ARCADIS Design & Consultancy for natural and built assets

THE FUTURE OF THE EUROPEAN BUILT ENVIRONMENT

A forward-looking description of Europe in 2030 and 2050

TABLE OF CONTENTS

EXECUTIVE SUMMARY

No one knows what the future exactly holds. Nevertheless, we look at trends and examine new developments today to define business strategies and to develop policies and regulations for tomorrow. In this report we present a forward-look on the European built environment in 2050. It applies to the entire built environment: residential, commercial, public and industrial buildings. This vision is based on eight essentials for buildings of the future. Buildings will become climate resilient, circular and deconstructable. They will deliver energy, be cognitive and will be flexible in use. Buildings will support a healthy lifestyle and enable working and living in a 24-hour economy and there will be a strong focus on the performance of buildings for all the essentials.

But how do we get there, what are these essentials based on? They are based on a more generic vision on Europe as a whole. We zoom in on five crucial trends that shape the future of Europe: (1) climate change, (2) resource scarcity, (3) changes in population, (4) urbanization, and (5) focus on health. Three enablers drive these trends: the (digital) technology, finance and policy and regulation.

The report addresses two milestones: 2050 and 2030. The long-term perspective of 2050 provides insights into shifting environmental, economic and social models. For 2050 we assume fruition of several trends. This is 'only' one renovation-cycle ahead of us. 2030 offers a shorter-term forward-look at how current developments may have matured or may have become mainstream. Business strategies can be based on this shorter-term perspective. By no means this report aims to be exhaustive. This forward-looking exercise does not set out to forecast or predict the future. It rather intends to provide a framework that can stimulate and inspire policy and decision makers and business strategists. It may serve to feed the discussion about which trends shape the next few decades of the European built environment.

1.1 OBJECTIVE OF THE REPORT

This report provides a forward look into how the European built environment may evolve towards 2050 with an intermediary milestone of 2030. 2050 offers the long-term perspective within shifting environmental, economic and societal models, while 2030 offers the shorter-term perspective where current trends may have become mature or mainstream and on which business strategies for 2030 can be based. For 2050 we assume full fruition of a number of key trends. For 2030 we assume only gradual changes without full deployment of identified trends. In this way 2030 and 2050 are anchor years on which a strategy can be developed. By no means, this report aims to be all exhaustive; these visions serve to feed a discussion on how the built environment may evolve.

1.2 EXPLANATION OF THE SET-UP

1.2.1 HOW TO READ THE REPORT

The second chapter presents the vision on the future of the European built environment in 2050. It addresses the essentials for buildings in 2050 and 2030. The third chapter addresses the general trends and developments in Europe that will significantly influence the built environment. Both visions in chapter 2 and 3 are elaborated in chapter 4 (Deepdive into the essentials of the future of the European built environment) and chapter 5 (Deepdive into the trends and developments that shape the future of Europe). Finally, in the sixth chapter, the report provides a reflection on the dynamics in the trends and developments and elaborates on how to develop a strategy based on these trends and developments.

1.2.2 SOURCES

The content of this report is based on publicly available resources, reports and information, but also on the senior expertise and judgement of the authors, who have an expert view on the shifting landscape in which they perform their daily work. An overview of used resources is presented in appendix 1.

2 | THE FUTURE OF THE EUROPEAN BUILT ENVIRONMENT

This chapter presents a forward-look into the future of European built environment. It is based on the trends and developments that shape the future of Europe in 2030 and 2050 as presented in chapters 3 and 5.

We have identified eight essentials of future buildings. Buildings will:

- … be climate resilient
- … be circular and deconstructable
- … be delivering energy
- … be cognitive
- … be flexible in use
- … support a healthy lifestyle
- … enable working and living in a 24 hours economy
- … focus on performance

The forward-look applies to the entire built environment. This includes residential buildings (homes, residential areas, rural planning and development) and utility buildings (offices, factories, etc.). All essentials are explained in more detail in the deep dive in chapter 4.

THE FUTURE OF THE EUROPEAN BUILT ENVIRONMENT

What will the European build environment look like in **2050**? It is shaped by the effects of climate change, resource scarcity, changes in population, urbanization, and focus on health and wellbeing. Buildings integrate a vast amount of technology that connect buildings to information management and sharing platforms. Buildings have evolved into temporary storage of circular materials and products and have become datahubs that support optimal (energy) efficiency and wellbeing.

BUILDINGS FOCUS ON PERFORMANCE

The sustainability performance, energy performance, and other performances are central drivers for comfortable living and working, and also determine the value of a building.

ENABLING WORKING AND LIVING IN A 24-HOUR ECONOMY

In our 24-hour global economy buildings will provide combined working and living space. Leisure, sports, shops and other amenities are combined in buildings that provide 24-hour connectivity.

CLIMATE RESILIENT

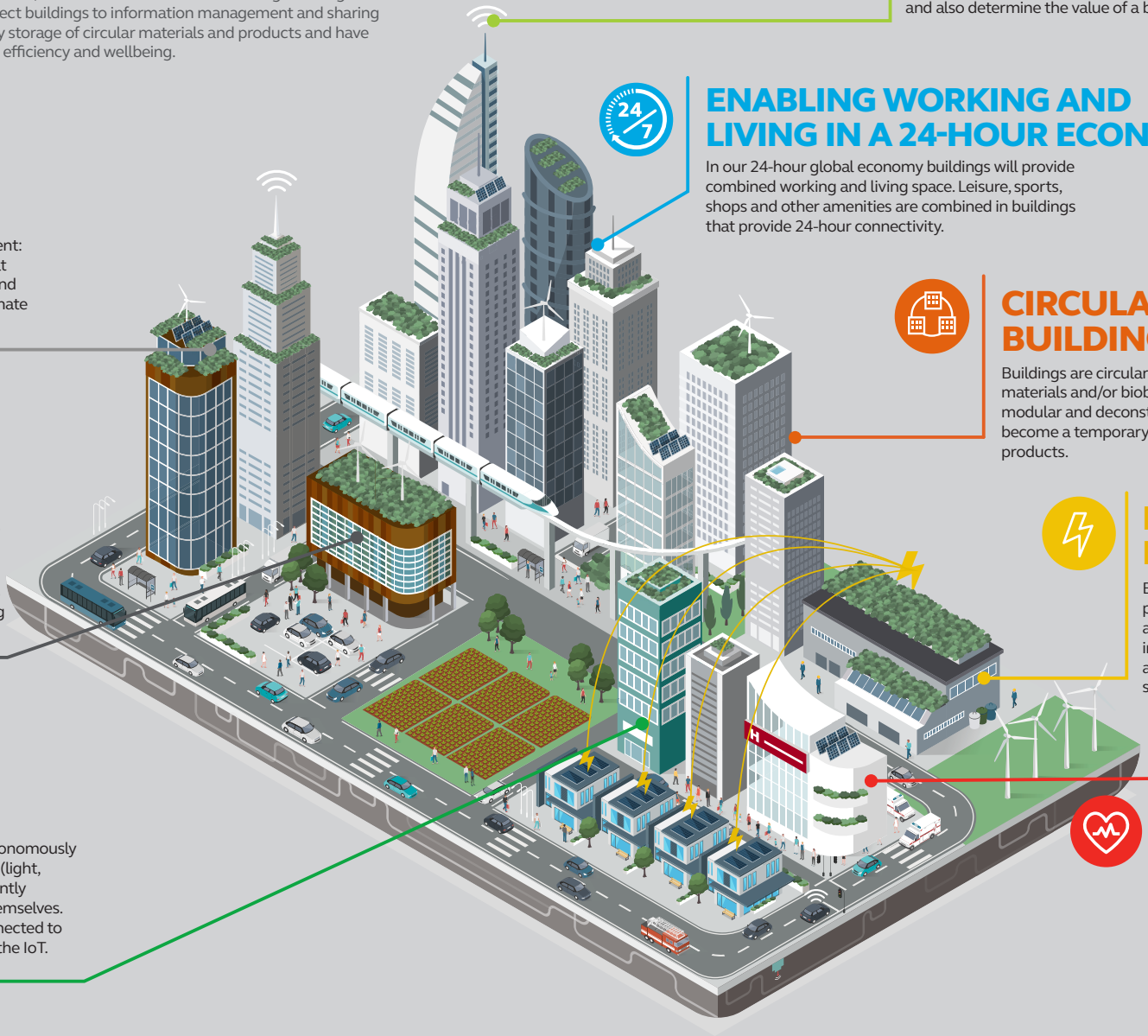
Buildings are entirely climate resilient: green, energy neutral buildings that are designed to withstand floods and heat stress and that are part of climate resilient cities and urban areas.

CIRCULAR BUILDINGS

Buildings are circular: built with reused materials and/or biobased materials, are modular and deconstructable. They have become a temporary storage of materials and products.

FLEXIBLE BUILDINGS

Buildings will facilitate flexible use. They are adapted for changes in use on the short term, while being constructed for the long term. Smaller and flexible units will provide living spaces for the growing urban population.



ENERGY POSITIVE

Buildings create energy through photovoltaic solutions and are highly energy efficient and independent of fossil fuels. Buildings are connected to a smart grid to share and store electricity and heat.

COGNITIVE BUILDINGS

Buildings will be able to autonomously manage its internal climate (light, temperature, air) and efficiently adjust e.g. energy use by themselves. Cognitive buildings are connected to smart grids and are part of the IoT.

SUPPORT A HEALTHY LIFESTYLE

Buildings provide a healthy environment: healthy noise management, optimal temperature management, clean air and daylight. The design fully supports the wellbeing of its users.

In describing the future of the European built environment we zoom in on eight essentials of future buildings. These essentials are explained in the table on page 7 - 12 below. The table shows the vision for 2050 and 2030 and indicates which trends and developments drive these changes. The essentials are explained in more detail in the deep dive in chapter 4.

	2050 What does the European Built Environment look like in 2050?	2030 How did we get there? An intermediate stop at 2030	What trends drives this essential? ***See also chapter 3***
CLIMATE RESILIENT	• Buildings will be designed to take into account spatial considerations in relation to climate resilience. The built environment near coastal areas or under influence of rising sea levels will become increasingly affected by climate change. New developments will occur further away from the coastline, the inland will need to absorb population leaving the coastal areas. In coastal areas both new and existing buildings will be reconstructied or redesigned to be more flood resistant, e.g. by placing energy management equipment at higher floors instead of the basement. • Entire cities need to be climate resilient; large spaces are designated for green and water, e.g. zones for storing superfluous water during severe weather events and for saving water periods of drought, more extensive water protection infrastructure, dikes, etc. Spatial planning will lead to islands of nature in a urbanized landscape in which the distinction between city and rural landscape disappears. These green areas have additional values e.g. avoid urban heat islands, but also provide recreational value. Buildings are integrated in these natural islands e.g. with green rooftops, roof forests and green façades. • The consequences of climate change and the urgency for climate resilience / mitigation play a role in all layers of a building (see also Figure 1). E.g. the skin should reflect heat and withstand drought / heavy rain and storm. At site level, green pastures may help to mitigate heavy rainfall, and the services and space plan should support the optimal indoor conditions under all outside circumstances.	• Inner city nature will gain importance due to the climate adaptation effects it can have on the city's micro climate. We will see new buildings becoming greener on the outside. In renovation, climate resilience (e.g. water management and inner climate control) are recurring principles. Water management will become important in urbanization projects, in terms of both defense and storing water for periods of drought. • Adaptation to climate change is still related to relatively small areas and individual buildings in 2030. New buildings that are planned in the 2020's and in which climate adaptation has been taken into consideration, may take several years to be constructed. Large scale projects, with multiple stakeholders may take even longer. In the decades after 2030 climate resilience solutions will no longer be developed at the level of single buildings and small urban areas (e.g. residential blocks), but will increasingly be part of city planning.	FOCUS ON HEALTH CLIMATE CHANGE

	2050 What does the European Built Environment look like in 2050?	2030 How did we get there? An intermediate stop at 2030	What trends drives this essential? ***See also chapter 3***
CIRCULAR AND DECONSTRUCTABLE	• Buildings have become a series of business models that have changed the way we look at ownership. For example, many elements of a building can be part of a leasing contract and not owned by the primary owner: lighting, elevators, façade, waste management, furniture, plants, etc. • All new buildings will be deconstructable. Buildings are no longer linear in terms of end of life, but circular in terms of end of use. The materials that are used in buildings are registered in material libraries. At end of use these materials can be repurposed. In these material databases, the quality and availability are registered, which stimulates effective re-use in construction. The materials used in the built environment are connected to an 'internet of materials'. Large databases provide information about LCA information of the majority of used materials and transactions can be transparently followed in the Blockchain or similar mechanisms. • Buildings will be modular to the extent that an entire building can be relocated. Modularity may relate to walls, entire floors, elements of the façade, etc.	• In 2030 we start to adapt to the increased volatility of construction material prices. The percentage of recycled content will increase, e.g. secondary granulates, sand replacers and metals. Biobased or renewable materials will benefit from increased focus on circularity, although traditional materials will still form the majority of the used building materials. Legal provisions will stimulate the application of secondary or alternative materials, e.g. through inclusion in standard specifications or in green public procurement. Nevertheless these developments are not yet reflected in the market, as market prices for traditional bulk materials are still lower than those of circular materials. • Stock taking of materials used in buildings, as pioneered today by Madaster in The Netherlands, will be increasingly common practice in construction. BIM (Building Information Management) enables big data storage in as-built models that will accompany the commissioning of new buildings. The total life cycle of materials will be increasingly monitored, but is not fully feasible yet as it continues to be complex and costly in the next decade. • Inventories of old buildings will not only focus on presence of hazards but also on the presence of marketable materials. Deconstruction will increasingly become a mining activity ffor which deconstruction companies will have to pay. • New buildings will be designed to increase their suitability for future uses and recycling. Older buildings will Increasingly be preserved rather than demolished and will adapt new functions. Also late twentieth century buildings will gain a certain heritage value. Because construction materials may already become more expensive due to increasing resource scarcity, refurbishing older buildings will be an attractive economic alternative to building new buildings.	CLIMATE CHANGE RESOURCE SCARCITY

	2050 What does the European Built Environment look like in 2050?	2030 How did we get there? An intermediate stop at 2030	What trends drives this essential? ***See also chapter 3***
ENERGY POSITIVE	• Buildings younger than 2020 are near net zero as demanded by the EU. By the year 2050, innovation and regulation will enable a shift of focus from near net zero to energy positive building. • Buildings will be designed to provide additional functionalities. Buildings will be self sufficient in energy (or net positive) and become a store or buffer for electricity as they are part of an energy grid. • In 2050 the buildings that have been developed in 2010-2020 will be renovated. They need to meet the energy neutral / energy positive requirements of 2050 and energy efficiency continues to be a top priority.	• All new constructions are at least Near Zero Energy Buildings (NZEB) across the EU; it has become mainstream for several years in after mandatory NZEB regulations implemented in 2020. • In 2030 there is a significant stock of near net zero buildings that need maintenance (e.g. replacing photovoltaic cells). Renovation of existing and older buildings needs to pick up speed to be able to meet the NZEB and energy efficiency targets as set by the EU. In the next decade and also after 2030 this is a key priority in the building sector. • The trend is towards energy positive buildings. A large share of buildings will either generate their own sustainable energy, or will benefit from symbiotic systems, for example the use of heat from industrial activities. Energy generation technology will for example evolve towards more flexibly applicable photovoltaic systems that can be better integrated in construction solutions. Both new and old buildings in the residential and the business/industry markets will be provided with energy generation technology. Also, the infrastructure like road coverings or larger projects will be equipped with energy generation technology.	CLIMATE CHANGE

	2050 What does the European Built Environment look like in 2050?	2030 How did we get there? An intermediate stop at 2030	What trends drives this essential? ***See also chapter 3***
COGNITIVE BUILDINGS	• Buildings will be able to provide a custom-made climate to its inhabitants based on a series of interconnected services. This concerns temperature, light, air quality and noise. • Houses will become entirely smart in energy management, will not be dependent on natural gas or fossil fuels and are part of a smart city instead of a single smart home. • Through mobile devices and applications, a building will be able to monitor its inhabitants and collect data about the way the building is used. Data is used for energy management, local climate control, etc. Buildings will also be able to communicate with each other and the equipment and technical appliances in it, e.g. through the IoT. • The availability of rich data about the use and state of a building enables data driven and automated maintenance.	• Buildings will increasingly become a collection of services that are linked to each other. We nowadays see many new systems emerging that manage part of the indoor climate of buildings. These systems will further evolve but are not yet interlinked. • After 2030 these systems will start to integrate as driven by increased demand for a 'one stop shop' and innovations that enable connectivity between previously separated systems.	FOCUS ON HEALTH CLIMATE CHANGE
FLEXIBLE IN USE	• Buildings will be designed to provide flexibility, allowing multiple adaptations of use during their foreseen lifespan. • As a result of cultural evolution and changes in population increasingly dwellings will be units for small family and singles. This increased demand for smaller dwellings can partially compensate a lower demand for housing due to the slower population growth projection.	• Buildings need to offer a flexible space to live, work and enjoy. In new buildings flexibility is integrated in floor planning to provide space for living, working, shops, etc. under one roof. IIn 2030 we will see this flexible spaces in new office buildings, but we see also combined residential and office buildings that provide a series of amenities to its users. In residential areas with family homes, the flexibility is provided by increasingly delivering modular buildings in which owners can design the interior themselves. • Large existing buildings will continue to be separated into smaller dwellings, to cope with demographic trends towards smaller families and more singles. New housing projects will be adapted to meet the needs of an aging population. • Industry buildings will scale down in line with new technology on tailor made local production, and due to a continued de-industrialization of the European continent. Older large industry complexes will need to be reconverted or will be demolished.	URBANIZATION CHANGES IN POPULATION

	2050 What does the European Built Environment look like in 2050?	2030 How did we get there? An intermediate stop at 2030	What trends drives this essential? ***See also chapter 3***
SUPPORT A HEALTHY LIFESTYLE	• Building design and management will increasingly focus on the health of its users. The indoor environment quality (IEQ) continues to be an essential parameter for design and maintenance. • Management of IEQ aims to provide a custom-made healthy environment for each user, based on smart technological solution that follow the presence of users in a building. • IEQ includes all health elements: air, noise, temperature, light, but also refers to the design of floors and furniture to maximise wellbeing and comfort. • Residential buildings will be adapted to home based elderly care and health care.	• Health concerns and concerns about the quality of the secondary materials after the use phase will stimulate phasing out of hazardous substances from the built environment. The REACH legislation is a first step towards an increasing ban on putting materials with specific hazard profiles on the market. • With increased understanding of how air quality, temperature, noise and light influence our health and performance, indoor health is essential for new builds and renovations. Based on the current pace at which technology develops, we estimate that by 2030 health issues will be organized through e.g. smart phones and specific apps that help users to control their own working and living climate. • Separate activities such as massage and meditation require separate spaces in buildings and are offered to employees.	FOCUS ON HEALTH
ENABLING WORKING AND LIVING IN AN 24-HOUR ECONOMY	• Buildings will combine living, working and leisure at one location. Connected communal service areas in which tools, food and care are centrally organized will become the new standard. • Buildings will provide full connectivity to social and professional networks and IoT. High speed connections (internet, Wi-Fi, etc.) will be standard .	• Connectivity is essential in new builds and renovations to provide a flexible working and living space. Due to globalization (e.g. in our working environment), the 24-hours economy will increasingly become a reality: 'the city that never sleeps'	CHANGES IN POPULATION FOCUS ON HEALTH

	2050 What does the European Built Environment look like in 2050?	2030 How did we get there? An intermediate stop at 2030	What trends drives this essential? ***See also chapter 3***
ARE FOCUSED ON PERFORMANCE	• A building becomes a tool to support daily life offering services on energy, water supply, food supply, information supply, recreation, cultural expression, and even biodiversity. All these services will be monitored to enable timely and preventive actions and to make adjustments. • The sustainability performance of a building will significantly determine its value and will be monitored continuously. Product manufacturers provide the verified environmental performance of all of their products. • Buildings performance is assessed based on an holistic framework that may be based on the predecessors such as BREEAM, GRESB, LEED and Level(s).	• Buildings already collect a vast amount of data.[1] Towards 2030 technical possibilities will further improve. At present, many information systems are not yet connected. Internal climate (air, humidity, temperature) can be managed, but is not linked to e.g. lightning, or coffee and paper consumption, desk time etc. Increasing connectedness is expected to result in semi-autonomous buildings in 2030. Only after 2030 full connectivity of these systems and "Internet of Things" (IoT) is expected to become reality. • The IoT will be connected to most technologies, including those fixed in buildings like heating, air conditioning, domotica. The basis for the 'internet of materials' will be established, but in 2030 this is still in an early stage. This nevertheless contributes to monitoring the performance of buildings. • There is a strong focus on the sustainability of building materials. Systems such as BREEAM, GRESB, LEED and Level(s) addresses the sustainability performance of buildings and are strong determinants for the value of buildings. They have become standard for both new builds and renovations. • All aspects of the performance of a building will be increasingly organized in contracts, not only for energy management, but also for other aspects such as lightning, climate control and air quality.	 FOCUS ON HEALTH  CLIMATE CHANGE

3 | THE FUTURE OF EUROPE

The future of Europe is shaped by trends and developments inside and outside Europe. In this chapter we present a look forward into the future of Europe on the back of five trends and developments that shape the European built environment. The identified trends are climate change, resource scarcity, urbanization, changes in population, focus on health. In addition to this we address political demographics. Three essential enablers of these trends and developments are (digital) technology, finance and policy/ regulation. These trends and enablers are explained into more detail in the deep dive in chapter 5.

THE **FUTURE OF EUROPE**

What will Europe look like in 2050? The effects of climate change, demographic developments and resource scarcity will shape the European economy that has transformed into a Circular Economy. Rapid technological advancement, a more sustainable financial sector and a policy framework focused on a sustainable future will strongly influence the shape and speed at which Europe evolves towards 2050.

3 ENABLERS

(DIGITAL) TECHNOLOGY

Europe is fully connected. Its population continuously communicates with its social and physical environment including buildings. The Internet of Things (IoT) autonomously manages many day-to-day aspects of our life and helps us to monitor our impact, performance, health and wellbeing.

FINANCE

The financial sector has embedded the principles of a circular economy and climate change in its criteria for access to finance and focusses on impact investing. The European economy has adopted new business models that have emerged in the circular economy, radically changing the dynamics of our economy.

POLICY / REGULATION

The scope of policies and regulation includes all relevant sustainable topics, from climate change, energy neutrality, resource management to management of chemical use. The successful criteria of current certification schemes have been adopted by legislation and regulations.

CHANGES IN POPULATION

The European population reaches a maximum at about 529 million inhabitants. Aging of the population has seized. The cultural composition changes as more climate refugees seek asylum in Europe.

FOCUS ON HEALTH

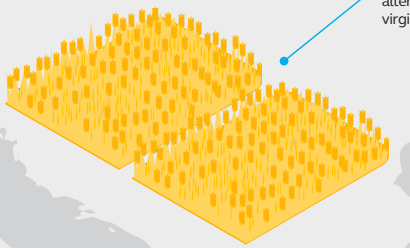
The focus on preventive health measures takes a central role. The environment we live and work in needs to prevent illness and increase our wellbeing. Technological solutions and non-toxic materials are key building blocks for a healthy Europe.

URBANIZATION

European cities have grown due to continued urbanization. Cities have merged and are surrounded by large rural-urban ('rurban') areas.

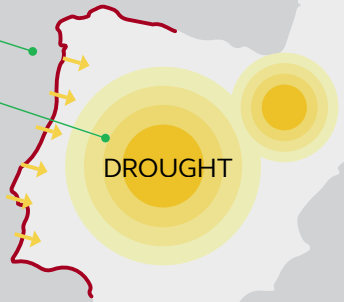
RESOURCE SCARCITY

The European economy has become circular. Europe will increasingly use locally produced biobased resources and apply innovative alternatives for expensive virgin materials.



CLIMATE CHANGE

Europe is confronted with drought, resulting in dry areas with a risk of desertification. In other regions, prolonged and intense rainfall provide challenges for water buffering capacity. Due to rising sea levels, the focus for new rural areas shifts inland.



5 TRENDS

- CLIMATE CHANGE
- RESOURCE SCARCITY
- FOCUS ON HEALTH
- URBANIZATION
- CHANGES IN POPULATION

Our description of Europe in 2050 is shaped by five essential trends and identifies three enablers. These are explained in the table on page 15 -17. We make an intermediary stop at 2030. As the European political arena has a strong influence on what happens in the Member states, we have also addressed the political demographics in Europe, but to a lesser detail level as the trends.

	2050 What does Europe look like in 2050?	2030 How did we get there? An intermediate stop at 2030
CLIMATE CHANGE	• Climate change mitigation influences all sectors. It is the most complex challenge: lowering our contribution to climate change and protecting our society from its consequences. It is one of the key drivers for spatial planning. • In 2050 the effects of climate change have manifested themselves as increased periods of drought, sea level rise, more frequent episodes of intense rainfall. In 2050 efforts to limit global warming to maximally 2° Celsius may have failed or succeeded. Nevertheless we still will experience the consequences of the temperature rise of the past decades. Wet areas in Europe will experience more rainfall and the dry areas will become drier. The south of Europe will experience significant water shortage. • All new production and construction (infrastructure, buildings, products, etc.) need to comply with climate neutrality standards. There is a strong focus on climate neutral building. • The effects of climate change will significantly impact European financial management as a consequence increased incidence of natural disasters, which will impact welfare in vulnerable areas. Climate change adaptation and mitigation are part of criteria for loans and investments.	• Climate change is irreversible and already perceivable in many aspects, although no major catastrophic events have taken place. • There is pressure on the construction sector to achieve energy efficiency targets. Especially the speed of renovating dwellings will be increased by 2030. Renovations should at least have a 75% improvement target in terms of energy efficiency. • Due to continued impacts of climate change in the African continent, the flow of refugees continues.
RESOURCE SCARCITY	• Resource scarcity is a massive challenge. The power infrastructure and storage capacity consumes a vast amount of specialty metals and even bulk materials such as construction sand are expected to become scarce. Scarcity drives prices of virgin materials and stimulates innovative alternatives and the circularity of materials and products. • Most governments struggle to meet their 2050 targets set for circular economy, climate neutrality and biobased production. This may lead to radical market disruptions, initiated by policy, tax and legislation reforms and strongly influences global market dynamics. • Circular economy has taken shape, but there may still be challenges in the availability of circular resources. Nevertheless circularity is integrated in buildings, from the design to the deconstruction phase. • In response to increased scarcity of non-renewable virgin resources, more biobased alternatives are needed. Biobased production will compete with food and feed production.	• Most resources, although increasingly subject to volatile prices, are still available for the economy. Only some materials like antimony are becoming scarce. These niche materials will nevertheless be very important for the development of technological solutions and the recovery and reuse of these metals will be essential by 2030.

	2050 What does Europe look like in 2050?	2030 How did we get there? An intermediate stop at 2030
 **CHANGES IN POPULATION**	• Europe has about 529 million inhabitants, and the population is expected to start decreasing. The composition of the population has taken a new relatively stable form. The aged population is at its highest level. • As a consequence of the aged population and reduced share of young people, the availability of labor forces is under pressure. • When economic growth does not continue or Europe was struck by an economic crisis, there is a huge challenge in providing a pension to retired elderly, possibly driving the retirement age further up. • Europe will experience a constant flow of climate refugees that seek asylum in countries that are expected to provide a better future. These can become a considerate annual contribution to a slight growth or continuous level of the population and can have cultural implications.	• The European population is expected to show negative growth rates related to higher life expectancy and lower fertility rates. The population transforms into a reverse demographic pyramid. • In 2030 the population is at a transitional stage, where the elderly population is still increasing and there is no new equilibrium. The population pressure affects the labor force and the way how we manage finance for pensions and healthcare.
 **URBANIZATION**	• European cities have grown as a consequence of continued migration from the suburban and agricultural areas towards cities. Immigration from outside Europe as a consequence of climate change puts additional pressure on cities. • The rising sea level leads to increasing and eventually unmaintainable costs for coastal protection, cities may be relocated more inland, and de-urbanization of coastal areas will be stimulated. • Rurban (rural/urban) areas will emerge around cities where residential buildings and rural production are scattered throughout the landscapes adjacent to big urban areas. These 'rurban' areas provide food and leisure to the big cities.	• Urbanization will increase with a steady growth of urbanized or rurban (rural-urban). The cities will not yet start relocating towards inward locations because climate adaptation measures are at this point sufficient to cope with the in 2030 expected limited climatic changes in coastal areas.

FOCUS ON HEALTH AND WELLBEING

2050
What does Europe look like in 2050?

- Our understanding of health impacts in combination with health innovations, leads to a focus on preventive healthcare, to keep expenses in check and to meet consumer demands. Preventive health measures are integrated in our daily life.
- There is an integrated approach to health, it also applies to the buildings we live and work in: these should be healthy to live in and provide comfort. City design as a whole will support health, including more green spaces and opportunities to relax. The health effects of climate change such as heat stress in urban heat islands receives special attention as it impacts health in the city.
- Prevention relates to phasing out the remaining unhealthy substances in our living environment, such as air pollution and toxic volatile components. In old and non-renovated buildings and infrastructure there is special attention to removal of toxic components.

2030
How did we get there?
An intermediate stop at 2030

- Health focus is driven by an aging population and better understanding of work related illness. Wellbeing will be higher on the agenda due to pandemic forms of burnout and stress that urge for action, already in 2030.
- Trends such as office spaces with flexible working areas, adaptive furniture, improved climate management, lighting services have become general considerations in new builds and renovations.
- As a consequence of e.g. REACH, and better understanding about the long term health effects of chemical compounds that we use today, implementation of new chemical compounds has become more complex and health effects are scrutinized even more.
- In renovation, the aspect of health is more important and toxic compounds will have to be handled according to more stringent regulation. European regulations will become stricter and applicable to all EU member states. Renovations and demolition may become more expensive when hazardous compounds need to be handled.

4 | A DEEPDIVE INTO THE ESSENTIALS FOR THE FUTURE OF THE EUROPEAN BUILT ENVIRONMENT

The future of the European built environment as described in chapter 2 is based on eight essentials. Buildings will be:

- … climate resilient
- … circular and deconstructable
- … delivering energy
- … cognitive
- … flexible in use
- … supporting a healthy lifestyle
- … enabling working and living in a 24 hours economy
- … focused on performance

These essentials are described in further detail in the following sections.

4.1 CLIMATE RESILIENT

The climate is increasingly changing, temperatures are rising, water becomes scarce and at the same time the threat of floods and heavy and prolonged precipitation is increasing. In response to this the built environment needs to become ready to adapt to major climatological changes. Our building stock needs to become climate resilient. Climate resilience has to be interpreted in a broad way as resilient to extreme weather phenomena, resilient to decreasing biodiversity (contributing to supporting biodiversity), resilient to changing sea levels, resilient to water scarcity, resilient to lower agricultural harvests, resilient to material depletion and resource scarcities; a resilient built environment should be as much as possible self-supplying on materials, energy, water, food and in essence support a microclimate.

The buildings we work and live in will be able to manage large fluctuations in water levels and increased heat pressure but also integrate local food production. New innovations are implemented to collect and buffer large quantities of rain water. Water systems are additionally split up into different water flows. Enhancing green spaces can reduce drought as there is considerable evidence that the suburban/strip mall model of rural development blocks billions of gallons of rainwater from seeping through the soil to replenish ground water. Due to the increased heat in the summer and the high insulation standards, buildings require smart technological applications to provide a healthy indoor climate.

4.2 CIRCULAR AND DECONSTRUCTABLE

The circular economy is about preserving the added value of existing things, both materials and buildings. Therefore, when possible it is preferred to engage in renovation of buildings to save the added value of its existing elements such as its structure. Renovation is especially relevant in economies with a vast amount of existing buildings, such as those in Europe. The circular economy includes: new business models, new ownership structures, a changed way of how we live and utilize buildings, the construction of building and water & energy management.

Buildings are considered as a temporary storage of materials that can be reused at end of life or end of use. Material life time extension, applying biobased renewable materials and especially reusing materials, products and building elements are fundamental principles for new builds and renovations. LCAs will be available for all building materials and eventually also for entire buildings. Cost structures will change to favor circular materials over non-circular materials. Buildings will become more modular to enable extension, to facilitate easy modifications for different utilization and to allow easy deconstruction and reuse of products and materials.

The increased focus on implementation of biobased materials will significantly impact the building sector. For example the building envelope and its construction may become wood based. Biobased materials will be used in the other layers of the building as well (Figure 1). Biobased materials may have become commonly applied by 2050.

Currently the reliability and knowledge of quality management of recycled materials or reusable elements is a challenge. There is limited experience with reusing materials at a wide scale. Investors have not yet developed proper mechanisms to assess the quality and hence value of recycled materials. We do not yet have a proven system that addresses quality management of reused materials or new circular materials. In the next decade we will experience improvements in these challenges and on many levels. 'By 2030 there is over 10 more years of experience with quality management. This may result in a more generic quality management system for circular products, recognized by the entire sector.

Elemental in the transition towards a circular economy are new emerging business models such as service as a product or life time extension models. Where in the linear economy owners possess all elements of a building, in the circular economy a building becomes a combination of various business models. Companies will provide smart technologies for a building, but will remain owner of it, e.g. light as a service. Other companies will change their value chain to include additional services e.g. after production of building elements a company will construct the ‘pre-fab’ elements of the building as well and at end of life will deconstruct and reuse the elements.

Technology is essential in creating truly circular buildings as the state of materials should be monitored to determine when to replace or reuse it. In that respect, it is essential that buildings become cognitive (see also 4.4). The entire lifecycle of materials should be monitored from beginning to end of use and beyond.

4.3 ENERGY POSITIVE

Energy efficiency will be a combination between improved insulation, better (technological) management of indoor climate, the use of renewable energy that is produced on or in the building and sharing of heat through smart local networks (e.g. from excess industrial heat). However, these developments evolve at different speeds, e.g. the development of networks takes longer than the insulation of buildings.

For new buildings the Members of the European Union have agreed to a directive that members shall ensure that by 31 December 2020 all new buildings are nearly zero-energy buildings.[2] In renovation one of the best ways to reduce building energy consumption is by improved insulation of the building envelope. The speed at which insulation occurs, is not sufficient to meet 2050 targets. For example, in the UK, according to calculations 25 million homes must be insulated before 2050. This means that in the UK alone 1.4 homes should be insulated every minute in order to reach an 80% carbon emission reduction by 2050. One third of those emissions are caused by unnecessary heating of poorly insulated houses. [3]

Buildings will become collectors and storage facilities for energy, aiming for a net positive energy management. Rather than being applied to surfaces of buildings and as add-ons, technology will be integrated within the structure of buildings. A building will be a battery and part of a smart grid. In this grid buildings will deliver and use energy. The grid consists of vehicles, buildings and clean energy sources (e.g. solar/wind/geothermal/tidal/hydrogen), which all together form a closed circuit. Materials will be engineered in such a way that they have a cooling or a heating functionality, without the need for energy (natural ventilation, surfaces that have a cooling effect, etc.).

4.4 COGNITIVE BUILDINGS

Cognitive buildings are an integrated approach to the Internet of Things (IoT) concept. The number of IoT devices is rapidly increasing along with new requirements for flexible operation. Cognitive buildings can autonomously integrate IoT devices and learn system and user behavior to optimize performance and to reduce costs. The structures in which we live and work follow us in our day-to-day activities; they learn about us and use this information to improve autonomous management of the environment we work and live in. Buildings will contain a network of sensors that is connected to internet, but also communicates with each other. Think for instance of health care facilities; a cognitive building would be able to identify which rooms have patients in them and subsequently manage the climate in the rooms that are used based on the number of patients. This could increase the wellbeing and recuperation time of patients and decrease the risks of contagion between areas of the hospital. In addition, the building could individually adapt to your preferences regarding energy, climate, food, sound and smell. These cognitive buildings can be connected to each other in order to create cognitive areas. In these areas, buildings can share energy and maximize on energy and use efficiency. In residential buildings smart houses will manage services such as light, locks, video cameras, thermostats, cars, garage doors and track our fridge for stock of supplies. Through communication between our wearables and our built environment we will be able to monitor our health. These smart buildings will also support better fire safety, e.g. through connectivity they are better able to show the best escape route (with smart sensors and dynamic lightning).

Autonomous machine learning can be used for maintaining buildings. Sensors can share information regarding building elements in order to inform asset owners about the condition of their buildings. Buildings will be self-sufficient, be able to self-optimize and will be self-healing, using data from their sensors. These smart solutions can help to lower maintenance costs and save money. The data from these smart, cognitive buildings can be used in the design process in order to develop better buildings, based on user experience of existing buildings.

In 2030 buildings are still operating as single smart units. New technologies are applied in these buildings but do not communicate with other buildings .[4] Exceptions to this are projects in which e.g. energy is shared. Gradually this will evolve into smart cities in which buildings will be connected and communicate on multiple levels to enable sharing energy such as electricity and heat.

4.5 FLEXIBLE BUILDINGS

Buildings will be developed with multiple functionalities in mind: combining working and living areas, retail and services (sports, laundry, etc.). As Circular Economy has become the cornerstone of the built environment, buildings will be developed to provide flexibility for future alternative uses. This flexibility is reflected in all layers of the building.[5] (Figure 1).

- The site should allow for changes in the environment of the building.
- The skin should allow for changes in the looks, structure, material and design to facilitate easy reuse.
- The structure should allow for changes to floor plans, create top-up constructions or subsurface extensions or change the function of the building e.g. residential, office, manufacture and production, distribution or cultural functions.
- The space plan should allow for flexible design of multiple purposes and simple re-configuration. E.g. within office buildings there should be room to discuss, call, relax, brainstorm, etc. The plan should allow for easy changes over time.
- Services such as climate system and sensory building management will provide a flexible management in energy (e.g. only climate control and lightning where users of the buildings are present) and will provide flexibility to tune the environment to individual demands.
- The stuff in a building (furniture, plants, etc.) needs to be e.g. circular, support flexibility of the floor plan and can e.g. be part of service contracts that 'lease' furniture.
- Our behavior may have changed as well, using the different environments in a building to optimally perform and to benefit from the services that buildings offer.

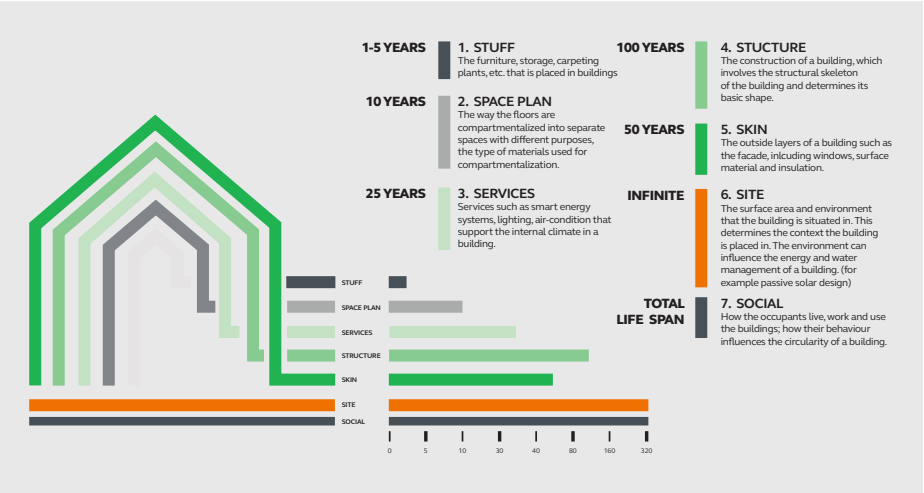


Figure 1 The 7 layers of a building. Building model consisting of six material layers (after Steward Brand (1994) and David Bergman (2011) and a seventh social layer. Each layer has an own life cycle, with different lifespans.

Because of changed composition of the population, with increasing age and more people over 50 years of age, households may become multigenerational. This requires an additional layer for flexibility as within one home different lifestyles may be joint and homes may also have to facilitate a role in health care. [6]

As advanced connectivity with e.g. holo-calls will allow people to work wherever they want, office spaces may become smaller. Instead of providing a space to work, they may become flexible spaces that stimulate social gathering including a setting that provides the freedom to socialize.

4.6 SUPPORTING A HEALTHY LIFESTYLE

Health

Any materials that may cause harm to our health will not be used. If use is unavoidable, there are very strict regulations in place. This applies to all life cycle phases: design, construction, operation and deconstruction. Buildings may also be fitted to foster healthcare at home. With increasing costs for healthcare, limited workforce and increasing elderly population, homecare is economically more feasible.

Wellbeing

In addition to strict prevention regulations related to compounds and procedures, the wellbeing or comfort of users in buildings plays a central role in its design, specifically in the floorplan, and furniture. Wellbeing also relates to multifunctional buildings that provide recreational services such as sports, or adjacent nature areas.

When constructing cost-effective buildings, it is easy to forget that the success or failure of a project may rest on its indoor environmental quality (IEQ) [7]. Healthy, satisfied employees are often more satisfied and productive. Unfortunately, this simple truth is often lost, for it is easier to focus on the initial costs of a project than it is to determine the value of increased user productivity and health. Salary expenses are generally a high proportion of the operational expenses of a building. Even a small gain in productivity, multiplied by the number of employees, can result in considerable savings. Facilities will be constructed with an appreciation of the importance of providing high-quality, interior environments for all users. Many of us have adapted to the indoor realm as our "natural" environment. IEQ encompasses indoor air quality (IAQ), which focuses on airborne contaminants, as well as other health, safety, and comfort issues such as aesthetics, potable water surveillance, ergonomics, acoustics, lighting, and electromagnetic frequency levels. IEQ improvements to an existing building can occur at any point during the use of a building. During the renovation, design and development process, projects need a comprehensive integrated perspective that seeks to:

- Facilitate quality IEQ through good design, construction, commissioning, and operating and maintenance practices;
- Value aesthetic and wellness concerns such as the importance of scenic views or the integration of natural and man-made elements;
- Provide thermal comfort with a maximum degree of personal control over temperature and airflow;
- Supply an adequate quantity and quality of ventilation and intake of outside air to ensure acceptable indoor air quality;
- Prevent airborne bacteria, mold and other fungi, as well as radon, through building envelope design that properly manages moisture sources from outside and inside the building, and with heating, ventilating, air-conditioning (HVAC) system designs that are effective at controlling indoor humidity;
- Use materials that do not emit pollutants, or are at least low-emitting;
- Assure acoustic privacy and comfort by employing sound-absorbing material and equipment insulation;
- Control disturbing odors through contaminant isolation and removal, and by careful selection of cleaning products. Pursue energy efficient strategies to remove harmful odors and recover energy used in conditioning the interior environment;
- Create a high-performance luminous environment through the careful integration of natural and artificial light sources; and
- Provide high quality potable water.

Buildings will foremost provide a healthy environment, absent of disease-causing components. A healthy building refers to both physical and psychological health. Healthy buildings provide an environment in which the user can live and work without any health risks.

4.7 ENABLING WORKING AND LIVING IN A 24 HOURS ECONOMY

We can work anytime and anywhere we want. Buildings will be able to facilitate plug and play connections. Work and private environments are merging, people can order private commodities during office hours and read their e-mail during the weekend. These changing demands influence on the way we use buildings: more flexible and with a focus on communal services such as pick-up spots and drone landing platforms. At the same time the need for physical shops is declining and the remaining shopping areas will become more leisure and service oriented.

With the circular economy fully implemented, the need for small scale local production, and distribution becomes more important to allow for reverse logistics, extended lifelong service, tailor made production, leasing and refurbishment business models. Neighbor communal service areas in which tools, food and care are organized will become the new standard. This will be driven by new technologies like additive manufacturing. Production, retail and consumption will merge into one single location.

4.8 FOCUS ON PERFORMANCE

Rethinking city design can greatly reduce costs over the long term. Building design is part of this revolution, creating circular, buildings with zero emissions. Energy self-reliant buildings are the new standard. The performance of buildings in terms of energy management, the sustainability of the building materials, but also the health of the users of the building and related aspects such as air quality control and temperature control are an essential aspect of design.

Buildings are becoming more than a shelter against outdoor conditions. A building becomes a tool to support daily life offering services on energy, water supply, food supply, information supply, recreation, cultural expression, and even biodiversity. The performance of buildings will have an influence on the performance of the people within these buildings. The value of buildings will become more and more related to the performance of buildings and the way people value these performances.

Building regulations increasingly require an LCA for new buildings, both residential and non-residential. This legislation links the minimum energy performance of buildings with a minimum performance on the embodied environmental impacts of the buildings.

4.9 NEW VERSUS EXISTING BUILDINGS

The essentials of future buildings are both applicable to existing buildings and new buildings. In Europe, buildings are responsible for 40% of energy consumption and nearly 36% of CO2 emissions. To achieve the 2030 and 2050 targets on energy efficiency in Europe and to meet the COP21 Paris Agreement goals, there needs to be a stronger focus on renovation of existing building stock. The vast majority of existing stock is inefficient and will require renovation between now and 2050.

However, the dynamics of meeting targets in e.g. energy efficiency and Circular Economy are different for new builds compared to renovations (Figure 2):

- In new builds each layer of a building (see also Figure 1) can be designed and constructed to meet all required energy standards (e.g. according to the Energy Performance of Buildings Directive). In renovation of buildings this mostly concerns the inner layers (furniture, floor plan and services).[8]
- Renovation typically takes place after 30 of 40 years and must improve a building that was designed according to standards of the past. This may limit the opportunities to e.g. make the dwelling energy neutral or circular. New buildings need to be fitted to the requirements of 2050 and incorporate circular design principles to be fit to take part in reuse of materials after its end-of-use.

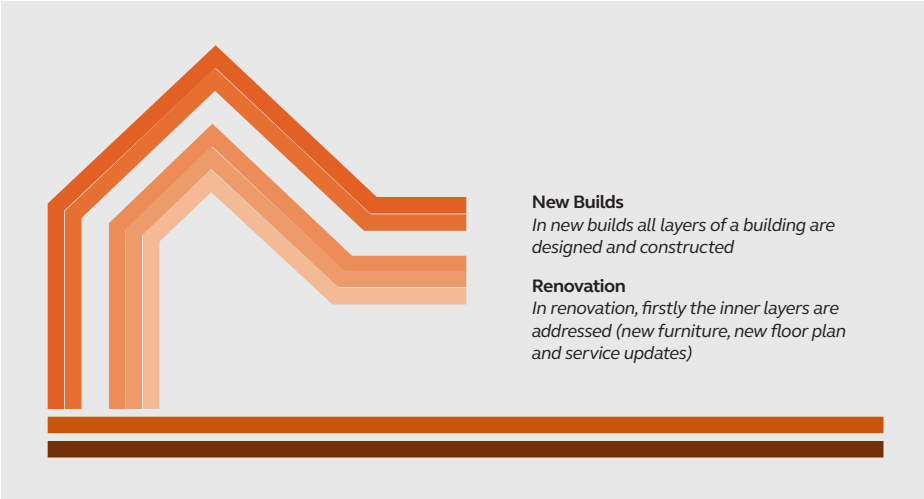


Figure 2: There is a different focus on layers in new builds versus renovation

Renovating buildings allows us to reuse, without loss of added value, of building layers (see also Figure 1) that are still usable in a reused or refurbished building. It will not entail the use of virgin raw materials, and even not of recycled raw materials from other sources. Material transport will be limited. While recycling always leads to energy use and to loss of some of the initial added value of materials reuse 'in situ' does not suffer from it. Renovation is by definition always space neutral, never using greenfields or unbuilt areas, it therefore has nearly no impact on the ecosystem services of the area. Furthermore it saves heritage. The disadvantage of renovation is that some buildings cannot be adapted to the newest standards on e.g. energy efficiency, but this can be traded off to the advantages of renovation.

5 | A DEEPDIVE INTO THE TRENDS AND DEVELOPMENT THAT DEFINE EUROPE IN 2050

5.1 FOCUS ON FIVE TRENDS AND DEVELOPMENTS

In this chapter we elaborate on five trends

1. Climate Change
2. Resource Scarcity
3. Changes in population
4. Urbanization
5. Focus on Health

These trends are interlinked (Figure 3). Climate change, resource scarcity and demographic shifts occur due to their own dynamics and are the most dominant trends in our report. They will sculpt the future society and markets and create the prerequisites of other changes.

The most essential trend is that of climate change. In the near- and long-term future we will have to deal with tangible consequences of climate change in our daily lives. Climate change is a trend that is difficult to influence while clinging onto the current economic model of growth and competitiveness. Resource scarcity will have a large impact on businesses that depend on raw materials. It is a key trend that will be influenced by climate change, but even more is related to our way of living and material use. Changing population, focus on health and urbanization in their turn will experience the pressure of climate change and resources scarcity. Resource scarcity will impact the functioning of the global and local economy.

Urbanization and focus on health are caused by these trends and developments. Trends in urbanization are driven by demographic changes and climate change. Health trends predominantly are driven by demographic trends.

5.1.1 CLIMATE CHANGE

Over 97% of climate scientists have no doubt about the huge impact of climate change and its anthropogenic causes. [9] Regions and countries are now focusing on combatting the effects of it. Extreme temperatures, intensified precipitation or prolonged periods of drought, the rise in temperature in oceans and rising sea levels are just a few of the challenges that are caused by climate change. Climate change dramatically affects socio-economic aspects and wellbeing.

Consequently, Europe has to stimulate mitigative actions and reduce its contribution to climate change. Adaptation to the observed and projected impacts in coming decades is equally important and complementary. The EU strategy on adaptation to climate change supports national adaptation strategies and other actions in countries aimed at mainstreaming EU policies, providing funding and enhancing research and information sharing.

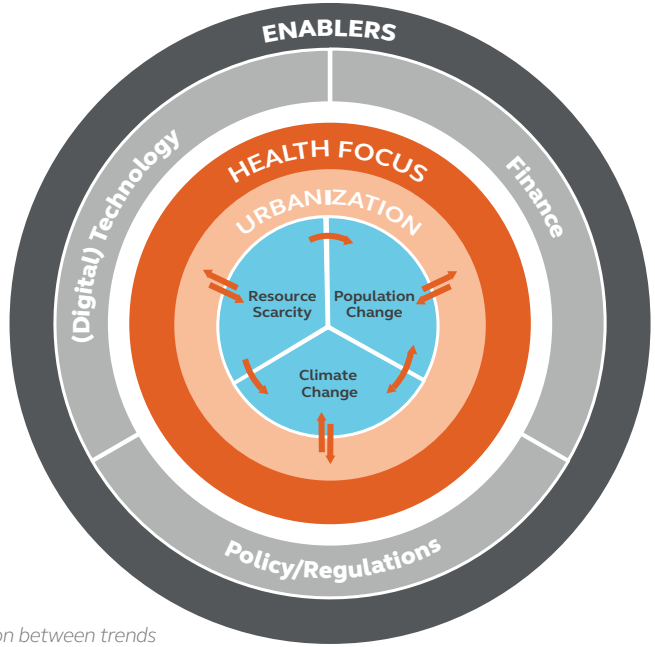


Figure 3: Relation between trends

Climate Change and European energy efficiency policies

The EU has set energy reduction ambitions [10]. The EU's 2030 climate and energy goals encompass a commitment to a 32,5% improvement in energy efficiency and achievement of a 32% share of renewable energy. When the EUs policy framework for clean energy will be updated and approved an GHG emission reduction of about 45% is foreseen by 2030, compared to 1990.[11] Recently, the EU has expanded its ambitions to climate neutrality in 2050.[12] The international energy agency, however, foresees a reduction in primary energy demand in Europe by 2040 as compared to 2016.[13] Globally, however, the energy demand will further increase at an average rate of 3.4% annually. In Europe, renewables account for 80% of new capacity and wind power becomes the leading source of electricity soon after 2030, due to strong growth both onshore and offshore.

Nowadays energy efficiency is a key focus of the residential building sector. The European Union has policies in place that will stimulate energy efficiency improvements at least up to 2030. In the EU reference scenario of 2016, the improvements will slow down approaching 2050, as relevant policies may not be in place or updated to cover this long-time span. This reference scenario projects that technology initially will accelerate efficiency and that eventually the energy use of buildings will be decoupled from its inhabitants as policies and technologies will further drive improving the performance of buildings, irrespective of its inhabitants.[14]

In 2012 the European Union developed the Energy Roadmap 2050.[15] The decarbonization scenario is focused on achieving high energy efficiency and energy savings targets. This requires serious political commitment to implementing regulations and stringent energy requirements such as: more stringent minimum requirements for appliances and new buildings; high renovation rates of existing buildings; establishment of energy savings obligations on energy utilities.

This should lead to a decrease in energy demand of 41 % by 2050 as compared to the peaks in 2005 and 2006. Since 2012, in many occasions the targets have become more ambitious, for example achieving climate neutrality by 2050. This indicates a high level of ambition and in the near future it can be expected that targets may become even more ambitious (i.e. higher ambitions or shorter time span).

Climate change impacts on resources

In the long term, the magnitude and rate of climate change depends on future global greenhouse gas emissions. As agreed globally under the UNFCCC (United Nations Framework Convention on Climate Change), the European Union has committed to limiting global temperature increase to below 2°C above the pre-industrial level. However, the projected rise in global average temperatures over the 21st century is 0.3 °C–1.7 °C for the lowest emission scenario, and 2.6 °C–4.8 °C for the highest emission scenario.[16]

Projected changes in annual mean temperature (left) and annual precipitation (right)

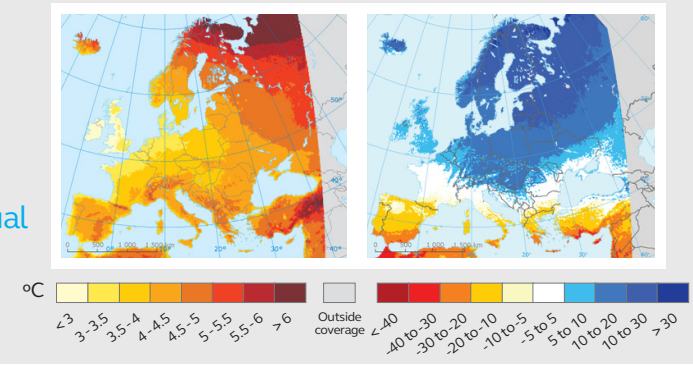


Figure 4: Projected changes in annual mean temperature (left) and annual precipitation (right)[17]

Annual average land temperatures over Europe are projected to continue to rise by more than the global average temperature, with the largest increases in the eastern and northern Europe in winter and in southern Europe in summer. The northern part of Europe is expected to experience increased precipitation while the south becomes drier. This intensifies the differences between currently wet regions and currently dry regions (Figure 4). The intensity and frequency of extreme weather events are also projected to increase in many regions, and sea-level rise is projected to accelerate significantly.

Nevertheless (fresh) water scarcity and drought are not limited to Mediterranean countries. In 2050 in Europe there may even be a water shortage of 40%.[18] Apart from some sparsely-populated northern regions with abundant water resources, this is a growing issue across the EU. Recent studies show that by 2050 most European regions are expected to be under medium or severe water stress – mainly due to unsustainable water use, exacerbated by the effects of climate change. Affected Member States have developed actions and policies to reduce pressure on water resources and restrict water use.[19]

Water shortage will also affect agriculture, reducing yields, destroying entire harvests. Apart from impacting our food production, this will also impact the availability of biobased resources as part of the circular economy.

Sea level rise will affect coastal areas which are often the more densely populated and urbanized areas. Maintaining these urban areas will become more complex and will require investments due to the need for expensive climate change adaptation measures. Some areas might need to be abandoned while new developments will take place in less affected (inland) areas.

Socio-economic impacts of climate change

Climate change may influence socio-economic imbalances in Europe e.g. because of increased coastal and river floods, significant reduction in water availability, and extreme heat events. Studies demonstrate that under a high-emission scenario and in the absence of adaptive actions, some climate impacts would roughly double by the end of this century. Heat-related deaths would reach about 200 000 per year; the cost of river flood damages would exceed EUR 10 billion/year; and every year forest fires would affect an area about 800 000 ha. In this scenario, people affected by droughts would also increase by a factor seven to about 150 million per year, and reduced welfare due to sea-level rise would more than triple to EUR 42 billion/year.[20]

Climate change will also impact migration into Europe, when prolonged drought and increased floods drive locals out of their countries into more promising regions. Europe may experience severe refugee challenges with up to 660,000 additional refugees per year, depending on the forecasting scenario. [21,22] There is a study of the MIT that even argues that some areas in South Asia could become too warm to survive in 2100 and thus become uninhabitable. [23] This could result in massive migrations at global level.

The contribution of buildings in climate change

The European Union aims to decarbonize the building stock, which by 2050 will be the cause of approximately 36% of all CO^2 emissions in the Union. At present, 40% of all energy in Europe is consumed by buildings. The European construction sector observatory has indicated that the residential building stock in the EU Member States is relatively old, with 21,6% built before 1945, 45,4% before 1969 and 75,4% before 1990. [24] It is estimated that more than 70% of buildings older than 50 years will still be in use by 2050. This means that in order to reach the 2030 and 2050 ambitions set by the EU, focusing on highly efficient and new buildings alone will not suit.

An old building stock in combination with a slow renovation rate (about 1% annually), means that the improvement in energy performance moves at a slow pace. The fragmented nature of the sector, ownership and user structures, makes it difficult to improve energy efficiency through policy alone. [26]

Various models developed with the EU CTI model by EURIMA (Figure 5) show that in all routes to achieve net zero in 2050, buildings must make a major contribution. If they fail to do so it will leave a greenhouse gas reduction gap of 10% to 14%. The renovation rate needs to be increased to at least 3% per year with an average energy efficiency improvement of 75% in order to stay on track. This should be achieved in 2030 at the latest. [27]

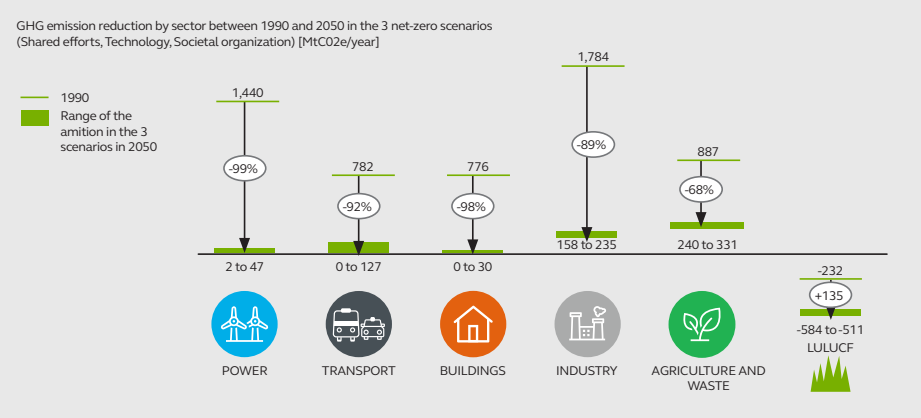


Figure 5: required ambitions across all sectors according to EU CTI model

5.1.2 RESOURCE SCARCITY

Europe will experience resource scarcity

The biggest consumer of raw materials in the world is the construction sector.[28] Primary resources, fossil energy sources as well as minerals and other virgin material, are running out. Several metals will become scarce before 2050, while other are unequally spread over the planet and access to resources will be hindered by political and macro-economic barriers. Europe is a relatively resource-poor continent, largely dependent on specifically Asia and Africa for its mineral resources and energy. To responsibly manage our mining stock we need to drastically reduce extraction rates (Figure 6).

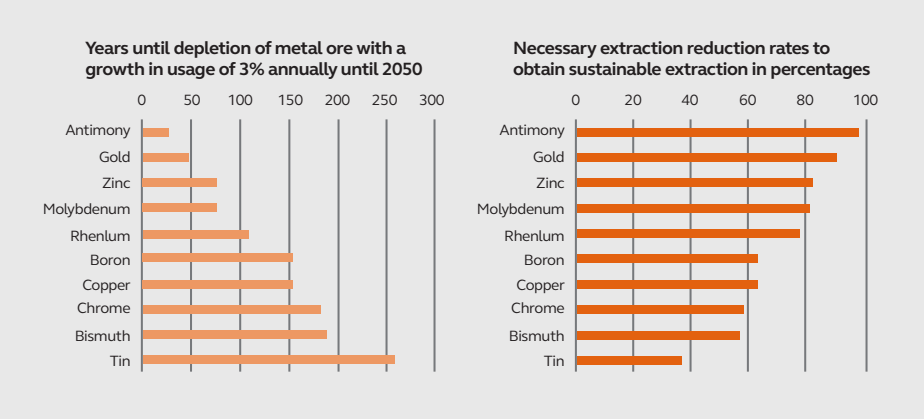


Figure 6: Overview of predictions of scarcity of several metal ores.[29] These graphs refer to winnable stocks, not to proven reserves.

The most commonly used metals in construction are lead, tin, zinc, copper, iron and aluminum. In 2050 primary antimony (used in e.g. batteries) will be exhausted and the world market will depend exclusively on recycled material. Primary zinc and molybdenum (used as alloying element in steel) will be scarce and thus expensive and difficult to supply, other metals will also become critical.

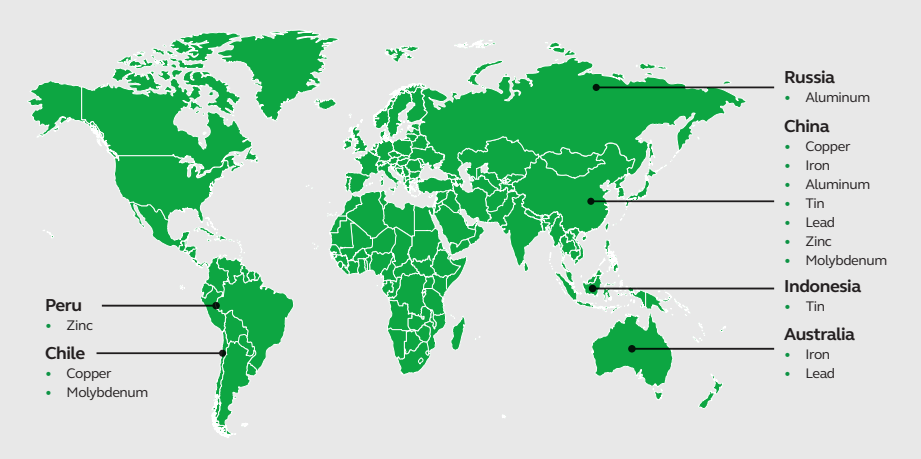


Figure 7: largest production countries of (future) critical raw materials [30]

Figure 7 illustrates where primary resources are being mined and demonstrates clearly the dependency of the European continent on other continents with more primary resources.

Even trivial and locally present resources are running out, like sand used in construction. Sand and gravel are globally extracted and account for the largest volume of solid material. Demand has risen exponentially in the past decades (from 1900 to 2010) and is expected to grow further as emerging economies will increase their construction works.[31,32] Marine sands and desert sand do not have the proper structure to be applied in concrete, and riverine sands are becoming increasingly scarce and difficult to extract. Even the free availability of drinking water may become a challenge with reduced amounts of available water and rising costs to clean the available water.

Because of scarcity alternative resources will be used, preferably renewable resources. Resources will be reused because of their remaining value and secondary resources from urban mining, landfill mining and other forms of enhanced recycling will gain traction. Policy strategies stimulating resource efficiency are emerging via the circular economy package from the European Parliament. More policies are expected when the sense of urgency becomes clear and industry will start suffering from resource scarcity.

Resource scarcity changes world economy

As the World Trade Organization notes, 'as this is a direct quote from a document of the WTO. In a world where scarce natural resource endowments must be nurtured and managed with care, uncooperative trade outcomes will fuel international tension and have a deleterious effect on global welfare.'[33] Insecure access to essential resources and price volatility pose a threat to economic development and living standards. Global commodity prices have spiked repeatedly in recent years, reversing long-term downward trends. These uncertainties and fluctuations in the global economy become a risk for the European economy, that depends on imported resources. The EU uses annually approximately 668 km3 of water (for production, consumption and exports). About 38% is 'imported' (originates outside its borders). The EU economy therefore is highly dependent on the availability of water in other parts of the world. [34]

Environmental concerns about resources further affect the European economy and put pressure on imports.[35] Escalating resource use imposes an increasing burden on the environment, through impacts related to resource extraction, use and disposal. Such impacts will increase if higher prices and growing concerns over scarcity induce countries to exploit sources such as tar sands, or shale oil, that were previously deemed uneconomic.

Growing scarcity and rising prices create strong incentives for investment in research and innovation for exploiting abundant or renewable energy resources. Governments can augment these incentives through ecological fiscal reform — increasing the tax burden on virgin resource use and pollution. Innovation can also alleviate resource demands by increasing efficiency or reducing waste, although such improvements can make products cheaper and stimulate consumption. For these reasons, reducing resource demand often requires a mixture of technological improvements and policy measures addressing consumption. Innovations can increase access to non-renewable or polluting resources. New fossil fuel sources could slow down efforts to boost efficiency and mitigate climate change. In globalized markets, governments may have difficulty correcting market prices and pursuing ambitious greenhouse gas mitigation due to opposition from businesses and consumers. The result would be to delay the shift to cleaner alternatives and greatly increase harmful emissions.[37]

How resource scarcity changes the building stock

Technical applications used in buildings, like domotica (smart homes) and photovoltaic installations (depending on e.g. antimony) will suffer from resource scarcity. But when the resource scarcity expands towards trivial materials like sand, the impact on the built environment may be much larger. Both aspects will drive the building sector to search for alternatives for virgin materials, stressing the importance of circularity. As a consequence, the value of construction material in the existing building stock will increase, and with it the value of buildings themselves. They become a storage of resources in addition to their primary function. Renovation and reuse of buildings will increase because of increasing costs for new builds and new building materials.[38] Research shows however that prices of rare materials have not risen significantly compared to abundant materials.[39] This is assumed to be caused by the short time span that both the market and the mining sector apply to market price predictions. The materials market (e.g. London Metal Exchange) does not look further than a period of ten years and mining companies anticipate a period of about thirty years.

As a consequence both the market and the mining sector do not project scarcity as the earliest exhaustion period of some scarce metals is about forty years. In 2030 we may yet start to experience the first signs of this exhaustion in terms of market prices. It can be expected that in 2050 the increased market price will significantly drive reuse and circular design. This is firstly expected with some of metals used in electronics and in a later stage with bulk materials used for construction. An exception to this is Molybdenum, used for high grade steel that is expected to become scares in a few decades (see also Figure 6).

The role of the Circular Economy

"As Europe is more dependent on imported resources than any other region in the world, moving towards a circular economy is an economic and ecological win-win scenario," Member of the European Parliament Sirpa Pietikäinen said in 2015. The Circular economy (CE) is emerging and driven by the imminent threat of resource scarcity, the demand for sustainable solutions and the necessity to close water, energy and material loops. This economic model will have a significant impact on our day to day operations including the built environment.

The circular economy can be defined as follows:

> The circular economy is an emerging economic model that covers both techniques and business models to keep materials and resources as long as possible, and ideally, forever in a closed cycle of extended use, reuse and recycling. Critical components of the circular economy are industrial symbiosis, share economy, 'product as a service', a close relation between producer and consumer, proximity economics, reuse and recycling, urban mining, detoxification of material cycles and sustainable consumption and production. Opposite to the circular economy are programmed obsolescence, downcycling, legacy substances or loss of added value.[40]

This definition illustrates how resource scarcity is one of the major drivers towards circular economy, but also how circular economy, as a new economic and societal paradigm, is much broader than resource efficiency or enhanced recycling. It is a new way of thinking and of organizing business models and society.

The impact on the built environment can be seen in ten key aspects of circular economy:

The circular economy and the built environment

If the CE would be fully mature in 2050, or a part of the transition towards CE would be realized, this will have following impacts on the built environment[41]:

1. Material use minimization. Compact construction maximizing the volume while minimizing the surface area, low-material usage, opt for renovation over newly constructed buildings, only renew structure layers (see also Figure 1) that need improvement. A building may for example be reconditioned completely, with new outer layers and facades, new space plan and new functions, new techniques, new furnishing while saving the structural skeleton of the old building.
2. Material lifespan extension, avoiding waste streams. Flexible design for multi-functional use, modular components for future refurbishment. When designing a building, the possible future use of all materials and elements is included. Will building and furnishing solutions be able to survive function changes? When elements enjoy a prolonged lifespan they do not, or only later, end up in the waste phase.
3. Reuse, maintain and refurbishment over recycling. The Circular philosophy will always state reuse, maintain and refurbishment over recycling. Secondary resources are to be used within all layers of a building. This business model proposes to implement assembly techniques in the design and construction phase (e.g. bolts and nuts instead of glue) that will improve disassembly and the reusability of materials and products in other buildings. Stock management of reusable components is essential to enhance its future use [42], providing material passports that prevent materials to end up in the anonymity of a waste fraction. Industrial symbiosis can be created between demolition yards and construction sites, within one or multiple companies, transcending different sectors and disciplines to share and exchange data and value.
4. Maximum re-introduction of materials in the use cycles. Circularity in material use means the maximum re-introduction of materials in the use cycles after they have gone through the waste phase. This concept covers the traditional idea of recycling. The business model maximizes at the back end the generation of recyclables and at the front-end maximal absorption of recycled content, acting as a recipient for circular materials. To facilitate circular use in later stages, the use of material passport and stock management is essential for this business model as well.[43] In the design phase material has to be selected based on its recyclability, excluding materials with hazardous substances that remain as legacy substance in the material stock.
5. The application of material use with a high level of lifecycle prospect and the avoidance or limitation of waste in the supply chain (hidden flows). The business model selects materials that are: (1) Biodegradable and regenerative (with a positive or limited impact on water, pesticides, biodiversity and other footprint aspects). (2) From a local source making use of harvest mapping techniques and lean transportation. (3) Recaptured out of the demolition on the site of the new building, maximizing re-introduction of materials. (4) Not originated from traditional mines, but rather from urban and landfill mines. (5) Limited in energy demand within the supply chain generating them. (6) Certified as circular products. (7) Abundant materials instead of scarce materials. Buildings need to be evaluated as a whole, e.g. in LCAs for entire buildings. This takes into account the trade-offs between different materials and alternatives, the impact on the lifespan of the building and its capacity to be renovated, refurbished or adapted and the impact of the materials after demolition.

6. Circularity in business models; product as a service combinations provide a leasing formula or repurchase clause through which the ownership of the materials and products remains with the developer or producer, causing the user to merely pay for the service. As a result, the developer or producer will pay attention to residual value, flexibility and reusability. This may apply to furnishing, (office) furniture, floor coverings, but also on raw materials used for construction materials. Adapted ownership structures must safeguard the availability of these materials for the original owner/developer in a demolition phase long time after the first use of the building. Initially this safeguarding is more relevant for the building layers with a shorter lifespan. In the long term and when combined with big data and detailed stocktaking this may also become relevant for layers with a long life time as long as the information does not get lost and remains updated.

7. Landscape and ecosystem integration; The business model designs buildings that will merge with the surroundings and its biodiversity in natural material cycles, as an alternative for technical material cycles. Apart from using biodegradable products, integration in the landscape and the ecosystems is achieved by choosing no-net-loss biodiversity developments, local/regional vegetation in the public gardens, integrated water management, managed impact and reuse of black(toilet), gray(shower) and rain water, management of the landscape and water supply, limiting noise, vibrations, odor, light pollution and others, integration in the natural or urban landscape, with attention to heritage and experiential value.

8. Industrial symbiosis and share economy. The business model of industrial symbiosis shares facility services, parking, water storage, public gardens, raw material and finished product storage, etc. When acquiring materials from industrial symbiosis, the waste materials of third-parties are used as raw materials for construction projects. The raw materials originate not necessarily from demolition yards (see above) but also from other branches of industry. This may be interpreted as recycling which can be a part of industrial symbiosis; Industrial symbiosis indicates peer-to-peer exchange between companies, both adapting their production processes in co-creation to support each other's needs. This is a different business model than traditional waste collection, recycling and selling recycled materials on the open market.

9. Co-creation and long-term customer relationships: Design in close collaboration with the designer/architect, the construction company and the client or final user. Design in co-creation involves other stakeholders as well, including potential users in the nearby future. Essential in this business model is to carry out stakeholder analyses to improve the wishes and needs of the client or user. It provides a long-term customer relationship between the developer and client or user. The relationship should not stop at the delivery of a building. The system of extended producer responsibility can have an impact on reducing the costs for maintenance and adaptation within the operational/residential phase for the client or user. Lifelong warranty models can ensure maintenance and life prolonging services to buildings in compliance with the needs of the client or user.

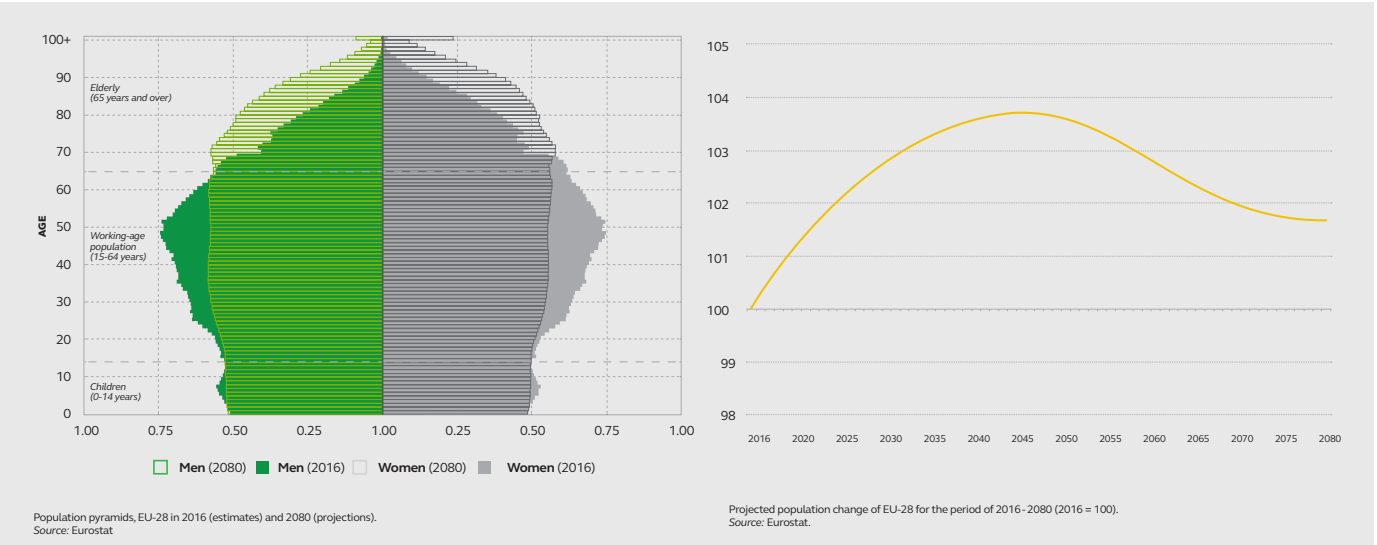
10. Nearby economy: in the general economy the role of producer and consumer of goods will be intensively interconnected, through tailor made production and through leasing, using, renting or repair business models. This requires a spatial restructuring of the built environment from current large and isolated production sites and plants aiming at mass production, to small and nearby production and service spots integrated in the urban fabric. The technology for such a dispersed production is already available, 3D printing for example, but will become increasingly optimized toward the year 2050. The built environment is not ready for such a transition just yet. New functions must be found for the large industrial plants. Moreover, these new technologies need to meet legal requirements and quality standards, which may take several years.

Several initiatives have started to measure the circularity of buildings. The Madaster Foundation, for example, introduced the building circularity index. This index indicates the degree to which buildings are circular.

A governmental initiative in the Netherlands is the 'environmental performance of buildings' (MPG). The MPG is mandatory when applying for a building permit. It is based on LCAs and calculates the 'hidden costs' of materials which are recorded in a national environmental database. The calculation results in an environmental cost per square meter per annum. Ultimately this will be a stimulus to use more environmentally friendly and more reused materials in buildings.

If we would place the development of the Circular Economy in a transition path, we are at the start, where pioneers and innovators explore the opportunities (see also Figure 15). Some developments demonstrate that we are moving towards clustering of promising initiatives and innovations. This may still take a decade before these reach their full market potential. This means that in 2030 the Circular Economy is in a phase where large scale application takes place, but it is not yet fully integrated in our economy. As resource scarcity of bulk products is not yet affecting the market, and biobased production does not yet cover the need for bulk resources, CE still needs to take several steps after 2030. However, McKinsey and The Ellen McArthur Foundation calculated that by 2030 in the built environment in Europe, industrial and modular processes could lower construction costs by 50 percent compared to traditional construction.[48] This is potentially a significant push for CE. Especially where the recycling and reuse of resources and products crosses sectors (e.g. the agricultural needs to produce biobased resources, where in the past most resources were produced by the extractive sector) and new cross connections need to be established, we expect that we'll certainly need until 2050 before the circular built environment has reached maturity.

In addition, we should realize that to create circularity we either need new circular resources (modular, biobased, etc.) or we need a vast amount of recycled resources (e.g. from renovations, demolition and refurbishment). We have to build this circular stock and that will take time. New Circular Buildings will only provide new resources after end of use (when a building has served its purpose). For example: before a façade will be replaced, 30 years have passed. Even if each new build would be designed, built and maintained 100% circular, it could take 3 more decades before resources become available for reuse.



Population pyramids, EU-28 in 2016 (estimates) and 2080 (projections).
Source: Eurostat

Projected population change of EU-28 for the period of 2016-2080 (2016 = 100).
Source: Eurostat.

Figure 8: Overview of changing composition (Source: Eurostat)

5.1.3 CHANGES IN POPULATION

The size of the population

The European population will start decreasing in size approaching 2050. In the next two decades, Eurostat foresees a slight increase in population until the population in Member states reach a peak of about 529 million inhabitants.[49] A declining European population is the result of the lower fertility and birth rates.

In a wider perspective, the world population is expected to stabilize in the long term (11,5 billion in 2100). On the African continent, the stabilization of the growth rate will be at a much slower pace than in Europe. This increasing population could result in an increased pressure on the European border if migration to EU continues, which is not necessarily a given. This pressure can be influenced by global developments like climate change, famine or war but also economic developments. An important note is that the pressure on the shrinking European workforce (e.g. because of relatively more elderly people in relation to the workforce) could lead to developments in migration policies towards 2050.

The composition of the population

The composition of the population changes in age and in economic status. Over 10% of the European population is expected to be over the age of 80 in 2050. According to the UN, older people (65 years and older) will represent 21.1% of the global population by 2050. There will be a growing middle class as inhabitants from emerging economies will increase their welfare.[50] At the same time, the number of young migrants in Europe increases but is strongly influenced by stricter immigration policies.[51]

The aging European population is putting pressure on productivity in Europe [52] and influences public spending [53] and labor shortages. The labor force is shrinking and the number of people using healthcare facilities is rising. [54] The increasing number of pensioners puts an even larger pressure on the working population. In several European countries, this has already lead to an increased retirement age (from 65 to 67 years).[56]

Economic impact of a changing population

All these developments relate to and influence the perspective of economic growth. The growth that is expected between 2018 and 2050 will cover, certainly in quantitative figures, the increasing need for pensions. The aging population can have consequences for the economy. Currently in most countries, retirement costs of workers are paid for by contributions from the current labor force. The entire economic system could suffer from increasing retiree/worker ratios unless pensions are substantially cut and/or contributions sharply raised.[56] For an equal period of 32 years, between 1985 and 2017, the GDP or wealth of an EU member state like France increased from $ 553 billion to $ 2,583 trillion which is a 367% increase. When the benefits of such economic growth could be redistributed evenly, the problem of an aging population doesn't have to become a financial problem.

The aging population leads to new challenges regarding logistics, services, employment and housing. It may also influence the innovation power in societies as innovative companies are predominantly established by younger generations.

Healthcare and pension expenditures will rise, while average saving rates of the aging population will fall. This is caused by an unprecedented stress on both cost and delivery of healthcare to elderly people over 80 years of age. This in turn affects retail demands for commodities, capital formation and the nature of the real estate market. Employment vacancies can appear limited for many younger people as some companies prefer to relocate their main operations to cheap and plentiful labor areas.

5.1.4 URBANIZATION

Although the definitions of urbanization and the way it is measured are point of discussion,[57] the movement toward cities has been steady for the last couple of decades. In the 1950's half of the European population lived in cities; this percentage grew steadily towards approximately 70% in 65 years. In the coming decades this trend will continue and put a greater pressure on the urban environment. Although the pace of this development is slower in Europe than in Asia and Africa, urbanization continue in the coming years.[58] According to the United Nations the projected urbanization in Europe will accumulate to +80% by 2050 (Figure 9).

In contrast to urbanization in Africa and Asia due to growing populations, attractiveness of the urban environment and perceived economic opportunism of urban areas, Europe's urbanization may not lead to bigger or more dense cities. It will however lead to a new rurban (rural/urban) landscape surrounding cities. These areas will increasingly become a fusion between rural and urban areas with no clear distinction between where cities end, and the countryside starts. These areas are also organized in such way to produce food and products locally.

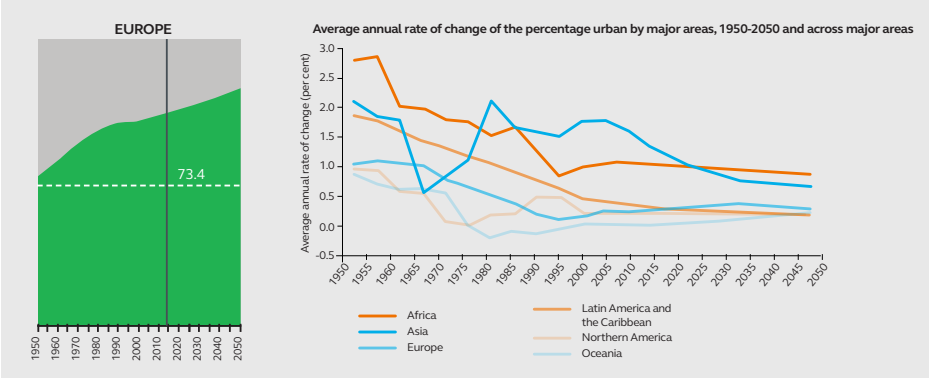


Figure 9: Urbanization in Europe (source: UN ESA, 2014)[59]

The shrinking and aging European population (see also chapter 5.1.3) increases demand for relatively small houses with amenities in close vicinity mostly in small towns and cities. The younger generation prefers living in the suburbs near the capital or larger cities. The latter group will put an increasing pressure on cities and their suburbs.

5.1.5 FOCUS ON HEALTH AND WELLBEING

As our awareness about building related diseases increases, it will become apparent that the way we develop and design buildings, needs to change to provide healthier living and working spaces. Towards 2050 the ergonomics of working equipment, office furniture and working environments will become elemental in design of buildings. We will experience increased focus on the intrinsic performance of buildings and its relation to our health and wellbeing. Poor quality indoor environment is, according to studies, associated with mental health effects, cardiovascular diseases, lung cancer, asthma-related health issues, obesity and productivity loss. [60]

PEOPLE SPEND ON AVERAGE 90% OF THEIR TIME INDOORS

With health we refer to the topic of preventing illness whereas wellbeing refers to our experience of comfort. For example, poor air quality can cause illness and hence impacts our health. Certain color schemes or lightning services may influence the comfort within buildings and hence influence our wellbeing but will not directly lead to illness or can avoid it.

Increased attention in city design

City planners are redesigning for health based on increasing scientific evidence that building and city design directly impact our life and our long-term health. There is more attention for creating greener and more bio-diverse spaces to enhance psychological health and to reduce urban heat islands and heat stress. This enhances physical health. Other measures include introducing light rail transit to reduce congestion (time spent in traffic directly relates to heart disease), changing zoning to reduce pollution (in polluted areas fetus size drops) and rethinking population density zoning and adding green zoning. Green buildings, while costing more initially, enhance productivity. Productivity gains are estimated at 16% and USD160 billion.[61]

Urban heat islands (UHI) have a significant effect on health in cities. Apart from health effects, UHIs lead to increased energy needs (for e.g. air-conditioning) that further contribute to the heating of our urban landscape. Anthropogenic heat production combined with the heat effect is caused by pavements, roads and roofs that are exposed to solar radiation are the main causes of UHIs.[62] This effect is further exacerbated by climate change.

Increased attention to health in building design

The buildings we live and work in are affecting our environment, our physical and mental health, our wellbeing and even our productivity.[63] People spend on average 90% of their time indoors (at home, at work and other indoor places). Almost half of the air we inhale in our lives, we inhale in our own homes. [64] One in six Europeans live in unhealthy buildings. Plus, studies show that in more than 40% of enclosed spaces, people suffer health and comfort complaints.[65]

In interviews for the Buildings 2030 whitepaper the majority (84%) of real estate professionals reported the impact of "health and wellbeing demand of occupiers/policy makers on the built environment" will be moderate to significant in the next 3-5 years. While sustainability has always seemed like a remote concept, health is personal, immediate and affecting everyone right now.

Drawing on existing research, industry efforts, and indicators used by leading initiatives, the four key aspects temperature, light, air and noise are proposed as means to assess the health of a building. Studies have indicated that with better indoor air quality, our productivity can improve up to 8%.[66] Temperature not only influences our comfort, but also influences e.g. the humidity, which is associated with respiratory diseases. Daylight is the key influencer of our circadian clock and hugely impacts our vitality. 65% of europeans who currently live in urban areas are exposed to, dangerously high levels of noise, which lead to various health risks. Each of these topics is described in detail in the following sections.

Temperature

To occupants that spend much time indoors in non-residential buildings, appropriate thermal conditions are vital.[67] One of the main complaints of employees is the thermal comfort of the workspace. Even when quantitative monitoring (e.g. through sensors) suggests that a building is within a thermal comfort zone, individuals may feel uncomfortable due to the location of air vents, internal air velocity, localized over/underheating, or frustration over the inability to control their local environment. Taking all these factors into consideration, it is clear that the "perceived" temperature is key to occupants, more so than that measured by thermometers.[68] Beyond space temperature, the dress code of a firm can also significantly impact the thermal comfort of its staff, leading to different perceptions of comfort for the same temperature level. Temperature management in buildings is related to topics such as insulation, natural ventilation, draft prevention, use of fabrics etc.

Light

Daylight and artificial lighting must be considered to assess appropriate lighting in non-residential buildings.[69] Lightning and illumination levels are measured as described in European Standards (EN). Direct sunlight is the most frequent source of discomfort glare, so appropriate shading technologies must be part of the total lighting design of the building. [70] People also need light to support their biological and emotional needs. Light is the most important influence to support our biological clock or circadian rhythm.[71] Our body does not differentiate whether this light comes from the sun or from artificial lighting. The right light at the right time at the right place improves our mood, has the power to energize, to relax, to increase alertness, to improve cognitive performance, and to improve the sleep-wake cycle of people. The so-called "Human Centric Lighting" supports health, well-being and performance of humans by combining visual, biological and emotional benefits of light.

Air quality

Many harmful pollutants in the air cannot directly be sensed even though they can cause serious health effects. Pollutants generated indoors can lead to a variety of symptoms and health conditions. Volatile organic compounds (VOCs), combustion byproducts and airborne particulate matter are known to trigger nausea, headaches, asthma, respiratory irritation and allergies. While ambient outdoor air is of better quality, natural ventilation methods, operable doors and windows, and general building envelope infiltration can diminish indoor air quality if external air quality parameters are poor. [72]

Poor air circulation in buildings is bad for occupants and may result in a range of symptoms such as sneezing and coughing, sinus congestion, fatigue, headache, nausea, dizziness and irritation of the throat, eyes, nose and skin[73] . Exposure to indoor air pollutants such as VOCs is associated with allergies, asthma and bronchitis, and even certain types of cancer, both to sensitive and non-sensitive groups. Dust is a highly influential factor of occupant health because it may contain large concentrations of unsafe agents such as fabric fibers, allergens (spores, mold, mites, pollen, pets), viruses, chemicals, bacteria, and residues from building materials (e.g. VOCs).[74,75]

Ventilation is essential to bring fresh air inside the building, filter it, and remove pollutants that are either generated by occupants (such as CO_2) or by products (e.g. VOCs). Polluted external air can also enter the building when doors and windows are opened. Adequate filtration and other means of preventing polluted air ingress, or otherwise efficiently removing harmful substances, is an important component of a healthy indoor climate.

Noise

Noise can not only be extremely disruptive, but it can also damage hearing or cause anxiety, distress, reduced concentration and hinder communication. It is also associated with high blood pressure, heart and circulatory diseases. The annoyance from noise is a form of psychological stress that causes discomfort, frustration, distress and irritation. [76] Noise from inside and outside the building can impact building users. Road traffic, aircraft, trains and construction sites can generate unhealthy levels of noise. The building's mechanical systems, such as HVAC (heating, ventilation and air condition), or the presence of repetitive sounds from office equipment, or even group conversations amongst occupants, can also cause discomforting levels of noise. Background noise can be unsettling and increase accidents, or impede employee abilities in simple tasks, e.g. in recognizing speech, but especially in more difficult and complex tasks. Office employees in particular report that ambient noise reduces their work performance and contentment. Exposure to noise raises a range of non-auditory concerns, as it affects the functioning of many human organs and systems, causing higher blood pressure, heart rate anomalies, and hypertension.[77] Plus, noise can result in productivity loss of 8%, according to the Smart Building Alliance. [78]

If you consider the life of a building over 30 years, personnel costs significantly outweigh any other building and operational costs [79]. By introducing health into buildings, we have the potential to reduce personnel costs (health, medical and productivity) in the long run. Studies show that a holistic people-centric renovation of a regular office could increase productivity by 12%, which translate to €500 billion in saved costs at a European scale. [80] Students achieved the same results 2 weeks faster with an optimal indoor climate. With optimal temperature, noise level, air quality and lighting, academic performance could be improved between 2% and 8%. Better indoor environmental quality could cause hospital patients to recover 10% faster on average. With optimal lighting this can be increased by an additional 1%. Average hospital stay could be reduced by 1 day on average resulting in nearly €50 billion in societal benefits.

Increased attention in material use

As we continue to learn more about the impact of building materials on health and wellbeing, the use of toxic materials is expected to decrease. This affects new builds and renovations and concerns production, application, maintenance and removal, in the entire life cycle of a building. Renovations can be complicated by having to safely remove toxic compounds. More stringent legislations may increase the costs for removal and renovation in general. These increased costs and efforts may affect the pace at which we are able to renovate our building stock.

Political and Macroeconomic Evolutions

In his book 'Material Matters Thomas Rau writes [81] :

> "Nobody knows the future, and our predictions are also limited. Those who do not know the future, can only do one thing, take an option. Preferably, of course, an option with a future. What we mean by this is that we will have to shape our actions in the knowledge that the needs from which the action originates are temporary. In a closed system, this means that we have to organize our options in such a way that, afterwards, we get everything we initially needed for them back intact, so that we can continue to take a new option in the future: an option on the future of the future. We must make the most of it with the information we have."

Especially in the field of political and macroeconomic developments we have to deal with these uncertainties. We do not know whether the future within 31 years will be one of progress and continued technological and economic growth, or one of war, scientific stagnation and depend on survival economies. We will have to adapt our actual strategy, leaving as much possibilities open to cope with the unknown needs of an unknown future. This future will be sculpted by the above mentioned trends, but will also be shaped by the economic dynamics in Europe, political decisions and mere fate and coincidence.

For the purpose of assessing possible future political and macro-economic developments, we'll assume that in Europe peace is safeguarded through international agreements. World trade continued although competition on the remaining resources can be harder than today. A certain level of intraregional and interregional collaboration and solidarity counteracts segregational tendencies.

Although largely uncertain, political developments may be a determining factor to describe 2050. Figure 10 contains a framework by Petrella and the group of Lisbon, in which six political scenarios are organized based on the interactions of tendencies towards fragmentation or integration and economic models based on market mechanisms and mixed cooperative mechanisms.[82]

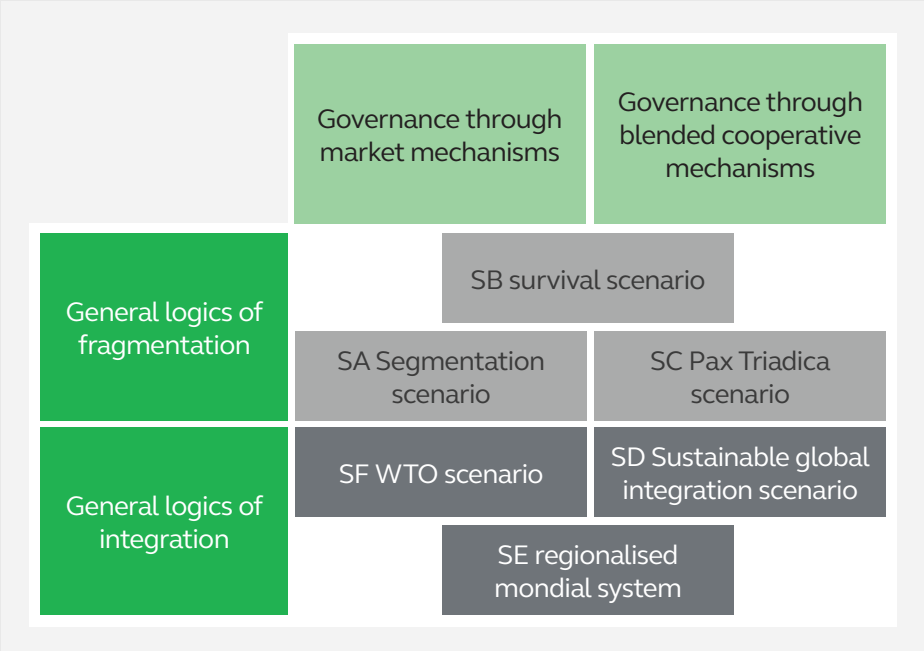


Figure 10: Overview of political scenarios

The SA segmentation scenario and the SB survival scenario

The SA segmentation scenario (see Figure 10) is a situation in which the well-developed high technology cities and regions keep in touch with each other but decouple from the rest of the world. This is a scenario referred to in literature as 'generation Z'; a generation with a closed garden view on the world, a bit paranoid and overprotecting.[83] A worldwide network will keep contacts and exchange between the privileged areas excluding the deprived areas that have to take care of themselves in survival mode.

The SB survival scenario (see Figure 10) applies to a situation in which fragmentation when fragmentation occurs in a fully free privatized deregulated and liberalized market economy, in which the driving force is survival based on out-competing each other. Technology races and technology wars, or resource wars, will destabilize the world economy. The segmentation will occur on a much smaller scale than in SA. In a survival economy the built environment will be based on the leftovers from better times.

In both SA and SB survival scenarios borders and border defense will become important to protect the islands of welfare. Resources will continue to be plundered from the deprived regions.

The SC pax triadica scenario and the SD sustainable global integration scenario

The SC pax triadica scenario (see Figure 10) describes a rather stable economic world order in which northern America, Asia and Europa are kept in balance, and where all three respect the mutual interest of searching for political stability and socio-economic development. The Asian region will be dominated by the giants China and India. World trade and exchange of resources will be continued.

The SD sustainable global integration scenario (see Figure 10) is as extreme as the SA segmentation scenario, but ruled by principles of global commons, human solidarity, fair division of welfare and universal tolerance. Collaboration and co-creation will be used to face global challenges like climate change. This scenario is based on an equal and fair redistribution or the scarcer natural resources and ores. A shift from competition economics to collaboration economics may occur.

The SF WTO scenario and the SE regionalized Mondial System

The SF WTO scenario (see Figure 10) shows an integrated world economy based on regional integrated unities modelled to the example of the European union, globally combined by strong UN bodies and international institutions like World bank, IMF and WTO.

Finally, the SE regionalized lower capital mondial system (see Figure 10) represents a replica of the EU free market model at a worldwide scale, with strong institutionalizing of the world economy.

In both SF and SE scenarios, the access to scarcer resources for Europe will depend on its economic strength and its competitiveness with other economic collaborations.

What the future may bring…

As indicated, we do not know which of these scenarios will substantiate, or perhaps a combination of these scenarios will arise. We may hope for the best, but we should already include sufficient precaution in the way we develop our built environment today to cope with the unknown future needs of any possible scenario. Circular Economy and safeguarding the value of materials is a good way to cope with an unknown future.

It is probable that future will be dominated by one or more of these models, while still showing characteristics of the other models in specific aspects. We may expect shifting international relations to have an impact on the availability of resources, making resource scarcity a more stringent problem for regions without own natural resources (SC, SF…). Housing may be more protected, with enclosed and secured compounds with controlled access and universal camera protection (SA, SB…). At business level however collaboration and co-creation and a shift from a competitive economy towards a collaboration economy may be the answer to future needs (SD, SE …).

And if we have a look at 2030 and 2050

By 2030 political and macroeconomic developments may be driven by a tendency towards populist solutions and street revolts made possible by the new media, but the old structures and the old relations between blocks or power may still remain untouched, with India following China in becoming a world political player at the expense of Europe and northern America. In 2050 the global balance in the market economy has drastically shifted towards huge economies such as China and India and a handful of African countries that have experienced a successful economic burst. In this arena Europe will struggle to remain independent of other economies in the provision of resources and labor force.

5.2 ENABLERS

We have identified three enablers that essentially follow the development in trends: technology, finance and policy / regulation. These enablers accelerate developments and stimulate progress or provide rules within which the trends can further develop. Below these enablers are explained in more detail.

5.2.1 (DIGITAL) TECHNOLOGY

Our society is increasingly technology based. Information Technology (IT) enables us to create, follow, mine and interpret large quantities of data and provides better understanding of complex systems. We are better in understanding where materials are produced, traded and originate from through technologies such as blockchain. We will experience increased transparency in the public and private sector, as information about organization performance including environmental and social aspects becomes readily available. These may also radically impact markets and (re)distribution of values in supply chains. Artificial Intelligence (AI) allows us to 'outsource' increasingly more complex tasks. Large sets of data can be analyzed using AI applications, and AI applied in robotics can replace manual labor. The internet of things in combination with AI allows us to measure and adjust the building to the occupants needs and preferences (such as light level, air ventilation and temperature). This ensures the energy use is constantly optimized. Monitoring will also allow for optimizing occupancy levels throughout the working week and help inform building managers on the efficiency of space utilization. This can in turn be used for optimizing the current building or the design of a new premise with a lower physical footprint.[84] After the development of the internet of things, the "internet of materials" - a next step in technological evolutions - will allow precise stock taking of materials present in e.g. the built environment, allowing more efficient exploitation of the urban mine when the traditional mines get exhausted.

Material innovations, such as light weight construction materials or biobased materials radically change constructions. Innovative materials will change the way we construct and design buildings (e.g. through 3D printing).

Related trends & developments

The enabler technology describes a combination of various other trends and developments that are linked to each other, reinforce each other and depend on each other:

Trends and developments	Explanation
Artificial intelligence	Artificial intelligence relates to the study of computer software that will be capable of making intelligent decisions, with reasoning and problem-solving capacities.
Block Chain / supply chain transparency and traceability	Supply chain transparency: being able to trace products and resources to the primary production facility or location. Blockchain is a new record-keeping technology that allows digital information about transactions or purchased to be stored in a block that is added to a 'chain'. It is designed so that everyone can have the same information at about a product or resource all times. It will change the way how we can e.g. trace back a source of materials.
Building information modelling (BIM)	Connected systems of sensors, intelligent machines, mobile devices and software applications will be integrated in buildings. These systems are part of the digital building information modeling (BIM). Information management is expected to become much more efficient. According to the Boston Consultancy Group global cost savings are estimated at $0.7 to $1.2 trillion within 10 years after full-scale digitalization in nonresidential construction.[85]
Connected buildings / SMART tech	Connected buildings refers to an approach in which various buildings or building systems are connected and controlled via a single operating system. The connectivity is based on advanced technology that controls and monitors the performance of a building.
IoT in buildings	The Internet of Things (IoT) is a network of sensors, devices, appliances, processors that can communicate autonomously (receiving and sending data). This network is expected to affect every aspect of a building, from construction to use and deconstruction. to management. The use of IoT in buildings has been growing 20% per year and helps helps to manage energy more efficiently, monitor the health of a building and the health aspects within a building such as lightning, air quality and temperature.
VR/AR technology	Virtual Reality and Augmented Reality will influence the way we will design buildings. Digital 3D modeling will allow us to visit the buildings before the start of construction.
Flexibility of labor	With plug and play office equipment, fast internet, mobile appliances and increased security protocols we will be able to work wherever we want to work. Communication technologies such as holographic representations will enhance working from remote locations and could alter the way we look at living and working space.
The internet of materials	The internet of materials is a step further in the evolution after the internet of things (IoT). This will allow precise stock taking of materials present in e.g. the built environment, allowing more thorough exploitation of the urban mine when the primary mines get exhausted.

5.2.2 FINANCE

Finance is a key enabler and essential driver for change. The built environment has always been an investment opportunity and remains so as it provides a relatively secure value for investors and lenders. As the financial sector focusses on quick returns and solid risk management, innovative approaches need to prove themselves to become relevant for financial support. Public sector financial support mechanisms such as subsidies or revolving funds can drive essential innovations, help organizations to scale up and stimulate sustainability initiatives.

Not all actors are aware yet that the monetized co-benefits of energy efficiency in the building sector far outweigh the investment requirements. Apart from their environmental impact, energy reduction policies and measures in the buildings sector: improve the quality of air and of indoor thermal comfort, reduce risks related to health and resource availability & boost energy security. Multiple sources [86] show a monetized co-benefit of two to three times the required initial investment, based on scenarios with 33% to 45% energy efficiency and renewable energy targets by 2030. In a 2050 timeframe, the benefits are expected to be significantly higher. Investments may result in indirect benefits such as improved health or avoided environmental damage.

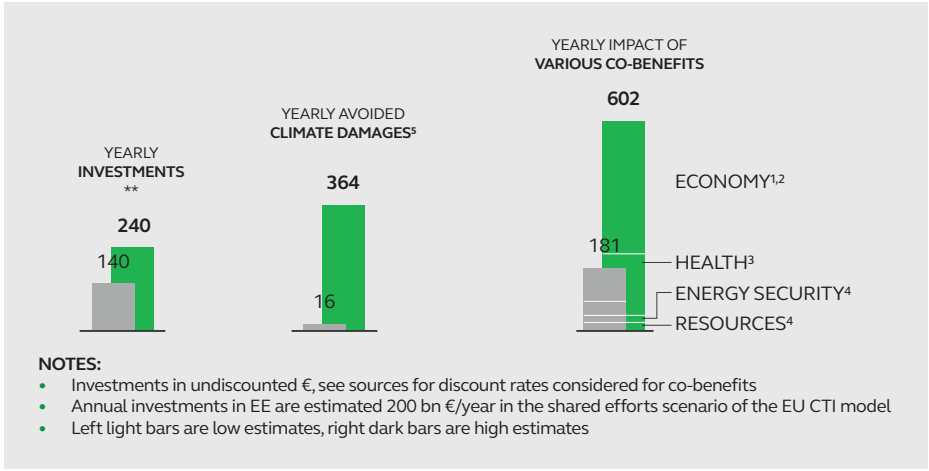


Figure 11: Investment costs and monetized co-benefits of energy efficiency measures [87]

The European Union recognizes the financial sector as a driving force for a sustainable building sector. It developed an action plan on financing sustainable growth [88] and adopted three legislative proposals to:

- establish a taxonomy on sustainable economic activities,
- improve disclosure requirements related to sustainability risks and opportunities
- regulate benchmarks for low-carbon investment strategies

The objective of the action plan can be summarized as: (1) improving the contribution of finance to sustainable and inclusive growth by funding society's long-term needs and (2) strengthening financial stability by incorporating environmental, social and governance (ESG) factors into investment decision-making.

Towards 2030 this action plan will be executed and together with EU's Capital Markets Union (CMU) project[89] , may influence significantly how the built environment will be financed and what sustainability requirements need to be met in order to access finance.

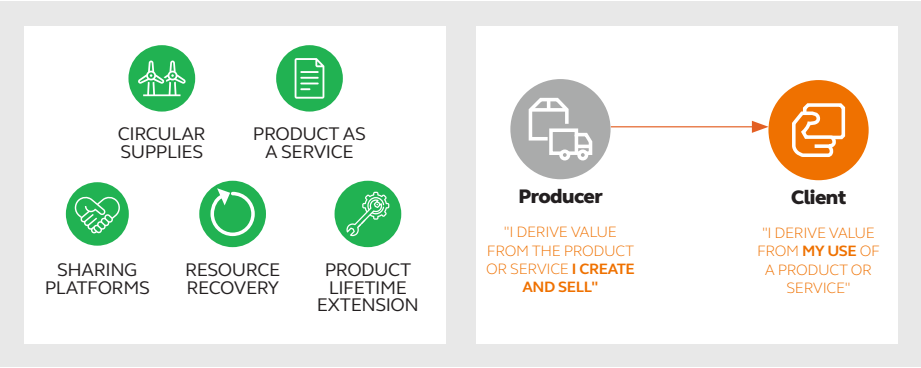


Figure 12: the emerging business models in the circular economy (left) and the linear and traditional economy (right)

We see a shift in new business models from the linear business models to customer centric business model. The conventional business model dictates that products and/or services are created and sold by a producer or re-seller to a consumer or business costumer. Only the products /services have inherent value. [90] These types of business models emerge in the circular economy as displayed in Figure 12 and are emerging in the Circular built environment. They can be defined as follows:

- The circular supplies model focuses on material use minimization and the application of life cycle thinking on materials. To reduce the consumption of raw materials, use non-toxic high-grade materials that can be reused and recycled or to produce renewable materials.
- The product as a service model focuses on circularity in business models. To deliver a service instead of a product and retaining ownership. This allows monitoring and staying in control of raw materials.
- The product lifetime extension model focuses on material lifespan extensions and avoiding waste streams & preferring reusing, maintaining and refurbishing over recycling. To maintain and extend lifetimes through smart maintenance, repairs, renovation and upgrades.
- The sharing platform model focuses on industrial symbiosis and sharing economy, co-creation and long-term customer relationships. To combat underutilization or surplus capacity by sharing products or assets and optimizing their use.
- The resource recovery model focuses on circularity in material use and the extension of producer responsibility. To use waste from used products and resources and process to make new raw materials and products. [91]

Buildings are increasingly owned or financed by a limited number of large players, at the expense of private or small property owners. By 2050 some big consolidated players may remain. This trend is similar to what happened in worldwide food production in 2018. These big property owners may originate from countries such as China that heavily invest in the European built environment. [92]

Related trends & developments

The enabler finance describes a combination of various other trends and developments that are linked to each other and reinforce each other:

Trends and developments	Explanation
New business models	New business models will arise, stimulated by the emerging circular economy that requires a different way of how we organize business. In the circular economy, five new models are identified: Circular supplies, Service as a product, Product lifetime extension, Resource Recovery and Sharing platforms. [93]
Broader scope of sustainability criteria for access to finance	In line with new business models, financial institutions (FIs) will develop different financial products that are based on risk models that include sustainability. Social and environmental impacts are included in criteria that FIs apply to their financial products. In the past decade methods were developed to calculate true costs, providing insight in the external or shadow costs of products. These calculations will become more common up to 2030, but it is uncertain to what extend the understanding of external costs, will lead to a different financial system in which the external costs are included in a true price, paid for by the private sector and the end consumer.

5.2.3 POLICY AND REGULATION

Policy and regulation at local, regional and EU level drive the market. They provide the legal frame in which innovation can be developed. The European Commission has developed several new initiatives to stimulate the built environment to become more sustainable. Figure 13 provides an overview of relevant European regulations and directives that define the outline of the European built environment.

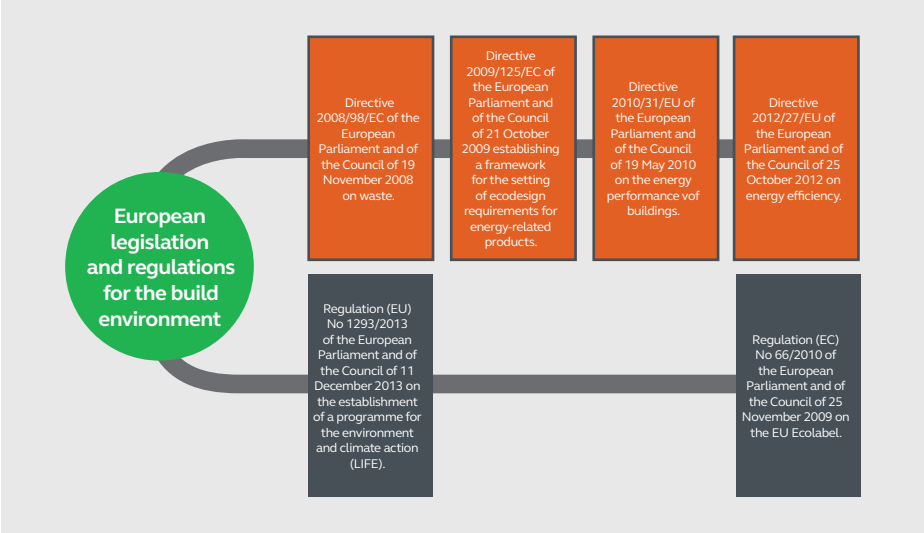


Figure 13: Overview of relevant European regulations and directives [92, 93, 94, 95, 96, 97, 98 and 99]

Nevertheless, the speed of innovation exceeds the speed of policy and regulation development. As a consequence, policies and regulations can become a barrier for innovation. Usually policy is a follower, observing societal or economic tendencies and regulating them afterwards. For the first time in the history of societal and technology transitions, the transition towards sustainability and climate resilience requests policies to be the driving force of the societal changes, because the short or medium term mechanisms of growth and competition will not be able to evolve in time.[100]

In order to speed up the transition towards a sustainable and more circular construction sector the European commission has developed the Level(s) framework. This framework provides a set of common indicators and metrics for measuring the environmental performance of offices and residential buildings.

The framework takes the complete life-cycle of buildings into account focusing on[101] :

- Greenhouse gas emissions
- Resource efficiency: Bill of materials, design aspects, LCA based assessments, impact indicators
- Water use
- Health and comfort: good quality indoor air, target list of pollutants
- Resilience and adaptation: Simulation of the building's projected time out of thermal comfort range
- Cost and value: Reliability ratings of the data and calculation methods

The level(s) framework aims to help real estate and construction stakeholders to reduce the environmental impacts of the buildings they build, occupy, invest in and design. This is done by implementing a reporting framework that links the buildings performance with European policy objectives. Level(s) is recognized as a promising initiative that works towards much needed alignment. As such it can become a leading framework in the next decade and influence standards such as BREEAM, WELL Building and LEED. The framework will be tested until end of March 2020. It is yet unknown when it will be effective but it can be expected that it will be a relevant framework in 2030.

Trends and developments	Explanation
European policy to move towards circular economy	Circular Economy is increasingly recognized as an inevitable future model for our economy and policies are developed that stimulate it. With its circular economy action package[102] the European Union aims to stimulate the transformation of the European economy to a more sustainable one.
Call for a robust policy framework	Especially the private sector calls for a consistent, long term and robust vision and policy framework in relation to climate change and sustainability to help the sector plan and make long term investments in a level playing field (in Europe)
Increasingly stringent regulations for the application of unhealthy substances and improved enforcement.	With REACH and increased understanding of possible health effects of existing and new substances, European legislation becomes more stringent for the application of substances. Longer and more complex administrative and testing processes require additional efforts and resources before substances are allowed in the market.

As shown in Figure 14 the reaction to changing conditions may be of a disruptive nature. We can assume that persistence of actual business models and societal and economic conditions will continue during the earlier stages of a change of external factors, until this cannot be sustained anymore and disruptive changes occur suddenly. This can happen when more catastrophic events urge society into change. We assume that they will take place after 2030 as many trends will need time to mature. Also, enablers such as the financial sector, are expected to take at least a decade before their experience with e.g. circular economy and climate change mitigation has become mainstream. For example, the debate on the threat of climate change has been going on for at least 20 years, but only now are starting to see wide scale adoption and exploration of the topic in e.g. lenders criteria.

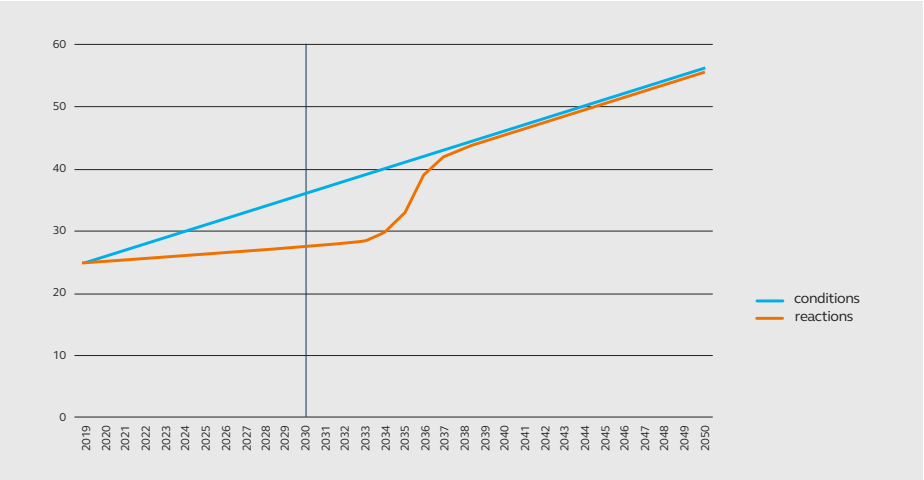


Figure 14: Disruptive nature of actions that follow linear development of conditions

6 | REFLECTION

This report has identified 5 relevant trends and developments that we consider to shape the European built environment in 2030 and 2050. The identification of these trends and the description is based on a wide variety of sources. Whether trends will develop in a way that we foresee at this moment…who can tell? The past has shown us that we may not be able to fully grasp the importance of new developments for our future. How can we use our current understanding of developments and extrapolate these into the future? In this final chapter we provide a reflection on the presented trends and the description of the European built environment in 2030 and 2050.

6.1 THE EUROPEAN BUILT ENVIRONMENT IN A GLOBAL AND BROAD PERSPECTIVE

The trends and developments have a huge impact on the built environment as a physical derivative of socio-cultural and economic developments. In light of this report, this concerns the way in which the built environment can or will respond to these developments and what the consequences are. In other words: how the supply side must respond to the demand side.

On the demand side, urbanization, globalization and a changing demography lead to a changing and dynamic demand for buildings. Technological innovations are needed to comply with the demand for improved performances. However, the core uncertainties are complex, dynamic and dependent on other global developments. Consider, for example, the influence of climate refugees or migrant workers as a result of climate change and a declining workforce in the EU. But also, the EU's economic position in the world with a declining workforce and a dependence on import of (raw) materials for economic development.

Core uncertainties include geopolitical stability versus global tensions, individualism and polarization versus collectivism and social cohesion and last government regulation versus market regulation. This increased uncertainty about the direction of socio-cultural and economic processes is closely linked to the complexity of modern society as a global system in which everything is interconnected and interferes. Changes in complex societies do not always take place linearly and gradually, but also abruptly and discontinuously.

On the supply side there is more certainty in the sense that the real effects of climate change and resource scarcity are indeed not predictable, but it is clear that -driven by among other things laws and regulations on- climate adaptation and circularity are setting emphatic demands on the built environment. These developments require huge investments, particularly in the existing built environment and entail a major financial issue.

We see an increasingly changing, dynamic and unpredictable demand to a relatively static supply. The changing demand is of a qualitative, quantitative, technical and financial nature. It requires on the one hand increasing flexibility, adaptability and facilitating user demands with technology to meet changing, dynamic and unpredictable demand and on the other hand (climate) resiliency and circularity to respond to climate change and resource scarcity. Technology and sustainability in all aspects become critical factors for the (value of) the built environment.

6.2 THE DYNAMICS BEHIND TRENDS IN THE BUILT ENVIRONMENT

Some considerations can help to understand the dynamics behind trends and to make it more tangible. These are explained below.

The building sector is relatively conservative

The uptake of new innovations in the building sector has been rather slow in the past decades. [103] New trends have a slower uptake in this sector as compared to other sectors. In determining when a trend will be effective, we may have to take 'lag time' into account in our future predictions. The building sector is a project driven sector with a relative short time focus. R&D requires a long-term investment and time span. This conflicting dynamic can explain slower maturity speed of new developments in this sector.

Furthermore in most western markets the sector is characterized by a high degree of fragmentation. Fragmentation slows down innovation as in all the separate fragments there are less resources available that stimulate innovation as compared to big clusters of e.g. companies or large development sites.

Transition takes time and evolves in steps

Transition may take a long time and can be modelled according to a transition path. A possible path is that of Lucas Simons about sector transitions.[104] In the first phase of the sector transition model (Figure 15), awareness of a topic emerges and pioneers explore new solutions. In the second phase early adopters copy successful solutions and competition emerges. In the third phase collaboration at sector level occurs and first steps towards development of legislation are taken. Finally, in the last phase, the topic is institutionalized, creating a level playing field.

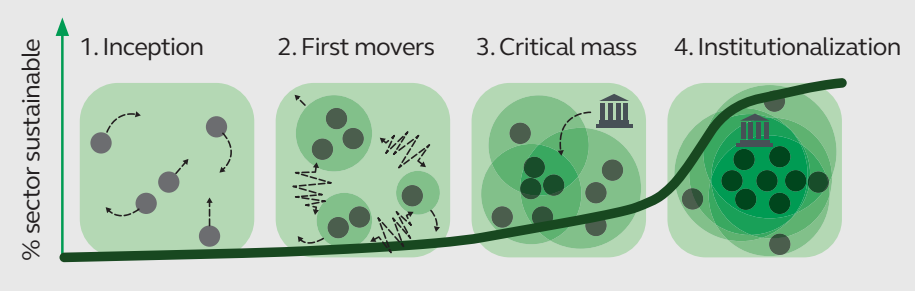


Figure 15: Sector transition model of Lucas Simons

Trends or sub trends follow the transition path. It helps to understand the current phase in which the trends evolves and what can be the next steps. These paths can take several decades to fully mature, for example depending on the complexity of a sector or the level of urgency of adaptation.

Disruptive forces can be unpredictable and move at an unforeseen pace

Climate change, especially if global warming crosses the point of no return at +2°C heating, can have devastating impacts and results in demographic disruptions and resource scarcities. Disruptive changes strongly influence the transition speed towards e.g. the circular economy as the level of urgency is a key driver of transition. The described trends and developments, in chapter 5, are large, fundamental and disruptive forces that bring about enormous changes. These trends do come in a linear form but at an exponential pace. This makes the impact of the change bigger than ever before. We see the disruptive effect they have (e.g. changes in climate, technology and demography) and although we know that these changes continue, the actual impact and the effect are incomprehensible and difficult to predict.

Different speeds within the build environment (e.g. in building layers and enablers)

A high degree of fragmentation in the sector leads to different speeds in uptake of trends. Fragments can move at a different speed e.g. residential buildings versus office buildings. Subsectors that are characterized by high turnover rates and short lifespans are more flexible than subsectors that build constructions with a long life span. Also, within buildings, amongst the different layers the pace at which changes take place may differ. E.g. the use of sustainable materials may be further developed in constructions, whereas this may take some years in furniture. Where energy efficiency is a key driver for innovation in the services layer, it may take some time before this also reaches the same level of awareness in the other layers.

Policy is a push, but is also slow

Policy can be a strong driver for e.g. market uptake or to create a level playing field. However, development of new legislation or regulation takes several years, and policy has the tendency to lag behind on new technologies. As demonstrated in Figure 15, institutionalization in which regulatory uptake takes place is the last phase in the transition process. Legislation can be perceived a barrier for development and uptake of new innovations. E.g. in the application of circular solutions existing legislation can be a barrier. In its report about barriers for innovation, the European Union mentions that the construction sector associates barriers with product safety regulation, environmental protection and labeling. [105]

Differences within Europe lead to different speeds of implementation

Difference in amongst others budgets, supporting services, culture, professionalism in population and governance have a strong impact on the speed and extend to which trends and developments spread throughout Europe. This applies to differences among countries, small and large cities, rural and urban areas and different cultures (also within countries). There can be a difference of several years between e.g. urban and rural areas before new technologies are equally spread. An example is the rate at which glass fiber is implemented in a country, in general starting in big cities and in a later stage also in the rural areas.

6.3 HOW TO MAKE IT MORE TANGIBLE?

Trend watching comes with uncertainty. Nevertheless, using the forecasts of what the future may behold needs some concrete actions to be able to develop long term strategies. In this section we provide some suggestions for actions.

A roadmap as a living document

A roadmap is one possible approach to map the actions that are needed to reach a certain milestone or target. In a roadmap the trajectory with intermediate steps is explained in more detail. The roadmap can e.g. use the vision on 2030 or 2050 as a milestone or focus on specific trends or essentials of the built environment as depicted in chapter 4 and 5.

Once a roadmap is created it is essential to integrate evaluation moments in the roadmap to assess the current state of developments. This helps to identify whether the trend is still developing in the foreseen direction and at estimated pace or that the action plan has to be adjusted to alterations. The roadmap is a living document that provides guidance, and may need regular updates to keep on track.

Monitoring trends is essential

As trends are interlinked, as we do not understand the full effect of disruptive forces, as enablers can become barriers and vice versa, it is essential to regularly monitor what directions trends take and at what speed transition pathways evolve; the uptake pace of trends.

Single issue scenario development

In this report we have described the future based on a combination of trends and developments. To explore how the various trends develop and their influence on the built environment, scenario's may be developed based on a single trend. Possible topics could be:

1. What would the European built environment look like if it was entirely digitalized?
2. What would the European built environment look like if it was entirely circular?
3. What would the European built environment look like if it was entirely focused on health?

Scenario development can be very complex and requires an approach that identifies e.g. drivers, barriers, relevant stakeholders and their roles and a time span. Interconnectivity between trends needs to be explored to see how trends mutually influence each other.

COLOPHON

THE FUTURE OF THE EUROPEAN BUILT ENVIRONMENT
A FORWARD-LOOKING DESCRIPTION OF EUROPE IN 2030 AND 2050

AUTHORS
David Thelen, Freek Wullink, Mike Van Acoleyen, Victor Pastoor, Maarten Thijs

GRAPHIC DESIGN
Francesca Aguilos

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Arcadis Nederland B.V.

P.O. Box 264

6800 AG Arnhem

The Netherlands

+31 (0)88 4261 261

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