure amount to around 2 to 3 million tonnes, equivalent to 1 to 1.5% of total Dutch emissions.[20] While infrastructure has a critical role in the transition to a circular built environment, the quantitative analysis of this report focuses on residential and commercial buildings. Where applicable, the role of infrastructure will be referenced in the report—however, it does not have a primary research focus.

A JUST TRANSITION: FOR PEOPLE AS WELL AS THE PLANET

Reimagining our current linear system brings potential benefits beyond the environment: it can, when managed well, also bring socioeconomic benefits, such as employment and opportunities for workforce development.[21] The construction sector in the Netherlands is struggling with decreasing levels of productivity during the last decade,[22,23] and it is labour-intensive, as well as cyclical and more volatile than the economy overall.[24,25] Cyclical demand leads to low capital investment, and bespoke requirements that limit standardisation. Construction projects and the logistics they require are also becoming increasingly complex. This calls for significant levels of manual labour—currently hampered by a significant shortage of skilled workers.[26] The relative instability of the workforce—stemming from a shortage of qualified workers with circular skills across disciplines and education levels—also presents a challenge: workers across the economy today lack the skills needed for new design and assessment methods. This is particularly relevant for the built environment, for which these skills are critical. Coupled with the existing challenges faced by the Dutch labour market, the need for a plan to manage the workforce, maximise employment opportunities and secure the human capital needed for the circular economy is clear.

MOMENTUM FOR A CIRCULAR BUILT ENVIRONMENT IN THE NETHERLANDS

While not without its challenges, the Dutch government, in collaboration with innovative front-runners in the construction sector, is eager to develop a roadmap for the high-quality use and reuse of materials. The government is also tackling challenges with excessive numbers of short term, flexible contracts by creating more security for workers. In its *Perspective for the market and government*,[27] the Ministry of Infrastructure and the Environment notes the crucial role of innovative learning projects that not only generate knowledge on material reuse but also the training and qualifications for bringing the skills needed to scale different circular strategies.

AIMS OF *THE CIRCULARITY GAP REPORT: BUILT ENVIRONMENT, THE NETHERLANDS*

1. Summarise insights on how the Netherlands can achieve a circular built environment, and shed light on the human capital required to do so.
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4. Support policymakers, industry associations, trade unions and urban planners alike in understanding their role and the actions they need to take to achieve a human capital agenda and circular, fossil-free built environment in the Netherlands.

2 THE DUTCH BUILT ENVIRONMENT

Illustration of the current state

Despite the strong targets for a circular economy put forward by the government, the Netherlands still has a long way to go in proving itself to be a frontrunner. Challenges like an ageing workforce, a skills gap and mismatch, the housing crisis, as well as immediate calls to limit emissions of greenhouse gases such as nitrogen and carbon, all threaten the ambitious goals put forward by the Dutch government—both for circularity and housing a growing population. While there are many facets and contributing factors that have shaped it to what it is today, this section aims to provide a high-level snapshot of the Dutch built environment's current state: from demographics and jobs and skills in the (fragmented) sector, to technology and policy supporting circular economy, to notable trends, innovations, and initiatives driving the transition.

2.1 A DENSELY POPULATED COUNTRY WITH A SURGING DEMAND FOR AFFORDABLE HOUSING

The Netherlands is one of the most densely populated countries in the world, and over 80% of the country's population lives in (sub)urban areas.[28] The population is expected to grow in the coming decades—while people are increasingly demanding bigger living spaces. And due to the limitations of current fiscal systems (*hypotheekrenteaftrek*, for example), people are progressing from student housing to studio apartments to larger houses far more slowly, meaning that less space is available for incoming students and young adults.[29] This has triggered discussion on how to meet housing demands, with initial estimates indicating a need for 300,000 to 1.6 million new homes by 2050.[30,31] Simultaneously meeting the housing demand while achieving the goals for a circular economy presents the challenge of optimally managing the flow of secondary materials from demolition to new builds. It also poses bigger questions such as how to best utilise and adapt existing spaces and structures, and how to determine the role of the sector and social partners in adapting to the transition.

> The built environment rests at the centre of a perfect storm—from climate targets and the nitrogen crisis, to the shortage of labour and affordable housing.

Taking stock of current buildings and the rate of new build and demolition

A key part of understanding how circularity fits into the Dutch built environment today is by looking at the current building stock and the kinds of buildings that are being constructed and demolished. In 2020, there were almost 8 million homes in the Netherlands and almost 1.2 million non-residential properties, including offices, shops and healthcare institutions.[32] In 2014, it was estimated that a total of 45,000 residential homes were constructed, of which there was roughly a 50-50 split between single-family homes and multi-family homes or apartments.[33] In 2020, the number of multi-family homes or apartments rose by one-third compared to preceding years, showing that there is an increasing focus on building smaller homes and boosting densification in cities where the demand is highest.[34] The amount of demolition only represents about one quarter the amount of new build projects, indicating that the potential availability of secondary materials is significantly lower than the total material demand.[35] Looking forward toward 2030, these trends are expected to converge slightly. It is expected that the rate of new build is expected to stabilise at around 50,000 homes by 2030, while the demolition of homes will gradually increase to around 20,000.

The housing crisis is pushing the need for affordable housing solutions

Since 2016, the Netherlands has outpaced Europe in terms of housing prices, making the housing market increasingly competitive. This is ultimately driving people outside of cities as they are unable to find a home with an attainable price.[36] Increasing land costs, a shortage of construction workers since the 2008 crisis, and increasing privatisation have now created an environment where private owners and developers have gained increasing power, and tenant's rights have been weakened.[37,38] Circular economy principles could offer a useful perspective to this crisis. Considering that the Netherlands averages more living space per person than Germany or Belgium, making the most efficient use out of the space that we have could help minimise the total number of houses that are forecasted to be built. Exploring various co-housing solutions, especially for students, the elderly and young professionals, could reduce the national housing shortage by 15,000 homes per year.[39] Some municipal governments—Amsterdam and Rotterdam, for example—have been proactive in promoting these types of projects, but further support for driving these initiatives forward is needed.

2.2 JOBS AND SKILLS: A SECTOR IN FLUX

The built environment employs around 685,000 people, 7% of the Netherlands' workforce.[40] However the sector has suffered losses in its workforce since the financial crisis of 2008, with more than 100,000 jobs disappearing since its onset.[41] Building up a strong transition to a circular built environment will require more than recuperating a strong workforce: it will require the mobilisation of human capital and radical new forms of collaboration and innovation. This must be supported, with the help of social partners, by upskilling, a culture of lifelong development and the provision of appealing, decent and secure jobs in order to attract talent into the workforce. If done well, this can offer the Dutch construction sector plentiful opportunities: new and different jobs that are safer, healthier and more secure—and that contribute to a cleaner future.

> The built environment employs 7% of the national workforce, but has lost over 100,000 jobs since the 2008 financial crisis.

Tackling fragmentation, volatility and pervading mindsets for a more resilient workforce

Of the 685,000 people working in the sector, 174,000 workers are employed in the construction of buildings, with an additional 57,000 thousand employed in the construction of infrastructure.[42] However, this number is declining—and in the next five years alone, the sector will demand 40,000 new employees just to cover the exit of older workers in construction. This figure doesn't account for the 70,000 experts who have left the sector since the economic crisis—and another 70,000 who no longer hold necessary qualifications.[43] The high level of small- and medium-sized enterprises and self-employed entrepreneurs also poses a challenge in terms of skills gaps. In sum: the built environment is a key sector in the Netherlands, but one that is facing severe challenges—more workers, with new and different skills, will be crucial to its success over the years to come.

The construction sector is cyclical and volatile: its actions are dependent on business cycles and it is impacted significantly by periods of prosperity and economic downturn—demands leading to low capital investment.[44] Its sensitivity to shocks is compounded by its fragmentation: in the Netherlands, there are more than 272,000 enterprises—the vast majority micro- and small-enterprises—in the sector, a strong increase of 42.3% over the course of the last decade.[45]

Barriers are numerous: a strict regulatory environment and tight competition makes it challenging for actors to innovate and take risks, thereby hindering the sector's transition to circularity.[46,47] In some specific instances, such as for bio-based construction, appropriate skills and capabilities are lacking, compounded by the need to support workers as the industry undergoes changes in an effort to become more circular.[48] This indicates that the sector has been slow to adapt and scale up more circular practices; this also impacts the necessary up- and reskilling that will be needed to advance circularity.[49] Fragmentation has also taken its toll on labour productivity, which has slowed over the past years: while the Dutch economy's hourly productivity outpaces the rest of the EU by 29%,[50] the construction sector has fallen behind, to 19.9%, for the last decade.[51]

Overcoming skill gaps and labour shortages

Climate concerns are featuring higher on political agendas; and as a result, more European objectives are being set for energy efficiency and circularity. What's more: a surge of innovations, resulting from increasing digitisation, are flooding the market—requiring skills for digital planning, software development and electro-engineering among others. Workers, entrepreneurs and employers in the sector will need continuous upskilling to ensure they can deliver on new innovations coming into the market, and that they can continue to contribute to government standards and goals.[52]

The construction sector has also traditionally been bound by tight regulations, low margins, and high stakes—making it hard to take risks in developing bold circular offerings.[53] This is further compounded by the often short-term, temporary contracts given to workers: high labour costs for employers mean that SMEs are less willing to hire permanent workers,[54] putting further strain on a sector already struggling to retain its workforce. What's more, efforts to upskill the workforce—and boost the number of qualified labourers and professionals—have fallen well short of objectives,[55] with insufficient vocational education and training playing a role in the labour shortage.[56] Preparing the workforce will mean that changes in the sector's priorities must be reflected in the education system, supported by companies that are already developing and providing innovative solutions. These companies can help to tailor training offers so that they reflect the needs of the market and bridging these skills gaps must come hand in hand with a collective shift in attitudes. This report seeks to highlight the potential labour impacts for a sector that must be transformed in order to keep up with the required circular transition. It sheds light on the main occupational needs and required skills for different circular built environment scenarios: for these, please see Chapters four and five.

2.3 POLICY DRIVING THE CIRCULAR TRANSITION

The circular transition will require a holistic and systemic approach that only a strong, fit-for-purpose, integrated policy framework can support and instigate—and this is already developing both within the Netherlands and the EU. While the EU has set minimum standards and outlined the 'rules of the game', the Netherlands has further polished and defined these, as well as set performance standards that help guide actors in the sector.

The construction sector is a key priority area in the circular economy transition strategy

The transition to a circular built environment is supported by the *Raw Material Agreement (Grondstoffenakkoord)*: a pact rolled out in early 2017, which primarily aims to increase resource efficiency throughout the Dutch economy. The agreement has spurred the creation of five transition agendas—notably, the *Circular Construction Economy Transition Agenda*.[57] This initial momentum was solidified by the 2019 *Circular Economy Implementation Programme (Uitvoeringsprogramma Circulaire Economie)*, which translates the transition agendas into concrete actions leading up to 2023. This programme has mandated that the Central Government Real Estate Agency and Rijkswaterstraat must be fully circular by 2030. Other conditions of the agreement make strong contributions to a circular built environment: all new buildings proposed after 2018, for example, must be energy neutral, while the construction and redevelopment of buildings must strive for secondary material use wherever possible. Various Dutch cities have also presented different initiatives to advance circularity in their urban built environments: some municipalities, for example, now demand a demolition plan to salvage and reuse high-value materials.[58]

Performance standards for circular and energy-neutral buildings are tightening

For several decades, the Dutch government has set energy performance standards through the Building Decree.[59] In 2013, the *Milieu Prestatie Gebouwen* (MPG) was added, which indicates the environmental impact of material choices in buildings: a lower MPG score indicates more sustainable building material choices.[60] This has proven to be a useful tool to help builders steer toward more circular solutions, however it does not come without its challenges. The norm *Bijna Energie-Neutrale Gebouwen* (BENG) supports energy goals by measuring the energy consumption, energy requirements, and the share of renewable energy of a building. All new buildings must meet this standard from 2021, and this poses challenges from a circularity perspective. For example, complying with BENG means that extra insulation or more solar panels are required, leading to a worse MPG score. The increasing interaction between energy and life cycle impacts of materials makes it clear that they both must be considered holistically, and further emphasises the importance of design phase decisions. To aid decision making, the Sustainability Performance Building (DPG or MPG+)[61] presents a combined performance calculation, making it easier to achieve the desired level of sustainability performance. Further bottom-up and top-down legislation are driving change: the Metropolitan Region of Amsterdam, for example, is requiring that one-fifth of buildings be constructed with bio-based materials by 2025,[62] while EU-level legislation for CO2 taxation is expected to hike up prices for unsustainable building materials.

2.4 LOCALLY-BORN INNOVATIONS AND INITIATIVES ARE STIMULATING THE TRANSITION

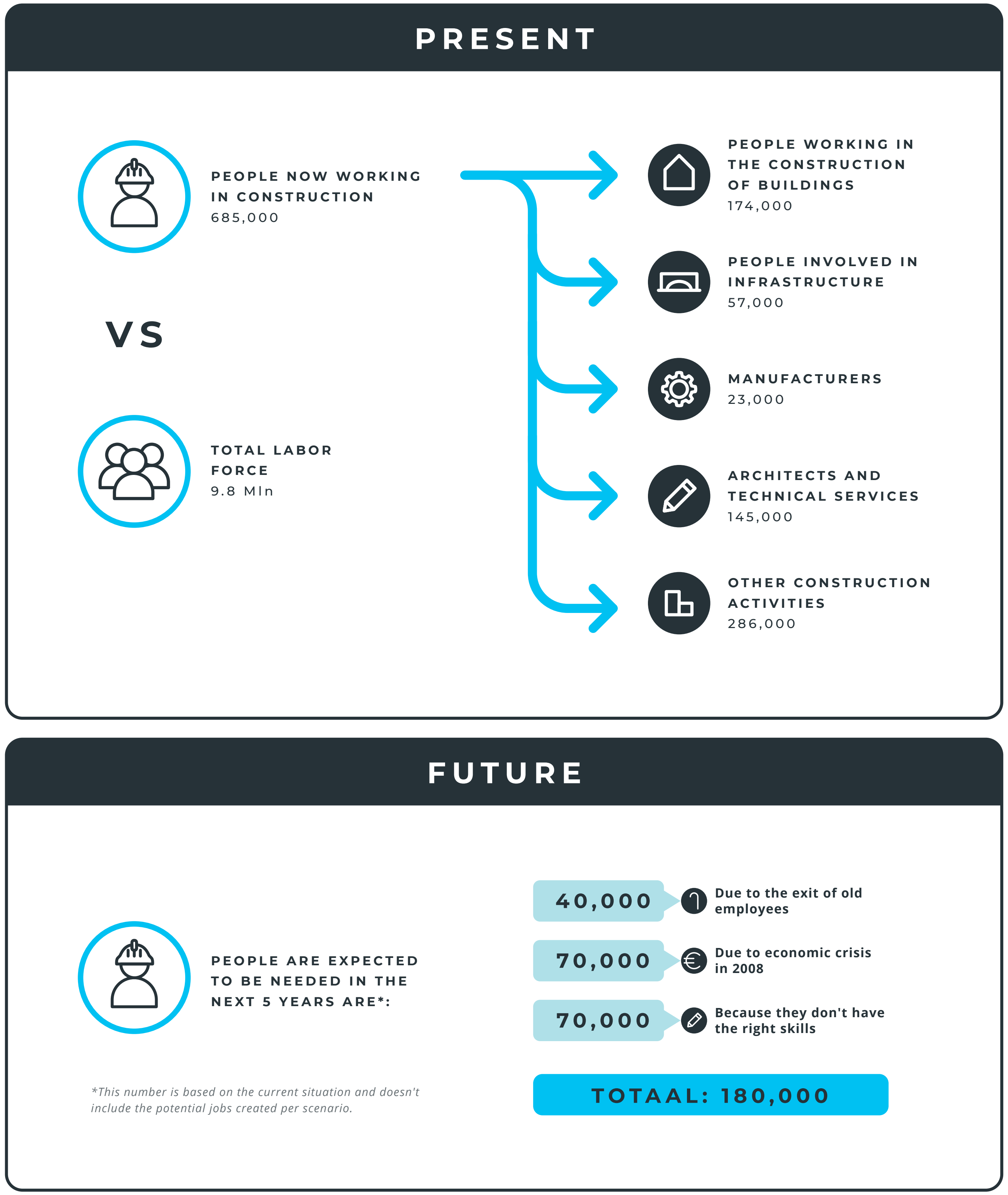
A number of innovations, technologies, and initiatives are expanding across the Netherlands and beyond, showing that the country has a strong enabling environment to foster innovation and enough initial demand and know-how to bring them to market. In many ways the Netherlands upholds its standing as a global frontrunner, however now that the groundwork has been laid—a big push will be needed to bring these initiatives to scale and ensure that trends continue in the right direction.

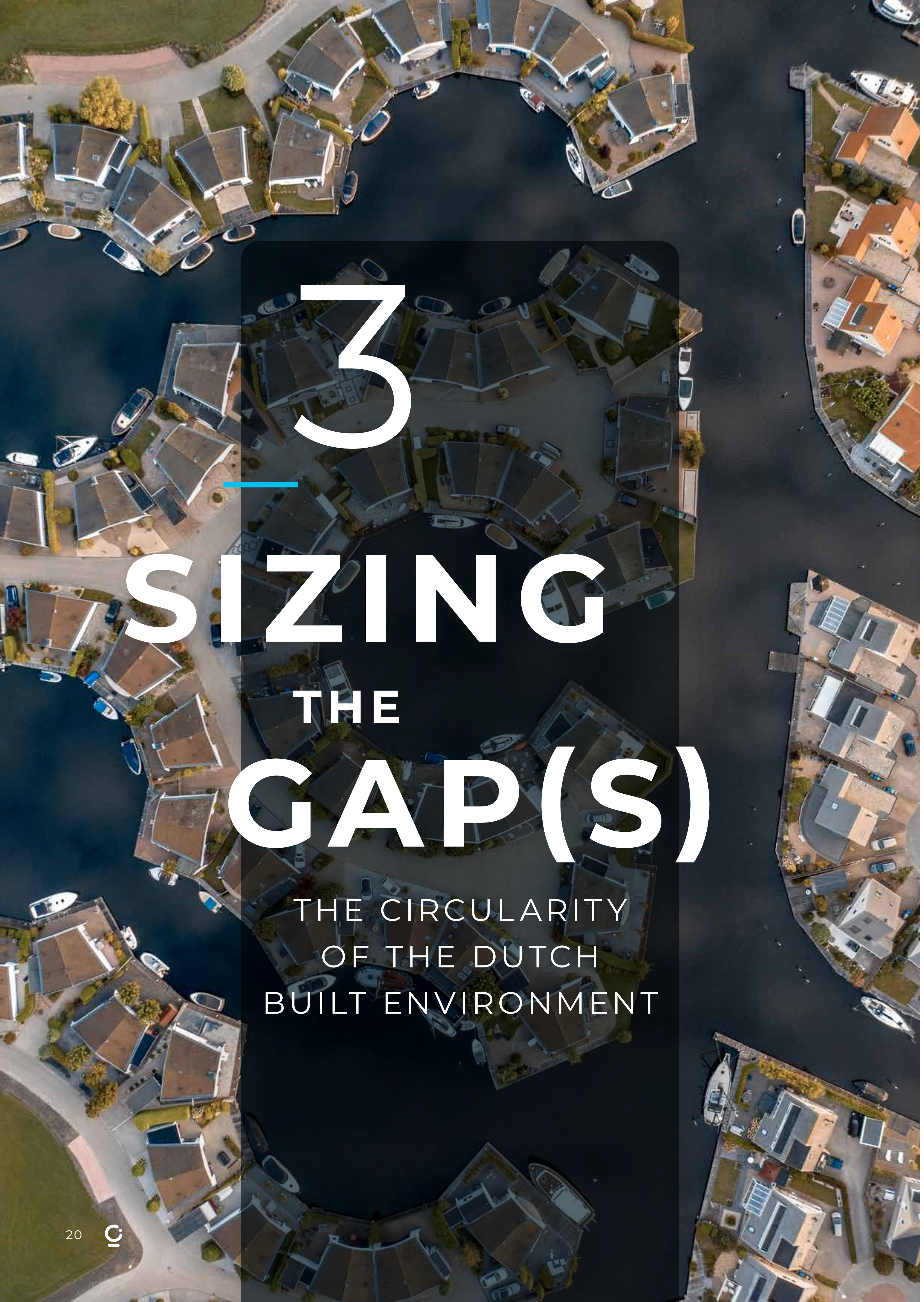
Digitalisation, automation, and artificial intelligence will accelerate efficiency

The construction sector is considered one of the least digitalised of the economy, yet forecasts predict significant development in coming years.[63] Data-driven solutions to manage building maintenance and operation, material design, distribution and logistics, construction itself, and waste management can help the sector to both innovate and cut material use and emissions.[64] Similarly, automation is on the rise in the sector, primarily to improve and speed up processes like construction safety management, quality control and site planning,[65] while mechanical robotic technologies are playing an important role in the conveying, aligning and connecting phases of construction assembly. Other digital trends include Building Information Modelling (BIM), which have been researched for 20 years and are now being put broadly into practice. Finally, recent years have seen designers and architects utilise artificial intelligence (AI) technologies[66] and offsite manufacturing approaches to building prefabricated buildings; which can be easily disassembled or interchanged.[67,68]

Initiatives driven by actors in the Dutch built environment

For circular construction to be a success, a broad understanding of circular principles is crucial. The platform **CB'23**[69] tries to create just this. Before 2023, the platform intends to spur nation- and sector-wide agreements on circular construction, tackling the lack of information that makes circular innovation difficult. To ensure that secondary materials are identified, collected, and used for the highest value application, **Madaster** and the **Transitieteam circulaire bouweconomie** are working as participants under the CB'23 initiative to develop clearly-defined agreements for the use of material passports in the construction sector.[70,71] Similarly, the **Cirkelstad** initiative is looking to support actors in the sector by developing a standard decision tree model for distinguishing high-value reusable building products through their project *Beslisboom Hoogwaardig Hergebruik Bouwproducten*.[72] Several urban mining initiatives are also gaining traction in the Netherlands such as **New Horizon**[73] and **Insert**, where companies like **Freement** are bringing products like circular cement to market.[74] To address the challenges posed by an economically unbalanced playing field and create a more enabling environment for circular economy solutions, the Dutch **Ex'tax project**[75] proposes to tax natural resources and pollution—and in tandem use the revenue to cut the tax burden on labour and boost social spending. Provided that this is not at the expense of social security contributions and leads to sustainable jobs. The principles of this tax shift are already being tested at the local level through projects in Amsterdam and the Dutch horticulture exhibition Floriade. Combined, these initiatives are well positioned to catalyse the transition from multiple, complementary angles toward a circular built environment. They're already beginning to tackle some key barriers to circularity—discussed in further detail in Chapter five—although gaps do remain, particularly regarding investments in large-scale and long-term projects and solutions.





3 SIZING THE GAP(S)

THE CIRCULARITY OF THE DUTCH BUILT ENVIRONMENT

The Dutch built environment is complex: and for the first time, we have boiled down this complexity into three Metrics, giving a more complete picture of the sector's circularity. This section dives into the sector's resource metabolism, exploring how materials are used to serve our need for housing and non-residential buildings. It also investigates how raw materials are added to stock to become a part of the Dutch built environment, as well as what happens at end-of-use: shedding a light on the accumulation of materials in the physical environment around us. Our findings paint a portrait of a resource-intensive sector that consumes a total of 20.6 million tonnes of materials. It boasts high recycling rates of 90%—yet only a small use of secondary materials, which make up around 8% of the total. The Dutch construction sector is a massive engine for downcycling.

CIRCLE ECONOMY'S CIRCULARITY METRIC AND METABOLIC'S URBAN STOCK MODEL

Measurements are critical to understanding the world around us. As the imperative for adapting our economic system to become more circular becomes increasingly urgent, it is necessary to provide clear data-driven insights on how we can navigate the transition. At the national level, we have done this by adopting one Circularity Metric: a consumption-based measure, expressed as a percentage, representing the fraction of an economy's secondary inputs out of its total consumption. The approach for this sectoral *Circularity Gap Report* differs: to adequately capture the circularity of the Dutch built environment, we dive deeper, exploring the complexities of material stocks and flows. In this first-edition sector-based *Circularity Gap Report*, Circle Economy and Metabolic present three Metrics for measuring circularity; this expanded dashboard aims to provide more precise goal-setting and targeted monitoring of progress over time. Circle Economy's approach has largely followed past Circularity Gap methodology while incorporating Metabolic's Urban Stock Model (USM). The USM has been developed by Metabolic as a bottom-up model that estimates material stocks based on the characteristics and size of individual buildings, which are scaled to higher spatial scales such as neighbourhoods, cities or countries.[76]

BROADENING THE SCOPE: NEW METRICS FOR TRACKING PROGRESS

National and regional *Circularity Gap Reports* report one 'headline' Metric as an indication of the share of secondary resources in the total consumption of that nation or region. To provide a more detailed picture of circularity in the built environment, this report focuses on three Metrics. This is intended to measure performance more granularly considering both input- and output-side activities. This helps provide targeted advice and detailed year-on-year monitoring. These three Metrics are described below:

1. **A measure of the proportion of secondary materials over total material consumption. For the Dutch built environment, this is slightly over 8%.**

   This Metric refers to the share of secondary materials in the total yearly input of materials in the built environment: parallel to the concept of the Circularity Metric, used in previous national and regional *Circularity Gap Reports*. Secondary materials are items that were formerly waste, but are cycled back into use, including recycled materials from both technical (such recycled cement and metals) and biological cycles (such as paper and wood). Measuring the input of secondary materials into the built environment is an important indicator of progress toward a well established circular flow of materials and reduced dependence on continued raw material extraction.

2. **A measure of the proportion of renewable materials over total material consumption. For the Dutch built environment, this is roughly 4%.**

   This Metric measures the share of renewable resources consumed in the total input of materials in the built environment. Renewable resources refer to materials that are generated through natural cycles, such as plants. Such that are consumed by the built environment include timber and wood products, fibres and other plant-based materials. Measuring the input of renewable materials into the built environment indicates the degree to which consumption draws on regenerative sources, like forests or agricultural crops. It is important to note that all renewable resources must be sustainably managed, so as not to damage the health of ecosystems.

3. **A measure of the materials reused and recycled out of total waste generation. For the Dutch built environment, this is 88%.**

   This Metric expresses the share of materials that are both reused and recycled out of total demolition waste production. This single Metric would ideally be expressed as two metrics: an indicator for reuse and an indicator for recycled share of total waste—but limitations in waste statistics do not allow for a meaningful estimation of each individually. Measuring the fraction of recycled waste materials is an important indicator of efficiency of functional material recovery, while the share of reuse indicates higher value retention and more fully integrated circular economy strategies throughout the value chain.

MATERIAL METABOLISM OF THE DUTCH THE BUILT ENVIRONMENT

The Figure on pages 24 – 25 dives into the material metabolism of the Dutch built environment, linking how resources—from cement and metal to wood and glass—satisfy the needs of the built environment. This report only examines the material flows for residential and commercial buildings in the Netherlands, with infrastructure and civil engineering—also a key part of the built environment generally speaking—beyond the scope.[77]

A resource-intensive sector with heavy consumption

Despite being well developed, the construction sector is highly resource-intensive and carries a massive primary resource footprint through its consumption of materials, energy and water. Recent years have seen nation-wide improvements in efficiency, with material productivity spiking 17% between 2008 and 2013, coupled with a 12% decrease in resource use. Direct emissions and waste production for the sector have experienced modest cuts—9% and 5% respectively.[78]

Concrete and brick dominate the material mix

In 2019, around 20.6 million tonnes of materials flowed into the construction of residential and commercial buildings—in addition to vast amounts of energy and water. The Figure on pages 24 – 25 illustrates the material footprint of the Dutch construction sector for each building typology,[79] and shows material input and waste management by four resource groups: Minerals (bricks & ceramics, concrete, gypsum, limestone and sand), Ores (steel and other metals), Fossil fuel-based products and others (plastic, asphalt, insulation and glass), and Biomass (wood and paper & cardboard). This is telling: concrete is emissions-intensive and is responsible for ecological impact worldwide—while on the other hand, bricks made from clay and wood represent more renewable options with a lower impact.

Of the 20.6 million tonnes of total material input into the built environment, Minerals account for roughly 19.1 million tonnes (93%), Ores for 0.8 million tonnes (4%), Fossil fuel-based products and others for 0.3 million tonnes (1.5%), and Biomass for 0.30 million tonnes (1.5%). An additional 1.4 million tonnes of secondary materials flow back into the residential and commercial built environment, with the remaining 2.2 million tonnes going to infrastructure.

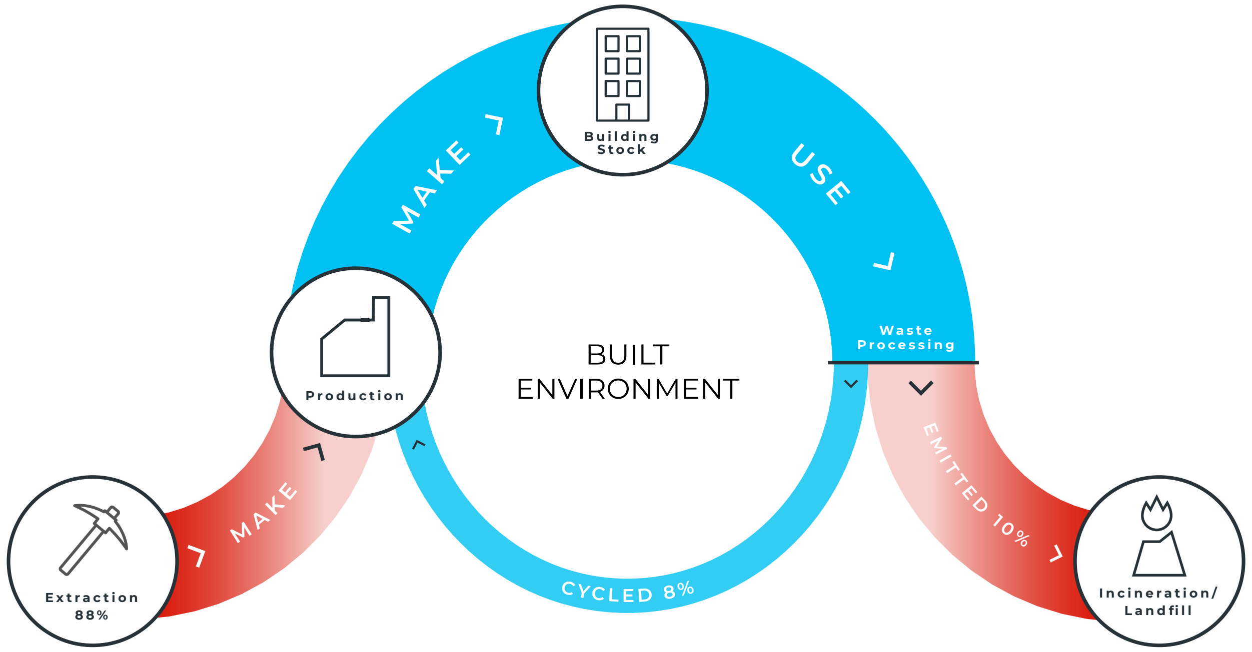


Figure one shows material life cycles for the built environment.

Virgin materials remain most prevalent, with minimal shares of secondary and renewable materials

The sector's material use is largely dependent on virgin materials. Metrics one and two, which quantify the share of secondary and renewable material inputs used out of the total, show that inputs of virgin materials stands at 18.1 million tonnes (88% of total material input to the sector)—just under 4% of materials used are bio-based or renewable (around 0.8 million tonnes), while slightly over 8% stem from secondary sources (1.7 million tonnes). These figures show a positive evolution: the share of virgin material input has improved (decreasing from 93% to 87%), and the shares of renewable and secondary materials have increased substantially: from 1.4% to nearly 4%, and from 5% to over 8%, respectively.

Still, considering the construction sector is the most material-intensive of the Dutch economy, the high proportion of virgin inputs is especially pertinent. Of these virgin materials, almost 90% is represented by resource-hungry, emissions-intensive concrete. Other virgin materials that stand out, albeit at much lower proportions, are gypsum (3.4%), sand (2.3%), and bricks and ceramics (2.2%). Considering total material input, the proportion of bio-based materials—like wood—is minimal in comparison, resting at slightly above 1%. Given by Metric two, the analysis finds that brick and ceramics—partially made from clay, which, if sustainably managed, could be considered a renewable resource to an extent given its particularly high rate of sedimentation in the Netherlands[80]—makes up the largest chunk of renewable inputs (around 5% of total material input), with wood coming in second at around 1%. Other materials—such as cardboard and paper—lag behind in far smaller quantities.

Materials flow into different building typologies: residential buildings are responsible for roughly two-thirds of total material input to the sector (14.8 million tonnes), while commercial buildings make up the rest (7.35 million tonnes).

Large waste generation

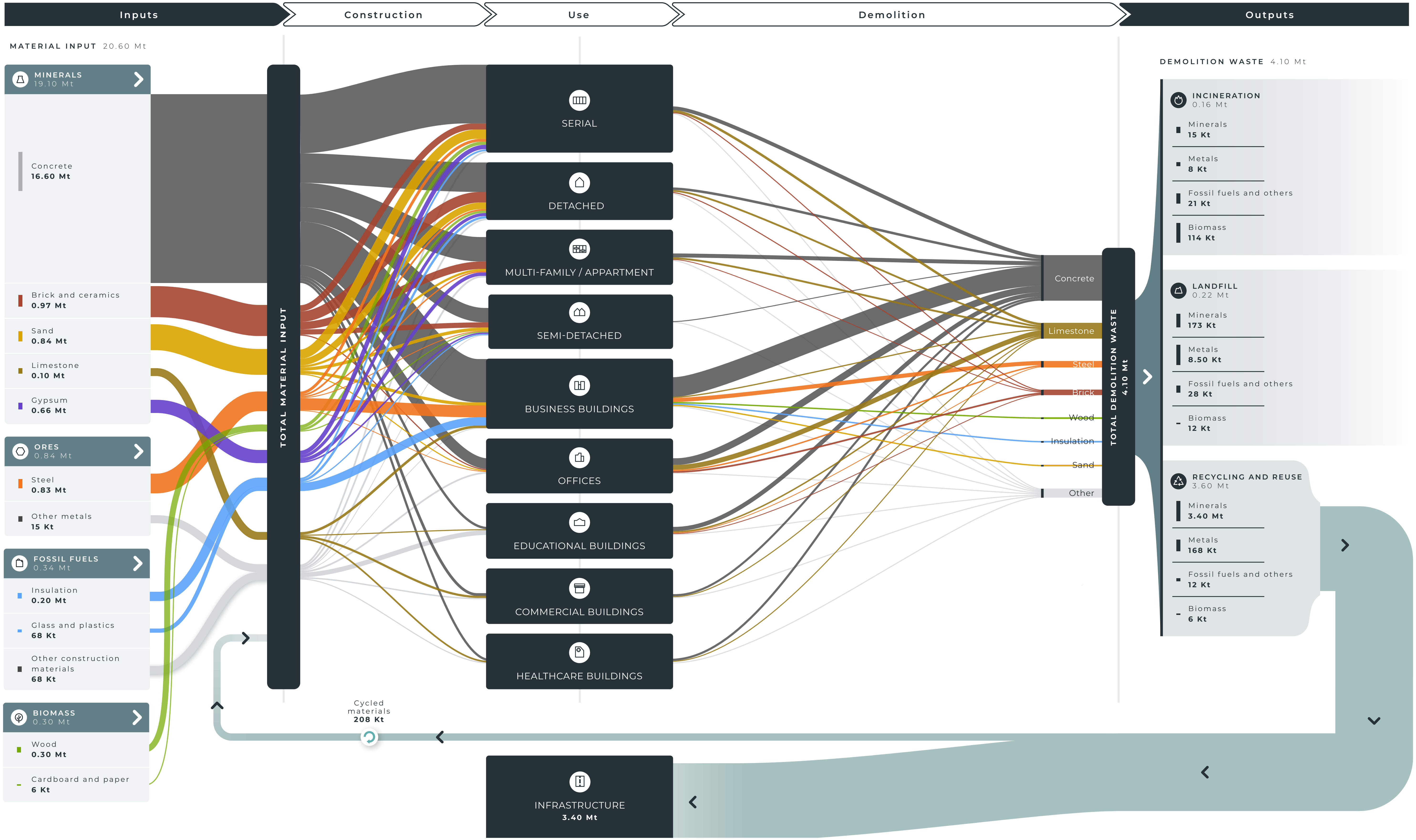
Demolition processes create vast amounts of waste: in the Netherlands, this tops 4 million tonnes, not including those for infrastructure, which accounts for 14.6 million tonnes—by far the largest waste stream by mass.[81] Minerals accounted for 3.6 million tonnes of demolition waste (90%), Ores for 185,000 tonnes (5%), Fossil fuels and others for 70,000 tonnes (2%), and Biomass for 132,000 tonnes (3%).

Waste type also poses a challenge

The sheer volume of materials left over from construction or after demolition are not the only concern: the type of waste is also critical, and feeds into how much and how well we can cycle. As polluted materials that contain hazardous waste—like asbestos or chemicals—cannot be cycled, and removing hazardous substances from polluted 'batches' can be costly, landfilling or incineration are often favoured by the sector. And as demolition remains the primary process for buildings at the end of their functional lifetimes, over less destructive means like deconstruction, the rate of high-value, closed-loop cycling is minimised. What we also see is that the demand for new construction is so great that even making use of all materials from demolition at their highest value and scaling repair and renovation practices would see the sector fall short: such strategies would meet less than one-fifth (19.6%) of the total demand for building materials—illustrating the importance of extending buildings' lifetimes through consistent maintenance and repair, and prioritising lifetime extension over new building projects. Sustainably managed renewable material use will be critical to boost circularity when virgin materials are needed.

MATERIAL METABOLISM OF THE BUILT ENVIRONMENT

Figure two shows the metabolism of the Netherlands' built environment.



High recycling rates—but with limited optimisation

In spite of significant quantities of hazardous substances, on the whole, the sector boasts a relatively high rate of cycling. Given by Metric three—the proportion of materials recycled and reused over total waste generation—the analysis finds impressive results: around 88% of construction and demolition waste is cycled, with 4% incinerated and just above 6% landfilled.[82] Concrete dominates recycling: it accounts for over 75% of total recycling. Brick (8.7%), limestone (6.4%), steel and iron (4.5%) and sand (3.8%) make up almost all of the rest. Concrete also dominates the landfilling of materials with around two-thirds of total (65% of total landfilling), with gypsum (12%), insulation (8.8%), wood (4.8%) and steel and iron (3.4%), making up the rest. In the case of incineration, wood accounts for over two-thirds of the total (71%), with insulation (8.6%), steel and iron (4.9%) and plastics (2.2%) representing most of the rest.

High recycling rates can largely be attributed to backfilling

Yet these figures aren't as environmentally beneficial as they might seem at a first glance: retaining value and complexity in materials and components is key in cycling—and is a core aspect of boosting circularity. Currently, of the roughly 88% of materials cycled, the vast majority are downcycled or used for backfilling (recycled aggregates) which are mostly low-value applications. The government estimates that up to 85% of construction and demolition waste recycled (essentially crushed concrete) is used as recycled aggregate for civil engineering projects, for example as a base for roads.[83] While backfilling for infrastructure can be useful, it both diminishes material value and precludes higher value options for reuse—yet certain bodies, such as the Ministry of Transport, recommend the use of recycled aggregates on the basis of their strong technical performance. All in all, secondary materials returned to building construction only represent around 8% of all construction materials used for new residential and commercial buildings. The material recycled into new buildings only represents 5.8% of the total outflow. The rest of the material is downcycled in infrastructural projects.

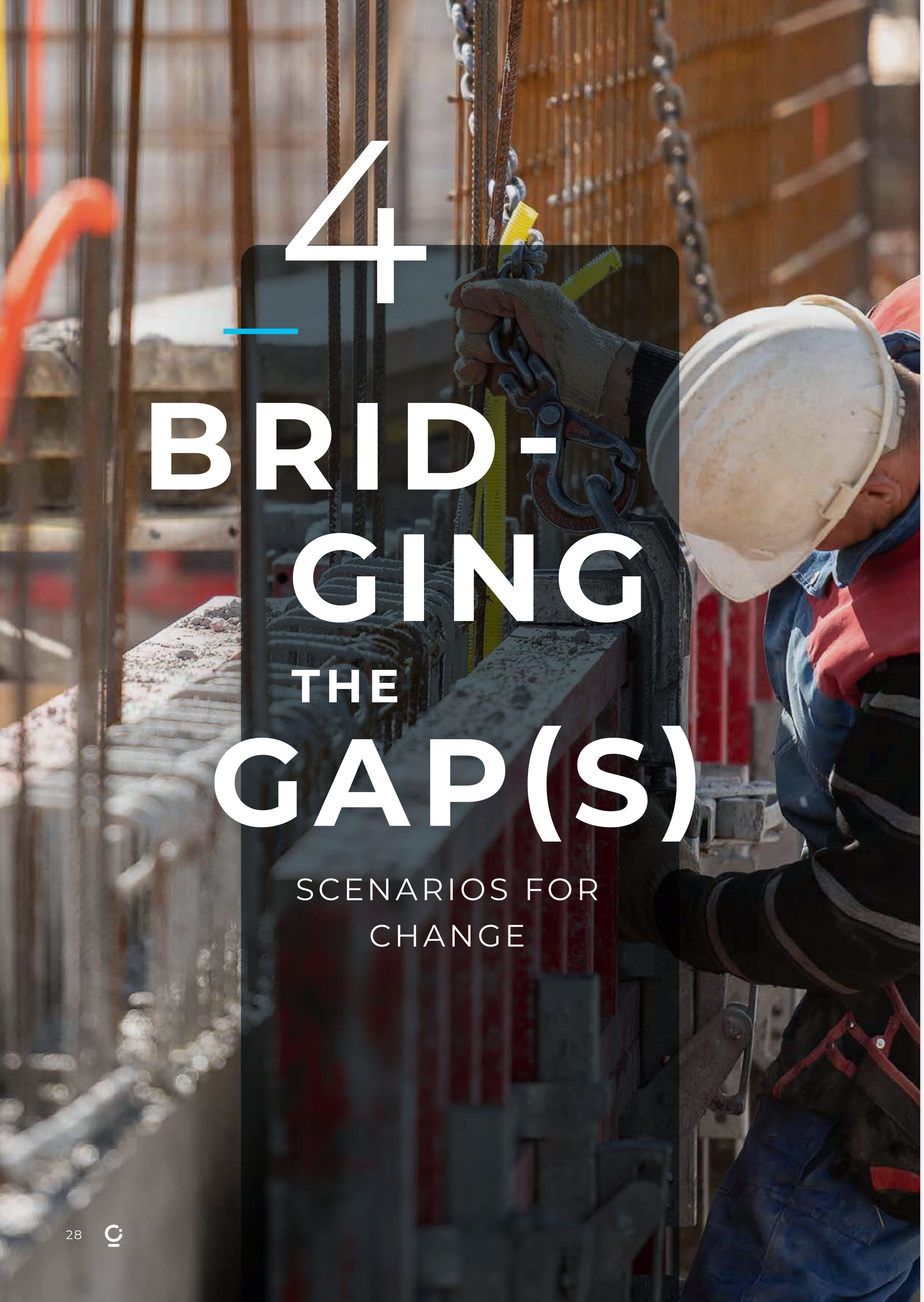
Backfilling is a form of downcycling due to lost value retention

Much debate centres on what constitutes 'high-value' cycling, with the needs of various stakeholders influencing definition: the infrastructure and civil engineering sector, for example, relies on construction and demolition waste as aggregate for backfilling, therefore considering it a high-value feedstock. The government agrees: aggregates are fundamental to creating high-quality and long-lasting infrastructure—roads, for example—given the country's lack of alternate options like stone quarrying residues. Nonetheless, the goal of a circular economy lies in value retention—and where better opportunities for cycling exist, materials should be funnelled into meeting these purposes at end-of-use. Unfortunately, data limitations prevent us from calculating the actual percentage of waste currently downcycled that could be used for higher value functions, or the theoretical maximum that could be achieved.

At the same time, while optimal cycling that maintains materials' value should be the norm, it is of even greater relevance to a circular economy to keep materials in use for as long as possible—through practices that extend building lifetimes, like durable design, repair and renovation.

Room for improvement remains: secondary material use is still too low, and loss of value and complexity is the norm

While low-value cycling already accounts for the largest portion of construction and demolition waste management, there is room to push percentages for incineration and landfilling even lower. Incineration should be strictly limited to only what is necessary—especially for wood. Landfilling rates are low—a mere 6%—and likely only occurs for hazardous waste (such as gypsum) or when hazardous waste contaminates other materials (such as concrete or insulation). All hazardous materials should be designed out of use to cut landfilling rates—and prevent pollution in the process—while existing toxic waste should be removed as efficiently as possible. Policy supporting this option, either through financial incentives to make separation more attractive or regulations that forbid landfilling, could serve to cut the practice to nearly zero.



4 BRIDGING THE GAP(S)

SCENARIOS FOR CHANGE

Now that we have quantified the circular state of the Dutch built environment, it is time to put forward solutions. Drawing from the analysis, we have journeyed along the built environment value chain and created four scenarios and estimated their impact on the sector's circularity and employment. These scenarios paint a picture of 'what could be'—free from political, social and behavioural constraints. They demonstrate the sector's true potential for circularity—facilitating a greater understanding of where we are, where we need to be and the jobs needed to get us there. They also highlight the importance of metrics: once we measure, we can begin managing. These scenarios can be used to inform policy makers and change agents of next steps—and provide a set of meaningful benchmarks and indicators that can be used to track and monitor progress.

The four scenarios that follow serve as an exploration of the strategies that can be best leveraged for impact—both for the environment and employment—and make the sector's circular transition come to life. Each scenario includes a number of strategies, which we explain alongside their labour requirements and the potential challenges that could hinder their implementation. The scenarios take a systemic approach to fundamentally reimagine how we use resources. We apply strategies that:

- **Narrow** the material footprint behind particular processes, through material efficiency gains in design and processes, or changes in the delivery of a functional value through, for example, digitalisation.
- **Cycle** material flows, primarily in the context of construction and demolition waste.
- **Regenerate** material flows by strengthening the circularity of biomass and reducing the footprint of non-renewable resources. This means modelling the regenerative sourcing and handling of biomass and replacing fossil fuels with regenerative alternatives.
- **Slow** material flows by extending the lifetimes of buildings, components and materials, in turn reducing the need for new buildings and components and the materials used to produce them.

Our model grasps the potential of possible solutions by modelling their full implementation. Not every scenario can be modelled due to theoretical limitations: we are only able to discuss concrete and quantitative results for Scenarios 1.1 (Prioritise the use of secondary materials over virgin materials), 1.2 (Prioritise regenerative materials), 2.1 (Design to reduce), 2.2 (Design for cyclability), 3.1 (Circular operations), 3.2 (Circular maintenance and repair) and 3.3 (Circular renovation and retrofitting). The quantitative analysis of the labour market encountered similar challenges. The remaining strategies are still crucial from a holistic perspective, and we have attempted to provide evidence of their impacts to fill methodological gaps. To this end, we often draw on expert interviews to enrich and expand on our findings.

In the case of labour requirements, the analysis covers three elements: jobs impacts, occupations and skills. The effects of the scenarios on these three elements have been explored both for the construction stage (what happens on site) and for the effects throughout the value chain, from extraction to manufacturing to end-of-life.[84]

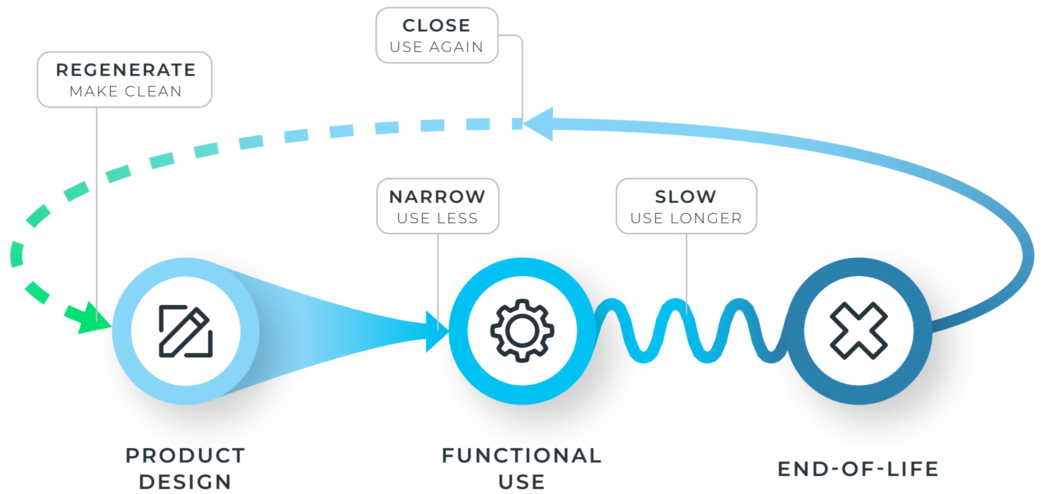


Figure three depicts the four flows to achieve circular objectives: narrow, slow, regenerate and cycle (here labelled 'close').

1 FACILITATE CIRCULAR SUPPLY CHAINS

Boosting the sector's circularity will first and foremost require action targeting the input side of the built environment: from prioritising secondary and regenerative materials to making the sourcing, manufacturing and transportation of materials as sustainable as possible. If implemented, this scenario will stimulate value chain innovation, reduce emissions embodied in materials, slash material consumption and safeguard biodiversity. It comprises three strategies:

STRATEGY ONE: PRIORITISE THE USE OF SECONDARY MATERIALS OVER VIRGIN MATERIALS

Prioritising the use of secondary materials—rather than extracting virgin materials—is at the core of the circular economy. Existing building stock can provide a wealth of materials for new construction projects, acting as an urban mine: reclaiming wood, concrete, metals and aggregates from buildings slated for demolition, effectively **cycling** material flows, can cut demand for virgin materials and ensure extraction is limited.

In modelling this strategy, we assume that secondary materials are used in all cases possible. A technical maximum was based on the volume of secondary materials available through demolition, while also considering the maximum volumes offered on the market. In some cases, demand for certain materials may exceed what's available from demolition: where secondary material use isn't possible, sustainable virgin materials—such as bio-based materials—can be used to meet the additional demand, as discussed in Strategy 1.2. This first strategy targets high-volume materials, such as concrete, bricks, stone, steel and iron, timber, insulation materials, glass, ceramics, gypsum and plastic.

By prioritising secondary material use—and shifting to more reuse rather than recycling—the mass of primary materials as a share of the total material footprint could be cut by 39%. If the maximum possible potential were achieved, the share of primary materials used for the Dutch built environment—currently 88%—could decrease to around 49%, while the share of secondary materials could theoretically shoot up to 49%: a strong increase from the baseline Metric of 8%. Increasing the reuse of materials such as concrete, brick, limestone, insulation and steel would drive much of the change, with concrete playing an especially crucial role. Cutting the volume of primary materials extracted and produced would also see substantial cuts in emissions, with a possible reduction of 18%. This largely stems from the reuse of materials like concrete, glass, steel and plastic, which are typically emissions-intensive to produce. The discrepancy in reduced volume and impact can be attributed to the processes needed to recycle the building materials.

STRATEGY TWO: PRIORITISE REGENERATIVE MATERIALS

In addition to using secondary materials, the use of **regenerative** and bio-based materials can successfully cut demand for virgin materials—thereby slashing the overall environmental impact of the built environment. Prioritising materials such as regenerative wood, fast-growing bamboo, hemp and crop residues provides a range of benefits: these materials have far lower embodied carbon and can even act as carbon sinks, sequestering emissions from the atmosphere. And in cases where secondary or regenerative materials (like cross-laminated timber) cannot fully be used, they can still be integrated or combined with business-as-usual materials. For example, hemp, wood fibre and seaweed can be mixed with cement to cut its impact, however it is important to note that material choices should avoid the lock-in of composite substances that cannot be cycled.[85] Crucially, covering the demand of this scenario would account for more than 200% of the Netherlands' potential timber production, necessitating that materials are imported from sustainably sourced and managed forests abroad. To this end, it is important to increase sustainable forestry practices and tackle possible transparency issues around regenerative materials as their import increases.

For this strategy, we assume a shift to nearly-full demand for bio-based materials, but have to acknowledge technical limitations to supply based on production capacity for the coming decades. We model the impact of swapping out less sustainable materials, like cement, for more regenerative alternatives like cross-laminated timber in high-rise buildings and timber frame construction in ground-dwellings, schools and medical buildings. Concrete screed is replaced with gypsum and cellulose fibre board, inner walls are replaced with timber frame elements, PUR and PIR insulation is swapped out for wood fibre insulation, timber cladding replaces brick facades, and EPDM and roof tiles are cut in favour of bio-based or timber shingles.

This strategy may bring substantial benefits in terms of material footprint and emissions reductions. Replacing heavy materials like concrete, brick, limestone and steel with bio-based options, such as timber, could cut the share of primary material use by 38%.[86] Because bio-based options are typically far lighter, the mass of materials—around 20 million tonnes based on current BENG standards—could plummet to around 7 million tonnes. The share of bio-based inputs would surge: from just below 4% to nearly half (48%) of all inputs. The carbon-storing properties of wood products would also bring major savings in emissions: greenhouse gas emissions could be slashed by a massive 123% by swapping out emissions-intensive concrete, steel, bricks and insulation in favour of regenerative alternatives that can be carbon negative. This total includes, however, the potential carbon-storing properties of bio-based materials, which are not accounted for by current MPG calculations. While there is progress in this direction, including the potential for negative emissions is a point of debate and is highly theoretical. With its exclusion, emissions would be cut by a still substantial 58%.

STRATEGY THREE: PRIORITISE MATERIALS THAT ARE SUSTAINABLY SOURCED, MANUFACTURED AND TRANSPORTED

We will likely continue to need virgin materials, even in a highly circular scenario: not all material demand can be met by secondary materials coming from urban mines. In the sankey diagram on pages 24 – 25 we can see that even if all materials are reused, only 19.6% of the total demand can be met with secondary materials. This strategy aims to ensure that all necessary virgin materials—such as cement, steel and ceramics—are sourced, manufactured and transported as sustainably as possible. Due to lacking data, we were unable to model the impact of this strategy—but desk research has indicated that we can expect substantial results from these strategies.

We can first examine the sourcing and extraction of the materials in question. The extraction of minerals used to make cement, for example, has been found to have relatively little impact.[87] Furthermore, the extraction phase for clay-based products, such as bricks, can even be considered beneficial: in the Netherlands, clay is usually extracted from embanked floodplains—and is considered renewable as large rivers continually replenish its stocks.[88] Clay is often the byproduct of creating wetland reserves in the Netherlands. Conversely, steel extraction is a highly carbon-intensive and polluting combination of processes, owing to the mining of iron ore used for production. While this kind of mining largely takes place outside of the Netherlands, diesel-fuelled machinery means that the greatest impact from extraction occurs during the loading and hauling of raw materials. Focusing on efficiency improvements and clean technology for mining equipment could potentially bring significant emissions savings to the extraction phase of steel production.[89]

Following extraction, the manufacturing phase brings substantial opportunities for impact reduction. Cement and concrete manufacturing—and clinker production in particular—are highly emissions-intensive processes owing to the use of fossil fuels. Decarbonisation strategies, from fuel or feedstock substitution to kiln electrification may bring substantial benefits. Technological improvements in procedures for grinding stone and gravel could offer a path forward, with research finding that this could deliver electricity savings of as much as 50% in Dutch facilities. Decarbonisation opportunities for ceramics manufacturing are also promising: substituting traditional fuels with green gas or hydrogen, and kiln electrification, could cut emissions by up to 74%, with residual heat use and improved process design also playing a crucial role. Fuel substitution will be similarly relevant for cutting steel manfuacturing's massive impact.

Changing the way construction materials are shipped from place to place could also bring substantial impact. The Netherlands should continue to make use of its natural advantages: coastal and inland waterway networks and well-developed rail systems should be optimally used to cut the environmental impact of material transport and deliver other benefits such as less noise pollution. Additionally, decarbonised road transport—such a hybrid, fuel-cell and electric technologies—could achieve significant emissions reductions; however, the wide electrification of truck transport will require large investments and innovative developments in electric road systemics, which are not currently available at scale. In addition to reduced carbon emissions, the decarbonisation of road transport and building site appliances could also serve to significantly address the nitrogen crisis currently taking place. And as bio-based materials are a lot lighter than their mineral counterparts, an all-electric building site becomes more attainable.

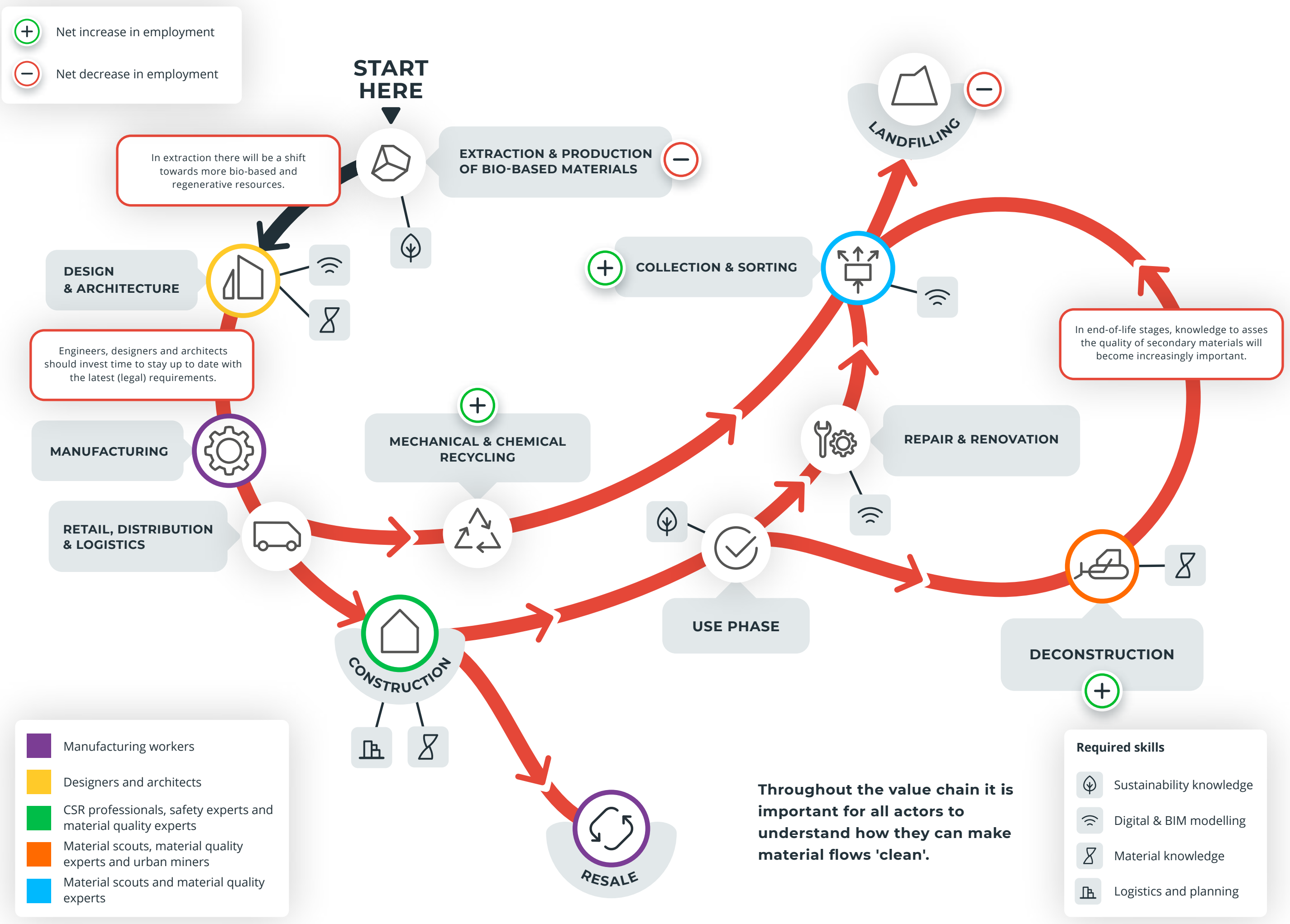


Figure four depicts the skills and roles needed to realise Scenario one.

EMPLOYMENT IMPACTS OF SCENARIO ONE

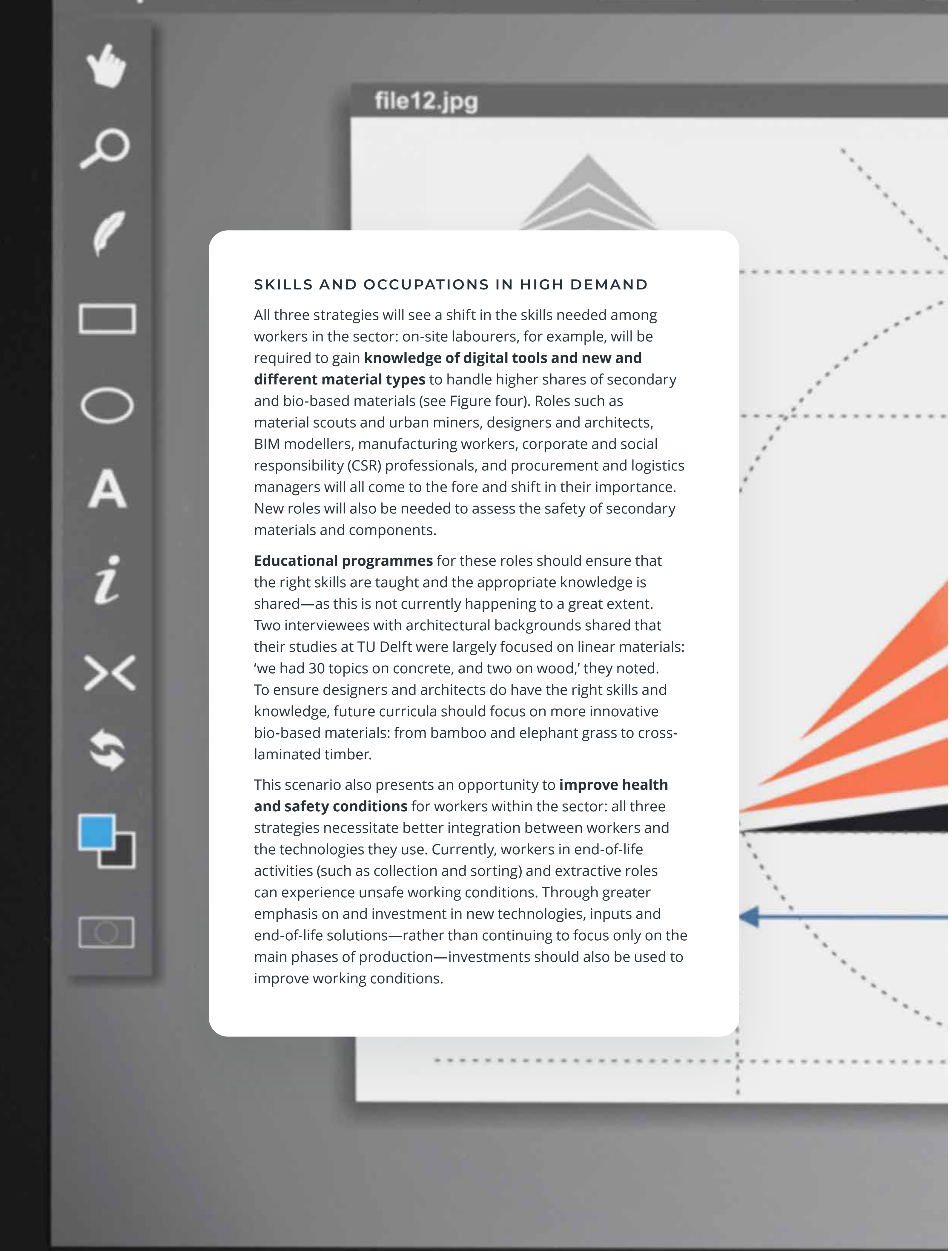
The above strategies are expected to generate net benefits for the labour market, as more workers will be needed to work on end-of-life solutions as material reuse increases. It's likely that the heightened demand for skilled labour in collection, sorting and recycling will make up for the drop in jobs in extractive industries, stemming from decreased demand for virgin materials. Good management will be needed to ensure that workers laid off from jobs in extractive industries will be given opportunities to transition into new jobs that will benefit from their skills. Professionals in design and architecture are also expected to be impacted: the changes in the sector modelled by this scenario will require a continuous evolution of knowledge and skills when it comes to designing and building with secondary materials (see Figure four).

Strategy one—using secondary materials over virgin ones—contributes the greatest employment increase of all the strategies in this study: with a **growth of 47%** in the share of secondary materials used, we can assume that the roughly 4,500 workers employed in the deconstruction, collection and sorting of construction and demolition waste **could expand to nearly 18,300 workers.**[90,91,92] The automation and digitalisation of activities will become increasingly prevalent. It is difficult to predict long term shifts, but this may mean that fewer workers may be needed to collect, sort and recycle each tonne of materials in the future—meaning it is difficult to understand how long-lasting the boost in employment described above might be.

The cut in material consumption resulting from **Strategy two**—prioritising regenerative materials—will not necessarily reduce employment along the first stages of the value chain. It instead implies a shift in the labour market: some of the workers in extractive industries, such as mining and quarrying, which are mostly based outside of the Netherlands, could eventually migrate to bio-based material production, such as forestry and logging, which currently employs 2,000 workers in the Netherlands.[93] The current supply for the Dutch market relies heavily on imports from within the EU[94]—so it follows that not all workers in extractive industries will be provided with new opportunities in regenerative industries if biomass production is developed locally.[95] This shift, if materialised, does not represent a considerable impact for the Dutch built environment as a whole due to its relative size: jobs in extractive industries represent only around 1% of the employment for the construction sector.

Prioritising sustainably sourced, manufactured and transported materials, as illustrated by **Strategy three**, will have little impact on employment levels. Workers employed in mining or quarrying activities—or in regenerative production activities—will likely not increase or decrease. This strategy does, however, imply that workers will need to be retrained to adopt sustainable best practices such as land management, logistics and planning, environmental assessment, auditing and reporting, and process-based innovations.

	STRATEGY ONE	STRATEGY TWO	STRATEGY THREE
Employment level	13,800 more workers in end-of-life activities	Shift in labour from extractive industries to other potential sectors	No changes expected
Skills	• Automation • Digitalisation • Material knowledge	• Material knowledge • Digital knowledge	NA
Occupations	• Material scouts • Urban miners • CSR professionals • Safety experts • Material quality experts	• Designers • Architects • Manufacturing workers	NA



SKILLS AND OCCUPATIONS IN HIGH DEMAND

All three strategies will see a shift in the skills needed among workers in the sector: on-site labourers, for example, will be required to gain **knowledge of digital tools and new and different material types** to handle higher shares of secondary and bio-based materials (see Figure four). Roles such as material scouts and urban miners, designers and architects, BIM modellers, manufacturing workers, corporate and social responsibility (CSR) professionals, and procurement and logistics managers will all come to the fore and shift in their importance. New roles will also be needed to assess the safety of secondary materials and components.

Educational programmes for these roles should ensure that the right skills are taught and the appropriate knowledge is shared—as this is not currently happening to a great extent. Two interviewees with architectural backgrounds shared that their studies at TU Delft were largely focused on linear materials: ‘we had 30 topics on concrete, and two on wood,’ they noted. To ensure designers and architects do have the right skills and knowledge, future curricula should focus on more innovative bio-based materials: from bamboo and elephant grass to cross-laminated timber.

This scenario also presents an opportunity to **improve health and safety conditions** for workers within the sector: all three strategies necessitate better integration between workers and the technologies they use. Currently, workers in end-of-life activities (such as collection and sorting) and extractive roles can experience unsafe working conditions. Through greater emphasis on and investment in new technologies, inputs and end-of-life solutions—rather than continuing to focus only on the main phases of production—investments should also be used to improve working conditions.

2 DESIGN TO DO MORE WITH LESS

Moving from material inputs into the first steps of the value chain, this scenario considers the impact of embedding circularity in design—making it a core parameter for sustainability in the built environment. As a precondition for enabling circularity further down the value chain, a focus on circularity in the design phase is crucial. Strategies for end-of-use, for example, may be inconsequential if circularity has not been initially considered: disassembly, repair and cycling—roles that also boost job creation and enable the development of new business models—are all facilitated by circular design. The built environment has a potentially enormous supply of materials stored in the form of stock held in buildings and infrastructure, yet in the past, have not been consciously designed for high-value reuse; nor can they be easily sorted into their component parts when demolished.[96] Circular design allows demolition waste to become a resource for future construction projects. It is also a key avenue for extending building lifetimes, which will be further addressed in the following scenario.

This scenario puts forward innovative design ideas for architecture that minimise material and land use, waste and the sector's carbon footprint. It also encompasses social issues, magnified now more than ever due to the impacts of the covid-19 pandemic; the basic human need for housing could be better supported by conscious developments that take the long-term into account, maximise social value, are resilient to crises, and support flexible use. This scenario comprises three strategies:

STRATEGY ONE: DESIGN TO REDUCE

Construction processes are highly polluting, wasteful and resource-intensive—making use of a vast quantity of materials, water and energy. As illustrated in the previous scenario, material choice can have a substantial impact on the sector's material footprint. The design phase can push this even further, maximising resource efficiency and minimising material intensity—thereby **narrowing** flows—through improvements in products and materials, structures, and processes. We must give priority to materials that can substantially reduce the resources needed to create buildings and structures while ensuring that use-phase energy consumption is not compromised.[97] Smarter design and planning, along with better communication between architects, designers, engineers and contractors, can also prevent waste by allowing for more precise calculations for the procurement of necessary materials.

Building with concrete and steel has already been optimised: the main route for cutting overall mass will be scaling the use of bio-based materials. This strategy assumes an uptick in the use of bio-based materials, as addressed in Scenario 1.2, largely due to their lightweight nature: rather than considering material composition, however, we model the impact of reduced mass compared to using business-as-usual materials. Biomimicry, another useful strategy for lightweighting, is also considered. A novel innovation—biomimetic concrete—also provides a promising means to drastically reduce volume without compromising structural performance. While research in this field is new, we assume a 50% concrete reduction through biomimicry technology—a theoretical possibility based on anecdotal evidence from current studies.[98] Further research would have to be carried out to assess the full feasibility of this process.

Assuming a 50% reduction in mass through the use of bio-based materials, the mass of primary material inputs could be cut by more than 81%. Using biomimicry and smart design to cut concrete use in the foundation and structure of buildings in half was found to potentially cut primary material weight by 18% and slash greenhouse gas emissions by nearly 7%. Exploratory modelling has only been done for biomimicry solutions in concrete. There are however examples of biomimicry being applied on other materials, such as steel.

Within our current business-as-usual approach to construction, not many options exist to cut material use, without reducing building stock expansion itself: lacking safety regulations and little pressure to innovate are contributing factors, and with the climate crisis looming, new options are urgently needed. Biomimetic strategies that make use of business-as-usual materials will therefore have limited impact—it will be far more crucial to make systemic changes and scale the use of bio-based materials.

STRATEGY TWO: DESIGN FOR CYCLABILITY

'Building to last' is a crucial strategy: as much as half of a building's total life cycle carbon emissions stem from carbon embodied through the manufacturing of materials and construction, most of which are emitted very early on in the life cycle.[99] Nonetheless, it's reasonable that very old buildings will eventually have to be replaced with new ones. Design is key to advancing high-value **cycling** in the built environment. This strategy looks at 'designing for cyclability' early on in the construction process: deconstruction, disassembly and modularity, for example—all of which ultimately facilitate reuse.[100] Design is also fundamental to creating adaptable buildings: those that can be endlessly reconfigured to accommodate desired changes in functionality or appearance,[101] cutting demand for new buildings in the first place.

This strategy primarily focuses on aspects of design for disassembly. We model the impact of reusing all products and components designed for disassembly at their end-of-use. We acknowledge that various products—from 1) wood claddings, doors, window frames, insulation panels and roofing tiles, to 2) dry stacked limestone and interior wall metal frames, to 3) manifold plumbing systems and 4) brick facade cladding all have differing expected lifetimes. We assume different levels of cyclability for these different elements.

This strategy is closely tied to and enables Scenario 1.1, which prioritises the use of secondary materials. At the moment, design for disassembly options are limited: less than 10% of building materials can currently be disassembled, despite technical potential to boost this up to as much as 45%. While reaching this 45% would be highly challenging, there is certainly room to boost the current rate to at least 10%. Constructing brick facades without mortar, for example, through innovations such as ClickBrick, holds great potential.[102]

While this strategy brings significant benefits, it won't usher in the impact reduction we need to see now: products designed to be used again will be locked into stock for decades to come, and benefits will only emerge in the second half of this century. From around 2080 onwards, large-scale design for disassembly will provide moderate benefits, reducing the volume of primary construction materials needed by about 9% yearly. Emphasis should be placed on high-quality cascading, which will maximise the impact potential of this strategy. In the interim, short-term actions will help us achieve such long-term goals.

STRATEGY THREE: DESIGN TO LAST

Design plays a critical role in maximising building lifetimes: it is in this phase that decisions can be made regarding physical durability, adaptability and potential repair, all strategies to **slow** material flows. The need for new construction is slashed when buildings are made to last—thus cutting pressure on land use. The issue of building vacancy is also addressed, as usability and flexibility may be increased through this strategy. For instance: flexible workspaces in office buildings, and the growth of co-living spaces, where kitchens, dining rooms and living rooms are shared among residents. Due to methodological limitations, we were unable to model the impact of this strategy. Data gaps mean that quantifying material or emissions savings would be very difficult; but, in spite of this, current initiatives are already providing some anecdotal evidence of benefits.

Buildings designed with flexibility in mind may show a lower environmental burden than their single-purpose counterparts.[103] One study has shown that buildings likely to change (in terms of use) can be given a longer lifetime through increased flexibility and adaptability in the design phase: this will bring substantial benefits in terms of material and energy flows.[104] It's also crucial to distinguish between structural and non-structural building components in designing for circularity: swapping out or upgrading non-structural elements will have far less impact and is key to optimising adaptability.[105]

Flexible design is already appearing in the Dutch built environment: building project Patch22[106]—a 30 metre high-rise made from wood—incorporated a range of technological innovations to achieve flexibility. Dividing walls between apartments, for example, can be easily added or removed: in the future, apartments could be further subdivided or merged, and residents are able to customise their own layouts for pipework and cabling through hollow floors with a removable top layer: allowing the building to cater to a variety of uses for years to come.[107]

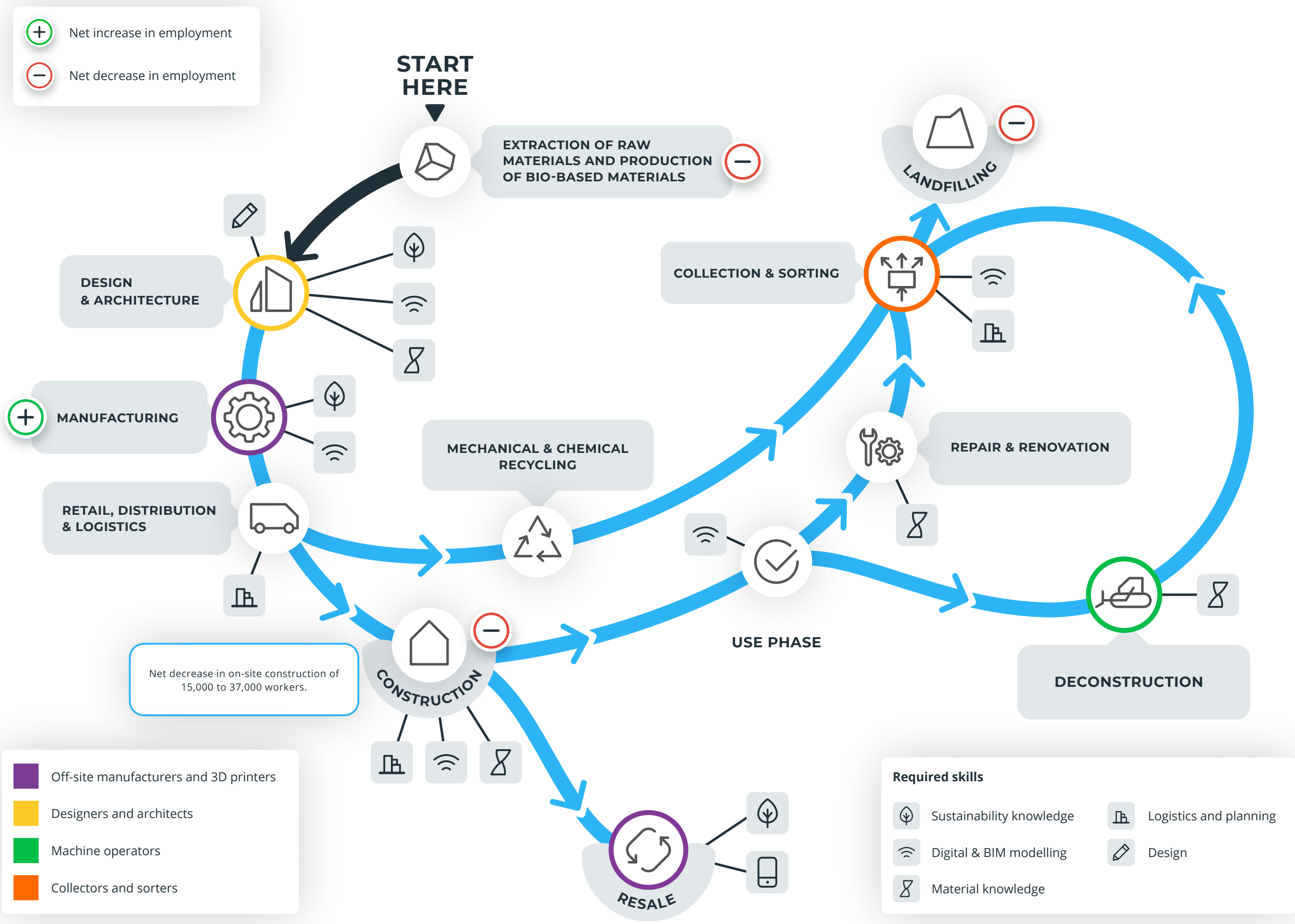


Figure five depicts the skills and roles needed to realise Scenario two.

EMPLOYMENT IMPACTS OF SCENARIO TWO

It is expected that this scenario would lead to a net decrease in on-site construction workers of between 15,000 and 37,000, due to our suggested designs requiring pre-assembly in off-site facilities.[108] This could be partially compensated by an increased demand for workers in manufacturing facilities. This was corroborated by interviews: experts concurred that there's an increasing need for new designs, and that traditional on-site activities are shifting towards off-site manufacturing facilities.[109] The strategies it entails will usher in a range of changes, with the need for workers to work more closely with technologies such as 3D printers and production machinery.

Strategy one—design to reduce—primarily assumes an increase in the use of lightweight, bio-based materials: according to experts, the sector needs to place more emphasis on the knowledge that is taught to new professionals. According to one interviewee, '*when I was in school, I had many courses on concrete, steel and other traditional materials and almost none on wood or similar bio-based materials.*' These developments could incentivise the opening of new opportunities in architectural planning, material manufacturing and recycling, and in construction processes.[110]

Our **second strategy**—design for recyclability—implies a substantial shift to off-site, modular construction, having a significant impact on the workforce: by increasing efficiency and cutting project timelines in half, the labour needed for on-site activities may reduce by 10 to 25%.[111] Currently, roughly 167,000 workers are employed in the on-site construction of buildings in the Netherlands—so a reduction of 16,000 to 41,000

	STRATEGY ONE	STRATEGY TWO	STRATEGY THREE
Employment level	No changes expected	Net decrease in on-site construction between 15,000 and 37,000 workers	No changes expected
Skills	• Material knowledge (particularly bio-based materials) • Design (biomimicry) • Digitalisation	• Design • Digitalisation	• Advanced manufacturing • Automation • Machine operation (higher interaction between machine and worker)
Occupations	• Designers • Architects • Off-site manufacturers	• Off-site manufacturers • Disassemblers • Collectors	• Designers • Machine operators • Off-site manufacturers • 3D printers

workers would be highly impactful, despite the transition likely taking years to take place. This reduction would represent between 3 and 7% of the entire workforce employed by the construction sector.[112] Nonetheless, employment in off-site construction could grow by between 5 and 15%, which represents an increase of 1,000 to 3,500 workers—somewhat offsetting the decrease in on-site construction.

Strategy three, design to last, will have the biggest impact on designers and architects, and their considerations during projects. Professionals in these roles—potentially supported by parametric design programmes—will have to decide whether additional material inputs (for example, additional water tap points) for more flexible designs are suitable for a given context. They will also be required to have knowledge regarding the adaptability of facades and installations and the development of durable structures. We do not expect a significant impact in terms of the labour needed to execute these plans on site.

SKILLS AND OCCUPATIONS IN HIGH DEMAND

This scenario will put a huge emphasis on **design, digitalisation, advanced manufacturing and management** (see Figure five). Designers and architects will be front and centre as this scenario's strategies take shape: in a circular future, we can expect to see these professionals closely collaborating with roles such as digital developers and off-site manufacturers.[113] Manufacturers that have been re-skilled and have knowledge of new developments will translate design into the real-life products and components—and as the shift to off-site facilities takes place, roles will adapt to match the current profiles of construction workers.[114]

It is expected that efficient, waste-avoidant production environments will see skilled production assemblers working alongside factory-based operatives, and that roles will be similar to those currently seen in production lines in the manufacturing sector.[115] And while on-site roles will decrease, for those that remain, it's likely that **workers roles will shift as technologies develop**: machines may take over individual tasks within a role (as opposed to the role itself), and the average construction worker will be expected to be multi-skilled and even operate technology like drones, rather than carrying out physical site walkthroughs.[116] These developments imply **safer conditions** as workers will not need to be physically making inspections or testing components and materials.[117]

3 CHAMPION CIRCULAR AND SUSTAINABLE BUILDING OPERATIONS, MAINTENANCE AND RENOVATION

We've moved from the first step of creating a built environment—material supply—to the design phase, and will now dive into the longest part of a structure's lifetime: the use phase. This phase accounts for the greatest energy and water use—and is the time for key decisions on lifetime extension to be made. Slashing energy and water use is key to cutting costs and enhancing circularity, while predictive and timely maintenance creates jobs and prevents buildings from falling into disrepair—keeping materials in use for as long as possible. This scenario comprises three strategies:

STRATEGY ONE: CIRCULAR OPERATIONS

Circular operations encapsulate sustainable and smart building use and management. Buildings are significant consumers—they guzzle energy and water—and also produce large amounts of waste; so a focus on lowering resource use in the use phase, post-construction, is crucial. Embracing circular strategies, which optimise day-to-day processes in waste, water and energy management and **narrow** flows, can cut buildings' footprints and slash running costs. Technology is a big ally in doing so: adopting new digital services and systems, for example, can help monitor energy and water efficiency, while Building Information Modelling (BIM) can be used to improve the planning and control of routine maintenance activities, as can standards such as BREEAM In-Use schemes[118] to net-zero buildings.[119] Improving insulation will also **narrow** flows by reducing energy consumption. Buildings may **regenerate** flows by powering their operations through regenerative energy sources, such as solar power.[120] If possible, installing solar panels directly on the roofs of residential buildings is most efficient, providing advantages in terms of the grid load due to panels providing energy to houses directly at its source. Renewable energy can also be stored on the building or neighbourhood level through the use of smart grids: energy generated throughout the day can light buildings throughout the night and on weekends, when energy consumption is highest.

In modelling this strategy, we assume that energy use is optimised in buildings. BENG regulated houses—the current standard for buildings in the Netherlands—were used as a baseline and compared with *Nul op de Meter-woning*, or net-zero houses. Differences between the two primarily relate to insulation and the amount of renewable energy: the latter requiring more insulation and solar panels. Metabolic's model acknowledges that doing so will initially require more materials, therefore hiking up emissions—but impacts will be cut in the longer term when considering benefits for energy usage. We also assume that nearly two-thirds of residential buildings are fitted with solar panels—a preferred option to expanding solar farms, which have more negative effects for biodiversity.

Energy savings through improved insulation and solar panel installation is quite attainable: the analysis indicates that only a small increase in insulation is needed to significantly cut energy consumption. Emissions stemming from insulation production will quickly be overtaken by emissions-savings from improved energy efficiency: this strategy will pay off in the short term as well as the long term. Given current gas prices reaching sky-high rates, energy efficient buildings are also likely to become more financially attractive for customers. Installing solar panels on the roofs of all newly constructed buildings is entirely feasible, and would require just about 28% of currently available solar installation capacity. While solar panel production is an emissions-intensive process, it would take just six years to break even and begin reaping the benefits of renewable energy, considering the current grid mix.

STRATEGY TWO: CIRCULAR MAINTENANCE AND REPAIR

Maintenance is an important facet of building management: not to be overlooked, it accrues expenses similar to that of energy use. Strategies that preserve buildings, keep facilities and systems operational and healthy, minimise resource input and waste and ensure cost efficiency all fall under the umbrella of circular maintenance. A proactive approach to stretching the lifetime and **slowing** flows is key: preventive and predictive maintenance, especially when combined with data analytics, can help anticipate necessary repairs, thus maximising

efficiency, boosting reliability and preventing the failure of critical building elements.[121] Incorporating digital technology—like IoT and BIM models— can provide powerful guidance on which parts and materials will need replacing, especially when combined with analytics. These also provide economic benefits: advanced predictive maintenance can slash maintenance and energy costs for a building by as much as 20%.[122] Circular maintenance and repair also create a space for new business models based on servitisation, from Product-as-a-Service[123] to reverse logistics for goods like lighting, elevators and air conditioners. Such business models can optimise costs and slash emissions—and also redistribute value along the supply chain by splitting ownership.

This strategy examines how we can extend the lifetimes of buildings already in the Netherlands' built-up stock, postponing replacement and optimising the value we glean from their materials and components. Claddings, windows and window frames, doors, roofing, heating, ventilation and air conditioning, steel coating and LED lighting are all appropriate targets for lifetime extension. We assume that each of these products is made to last as long as possible—which varies from product to product—through optimal repair and maintenance.

Extending component lifetimes isn't a big win in terms of impact. However, extending the lifespan of entire buildings by making structural repairs is quite effective: it can prevent new construction and generate substantial material savings, with desk research indicating that 33% of buildings could be saved from demolition.[124] This could cut the total volume of materials needed for construction by 2%. However, structural faults aren't the leading cause of demolition in the Netherlands. Economic aspects are the main driving factor: for example, demolishing single-family homes to make room for large apartment complexes. This will need to be addressed through more systemic measures, such as a set of rules and regulations that protect buildings from demolition and incentivise renovation.

STRATEGY THREE: CIRCULAR RENOVATION AND RETROFITTING

Renovation **slows** flows by stretching the lifetime and of structures in the built environment. This strategy is centred around preserving as many building elements as possible—from whole structures to materials and components—with the aim of extending lifetimes and ultimately preventing demolition and new construction. Circular renovation and retrofitting can take many forms, but the most common include those related to energy efficiency and adaptive reuse. Currently, however, energy efficiency renovation processes don't prioritise the use of secondary materials or (industrial) by-products, resulting in greater material intensity. The alternative? Using secondary sources—such as low-quality wool, scrap metal, straw and recycled plastic—to carry out renovation and insulation practices.[125] The Netherlands has great potential to scale this strategy[126]—but this will have to be done with care to balance resource consumption and environmental impact reduction to avoid trade-offs and rebound effects.[127,128] Focus must also be placed on advancing technology, which plays a key role in circular renovation and retrofitting: the use of BIM models, for example, can optimise the repair and substitution of materials with high replacement rates, while 3D modelling can facilitate smarter renovation, planning and logistics.

Adaptive reuse, the practice of reusing existing buildings for purposes other than for what they were designed, presents one opportunity to extend building lifetimes through renovation practices. Within the Netherlands, potential for adaptive reuse is high, and many new homes are added to the building stock through this practice.[129] With over 6% of office spaces sitting vacant, there is even greater opportunity to create new living spaces while addressing the Netherlands' housing crisis. One-third of empty office spaces in the Netherlands could realistically be retrofitted[130] and used for residential purposes.[131,132] The model assumes that this potential is maximised following a steady but conservative yearly increase: this represents approximately 1.8 million square metres of space to be converted. For this space, structural elements—from foundations and floors to stairs and roofs—won't need to be built, generating substantial material savings.

This strategy also assesses the potential to cut material use by preventing new construction through renovating and retrofitting existing buildings. Through desk research, it is possible to determine the yearly percentage of stock currently converted into housing, and predict how this could increase year-on-year based on vacancies in the current market. Potential in this realm is substantial: around 135,000 square metres (or 7%) of residential construction could be prevented each year leading up to 2050. However, when including non-residential stock build-up, this represents less than 1% of the entire sector's construction. While this strategy may only be applicable for a small share of the building stock, its impact could be massive: by using up to 180 kilograms of renovation materials per square metre, the 1,450 kilograms per square metre needed for new construction can be saved. Other benefits are also apparent: protecting cultural heritage, for example, by preserving old buildings, and maintaining aesthetic consistency within cities.

EMPLOYMENT IMPACTS OF SCENARIO THREE

Scenario three revolves around the use phase of buildings: championing circular operations, maintenance, repair and renovation. Across all three strategies, digital technologies that optimise material management will rise to the fore—and workers will need appropriate training to properly put them into practice. Overall, it's likely that this scenario would lead to a net increase in employment, largely due to the numbers of workers needed for yearly retrofitting and solar panel installation.[133] Additionally, during the use phase, new business models such as Product-as-a-Service will demand an increase in certain positions—such as craftsmen, technicians and skilled trade workers—particularly for renovation and maintenance.

Strategy one—circular operations—will require solutions that predict and prevent equipment failures and building deterioration—improving waste management systems in the process. More efficient building management will boost productivity—which research suggests could increase profitability by as much as 10% for some companies. This may stem from lower staffing costs, as digital management tools replace the jobs of people.[134] Regardless: these activities will require a skilled workforce that can keep sustainable buildings functioning efficiently. This strategy also captures the rise of net-zero buildings through regenerative energy sources like solar. According to the scenario modelling, outfitting all the roofs of newly constructed buildings in the Netherlands with solar panels is entirely possible, and would require about 28% of currently available solar installation capacity. This would represent important job opportunities for the workers in this sector, which currently employs 9000 FTEs.[135]

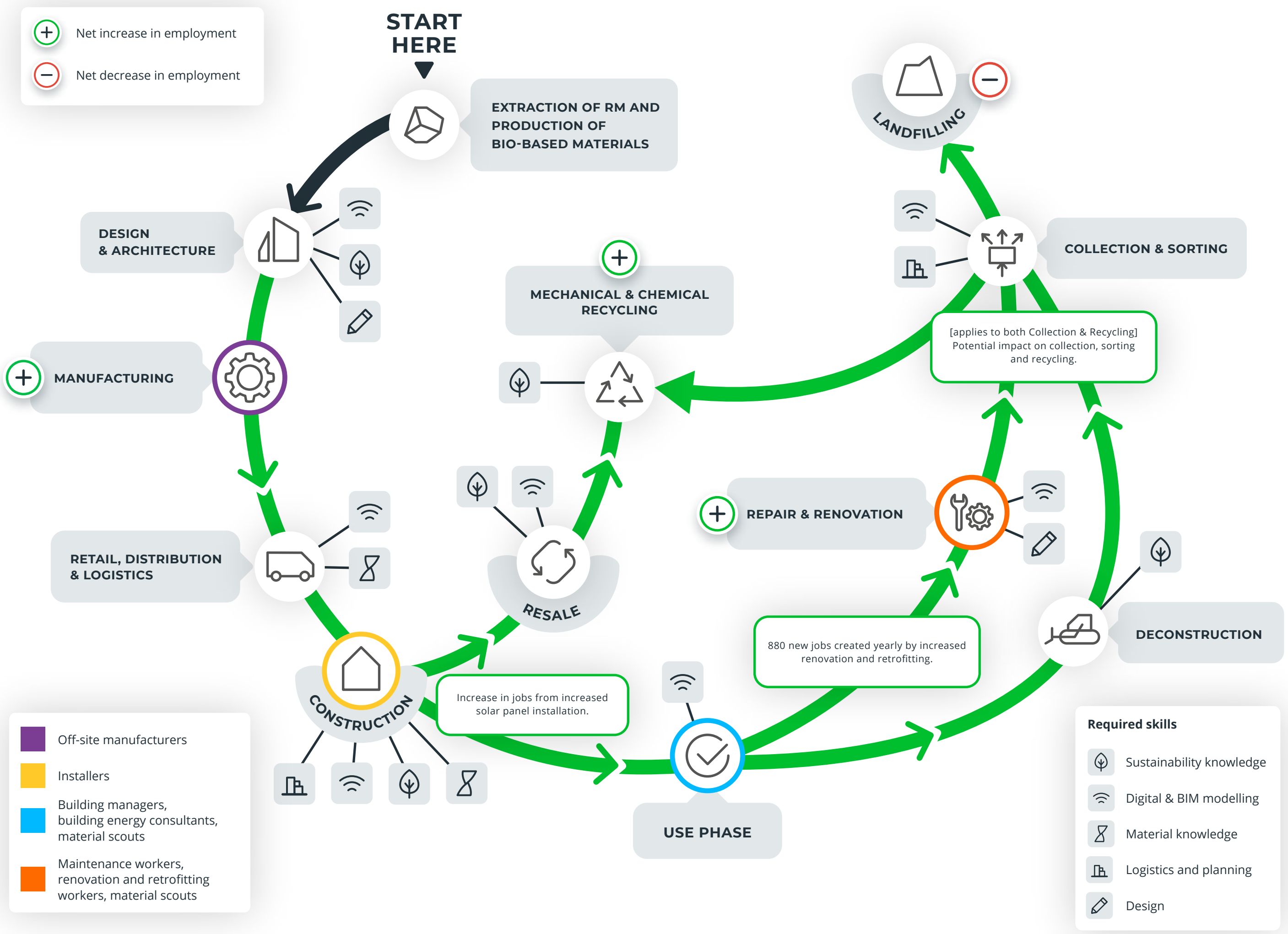


Figure six depicts the skills and roles needed to realise Scenario three.

	STRATEGY ONE	STRATEGY TWO	STRATEGY THREE
Employment level	Increase through solar panels installation	Potential effect on collection, sorting and recycling	880 new jobs created yearly for renovation and retrofitting
Skills	• Digitalisation • Material knowledge	• Sustainability knowledge • Material knowledge	• Sustainability knowledge
Occupations	• Building managers • Building energy consultants • Installers (insulation, roofs, windows, facades, ventilation systems, renewable energy)	• Building managers • Maintenance workers better connected with end-of-life activities • Material scouts	• Off-site manufacturers • Renovation and retrofit workers

Our **second Strategy**—circular maintenance and repair—will benefit greatly from tools that facilitate predictive and preventive maintenance. These will boost productivity and cut maintenance costs, while potentially indirectly (and positively) influencing employment in material collection and sorting, and component substitution. According to the value chain experts interviewed, these effects could be enhanced if maintenance activities were to be better integrated with collection, sorting and recycling—which at the same time would enable the implementation of high-value recycling practices.

Strategy three—circular renovation and retrofitting—would likely be the most labour-intensive activity of this scenario, and would therefore significantly increase demand for employment: renovation and retrofitting works are predicted to demand 880 jobs per year over the next 28 years.[136] Public institutions have supported these types of projects, making the Netherlands a frontrunner in retrofitting and insulation works, with some funding available to drive this forward. Private household or social housing associations have access to a set of funding options from both national and local governments, as well as European funds, for example;[137] and the City-Zen project in Amsterdam, which aimed to retrofit 52,000 square metres of buildings, received subsidies for 13% of the total costs.[138]

SKILLS AND OCCUPATIONS IN HIGH DEMAND

The circular strategies laid out in this scenario will require a range of new occupations and skills: installers specialised in insulation, roofs, windows, facades, ventilation systems and renewable energy systems, as well as building managers, service specialists and building energy consultants and will all be crucial (see Figure six). Education and training in new **digital tools** will be applicable for all of these roles, as growth in productisation and off-site construction will usher in new technologies. The operational and use-phase of buildings will demand new skills in particular, to support material passports and provide timed updates for circular maintenance. In general, operation and maintenance managers must be kept up-to-date with new trends in sustainable buildings.[139] This knowledge will also be crucial for trade workers involved in renovation and retrofitting: **circular renovation requires skills in low- to zero-waste materials and low emissions**. Workers will also need to be familiar with a broad range of materials to identify those suitable for reuse and recycling, to effectively support high-value cycling through maintenance and renovation practices.

4 ADVANCE HIGH-VALUE RECYCLING PRACTICES TO CLOSE THE QUALITY GAP

The final step: when buildings reach the end of their service life, and renovation or adaptive reuse is not possible, the aim should be to spur material reuse and high-quality recycling. Currently, the Dutch construction sector boasts relatively high rates of material recovery (albeit at a lower value than desirable)—but this will have to be scaled even further to achieve a truly circular built environment. Bridging the quality gap necessitates the high-value reuse and recycling of construction and demolition waste: and to this end, this scenario is two-fold. To guarantee the availability of high-quality materials for reuse, demolition practices need to be advanced via a boost in urban mining. Secondly: infrastructure that can connect the supply of available secondary materials with demand is needed to ensure materials are actually reused at end-of-use. This scenario comprises two strategies:

STRATEGY ONE: ADVANCED DECONSTRUCTION AND DEMOLITION PRACTICES

This strategy is closely interlinked with Scenario 1.1: the model shows high technical potential to boost the use of secondary materials, but doing so will require more advanced practices. Currently, buildings require brute force to be dismantled, making material separation on-site difficult and preventing reuse elsewhere. Advancing deconstruction practices and leaving traditional demolition—which renders materials unrecoverable—behind can boost the proportion of materials that are reused and **cycled**, improving the built environment's waste problem. Putting this strategy into practice could be done by enabling the uptake of selective demolition, which removes hazardous materials through pre-demolition audits and dismantles building parts, allowing the recovery of pure materials for reuse.[140]

Due to methodological limitations, we were unable to model the impact of this strategy. However, qualitative desk research has shown that the Netherlands may have substantial potential to advance urban mining—especially in larger cities such as Amsterdam—and therefore boost high-value reuse of materials. It also reveals the economic potential of selective demolition: with similar costs to conventional demolition,[141] this practice isn't being prevented by financial barriers. One case—Maassluis in the Netherlands—used advanced practices such as deconstruction and selective demolition to achieve material savings while incurring no additional costs.[142]

While case studies only provide context-specific examples, potential for scaling successful material reuse is there. Using the strategies discussed, almost complete component and material reuse is attainable: the SUPERLOCAL project in Kerkrade, for example, aimed to develop a range of new properties entirely from reused and recycled materials. So far, it has been a success: 95% of the expo building, developed in June 2017, is composed of reused materials.[143]

STRATEGY TWO: ADVANCE DIGITAL AND PHYSICAL INFRASTRUCTURE CAPACITY

As laid out in Scenario 1.1, prioritising the use of secondary materials, will bring substantial benefits in terms of material use and emissions. But stimulating demand for secondary materials for high-quality reuse applications requires a space for supply and demand to meet. Deconstruction hubs are one such spot: physical places where salvaged materials can be stored prior to reuse, recycling, repair or refurbishment. Online marketplaces represent a digital counterpart: these public-facing tools provide open-access platforms and technologies for public or private actors to source secondary materials, thereby boosting **cycling**. Material passports are an important building block to develop the necessary digital infrastructure, as they highlight which materials buildings are made of, and where these materials can be found.[144,145,146] Online platforms can track and optimise resource use, strengthen connections between stakeholders along the supply chain and facilitate circular business models.[147] The marketplaces enjoy low capital costs, as inventory is handled by suppliers, and increased product transparency, as buyers can evaluate their options based on cost, performance and availability. For these reasons, they may be seen as preferable—deconstruction hubs, on the contrary, require higher upfront investments.[148] Deconstruction hubs also play an essential role in the repairing and testing of secondary materials. To make sure the (structural) integrity of secondary materials is up to standard, the repairing and cleaning of secondary materials need to be incorporated into the production chain. There's also something of a 'chicken or egg' paradox: physical and digital infrastructure are needed to support advanced practices for construction and demolition waste, yet if these practices don't grow, there's little incentive to invest in this kind of infrastructure in the first place.

Due to methodological limitations, we were unable to model the impact of this strategy—but initiatives to scale infrastructure for material storage are already under development in the Netherlands. The city of Apeldoorn, for example, plans to renovate neighbourhoods built 40 to 60 years ago—reusing their concrete and asphalt in the process. Pavements, sidewalks, green spaces and parking areas will all be reconstructed in a circular way—and material data banks will be used to store information on demolished materials' quantity and quality.[149] While outcomes are still to be seen, this project is paving the way for future developments in digital and physical infrastructure in the Netherlands.

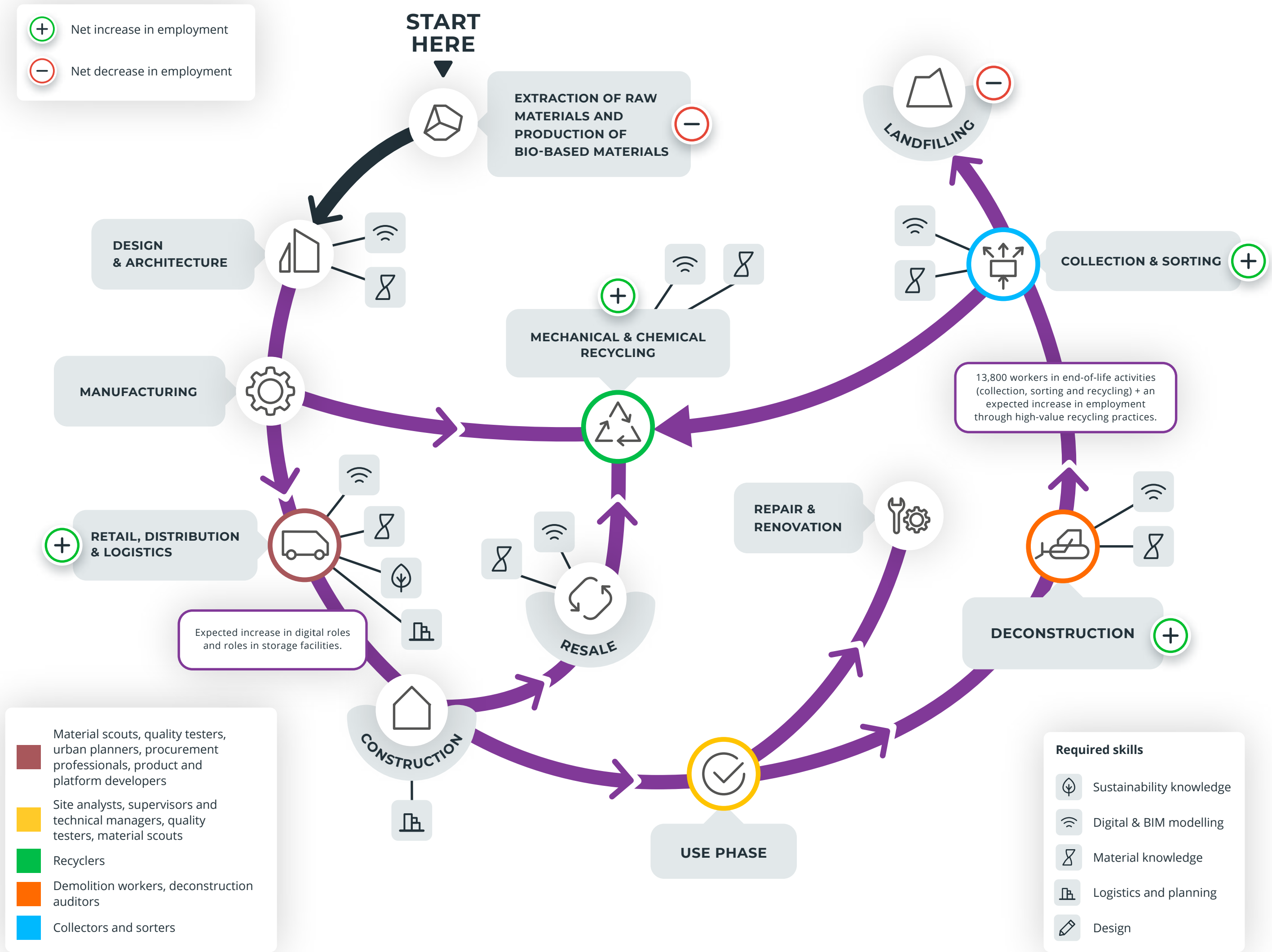


Figure seven depicts the skills and roles needed to realise Scenario four.

EMPLOYMENT IMPACTS OF SCENARIO FOUR

This scenario's strategy for advancing construction and demolition practices could bring substantial employment gains in end-of-life stages, on top of the job creation expected from the boost in secondary material use discussed in relation to Scenario one, which **could boost employment** in construction and demolition waste activities by approximately **13,800 jobs**. This will require a systemic overhaul, marked by new forms of collaboration and strong growth in the waste management sector. Moreover, specialised practices that recover high-quality materials through construction and demolition are, by definition, more input- and time-intensive.[150]

Scaling high-value reuse applications will also require significant **advances** in both **digital and physical infrastructure**. Physical storage facilities should be strategically located—to cut transport distances from deconstruction sites—coupled with data on the quantity and quality of materials available, reverse logistics and processing. The need for these new facilities will positively impact employment as new workers will be needed for material and supply chain management. Deconstruction hubs could demand more material scouts, in charge of locating buildings that may soon reach their end-of-life stage.

Tracking building materials will also become an important part of this process, and some workers in the collection, sorting, recycling, and logistics and planning fields will need to be **able to use digital tools and platforms** to facilitate this.[151] Similarly, industry experts will need to stay up-to-date with the growing role of BIM-based skills, artificial intelligence-integrated technology and IoT-based devices in the construction industry, to appropriately integrate them into new projects. AI-based intelligent robots, for example, have demonstrated remarkable abilities to recover and sort mixed construction waste.[152]

	STRATEGY ONE	STRATEGY TWO
Employment level	13,800 more workers in end-of-life activities + expected increase through high-value recycling practices	Expected increase in job positions for digital roles and storage facilities
Skills	• Digitalisation • AI technology • Material knowledge • Sustainability knowledge	• Material knowledge • Sustainability knowledge • Digitalisation • Automation
Occupations	• Demolition workers • Supervisors and technical managers • Site analysts • Quality testers • Deconstruction auditors	• Material scouts • Quality testers • Urban planners • Procurement professionals • Product and platform developers

The need for **specific knowledge on materials and sustainability** will grow in tandem with the rise of digital technologies: more circular deconstruction will require skills to identify high-value recovery options and optimise reuse (see Figures seven). Knowledge of component quality, testing and potential reuse applications will rely on proper tracing, mapping and analysis of all the various material components engaged in a building's design, construction and use phases, and will be particularly relevant to demolition labourers, supervisors and technical managers. Roles such as site analysts, quality testers and deconstruction auditors will be needed to locate reusable components and recoverable materials. Site harvest management plans will replace site waste management plans, reflecting the value that can be harvested from buildings slated for demolition or deconstruction.

Urban planners and procurement professionals working in the public and private sectors will have a substantial role in incentivising the use of secondary materials in new developments. They can also support improved infrastructure for collection, sorting and recycling—including the employment requirements for each of these phases.[153] Marketplaces for secondary materials are currently fragmented;[154] to grow the market, product and platform developers will be crucial for creating digital storage hubs—while material scouts will make use of these new tools to map materials available across the Netherlands, and boost the visibility of physical storage facilities and their stocks. This will help scale the uptake of secondary materials. In tandem, designers and architects will be expected to make use of the secondary materials on offer, with a focus on innovation and design for disassembly to further reuse practices in future decades. Roles like low-carbon specialists and sustainability advisors may also emerge further, aiding design professionals and increasing the circularity of logistics and transportation to ensure the weight, method of transport and distance don't outweigh the emissions savings of secondary material use.[155]

5

SCOPING CHALLENGES AND

LOOKING TO THE FUTURE

Achieving the bold transformation toward a circular built environment will not be without its challenges. The built environment is a complex system with many cross-cutting and systemic barriers that can often make it difficult for actors to take the necessary steps to invest, innovate, and compete in circular business practices. Compounded by societal pressures like the need for housing and a shortage of workers tends to further entrench linear 'business as usual' practices, and build risk aversion to alternative approaches that would forge a path toward more circular systems and practices. The potential impact of the four scenarios described in the previous chapter is substantial: embracing circularity would bring the Netherlands much closer to achieving its 2050 material circularity goals,[156] as well as generating significant environmental benefits and changes in the labour market. This chapter will examine some of the key barriers that stakeholders in the Dutch built environment will have to overcome to realise the four proposed scenarios, as well as some of the key levers and actions that can be pursued.

HARD TO INVEST IN LARGE-SCALE, LONG-TERM SOLUTIONS

Scenario one (Circular supply chains) and Scenario four (Advanced infrastructure for cycling) call for the large-scale consumption of secondary and renewable materials as well as streamlined processes that allow for efficient disassembly and high-value material recovery, reuse and recycling. To realise such a system at scale will require significant investments in physical infrastructure, advanced recycling technology, the knowledge and capacity to apply secondary materials, and new, circular business models. The investments needed for training and organisational change, as well as the infrastructure needed to facilitate recycling and reuse of materials at scale, currently represent significant barriers to actors in the sector. The returns are uncertain, due to misaligned incentives and a lack of a clear business case, while the value chain operates with low profit margins and complex project management due to the multitude of actors involved in real estate development and construction. Misalignment in incentives between builders and users of building projects also creates barriers to longer term investments. The so-called 'split incentive' is a barrier for circular solutions, since these circular solutions require higher initial investments, but often result in a lower total cost of ownership, including maintenance and disassembly.[157] This is only if commissioners take the complete life cycle into account and focus on the long-term usage of the end product and materials.

Shifting to circular practices requires 'long-term' thinking, demanding the upskilling of planners and current and future entrepreneurs. It also often demands higher capital investments and upfront labour and material costs.[158] These initial investments are out of reach for many companies willing to innovate, mainly due to difficulty in achieving the right scale within their own value chain to be cost-competitive.[159] Even if the upfront investments can be made such that buildings are designed with high volumes of secondary materials and can be easily disassembled, the return on investment through the recuperation of materials may only be achieved perhaps 50 years or more in the future.[160] Because these future cash flows contribute very little to current valuation, the long-term investments in circular solutions are hard to be broadly adopted within the industry.

Another key barrier is the investment in the necessary physical and technical infrastructure to efficiently sort, process, and store large volumes of materials. While investments in recycling infrastructure have been growing, especially in the field of automation and machine learning, they remain labour- and capital intensive, thus prohibitive to achieving the necessary scale beyond a handful of specialised actors. Because human labour is still so crucial to successful material recovery processes, yet is priced much more highly than materials, there is a poor investment case for the necessary infrastructure at the right scale.

HARD TO INNOVATE WITH LITTLE INFORMATION AND SECURITY

Each of the four scenarios that have been explored will require a myriad of innovations and new forms of collaboration from companies across the value chain. In the past few years there has been movement toward servitisation, greater use of renewable materials, and prefabricated designs, which is encouraging. Yet, a number of key barriers to innovation persist, such as lacking information, knowledge and skills, and legal and regulatory challenges, as well as market complexities. The workforce is largely trained to work in a linear manner, for example: knowledge of bio-based materials like timber falls short in comparison to knowledge of working with concrete—and these are the skills still largely taught.

A lack of information and data come into play when actors attempt urban mining: the reuse and recycling of secondary materials stored in buildings. This is especially relevant for Scenario one (Circular supply chains) and Scenario four (Advanced infrastructure for cycling). Despite the vast volume of materials locked into the current building stock, it is difficult to know how materials or components can or should be reused, in comparison to other sectors. It is currently very difficult to provide detailed performance data sheets, value estimations, disassembly instructions and potential reuse applications for materials, components and products that have sat in buildings for several decades or even centuries. Information systems that report on secondary material characteristics—providing clarity on quality, for example—are often lacking or inadequate for companies to significantly increase their uptake.[161] As an example, the use of recycled materials in building projects can be dissuaded by obligatory environmental impact reports, and there is currently no certification system that can guarantee 1) the type of materials or 2) the quality or environmental performance of the reused materials.[162,163] This lack of transparency and additional bureaucracy is a clear disincentive for companies willing to innovate.

In circular operations management (Scenario three, Champion circular and sustainable building operations, maintenance and renovation) where repair, remanufacturing and refurbishment activities are critical in extending the lifetimes of buildings and components, a building product or component might change hands a number of times over several decades. This poses a number of complex legal issues around ownership, liability, and intellectual property.[164] In the 2012 Building Decree, guarantees on secondary components are blocked, creating clear legal liabilities for companies interested in innovating into circularity.[165] Furthermore, there is an absence of an official accounting and certification system for secondary materials. Both these obstacles make it difficult to tell who would be legally liable for faulty secondary materials: the original manufacturer versus the construction company that reused it. This is especially problematic because secondary materials change hands several times.

HARD TO COMPETE ON AN UNBALANCED PLAYING FIELD

Shifting towards mainstream use of secondary materials and circular designs (Scenarios one and two) clearly show the environmental benefits that circular solutions can generate. However, this often comes at a higher economic cost due to novel and often more labour intensive processes to bring secondary materials back into use. The economics of circularity in the building sector make it very difficult for companies to compete, further entrenching 'business as usual' practices.

A core barrier to realising material circularity is that virgin materials are far cheaper than their secondary counterparts. This is largely due to the lack of price incentives to promote or foster the uptake of secondary materials over virgin ones, and is linked to the taxation system that disincentivises sustainable practices. Common building materials like steel, aluminium and timber are traded through high-volume, international production chains, meaning that prices are generally quite low and stable. Secondary, and even bio-based materials are significantly lower volume, more local, heterogeneous, and are largely of unknown quality due to lacking certification. This means that procuring virgin materials is almost always less expensive than utilising secondary materials or pursuing lifetime extension activities like renovation or repair.

In addition to economies of scale, the exclusion of externalities plays a critical role in pricing mechanisms and creates an incentive to use primary, conventional materials. Secondary materials often carry a lower impact, due to its total life cycle impact being extended over multiple cycles. Yet the market prices of materials don't tend to accurately reflect their externalised costs to the environment.[166] While there has been some progress towards pricing emissions, it's not mature, uniform or stringent enough to create a suitable economic disincentive for the use of unsustainable materials.

Increasing the use of secondary materials poses a number of practical challenges for businesses. Where standards on maximum usage of recycled content exist, they can already exceed what Dutch law allows.[167] On the other hand, an absence of regulation for certain processes—such as household renovation—means that some construction activities often take place informally and are therefore far more difficult to influence in terms of material use, processes and waste management. Considering that there are 7.9 million existing homes and the more than 460 million m² of non-residential buildings in the Netherlands,[168] this very much highlights the issue of split incentives and ownership of buildings and materials, as activities on private property are much harder for the government to regulate.

RECOMMENDATIONS FOR ACTION

To make the broad shift to a circular built environment a reality over the next thirty years and achieve the government's goal of being fully circular by 2050, it needs to be much easier for actors to invest in, innovate towards, and compete using circular offerings. This section of the report attempts to outline some of the key levers and actions needed by stakeholders in the built environment to overcome the barriers that have been identified and achieve the needed scale to meet the ambitious circularity goals set out by the government.

GET THE ECONOMICS RIGHT

The exclusion of environmental externalities is a fundamental barrier in accelerating the uptake of secondary and renewable materials as well as more circular business models. Adjusting the pricing and economic incentives to reward solutions that generate lower environmental impacts will substantially shift the playing field, and reduce the risks of moving toward circular economy business models.

- **Set a level playing field for circularity:** Fiscal mechanisms can be explored to make circular economy solutions competitive or even less expensive than linear practices. For example, the EU carbon tax increase will serve to hike up the prices of unsustainable materials, while Dutch initiative Ex'tax is a well-lauded approach for internalising externalities by shifting taxes from labour toward virgin material extraction. This must not be at the expense of social security contributions and should lead to sustainable jobs. Provided these conditions are met, such a tax shift could allow actors to invest in more labour-intensive practices that are needed to handle secondary materials, while significantly discounting the cost of secondary materials relative to virgin resources.[169] The MPG standards should continue to evolve to enable production of (and storage of bio-based) materials within the national emissions and circular economy targets.[170] Similarly, because buildings have to comply with new standards like the Bouwbesluit and BENG, demolition is often considered easier and faster than a complex puzzle of renovating an existing building or structure. This leads to demolishing and constructing new, well insulated buildings in the name of the climate, which can run contrary to the principles of circularity.
- **Set explicit targets for secondary and bio-based material use:** Our scenarios show that secondary materials will not be enough to meet total material demand, therefore a more open, enabling environment for innovation with the use of secondary and bio-based materials is crucial. Mechanisms to achieve this could include Extended Producer Responsibility (EPR), which has proven to be an effective mechanism for securing streams of secondary materials and internalising environmental costs. The Dutch government is already considering introducing an EPR for construction and demolition waste.[171] Similarly, the national government can stimulate desired behaviour by providing subsidies, for instance via the MIA/Vamil, where material passports are a condition.[172] Targets may also be set for bio-based material use: as noted previously, the Metropolitan Region of Amsterdam is already doing so by requiring that 20% of new housing projects use bio-based materials such as timber.[173] It is important to note that these mechanisms should ultimately be designed in a way that incentivises manufacturers toward more circular products and business models and raise the cost of doing business-as-usual by holding producers responsible for the true 'costs' of their products, while reducing unintentional effects.[174]
- **Create long-term economic incentives:** Because buildings are long-lasting assets, ensuring that long-term economic incentives are structured to

reward circular behaviour through public-private partnerships is also important. The efficient utilisation of space is a key aspect of circularity that was explored in Scenario two, thereby raising the need to think about how to incentivise people to live in spaces that adapt to their needs. For example, making it attractive to move to a smaller home when children leave a large family home could be addressed through adjustments to the mortgage tax relief. Similarly, as buildings change hands through different owners and perhaps renters over the years, split incentives need to be considered. Solutions like on-bill financing or property assessed clean energy financing could be implemented to enable building users to make investments that generate greater resource efficiency through a building's full use phase.[175] As an extension to energy grants for landlords, conditions in the grant agreements could help ensure that renovation activities include high-value recovery of materials and other relevant circular design criteria.

DRIVE DEMAND IN THE MARKET AND SET NEW RULES OF THE GAME

The success of scaling the transition towards a circular economy is strongly tied to sufficient market demand. Governments on local, provincial and national levels have the ability to drive a large part of the total demand in the country, and furthermore, can set new rules of the game in favour of circular economy models.

- **Write mandatory circular procurement into public tenders:** National government procurement amounts to upwards of €73 billion per year in the Netherlands,[176] meaning that targeted procurement can be a powerful lever for achieving circular targets. In practice this could include prioritising circular design approaches and business models in tender requirements. (Local) governments can also invest in surveying and documenting existing building stock, and facilitate the development of robust certification schemes for secondary material use (especially for critical structural elements).
- **Stimulate desired behaviour by rewarding frontrunners:** Companies that pave the way by taking risks in investing in new ways of working should be rewarded for doing so. Rewarding circular solutions and projects can create sufficient incentives to overcome the barriers in the adoption of best practices, and accelerate their adoption. Willingness to change should also be enabled and supported through upskilling and advice on how to shift to circular business models. Good progress has been made on incorporating sustainability criteria, such as the *milieukostenindicator* (MKI) in infrastructure tenders, however where legally possible, the bar should be raised for circularity for every area development, including spatial planning, area development plans and visions, and demolition projects.[177]

SIMPLIFY AND STREAMLINE REGULATIONS AROUND GOALS

Addressing regulatory inconsistencies, definition issues and inflexibilities will be key in creating a harmonised and enabling regulatory environment. Laws and regulations should be updated and clarified across the board to make them fit-for-purpose and allow for greater flexibility toward the desired long term goals for a circular economy.

- **Better monitor circularity in the built environment:** Better monitoring and harmonisation of waste data can make it easier to track reuse and remanufacturing flows. Regulations should be updated to remove barriers, and monitoring of material flows should be used to pinpoint where downcycling is taking place and why. This is critical to navigate and steer policy over the coming years. The government could establish more informed monitoring and harmonisation for the quality of waste materials, clarify definitions and distinguish between 'waste streams', 'reuse flows' and 'by-products' to drive innovation in the private sector.[178] It's especially important that high-value reuse is distinguished from recycling or downcycling in reporting. The development of new metrics and standards to track circularity in more granularity, including end-of-waste criteria, will better enable demolition materials to be reused.[179]
- **Update regulations to remove barriers to circularity:** Clearer quality assurance through an official certification and accounting system and better product performance standards could help overcome some of the risks related to circular construction.[180] Updating regulations, such as the 2012 Building decree (Bbl), can guarantee that secondary components can further support high-value reuse of materials and products, as well as alleviate constraints and uncertainties in secondary material use and ownership.[181] It should also be ensured that environmental and civil codes do not contradict other rules and are well-aligned with circular construction and design.

INVEST IN COMMON INFRASTRUCTURE

To facilitate circular supply chains (Scenario one) and advance high-value recycling practices to close the quality gap (Scenario four), the development of the necessary infrastructure and marketplaces where supply and demand for secondary material meet is indispensable and requires a national impulse.
In order to achieve the aspired goals, we recommend the government to play a facilitating and stimulating role in this area.

- **Physical infrastructure:** Develop material hubs and marketplaces that combine multiple value chain steps such as storage, repair and remanufacture facilities. This approach can be applied within existing logistics infrastructure and preferably combined within a greater area of upcycling industry and crafts that enable economies of scale to create cost competitive, affordable circular products and projects. This may also be achieved through partnerships and direct investments in storage facilities and processing equipment—such as the Smart Crusher[182]—in crucial locations around the country, such as ports or logistics hubs near large cities. Governments should also act as facilitators and increase cooperation between construction sector stakeholders. Through the government commission of living labs, the infrastructure needed to enable circularity currently lacking could be 'co-created' and better aligned and adapted with longer term targets.
- **Digital infrastructure:** The national government can take a leading role in setting the rules of the game for secondary materials data trading systems, and develop partnerships to implement them. Designers of new buildings, large scale renovation, and demolition companies are often not linked in a way that leads to optimal cycling pathways for materials. To build a strong business case for each actor, digitally mapping out the expected demolition and renovation projects in the coming two to three years can greatly increase the chance of a matching supply and demand, and higher value cycling pathways. Because of the many actors involved, it could be sensible to construct a public-private partnership to ensure the necessary agreements about data, ownership, storage, maintenance, delivery, security, and privacy are reached.[183]

BUILD CIRCULAR EXPERTISE AND SKILLS

Embracing and accelerating the transition to a circular built environment is predicted to bring shifts in jobs. However, the Netherlands can't reap the benefits of circularity if the labour market is not ready to adapt to and take advantage of the coming trends, from automation to the use of digital technologies. Transitioning Dutch workers from the linear to circular economy needs to be underpinned by strong institutions and collaborations.

- **Train employers and staff around circularity:** Companies can equip their relevant departments such as procurement, finance, accounting, design, craftsmanship and project management with tools, skills, and knowledge to realise circular projects. To ensure that training isn't happening in silos, work on establishing long-term relations to realise circular projects and foster innovation internally and between companies in the value chain.
- **Upgrade education and skills policy.** The national government has a key role in enabling a just transition by nurturing a future and skills-focused education system. Ensuring that the circular transition offers workers solid opportunities will require forward planning and a conscious updating

of education and skills strategies, such as skills passports.[184] Encouraging skills and knowledge development through professional training, trade internships, HBO institutions and research universities can provide immediate opportunities for those entering the workforce. Specific support programmes and incentives for businesses, alongside curricula development within technical education institutions, can target specific skills gaps across the labour market: parametric design, timber frame and passive house construction techniques, as well as disassembly and material recovery, for example. Cross-disciplinary approaches should drive holistic, systemic school-based and work-based education across the Netherlands.[185] An example of this is the effort led by the Amsterdam Economic Board through the House of Skills, a skills-oriented programme for the labour market. Some of the courses offered by House of Skills are focused precisely on the construction sector, such as the career paths for Technology and Construction or Engineering and Construction.[186] The EU Horizon 2020 project BUS-GoCircular also enables skills-based learning by translating key elements for circularity in a task-based qualification with clear learning outcomes.[187]

- **Prioritise better working conditions throughout the transition.** It is critical that a shift to circularity doesn't repeat the mistakes of the linear economy, maintaining the often less-than-desirable working conditions currently experienced by the workforce. Transitioning to a circular built environment will require technical solutions, but there's a risk that health and safety conditions could fall by the wayside if not afforded proper attention. Already, the standardisation of building codes has significantly contributed to this: Dutch labour unions may further these efforts by convening with the private sector to develop new norms that better reflect workers' needs. The *Bouwplaats ID* is a tool that can function as a digital CV, allowing greater transparency on job sites. This can be a crucial instrument in creating more safe working environments, especially for large projects with many layers of subcontracted temporary workers.[188]

- **Address problematic labour market trends.** The Federation of Dutch Trade Unions (FNV) has noted that labour contracts within the construction sector are becoming increasingly flexible,[189] which may pose certain risks if they are not decent—and the outsourcing of temporary workers and self-employment are both becoming more prevalent. Outsourced workers—which now represent the majority of workers on large projects—may lack HR support and be left unsupported in the case of accidents or other work-related issues. Self-employed workers usually lack coverage through a Collective Labour Agreement, making them vulnerable to economic shocks as well as issues that may occur during working hours. As these trends become more commonplace, labour unions must work to address these potential issues by extending the traditional labour rights for employees to self-employed workers. In the Netherlands FNV Zelfstandigen is already addressing this challenge, however, there is still a long way to go to provide this particular labour force with accessible insurance coverage.[190]

- **Collaborate with private and public actors to promote career opportunities.** The *Pact for Skills in Construction* highlights five key avenues of action: 1) Building strong partnerships—including with VET institutions—2) monitoring occupational supply and demand and anticipating knowledge, skills and competences needs, 3) working against discrimination, 4) attracting more young people and women to work in the sector, and 5) promoting a culture of lifelong learning for all, supported by adapted incentives. The role of labour unions will be crucial in realising these five goals: it can look at opportunities to form strong collaborations between public and private sector actors, to build strong career opportunities for the workforce.

6 THE WAY FORWARD

The Netherlands has transformative potential: by embracing the circular economy for its built environment, it can substantially reduce its material use and emissions. This report gives a first approximation of how materials are used to meet the Netherlands' need for residential and commercial buildings—and provides a roadmap for how the construction sector can boost its circularity and cut material use. The scenarios presented show the opportunities for the sector to improve: prioritising secondary materials, and adopting more lightweight bio-based materials, for example, could significantly cut the mass of virgin materials used and deliver a substantial decrease in emissions. Realising this potential won't be simple, but the changes it could bring for climate, biodiversity and society could be revolutionary.

The Netherlands is a critical change agent. As a global frontrunner in the sphere of circular economy—with the ambitious goals surrounding circularity to match—the country has an important responsibility to drive the transition. This will be particularly important within the construction sector, which is currently a huge contributor to the Netherlands' material footprint and emissions profile. Linearity is deeply ingrained in current practices: overconsumption and waste are all too common, and impacts on both people and the planet are less than ideal. Shifting to a circular built environment could help shift pervasive norms and values present in the Netherlands and other high-income nations.

Closing the Gaps: crucial next steps. This is not the time to work in silos: all steps of the value chain—and its workers—must be considered, from material sourcing and manufacturing to design to use to end-of-life. This report provided a startling finding: while 88% of construction and demolition waste is said to be recycled, less than one-tenth of building materials come from secondary sources. Downcycling is rampant—and if the Dutch built environment wishes to truly go circular, keeping materials in use or optimising their value through multiple cycles of use will be a crucial next step. It is of even greater importance to a circular economy to keep materials in use for as long as possible: practices that extend building, product and component lifetimes should also be prioritised, such as durable design, repair and renovation.

Building a happy, healthy and secure workforce will require careful planning and collaboration. The Dutch construction sector is in flux, with a large number of workers expected to retire over the coming years—and labour and skills shortages, as well as the sector's cyclical and volatile characteristics. Radical collaboration between businesses, governments and labour unions will be crucial, and can help ensure that workers overcome knowledge barriers that a transition to a circular economy may bring. Pilot projects, living labs and continuous knowledge sharing can all help companies and individual workers adapt and equip the workforce with the skills needed to thrive. In the end, collaboration is key to a successful, resilient circular economy[191]—especially within the construction sector.[192] Those at risk of being phased-out—such as older or less skilled workers—must also be considered throughout the transition, placed at the centre of a skills development policy that is beneficial for work and workers. It is inevitable that shifting to a circular economy will impact the labour market—but approaching the transition in a holistic way that puts both people and planet at the fore will bring the positive social outcomes that our current linear model has often overlooked.

A huge opportunity for the Dutch built environment. The construction sector still has a way to go: it's more linear than it appears on paper, with rates of consumption far surpassing what the Earth can provide—and recycling practices that largely result in value being lost. It's also hindered by a strict regulatory environment and under-developed market for secondary materials, for example. However, the necessary ingredients for success are there: the Dutch government is eager to develop a roadmap for high-quality use and reuse of materials and on the whole, the sector is fairly advanced. With national and EU-level policy already supporting its realisation, a circular built environment will deliver strong wins for both environmental and socioeconomic agendas.

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92. It's important to note that evolution in the sector will likely result in less labour-intensive end-of-life processes in the future, which are not taken into account in this projection and means this estimation must be considered an upper bound of the expected increase.

93. It is important to highlight that even in a circular built environment scenario for the future, the extraction of raw materials will not be eliminated completely. While this strategy could feasibly play out on an EU-wide level, Dutch suppliers will not likely be able to meet the new demand for bio-based materials modelled in this strategy.

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