A LIFE-CYCLE PERSPECTIVE ON THE BUILDING SECTOR

GOOD PRACTICE IN EUROPE

GOOD PRACTICE REPORT

APRIL 2022

INTRODUCTION

Integrating a life-cycle perspective into the building and construction sector is crucial to decarbonise the European building stock. It will allow to account for carbon emission along the building's life-cycle (whole-life carbon, WLC) and introduce circularity principles in construction. Ample examples in the EU already showcase how to reduce embodied emissions and improve circularity in the building sector.

Frontrunning governments and companies are already developing innovative policies and products to accelerate decarbonisation throughout the building's lifetime. In parallel, EU policy proposals like the EPBD recast, the Renovation Wave and the Circular Economy Action Plan illustrate the awareness among policymakers about circularity and WLC and indicate a broadening of the scope from the operational emissions occurring during the use-phase of a building, towards emission during its entire life cycle. Lifecycle assessments (LCA) of both, construction products as well as complete buildings shed light on where other emissions occur and provide direction towards achieving comprehensive emission reductions. Insights obtained by LCAs are used by EU Member States to regulate the emissions over the entire lifetime, and construction companies develop products that have a better WLC performance and illustrate low-carbon construction is possible today.

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0802&qid=1641802763889
[2] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0662&from=EN
[3] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020DC0098&from=EN

THE EPBD RECAST

The EPBD recast has been published in December 2021 as part of the Fit for 55 legislative package, aiming to reduce the EU carbon emissions by 55% in 2030 as part of a vision for a climate neutral continent by 2050. The EPBD recast includes requirements for EU Member States to measure WLC for new construction projects in line with the Level(s) Framework starting in 2027. The recast proposal also includes a draft guideline for calculation of Global Warming Potential and should be mentioned on energy performance certificates (EPCs).

THE RENOVATION WAVE

The Renovation Wave aims to drastically improve the energy performance of the existing building stock to achieve the 2030 GHG-reduction target in the building sector through a wide range of policies and measures including an increase of the renovation rate to at least 2%. Among its key principles are life-cycle thinking and circularity, focussing on resource efficiency, promoting green infrastructure and use of bio-based materials. One of the key actions part of the Renovation Wave includes the development of a 2050 WLC performance roadmap.

THE CIRCULAR ECONOMY ACTION PLAN (CEAP)

The plan is one of the pillars of the EU Green Deal and includes measures to stimulate the circular economy, covering the complete life-cycle of products. While the Eco-Design Directive is essential to integrate life-cycle thinking into the design phase of products, the CEAP also aims to improve circularity of construction products specifically through the Construction Product Regulation, integration of the Level(s) framework into public procurement and set material recovery targets for EU demolition and construction waste.

In a first section we present policies that EU Member states have already implemented in to foster circularity and to regulate WLC. Secondly, we will showcase examples of solutions developed by the construction industry illustrating innovative ways forward. The examples in this report have been researched in the context of the German project "Kreisläufe Konstruieren – Ein Lebenszyklusperspektive für Gebäude".

NATIONAL AND SUBNATIONAL POLITICAL INSTRUMENTS IN EU MEMBER STATES

DENMARK

The Danish regulation for sustainable construction ("National strategi for bæredygtigt byggeri") requires life cycle assessments for all new buildings from 2023 on. For renovation projects with a floor area smaller than 1000 m^2, a life cycle analysis is also mandatory. For residential and non-residential buildings with a floor area larger than 1000 m^2, an upper limit for CO_2 emissions per square meter applies [1][4]. The regulation foresees that the upper limit of 12 kg CO_2 eq/m^2/year for emissions during the whole life cycle of buildings with a floor area larger than 1000m^2 will be gradually reduced in the future, once the construction industry has gained more experience with sustainable construction techniques.

SWEDEN

In 2020, the government of Sweden presented a draft law, the "Climate Declarations" (Klimatdeklaration) for buildings, to be implemented in 2022.[5] Project developers will then be required to provide a climate declaration for each new building, including information on the environmental impact of the building throughout its life cycle. During the initial phase, there will be no cap on emissions, but it has been proposed to introduce caps from 2027 onwards.[6]

Sweden is also a positive example for the digitalization of the construction sector, which can also help to reduce carbon emissions: through the digital storage of building information and calculation of emissions, emission hot spots can be identified and accordingly be effectively reduced. Building Information Modelling (BIM) can facilitate this process, as it allows relevant data - including on emissions - to be digitally modelled, recorded and combined. The use of BIM in public tender processes is already mandatory in eight European countries.[7, 8] The use of digital building logbooks, which among other data also store information on emissions, as for example in the case of the Swedish climate declaration[9] shows the manifold opportunities for emission reductions in the construction sector through digitalisation.[10]

[4] Danish Domestic and Building Ministry, "New agreement ensures sustainable construction - Denmark," 2021. https://im.dk/nyheder/nyhedsarkiv/2021/mar/ny-aftale-sikrer-baeredygtigt-byggeri.

[5] https://www.regeringen.se/4a4044/contentassets/3e13a513131b447f8b1e41eddcbbf6b5/klimatdeklaration-for-byggnader-ds-20204.pdf

[6] https://www.boverket.se/globalassets/publikationer/dokument/2020/regulation-on-climate-declarations-for-buildings.pdf

[7] Spain, Italy, Germany, the United Kingdom, Belgium, the Netherlands and Finland.

[8]https://www.researchgate.net/publication/339018632_Supporting_digitalisation_of_the_construction_sector_and_SMEs_Including_ Building_Information_Modelling_EUROPEAN_COMMISSION_LEGAL_NOTICE

[9] The Swedish authorities have a central database to store climate declarations. Project developers are required to store the underlying data for 5 years.

[10]https://www.boverket.se/en/start/building-in-sweden/developer/rfq-documentation/climate-declaration/questions/

THE NETHERLANDS

Since 2018, all construction projects required a permit to calculate and report on the environmental impact of a project. For this purpose, an environmental assessment methodology has been developed, which is managed and regularly updated by the national environmental database (Nationale milieudatabase). This methodology is based on life-cycle assessment. The different impact categories are collected and translated into so-called "shadow costs"[11] of a project, which must not exceed the legal upper limits. The goal is to reduce the shadow costs of new construction projects from €1.0/m²/year in 2018 to EU 0.5/m²/year by 2030. The city of Amsterdam has signed an agreement to build 20% of new residential buildings from wood by 2025[12]. The Amsterdam Wood Pact[13] brings together material choice (positive impact on emissions[14]) with a focus on circular design, demountable building sub-parts, modularity and prefabrication. To achieve the latter goals, the municipality of Amsterdam is collaborating with 47 other authorities and market participants in the City Deal "Circular and Conceptual Building".[15]

FRANCE

France has enacted a law (RE2020) to reduce emissions from all new buildings, with upper limits related to life-cycle emissions for all new buildings. The ceilings (640 - 740 kg CO_2 eq/m^2)[16] depend on the type of building (single-family house, multi-family house) and climate zone, and will be gradually reduced.[17] The freely available INIES database provides the environmental data on building products needed to perform LCA.[18] Furthermore, a building logbook (Le Carnet d'Information du Logement) will be legally mandatory from January 1, 2023, for new construction and comprehensive energy retrofits of residential buildings.[19]

FINLAND

In 2019, the Finnish government published the first version of a methodology to assess emissions for the entire life cycle of a building. As the methodology is still under development, no performance standards or indicators have been set yet. However, the expectation is that performance standards will be introduced starting in 2025. The performance standards will likely apply to both residential and new non-residential buildings.[20]

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[11] Shadow costs are based on 19 different environmental impact indicators that are monetarised and aggregated in a single sum expressed in Euro/m^2/year. Source: https://milieudatabase.nl/milieuprestatie/milieuprestatieberekening/
[12] For single family buildings 80% biobased materials, 65% for multi-family buildings and 55% for buildings with more than 10 floors.
[13] https://www.bouwwereld.nl/wp-content/uploads/2021/10/MRA-Convenant-Houtbouw.pdf
[14] Depending on the treatment of the wood at the EoL of the building
[15] https://agendastad.nl/content/uploads/2021/02/Dealtekst-City-Deal-Circulair-en-Conceptueel-Bouwen-DEF-230221.pdf
[16] Over a lifetime of 50 years this equals 12,8- 14,8 kg CO_2 eq annually.
[17] https://www.legifrance.gouv.fr/jorf/id/JORFARTI000043877205
[18] http://www.rt-batiment.fr/IMG/pdf/guide_re2020_dhup-cerema.pdf
[19] https://www.legifrance.gouv.fr/codes/id/LEGIARTI000043966763/2021-08-25
[20] https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/161796/YM_2019_23_Method_for_the_whole_life_carbon_assessment_of_buildings.pdf?sequence=1&isAllowed=y

EXAMPLES FROM MEMBER STATES

Country	Residential/ Non-Residential	Metrics	Limit	Performance specified by typology (e.g. size, usage target, climate)	Launch
Sweden	Both	kg CO_2eq/m²/y	-	Yes	2022 -2027*
Denmark	Both	kg CO_2eq/m²/y	12kg	Yes	2023
The Netherlands	Both	Euro/m²/y	1,0	Yes	2018
France	Both	kg CO_2eq/m²	12,8 – 14,8 kg*	Yes	2022
Finland	Both	-	-	Yes	2025

Table 1 Overview of emission ceilings in WLC policies in Europe

BELGIUM

The Public Waste Agency of Flanders (Openbare Vlaamse Afvalstoffenmaatschappij) has published a guideline on the evaluation of environmental impact of building parts. The methodology includes a stepwise approach to calculate the carbon and environmental impact of materials, construction processes, and building elements with help of environmental databases.[21]

FINLAND

The Royal Institution of Chartered Surveyors (RICS) published a comparable guideline in 2018 in the United Kingdom. Although the focus of this guideline was whole buildings, rather than building elements.[22] This is part of a broader trend to quantify carbon impact for buildings in the UK, in which for example, the London City Council has also made the calculation of embodied emissions for large construction projects2[3] mandatory. The "London Plan 2021"[24] has integrated WLC considerations focusing on construction materials, emission free construction sites and end-of-life emissions for buildings. A guidance document to assess the whole life carbon impact of buildings was published in 2021 by the London City Council to facilitate the calculations.[25]

* Over a lifetime of 50 years.
* Disclosure starting in 2022, limits from 2027.
[21] https://www.ovam.be/sites/default/files/atoms/files/Environmental%20profile%20of%20building%20elements%20-%20update% 202020.pdf
[22] http://www.rics.org/Global/Whole_life_carbon_assessment_for_the_BE_ PG_guidance_2017.pdf
[23] Projects with more than 150 dwellings, buildings larger than 30 meter or projects on green areas.
[24] https://www.london.gov.uk/sites/default/files/the_london_plan_2021.pdf#page=357

NORWAY

Emissions during several phases of the life cycle of a building can be calculated in Norway following tailored standards. The methodology to calculate the environmental impact over the lifetime of a building has been formalised in the national standard NS 3720:2018, for example.

Norway's local administrations are also implementing policies to decarbonise construction sites. The City Council of Oslo has set requirements for public building sites to become emission free, which include fostering the usage of electric construction machinery.[26] Guidelines from the Oslo City Council also include a concrete plan on how this can be implemented in practice.[27] The degree to which emission requirements for heating, machinery and transport are applicable depends on the overall costs of a project, whereby stricter rules apply to larger projects.[28]

Other cities like Trondheim, Bergen and Stavanger have set a shared goal, together with Oslo, to make all construction sites for public buildings fossil free from 2021 onwards (e.g. by using biogas), emission free from 2025 (e.g. by using electric construction machinery) and to make all other construction activities emission free from 2030 onwards.[29] The initial successes in Oslo led to the establishment of a working group (ZemCons) and to pilot projects in Copenhagen and Helsinki in 2020. Simultaneously, other European cities including Vienna, Brussels, Budapest and Amsterdam have been looking for suitable construction sites for pilots as well.[30]

SWITZERLAND

The Swiss Engineering and Architect Association published a standard for the calculation of carbon and environmental impacts of building parts and complete buildings.[31] These standards are in line with interna tional (ISO) and European (EN) standards.[32] There is a broader trend in Switzerland to foster the increased use of recycled and reusable materials. The City Council of Zurich, for example, has implemented a requirement for the usage of at least 25% recycled concrete for public buildings.

[25] https://www.london.gov.uk/what-we-do/planning/implementing-london-plan/london-plan-guidance/whole-life-cycle-carbonassessments-guidance
[26] https://www.klimaoslo.no/2019/04/10/moving-on-from-fossil-free-construction/
[27] https://www.klimaoslo.no/wp-content/uploads/sites/88/2018/06/Veileder-Utslippsfrie-byggeplasser-ENG.pdf
[28] https://procuraplus.org/fileadmin/user_upload/participants/City_of_Oslo_-Requirements_Zero_Emission_Construction_Sites.pdf
[29] https://procuraplus.org/fileadmin/user_upload/participants/City_of_Oslo_Requirements_Zero_Emission_Construction_Sites.pdf
[30] https://bigbuyers.eu/working-groups/past/zero-emission-construction-sites
[31] https://ec.europa.eu/environment/gpp/pdf/news_alert/Issue_88_Case_Study_168_Zurich.pdf 32EN 15803 and ISO 14025
[32] EN 15803 and ISO 14025

GOOD PRACTICES FROM THE INDUSTRIAL SECTOR

Building related emissions are generated during all phases of a building's life cycle. Market platforms for reused materials, new building design software and data storage solutions like Digital Building Logbooks allow architects to design circular and efficient solutions. Buildings designed based on circular principles reusing building parts or integrating recycled materials, or constructed with electric machinery, illustrate steps local authorities and construction companies are making to achieve net zero construction.

MATERIALS AND MANUFACTURING

In order to build circularly, the use of recyclable materials is indispensable. Digital platforms and tools are therefore emerging in various EU countries that promote the reuse of recycled materials through thorough and transparent data collection. To reuse materials from existing buildings or ensure high quality recyclable material flows, building logbooks that store information on the construction products and installations are essential. By storing the data about construction products in logbooks, building owners can sell their materials at secondary product and material markets at the deconstruction phase of a building.

The Dutch company "Insert" has developed a marketplace for recyclable materials where companies can buy reusable building materials or offer their own used materials.[33] In addition, *Insert* also offers a digital material pass, advice for specific material flows and storage space for recyclable materials. In this way, Insert supports the development of an ecosystem for a circular economy for buildings.

The Norwegian company "Loopfront" offers an integrated service for building owners to promote circular building. Users can create an inventory of their building themselves.[34] With the help of photos, all parts of a building can be stored in a digital material card and categorised for reuse. They can then be offered for sale on the *Loopfront* marketplace. There is also the option to retrieve reports on cost savings, emissions and waste volumes of construction projects in an automated way.

In France, "Cycle-up" also offers a service where building elements can be sold on a marketplace. *Cycle-up*'s unique selling point is a comprehensive offer linked to three digital tools: the *Digi-it App*, the *Banski* BIM modules and the *Cycle-up* library. The *Digi-it App* enables the production of a material certificate, but also project planning, calculation of environmental impacts and emissions based on the National INIES database. The *Banski* BIM Module app allows the import of BIM to directly display which materials are available in the marketplace for the appropriate project.[35]

All these companies show how circular construction with reusable materials is facilitated by integrated digital platforms. In addition to digital tools, other examples include the use of innovative technologies on the construction site to promote the reuse of materials. In the Netherlands, the company "Circuton" has developed a mobile factory for recycled concrete that can produce high-quality raw materials on site.[36]

[33] https://www.insert.nl/
[34] https://www.loopfront.com/en/product
[35] https://site.cycle-up.fr/outils/
[36] https://strukton.com/nl/civiel/betonbouw_circuton

PLANNING AND DESIGN

Platforms such as *Insert, Cycle-up* and *Loopfront* require information on materials in buildings, for which Digital Building Logbooks can be a useful source of information. There are already several examples in Europe of public and private initiatives promoting the use of Building Logbooks, such as the Buildings as Material Banks (BAMB) project[37], where the material passports developed aim to make buildings material providers rather than consumers in the long term.

Governmental examples such as the "Woningpas" in Flanders have been developed for building users and provide a comprehensive digital repository of information on energy efficiency, renovation measures, renewable energy and other data collected by different public authorities. It allows users to share this information with building experts.[38]

in Sweden, the increasing demand for product certifications, such as Environmental Product Declarations (EPDs), has increased interest in Building Logbooks. In addition to providing a storage facility for a project's building product information, the "Basta Logbook" gives insight into a building's environmental impact and emissions.[39] It also allows work and information to be shared in different digital 'workspaces' and is directly connected to a database for building product information.

"Madaster" from the Netherlands offers builders and building experts the possibility to store buildings online in the Madaster database and create an individual material certificate.[40] With Madaster, information from BIM can be uploaded directly into a material certificate and linked to other data sources on emissions, environmental impact, but also data on financing. Madaster currently has a database with more than 4000 registered buildings (>13Mn m^2) and collaborates with over 100 partners in five European countries (Netherlands, Germany, Norway, Switzerland and Belgium).

BIM is an important driver for digitalisation in construction. The use of BIM can reduce costs and improve cooperation between actors along the value chain. Therefore, a BIM task force has been established at European level to share experiences between member countries and promote the use of BIM.[41]

There are several companies in the EU developing or using innovative BIM applications, such as the national collaborative BIM platform "Kroqi" in France[42] or the collaborative BIM tool Bimsync Arena from Norway developed by the company "Catenda".[43]

The Circular Concrete (CICO) project in Austria shows how a combination of BIM and the reuse of materials can be implemented in practice. BIM and specific digital technologies are designed to ensure the future deconstruction of the building as early as the construction stage. The exposed materials can thus be separated again, processed and reused for a new construction project.[44]

[37] https://www.bamb2020.eu/
[38] https://joinup.ec.europa.eu/collection/egovernment/solution/building-passport-flanders-woningpas/about
[39] https://www.bastaonline.se/basta-loggbok/?lang=en
[40] https://madaster.nl/
[41] http://www.eubim.eu/
[42] https://kroqi.fr/
[43] https://catenda.com/
[44] https://klimaforum-bau.de/news/forschungsprojekt-cico-aus-einem-alten-haus-ein-neues-bauen/?utm_source=linkedin&utm_medium=news

CONSTRUCTION AND MAINTENANCE

In addition to materials and their reusability, the construction stage itself is also important for reducing emissions. Zero-emission construction also requires electrical machines and generators on the construction site, which are powered by renewable energy. Generators today can run on batteries or hydrogen instead of diesel, as shown by E-power International[45] (hydrogen) and Atlas Copco[46] (batteries). Emission-free energy sources can also be used to power electric construction machines such as excavators (e.g. ZERON by Nasta[47]), electric concrete trucks (NorBetong and Liebherr GmbH[48]) or heaters (*SmartHeater* by RoMy Clima AS[49]). When considering the life cycle of a building, this is of great importance, as decarbonisation can be achieved here with straightforward measures.

Business models for serial renovation are gradually spreading throughout Europe. The underlying idea is that if enough is produced, the cost of prefabricated facades, roofs and other building components can be reduced. Moreover, such components can be quickly installed on site. A well-known example is the Energiesprong renovation concept, which is already being used in five European countries.[50] The European Association for Prefabricated Construction and its members have already applied various options to produce whole building components based on wood in pilot projects. Since wood usually produces lower CO_2 emissions in production and transport and at the same time binds CO_2, such projects can also contribute to a reduction of emissions in buildings.[51]

CIRCULAR BUILDING PROJECTS FROM EUROPE

Many innovative, sustainable European architectural projects have already been developed up to the year 2021. This section focuses on the reuse of building parts during the deconstruction phase.

As part of the *BRIC* project, a demountable education building 'EFP' was built in Brussels, which is constructed, used and disassembled every year. In the process, the individual parts of the building are also given other functions, for example roof panels become the facade cladding during reconstruction. The construction and disassembly work is carried out in collaboration with students, and the building thus acquires different functions (office and meeting rooms, business premises, exhibition spaces) within its life cycle.

In the Netherlands, there are already several construction projects where the building can be completely deconstructed and then moved in its entirety. A well-known example is the new city administration of Venlo, which was built according to the principles of the circular economy ("Cradle to Cradle"). Not only are the parts of the building deconstructable, but also the water use, energy production and air purification are circular. Here, an investment of €3.4 million has generated savings worth €16.8 million.

[45] https://e-powerinternational.com/zero-emission
[46] https://www.atlascopco.com/content/dam/atlas-copco/construction-technique/portable-energy/documents/energy-storage-systems/Brochure-ZenergiZe-energy-storage-systems-English-v01.pdf
[47] https://www.nasta.no/anleggsmaskiner/spesialmaskiner/elektriske-anleggsmaskiner/zero-emission-construction-machinery/
[48] https://www.norbetong.no/no/TrommEL_Transport
[49] https://romyclima.no/english/
[50] https://energiesprong.org/
[51] http://e-f-v.relaunch.net/about-prefabrication/index.html

DECONSTRUCTION AND RECYCLING

in 2015, the Dutch Real Estate Agency of the central government experimented with innovative award criteria for a temporary construction project for a court in Amsterdam. Importantly, the materials had to be deconstructible. In July 2021, the building was disassembled, and in 2022 it will be put back into use at the Technical University of Twente. Materials that cannot be reused will be used in other projects and a small part will be recycled to a high quality. In another tender, the Dutch Real Estate Agency invited tenders for a temporary restaurant that will be recycled at its location after a period of 15 years. “The Green House” is the outcome. The restaurant with meeting rooms is built from prefabricated wooden parts and consists of a re-usable steel structure, triple glazing and a concrete foundation.

The new Kunsthaus in Zurich excels in its use of materials. The use of sustainable Modero 3B cement makes it possible to significantly reduce CO_2 emissions and is suitable to produce recycled concrete. For the entire Kunsthaus Zurich, 95% recycled concrete was used, which shows that high-quality architecture is feasible with recycled materials.

SUMMARY AND OUTLOOK

This report has shown that in terms of policy developments many EU Member States are taking the lead and implementing WLC in buildings. Key policy take-aways include:

- Member States especially in North- and Western Europe are leading policy innovation related to WLC in buildings
- Some national standards and guidelines are more ambitious than EU counterparts, leading the way and providing examples to other Member States for what is possible
- European local authorities are pioneering in developing emission-free construction sites
- Collecting and storing qualitative data is a pre-requisite for reducing WLC-emissions in the construction sector and fostering circularity

These good practices illustrate the growing interest in life-cycle perspective among policymakers, and show that several WLC-regulations will be implemented in the coming years. It can be expected that other EU Member States will follow suit, and that standards and guidelines for emission free construction sites and calculation methodologies for WLC will be further refined.

The industry examples show that markets for recycled and reusable materials are emerging, and that these materials are being used in new building designs. This highlights the potential for reusability of complete buildings and building parts and could contribute to the reduction of material scarcity. Key takeaways from this good practice brief include:

- Data collection and storage solutions are becoming more widespread, improving data availability and allowing architects and designers to re-use materials from deconstructed buildings
- Zero-emission construction sites are feasible through electrification and innovative energy solutions
- Buildings designed with reused materials already exist, showing feasibility and potential of integrating re-use principles in building design
- Buildings designed to be de- and reconstructed illustrate the potential of re-useability of complete buildings or building parts.
- Recycled materials can be used in design and could reduce material scarcity.

Re-using and recycling of building materials with the help of digital tools and circular designs is becoming more commonplace within the construction sector. The exemplary cases discussed in this good practice briefing illustrate the innovative capacity of the construction industry and the direction into which digitalisation and life-cycle perspectives are driving its transformation.

How to cite this briefing: BPIE (Buildings Performance Institute Europe) (2022). A life-cycle perspective on the building sector– Good practice in Europe; Available at:

https://www.bpie.eu/publication/a-life-cycle-perspective-on-the-building-sector-good-practice-in-europe/

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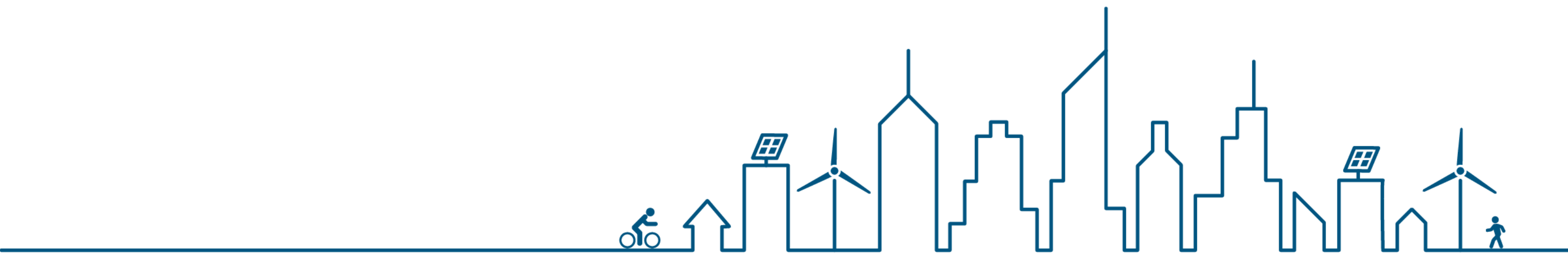

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