Lowering our impact through distinctive structural design.

SUSTAINABILITY PLAN

NEY +PARTNERS

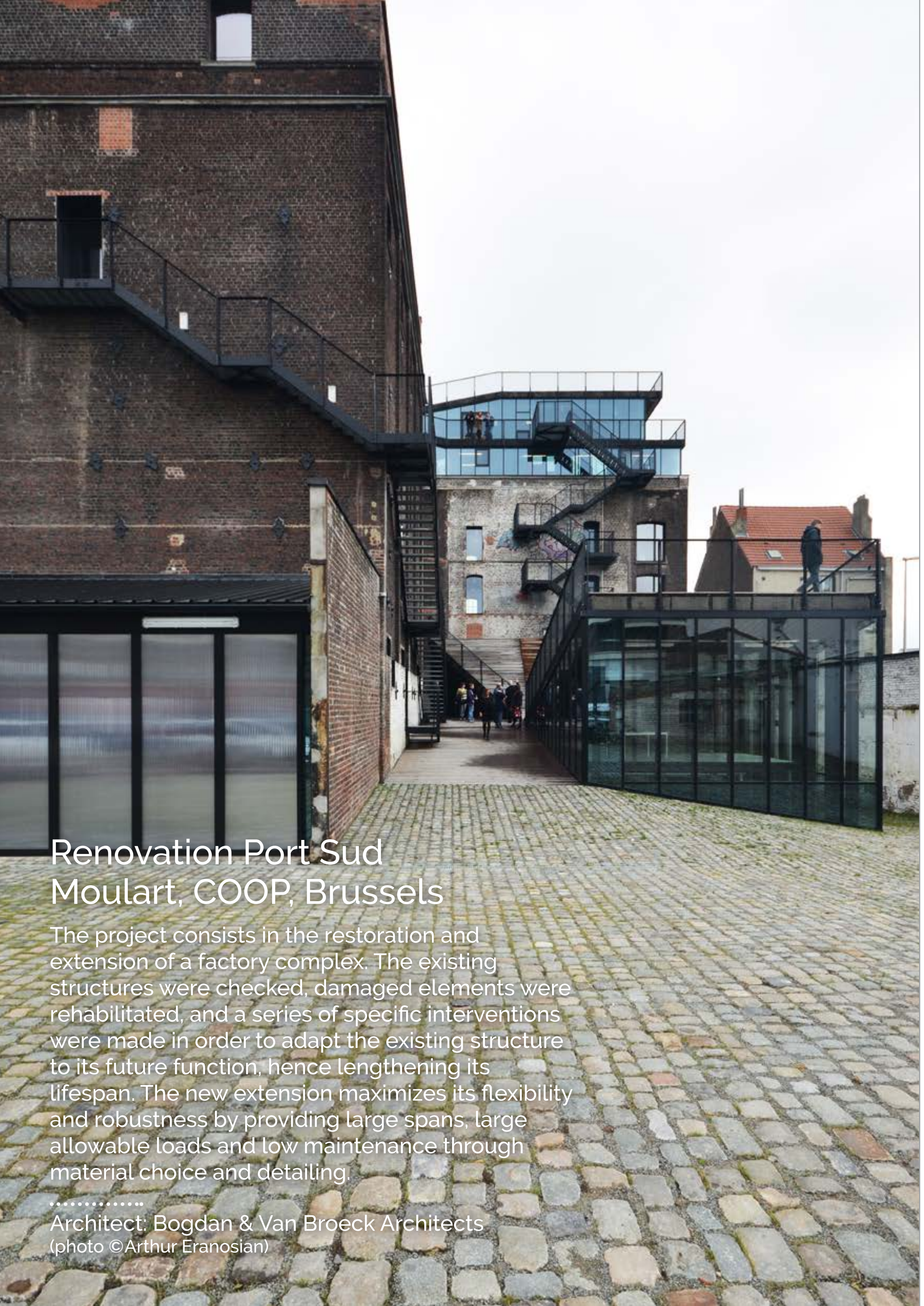
Reading guide

Ney & Partners is a team of engineers and architects working on the design of infrastructure and structures. As structural engineers we have a major impact on the sustainability of a project. This document is a summary of the experience we have built up over the years. It was created together with Jean-Didier Steenackers and Catherine De Wolf, two experts in the field of sustainability. The sustainability plan is an assessment framework used within Ney & Partners to support the design process of infrastructure projects and building structures.

In the first part **WHY** we indicate the impact of structures. By understanding the causes of its impact and quantifying it, Ney & Partners wants to lower its impact through distinctive design. By integrating sustainability as an inherent constraint in the design process, Ney & Partners is convinced it has a competitive advantage.

The second part **HOW** not only provides insight into conventional Environmental Performance Assessment (EPA) tools such as Life Cycle Assessment (LCA) to lower our carbon footprint, but also indicates how Ney & Partners looks further. Two distinctive design goals can be targeted: minimizing the impact of a structure through materiality (quantity) and maximizing the life cycle of a structure through flexibility and robustness (quality).

The third part **WHAT** describes in detail the tool Ney & Partners has developed to assist the design process. It consists of two scoring methods. The first is an LCA score according to the European Standards. The second is a trade-off matrix illustrating Ney & Partners' view on sustainability including flexibility, robustness and maintenance.



Renovation Port Sud
Moulart, COOP, Brussels

The project consists in the restoration and extension of a factory complex. The existing structures were checked, damaged elements were rehabilitated, and a series of specific interventions were made in order to adapt the existing structure to its future function, hence lengthening its lifespan. The new extension maximizes its flexibility and robustness by providing large spans, large allowable loads and low maintenance through material choice and detailing.

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Architect: Bogdan & Van Broeck Architects
(photo ©Arthur Eranosian)

WHY?

Lowering our impact

Architectural and civil works have impacts: socially, on the landscape, on nature. The use of these works can change over time: from a railway line to a bicycle path, from a bridge to a pedestrian path, from an abandonned factory complex to an innovative business centre. However, the way these works are integrated into the landscape, whether urban or rural, will leave its mark for centuries to come.
A structure derives its durability and sustainability not only from its materiality, but also from its capacity to adapt over time to new challenges and new demands that impose a spatial context upon it.

The building industry is the most resource-intensive sector in all industrialized countries,[1] producing a third of all waste generated in Europe[2, 3, 4] and more than a third of global greenhouse gas (GHG) emissions.[5] In the best examples, bridges are pure structures and it is clear that the structural elements have the biggest impact on the sustainability of the project. But even in building projects, 75% of the building materials are structural elements, even if they only represent 25% of the building cost. As the energy performance of buildings improves, the share of embodied CO_2 from used materials, hence the structural materials, increases even more.

The Ney & Partners team, aware of its impact through design, wants to build a vision for a sustainable development process by understanding the causes of its impact, quantifying it and lowering it through distinctive design. To do so, we not only look at conventional Environmental Performance Assessment (EPA) tools such as Life Cycle Assessment (LCA) to lower our carbon footprint, but we also look at the circularity of our projects. Indeed, we assess the robustness, flexibility, constructive mode, reusability and dismantability of our building structures. Moreover, we optimize the robustness of our infrastructure projects through flexibility, reserve and inherent quality. Especially for (road) bridges, we minimize nuisance, land use and maintenance.

Ney & Partners' design is related to the principles of Cradle-to-Cradle (C2C), a philosophy which eliminates the concept of waste while providing enduring benefits for society from safe materials, water and energy in a circular economy. By ensuring these key aspects of sustainability are at their best, the design of Ney & Partners' projects goes beyond the traditional engineering practice of combining aesthetics and budget: sustainability becomes an inherent part of the design process.

Some key data

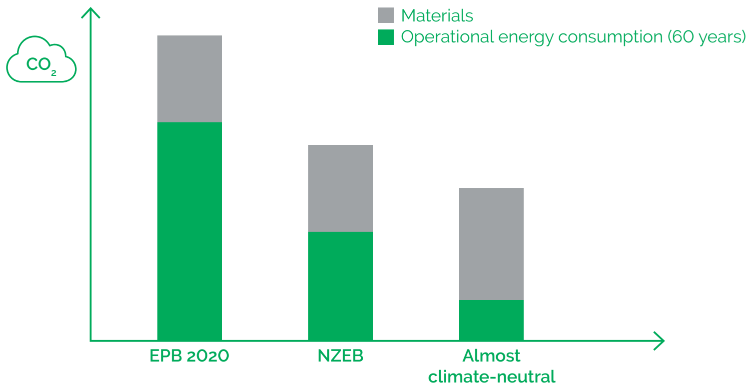
35%

Waste in Construction and Demolition represents **35% of all solid waste** in Europe.

The building sector is the highest consumer of energy.

75% 25%

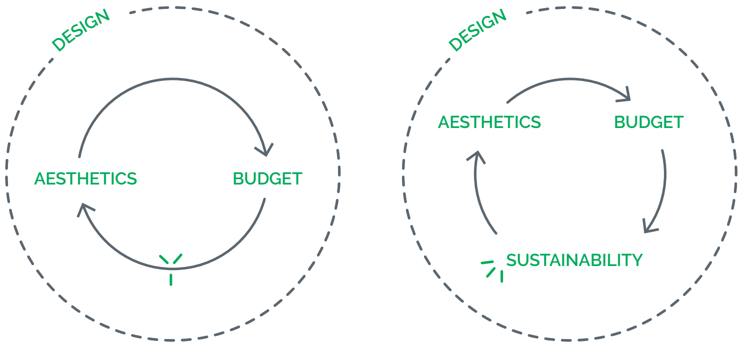
75% of the materials in a building are **structural elements**. But these represent **25% of building costs**.

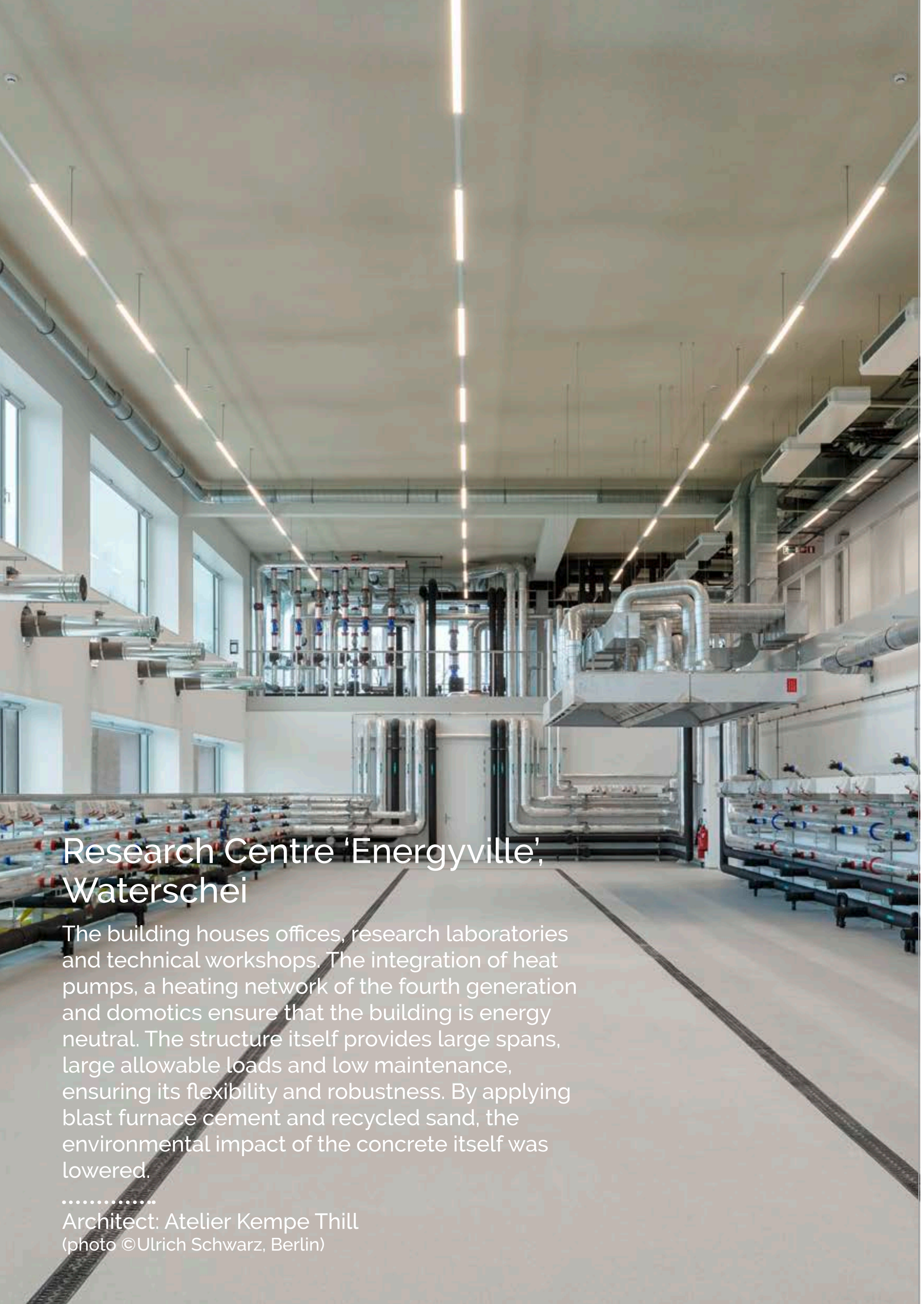


As the energy performance of buildings improves, the share of embodied CO_2 from used materials increases.

A competitive advantage

Life-cycle impacts (e.g. Global Warming potential in $kgCO_2eq$) are either a demand from the tender or an element than can be addressed by the design team.
In both cases it should lead to securing winning proposals. In the iterative process that leads our proposals to the final design, we need to change the logic from an "aesthetic - budget" design process to an "aesthetic - sustainability - budget" design process. In an ideal scenario the design goals should be integrative and not distributive.





Research Centre ‘Energyville’, Waterschei

The building houses offices, research laboratories and technical workshops. The integration of heat pumps, a heating network of the fourth generation and domotics ensure that the building is energy neutral. The structure itself provides large spans, large allowable loads and low maintenance, ensuring its flexibility and robustness. By applying blast furnace cement and recycled sand, the environmental impact of the concrete itself was lowered.

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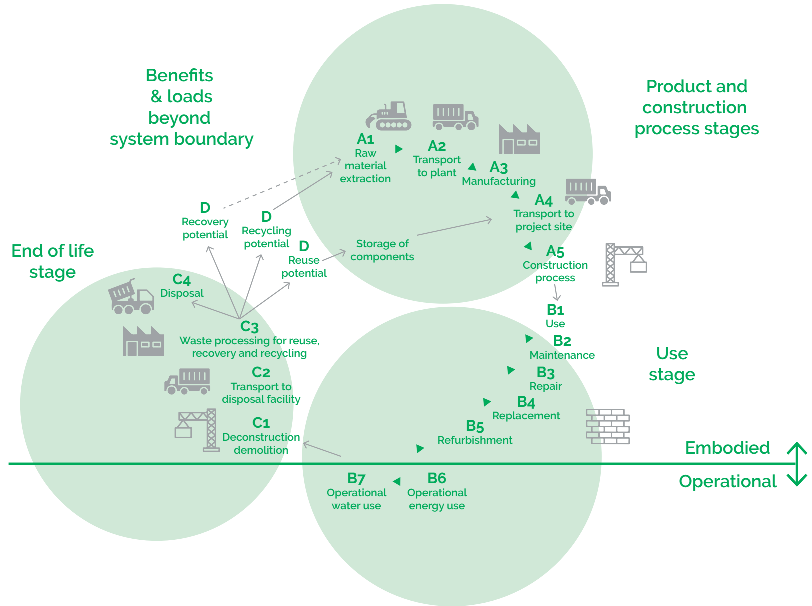
Architect: Atelier Kempe Thill
(photo ©Ulrich Schwarz, Berlin)

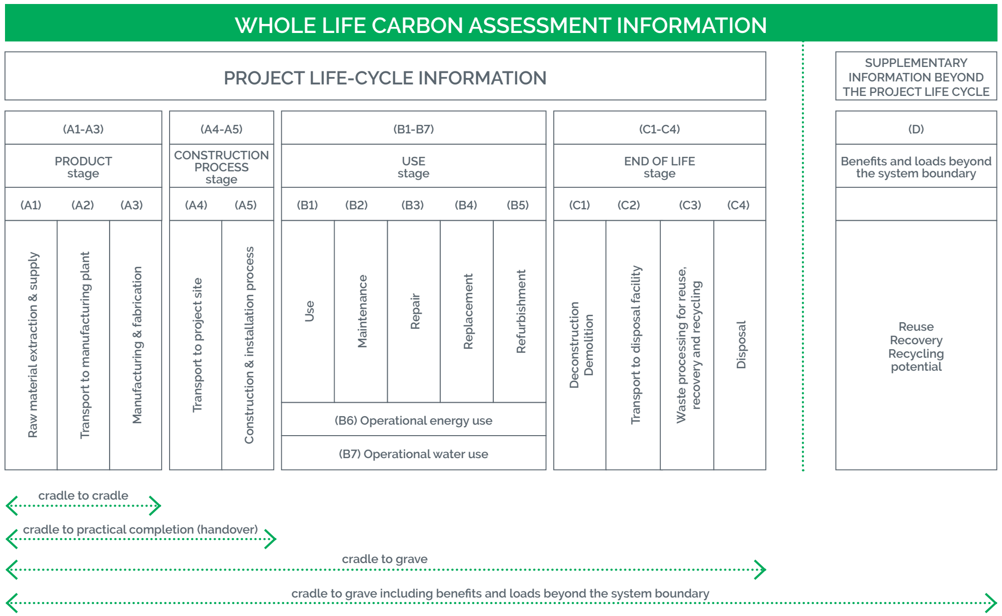
HOW?

The ‘traditional’ view on sustainability

The Intergovernmental Panel on Climate Change[6] (IPCC) states that the building sector needs to be “zero-carbon” (i.e. removing or offsetting its greenhouse gas emissions) (GHG) by 2050 to meet the targets set by the Paris Climate Agreement[7] and avoid extreme climate catastrophes. GHG emissions of buildings can be divided into (EN 15978)[8]:

a. **operational impacts** related to the operation of buildings: heating, cooling, lighting, ventilation, hot water, electricity;
b. **embodied impacts** related to the rest of the building’s life cycle: material extraction, production, transport, construction, maintenance, repair, replacement, refurbishment, demolition, transport to disposal facilities, waste treatment.





Life-cycle stages and modules,
according to the European Standards

Structural engineers should aim to reduce the embodied carbon of their projects. For the embodied phase, most of the GHG emissions occur in the early construction stage. To enable structural engineers to reduce the embodied carbon of their designs, practitioners emphasize an urgent need to benchmark the embodied carbon of existing structures, and yet there is currently no consensus on the data and methods to properly benchmark embodied carbon. Developing a basis for design of structures with low embodied carbon is essential.

Traditionally, assessing the environmental performance of buildings and infrastructure is done through the Life Cycle Assessment (LCA). The LCA evaluates environmental impacts associated with all the life-cycle stages of a product, process or service, e.g. a building structure, from raw material extraction (cradle) to the recycling or disposal of the materials composing it (grave). Many indicators can be evaluated (toxicity, ozone layer depletion, carbon footprint, etc.), but one often looked at in policies and labels is the Global Warming Potential (GWP): kgCO_2 equivalent (kgCO_2eq). The Reference Study Period (RSP) in the European Standards EN 15978-7.3 is 60 years for domestic and non-domestic projects. It can be raised to 120 years for infrastructure projects (according to case studies PAS 2080). The calculation method is set by EN1597 but no European common database is known to find the coefficients necessary to make the LCA. Being critical about the database is key to ensuring a reliable result. Therefore, we recommend working with Environmental Product Declarations (EPD) from material manufacturers Ney & Partners often works with and use their average values for preliminary evaluations during the conception stage.

Current policies and certification systems such as Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), PassivHaus and Minergie have mainly focused on reducing operational impacts, with little attention to embodied impacts (e.g. adding certain insulation materials may reduce operational impacts but increase embodied impacts).

The European Standards EN 15978 define different modules for a whole life-cycle assessment.

- Module A1-3 – PRODUCT STAGE
- Module A5-5 – CONSTRUCTION PROCESS STAGE
- Module B – USE STAGE
- Module C – END OF LIFE
- Module D – BENEFITS & LOADS BEYOND SYSTEM BOUNDARY (including REUSE / RECOVERY)

As operating emissions decrease, the importance of reducing the embodied emissions increases.

Ney & Partners' view on sustainability

Two distinctive design goals can be targeted by Ney & Partners: minimizing the impact of a structure through **materiality** (quantity), and maximizing the life cycle of a structure through **flexibility/robustness** (quality).

The first design goal includes minimizing the impact of a structure through **materiality** (quantity): this encompasses minimum mass, minimum waste and minimum embodied carbon. Three main strategies are followed:

- **Material choice:** correct application, renewable material, reduce maintenance;
- **Optimized design versus reuse:** build only what is necessary, reduce surfaces and materials;
- **Design for disassembly:** if compatible with above, make the structure dismantable or recyclable (this is often more applicable to buildings).

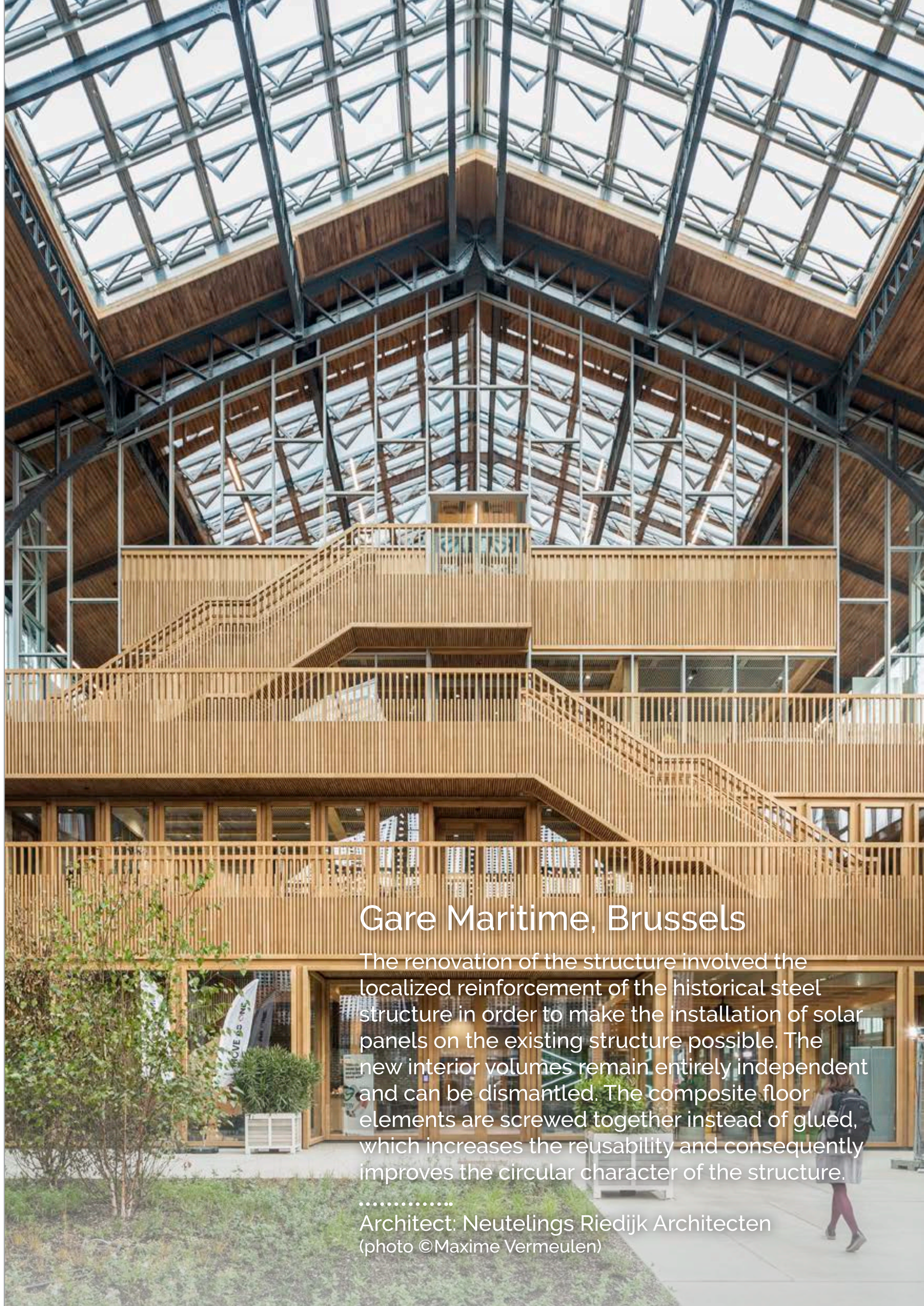
Ney & Partners' view on sustainability evaluates more than just the life-cycle impact of buildings and infrastructure. It also encompasses concepts such as flexibility, robustness, reduced nuisance and maintenance, etc. These can be seen as contributing to a paradigm shift from a linear to a circular economy.

The second of the two distinctive design goals targeted by Ney & Partners is: maximizing the life-cycle of a structure through **flexibility and robustness** (quality). Indeed, the view of Ney & Partners also adds to this the flexibility or qualitative aspects of sustainability. This applies in slightly different ways in our two fields of action.

BUILDINGS

Maximizing the life-cycle of a structure through flexibility and robustness (quality) entails the capacity to adapt. Three strategies are followed:

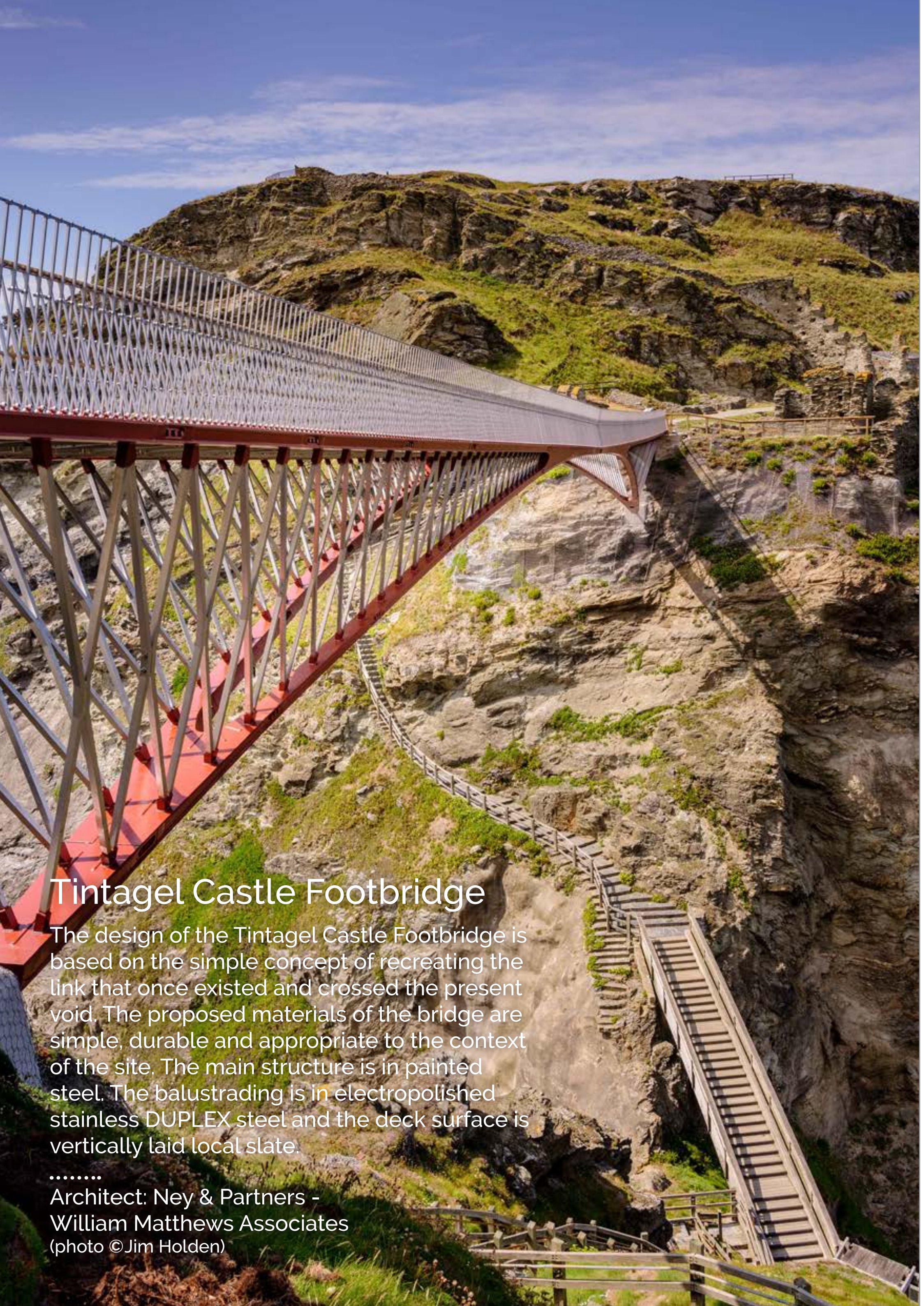
- **Robustness of the structure:** reaching the highest robustness with fewer quantities (e.g. spans, free height, loads, horizontal and vertical extensions), detail (e.g. slope for flat roofs not in concrete);
- **Timeless design:** detailing, reducing maintenance to the minimum, versatility, lengthening the lifespan of a building through a distinctive design liked by users, forecasting a 2nd use life, pushing for a free plan and free section, quantifying additional loads to open to new functions;
- **Separation of layers:** making it possible to separate materials from each other based on expected lifetime (main structure vs façade and non-load-bearing walls) through dry connections.



Gare Maritime, Brussels

The renovation of the structure involved the localized reinforcement of the historical steel structure in order to make the installation of solar panels on the existing structure possible. The new interior volumes remain entirely independent and can be dismantled. The composite floor elements are screwed together instead of glued, which increases the reusability and consequently improves the circular character of the structure.

Architect: Neutelings Riedijk Architecten
(photo ©Maxime Vermeulen)



Tintagel Castle Footbridge

The design of the Tintagel Castle Footbridge is based on the simple concept of recreating the link that once existed and crossed the present void. The proposed materials of the bridge are simple, durable and appropriate to the context of the site. The main structure is in painted steel. The balustrading is in electropolished stainless DUPLEX steel and the deck surface is vertically laid local slate.

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Architect: Ney & Partners -
William Matthews Associates
(photo ©Jim Holden)

INFRASTRUCTURE

The view of Ney & Partners on the means of evaluating the durability of a project can be categorized in two fields: Life-Cycle Optimization (LCO) and Impact on Living Environment (ILE).

Life Cycle Optimization

The importance of the real **duration** of the life cycle is essential in evaluating the sustainability and durability of an infrastructure project. Many important factors which have an impact on the life cycle of a bridge are not measurable or tangible, but that does not mean that they are not essential. We can categorize the following factors:

ROBUSTNESS

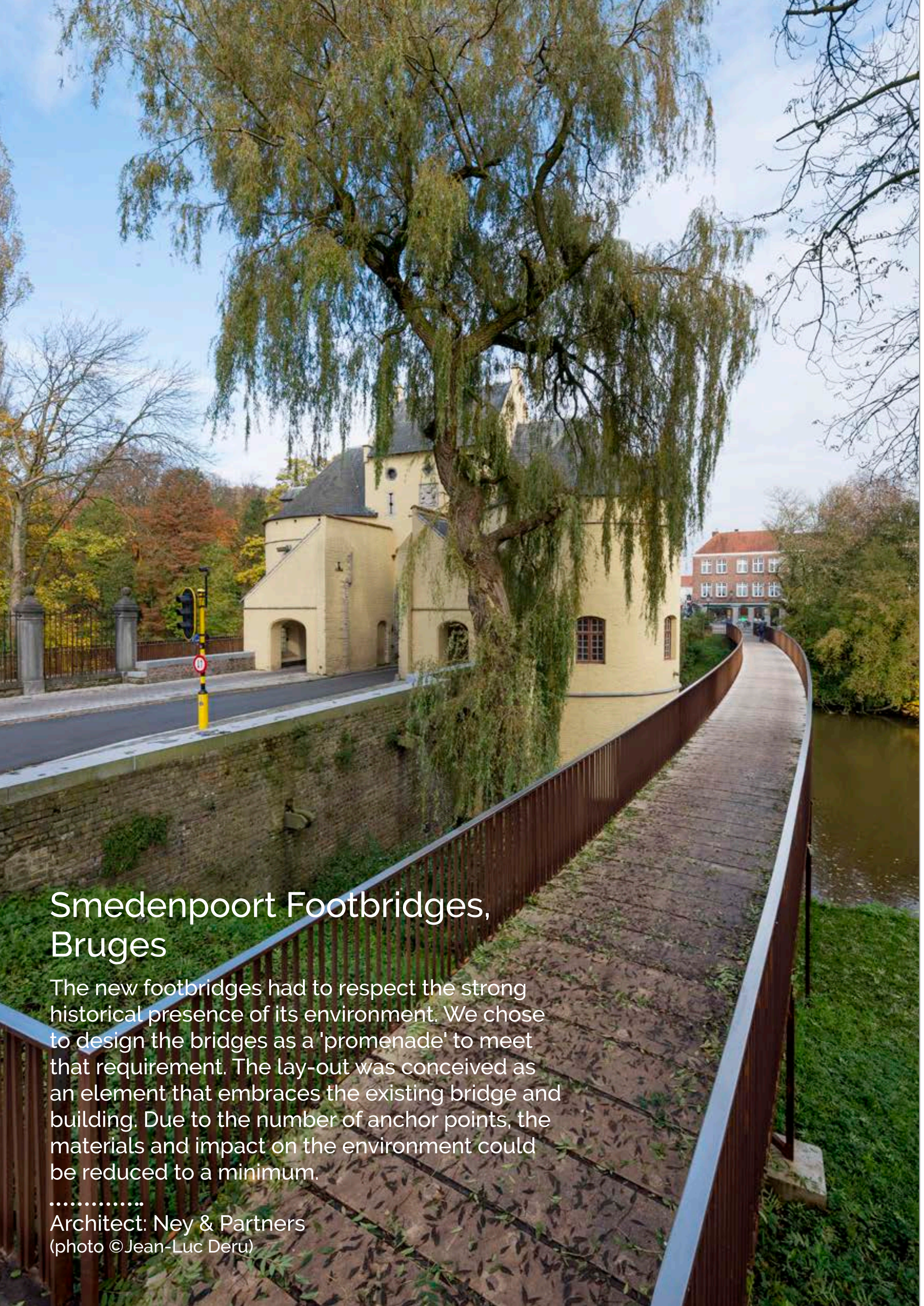
- Robustness through flexibility on the bridge: e.g. no central structure, equivalent loads on the entire width, flexibility in traffic lanes or in replacing some lanes by a tramway, etc.
- Robustness through flexibility under the bridge: for example, one big span instead of three smaller spans to allow flexible/futureproof "underworld".
- Robustness through reserve: e.g. over-dimensioning, redundancy such as a suspension bridge which stays stable with one of the cables broken in the case of an accident, a lack of maintenance, bad execution or replacement.
- Robustness through inertia: the object resists the pressure of change due to its intrinsic aesthetic and technical quality, e.g. by limiting the number of details, an integrated approach to design with elements that fulfil different functions and that will be kept for its "spatial quality".

MAINTENANCE

- Bridges are very different than buildings in this aspect: maintenance is often overlooked or forgotten, but bridges often require maintenance, with obviously major consequences if not maintained. Limiting maintenance is key.
- Reduced maintenance through material choice (stainless steel, weathering steel, etc.).
- Reduced maintenance through detailing (integral bridge or not, type of bearings, number of joints, quality of steel conservation, etc.).

Impact on Life Environment

- Reducing land use (m^2).
- Integrated infrastructure: keeping nature and infrastructure divided. This is the contrast between Hi-Tech and Low-Tech landscapes. For example, integrating solar solutions on a bridge edge instead of in a rural field next to the road.
- Less nuisance for users and local people, both in the execution phase as well as when it is realized: flow of people, better, shorter, safer and easier connections.



Smedenpoort Footbridges, Bruges

The new footbridges had to respect the strong historical presence of its environment. We chose to design the bridges as a 'promenade' to meet that requirement. The lay-out was conceived as an element that embraces the existing bridge and building. Due to the number of anchor points, the materials and impact on the environment could be reduced to a minimum.

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Architect: Ney & Partners
(photo ©Jean-Luc Deru)

WHAT?

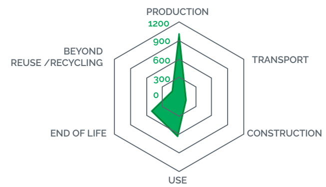
Ney & Partners developed a tool to assist the design process with a sustainable design philosophy.

In order to evaluate both approaches, two scoring methods are offered in our tool:

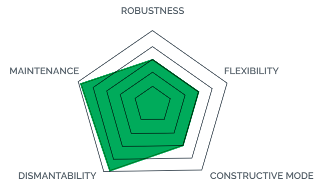
1. LCA score (with focus on GWP expressed in CO_2eq), according to European Standards (quantity);
2. A trade-off matrix illustrating Ney & Partners' view on sustainability including flexibility, robustness and maintenance (quality).

A graphical tool can be used in tenders and design phases. The first part includes a score for different indicators and/or life-cycle phase, presented in a web diagram, including embodied carbon values. The second gives a trade-off matrix, as it discusses mainly non-quantitative aspects.

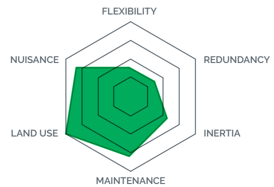
Global Warming Potential (kg CO2eq)



Ney Sustainability for buildings
(Robustness & Flexibility)



Ney Sustainability for infrastructure
(LCO & ILE)



Example of the carbon webdiagram

Web diagrams based on the results of the trade-off matrix illustrating Ney & Partners' view on sustainability

LCA + CO_2 score

TOOLS
An overview of existing tools is summarized in Appendix.

Belgium

- The Tool to Optimise the Total Environmental impact of Materials (TOTEM) tool[9] is a tool developed by the Flemish Public Waste Agency (OVAM), the Walloon Public Service (SPW), and the Brussels Environment Agency (Bruxelles-Environnement). Its target market is Belgium. The tool is construction-specific and allows to model the whole building. It is aligned with European Standards EN 15804, but also offers extra indicators.
- GRO[10] is a manual that was developed in 2017 to implement a parallel and holistic level of sustainability in the construction projects of the facility services. It is the replacement and update of the Valuation of Office Buildings Manual. GRO's ambition is to arrive at future-oriented buildings through an integrated design process. The People Planet Advantage principle forms the framework for GRO.

DATABASES
In **Belgium**, the B-EPD database of the Belgian Federal Public Service of Health & Environment is being developed and can be accessed at www.b-epd.be. EPDs (European Product Declaration) can be consulted online by the user for free. The owner of the EPD can in some cases opt not to disclose it to the public but only allow it for use in TOTEM, the building calculator. TOTEM will be able to download the EPD datasets. The manufacturer can declare scenarios for multiple countries in his EPD and in this database. This option has not yet been used, however. The field names are available in three languages: Dutch, French and English. The data are to be provided in one of the three languages, with a possibility to include translations for those text fields used by TOTEM. For the modules, A1-3, A4, C2, C3, C4 and D are mandatory. In some cases, also module A5. The other modules are optional. How TOTEM deals with missing modules is communicated on the website, stimulating manufacturers to also declare those.

Considering the sparse information in these databases, it is recommended to work with the EPDs from the manufacturers with whom Ney & Partners often works. An average of the few most used concrete, steel, and timber manufacturers could be made to give a range of the environmental impacts of the material choices in the design stage. Rather than an end result of the GWP, an LCA could also give the entire range of results depending on the material chosen. It is crucial that the environmental performance of a building structure or infrastructure project becomes part of the tender, such as the load-bearing capacity.

Emile Bockstael School building, Brussels

The primary school 'Emile Bockstael' in the Heyzel area in Brussels is a passive three-storey building with a surface area of about 1200 m^2. The superstructure is entirely made of timber.
The flexibility and robustness are maximized by a logical grid, a separation of layers and a limited number of internal beams. Due to the use of mechanical connections the superstructure can be entirely dismantled.

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Architect: Nimptsch Architekten - Bureau Bouwtechniek
(photo ©Jean-Luc Deru)

Ney & Partners sustainability trade-off matrix

To develop an internal rating system to assess the full sustainability, Ney & Partners uses trade-off matrices.

BUILDINGS / CRITERIA TRADE-OFF MATRIX

ROBUSTNESS

This is measured through the allowable load on floors and roofs as well as the potential to expand with additional floors or solar panels.

- Allowable load for floors: it is possible to have different uses with light loads, but you'll need to compromise (no heavy walls, not all possible finishes, etc.) – the trade-off matrix addresses a range from 4 to 8 kN/m² for the pEk is addressed in the trade-off matrix.
- Allowable load for roofs: these values are equal to the “floor” loads because it should be possible to have a normal floor on the roof if you want to add new storeys. On the other hand, these values also reflect the necessary loads for increasing roof uses.
- Additional floors can be taken into account for considering columns, cores and foundations. These values are equal to the “floor” loads because it should be possible to have a normal floor on the roof if you want to add new storeys. On the other hand, these values also reflect the necessary loads for increasing roof uses.

FLEXIBILITY

Architectural **plan** aspects: several checked criteria evaluate the position in the trade-off matrix:

- No dividing load-bearing walls
- No closed load-bearing façades and sill-beams
- Enough light incidence in the central parts of the building
- Typical span > 7 m
- Possibility for enough cores
- Repeating plan grid
- Aligned grid

Architectural **section** aspects: several checked criteria evaluate the position in the trade-off matrix:

- No internal beams
- Aligned structural elements
- Storey height between structural floors > 3.2 m
- Repeating façade grid
- Possibility for enough vertical technical transit

Architectural **concept** aspects: several checked criteria evaluate the position in the trade-off matrix:

- Future horizontal expansion possible (peripheral structure/foundations)
- Future vertical expansion possible
- Future terraces can be added
- Parts can be removed

CONSTRUCTIVE MODE

Several checked criteria evaluate the position in the trade-off matrix:

- Future local perforation possibilities
- No acoustic limitations (hollow core slabs, etc.)
- No necessary specific maintenance of structural elements (coatings)
- No MEP in structural elements

DISMANTABILITY

The ability to facilitate or not hinder future dismantability of elements - several checked criteria evaluate the position in the trade-off matrix:

- “Use of BIM”
- Not monolithic
- Mechanical connections
- Homogeneous materials (for recycling)
- Use of standard sections
- No coatings

MAINTENANCE

Maintenance as scheduled is often not followed at the scale of the building life-cycle. Maintenance efforts should be reduced as much as possible.

- Reduced by adapted detail
- Reduced by adapted material choice

INFRASTRUCTURE (BRIDGES)

This chapter is most relevant for Ney & Partners' "infrastructural" (road) bridges. It can also be used for bicycle/pedestrian bridges, though their impact is less relevant. This document is not meant to be applied to other small types of projects such as bus stops, canopies, staircases, etc.

Two criteria are assessed:

1. robustness (through Life Cycle Optimization);
2. durability (trough Impact on Life Environment).

ROBUSTNESS

can be defined according to three parameters:

Flexibility: The object can easily adapt to possible modifications that are integrated in the concept. We can talk about flexibility on the deck (interchangeable traffic band, no central structure, equivalent load across the width). We can also talk about flexibility under the bridge by limiting the number of support lines.

Redundancy: We can speak here of oversizing, redundancy of certain elements. For example, for a cable-stayed bridge, in the event of a cable break (impact, lack of maintenance, poor execution), the overall stability of the structure is not endangered.

Inertia: The object resists the pressure of change. This is the intrinsic quality of the object (aesthetic and technical). We are talking about limiting the number of details, an integrated approach to design with elements that fulfil different functions and that cannot be dismantled and replaced.

DURABILITY

is assessed through using the LCA + CO_2 score, but also through the matrix:

Limitation of maintenance through an adequate choice of materials (stainless steel, Corten, etc.).

Limitation and ease of maintenance through proper design of details (easy access to critical elements, integral bridges without jointless support).

INFRASTRUCTURE (BRIDGES) / CRITERIA TRADE-OFF MATRIX

FLEXIBILITY

On bridge: no central structure
On bridge: equivalent loads on entire width
On bridge: flexibility in traffic lanes
On bridge: flexibility to replace some lanes by a tramway
Under bridge: one large span rather than three smaller spans

REDUNDANCY

Over-dimensioning
Redundancy (e.g. cables of suspension bridge)
Margin for lack of maintenance
Margin for bad execution
Margin for bad replacement

INERTIA

Aesthetic quality
Technical quality: limited number of details
Technical quality: integrated approach fulfilling different functions
Spatial quality

MAINTENANCE

Reduced through material choice (weathering steel, stainless steel, etc.)
Reduced through detailing (integral bridge, type of bearings, number of joints, quality of steel conservation)

LAND USE

Compact surface on soil
Keeping nature and infrastructure divided
Integrating technical (e.g. solar) solutions on bridge edge instead of in rural field

NUISANCE

Reduced in execution phase
Reduced when realized through better flow of people, safer and easier connections

CONCLUSION

Architectural and civil works have impacts, and the way these works are integrated in the landscape, whether urban or rural, will leave its mark for centuries to come. The Ney & Partners team wants to lower its impact through distinctive design.

The first design goal includes minimizing the impact of structure through **materiality** (quantity). This encompasses minimum mass, minimum waste and minimum embodied carbon. The three main strategies focus on material choice, optimized design and design for disassembly if compatible with the above. The second design goal maximizes the life cycle of a structure through **flexibility and robustness** (quality). This entails the capacity to adapt. For building projects the three main strategies focus on robustness of the structure, timeless design and separation of layers. For bridge projects the main strategies focus on Life Cycle Optimization through robustness and maintenance and Impact on Life Environment.

A tool has been developed to assist the design process towards a vision for a sustainable design philosophy. The tool offers an LCA score (quantitative), according to European Standards and a trade-off matrix including flexibility, robustness and maintenance (non-quantitative).

By ensuring the key aspects of sustainability are at their best, the design of Ney & Partners' projects goes beyond the traditional engineering practice of combining aesthetics and budget: sustainability becomes an inherent part of the design process. Every project should be built to last.

APPENDIX

REFERENCES

Brussels Bouwmeester Architect

The impact of structure on the building's Expected Life Span (ELS) is essential, as mentioned in the circularity evaluation framework (BMA – Brussels Bouwmeester Architect). It is easier to obtain a permit if sustainability is taken into account.

How is the choice of rebuilding from scratch observed?

- **HERITAGE** – Easy answer: Not demolished
- **SUSTAINABILITY** – Better to refurbish rather than demolish. Adapt the existing to NZEB as much as possible.
- **ECONOMY** – Sometimes easier to refurbish: Building permit, duration of works, neighbourhood reaction.
- **URBANISM** – Is the building blocking the urbanistic context? Blocking a flow, a street, a pathway? Does its size still match the surrounding built cityscape? Can be reasons to demolish or adapt.

The case of Brussels:
Historically Brussels has seen lots of buildings demolished, even heritage, and rebuilding has followed trends and façadism.

Proposal:
Aim to replace a total demolition by a partial demolition. Keeping the whole structural skeleton would show significant versatility and robustness.
The proposal to keep the structure through successive retrofitting would have the following impacts:

- Faster work site
- Easier permit process
- Limited CO_2 impact for works
- Improved structure lifespan.

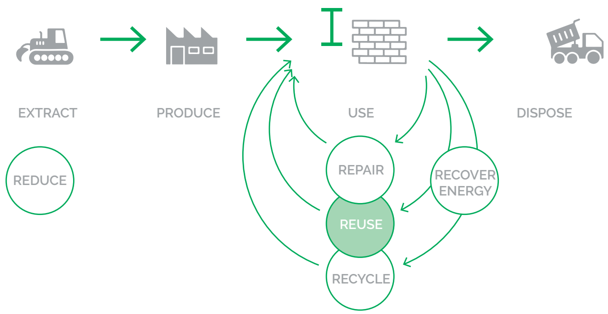
Building structures must be seen as multi-use, versatile and adaptive. A single life cycle for the structure should adapt to multiple façade/finishing/HVAC life cycles.

LEXICON

SUSTAINABILITY[11]
Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The three pillars of sustainable development are environmental, economic and social.

LINEAR ECONOMY
RESOURCE > MAKE > USE > DISCARD
CIRCULAR ECONOMY
RESOURCE > MAKE > USE **> REPAIR > REUSE > RECYCLE** > DISCARD

Current efforts to remediate both operational and embodied emissions of the building sector are underway, but they often do not close the loop of materials and energy flows, which would also remediate the excessive exploitation of resources and raw materials as well as the problematic generation of waste. To address not only global warming but also resource depletion and waste generation, we need to shift the construction sector away from its linear extract-produce-use-dispose model. This is what a circular economy brings: it extracts maximum value from goods by extending their service life or reusing them at the end of their service life as new resources, while minimizing their environmental impact.



Linear-to-circular paradigm shift in the construction industry

CO_2 LEVEL

Mono-criteria analysis based on Greenhouse Gas Umissions only. Widely used in the EU.

LIFE CYCLE ANALYSIS – LCA

Multi-criteria method, widely used in the EU. ISO 14040/44. Is used for forecasting the total environmental impact of products/services throughout their life cycle. Includes CO_2 and criteria like toxicity.

EMBODIED CARBON COEFFICIENT (ECC)

A coefficient that gives the embodied carbon impact of a material expressed in $kgCO_2eq$ per kg of material.

GLOBAL WARMING POTENTIAL (GWP)

The GWP of a structure is the embodied carbon expressed in $kgCO_2eq$/unit. This can be obtained with the following equation.

$$\sum_{i=n}^{n} ECC_i \times SMQ_i = GWP$$

$$\sum_{i=n}^{n} \underset{(kg_{CO_2eq}/kg_{material})}{\text{Embodied Carbon Coefficients}_i} \times \underset{(kg_{material}/m^2)}{\text{Structural Material Quantities}_i} = \underset{(kg_{CO_2eq}/m^2)}{\text{Global Warming Potential}}$$

CRADLE-TO-CRADLE (C2C)

Cradle-to-cradle[12, 13] (C2C) is a philosophy which eliminates the concept of waste while providing enduring benefits for society from safe materials, water and energy in a circular economy. The main principles are: waste becomes a resource for others and everything can be designed to be dismantled and return as biological nutrients or reused as technical nutrients. This philosophy was developed by Michael Braungart and William McDonough.

THIRD INDUSTRIAL REVOLUTION

Theory and book by Jeremy Rifkin published in 2011. The premise of the book is that fundamental economic change occurs when new communication technologies converge with new energy regimes, mainly, renewable electricity. “The pillars of the Third Industrial Revolution are shifting to renewable energy; transforming the building stock of every continent into green micro–power plants to collect renewable energies on-site” – Jeremy Rifkin, The Third Industrial Revolution

OVERVIEW EXISTING TOOL LCA + CO_2 SCORE

EUROPE

- Level(s)[14] is developed by the Joint Research Centre (JRC) of the European Commission to harmonize existing European LCA tools and databases through a common EU framework of core sustainability indicators for office and residential buildings.
- BAMB[15] developed a European Reversible Building Design, Reuse Potential Tool to assess the circularity of building projects.

FRANCE

A list of tools used for the E+C- label (Bâtiment à Energie Positive & Réduction Carbone) in France is given on http://www.batiment-energiecarbone.fr/en/list-of-software-tools-available-a20.html

- ArchiWizard[16] is an energy simulation software for optimization and regulatory validation of the energy performance of the building from the concept stage and until the completion of the works, in design and renovation, in direct connection with the building information model (BIM).
- EIME[17] is a tool to quantify the environmental impact of your products and services throughout their life cycle, identify eco-design paths and develop your product environmental policy.
- ELODIE[18] is software analysing of the overall performance of buildings aimed at all construction stakeholders engaged in a performance-based environmental approach. It is a collaborative tool for quantifying the environmental impacts over the entire life cycle of a building, be it tertiary or residential.
- EQUER[19] is a tool developed at ParisTech Mines Energy Efficiency Center and carries out the LCA of buildings and neighbourhoods and evaluates 12 environmental indicators, in particular grey energy and the contribution to global warming. It can also use the calculation results of the STD COMFIE module and those of the RT2012 module or perform an analysis from scratch. The calculation is based on Ecoinvent environmental databases.
- Vizcab[20] uses advanced technology to get qualified data and display it as data visualization. The tool is approved by the State as part of the experiment ‘Énergie positive - Réduction carbone (E+C-)’.
- TEAM[21] is an LCA software offered by pwc Ecobilan.

NETHERLANDS

- DuboCalc[22] is a software tool for calculating quickly and easily the sustainability and environmental costs of design variants. DuboCalc is used by clients and (potential) contractors for writing and assessing (EMVI) tenders for construction works.

- GPR Gebouw, GreenCalc+, MPGCalc, MRPI MPG-software are nationally led tools in the Netherlands for LCA.
- SimaPro[23] has been a leading LCA software package for 25 years. It is trusted by industry and academics in more than 80 countries. SimaPro was developed to help you effectively apply your LCA expertise to drive change – to provide the facts needed to create sustainable value.

UK

- eToolLCD[24] is a web-based Life Cycle Design app for the built environment, developed originally in Australia, but also used in the UK.

Table 1 gives an overview of the discussed tools in terms of system boundaries and scope, indicators, quality assessment, transparency and verification, accessibility, data exchange and interoperability.

In **France**, Base carbone ADEME and INIES are often used. In the **Netherlands**, the national database is called Milieudatabase. LCA environmental data for the Dutch database must be drawn up following a public assessment protocol. A weighting to a 1-point score is possible for the indicators. In the UK, a much used open-source database is called Inventory of Carbon & Energy (ICE), developed by Craig Jones at Circular Ecology (originally University of Bath). This database only gives the GWP results, not the other indicators.

	System boundaries & scope	Indicators	Quality assessment	Transparency and verification	Accessibility, data exchange, interoperability
TOTEM Free tool Free demo documentations and training sessions	- Allows assessment of A1-A5, B2, B4, B6-7, C1-C4 - Uses national database - Available in English, French, Dutch	Full coverage of indicators set in EN 15978 + reporting of extracted materials + additional PEF indicators	Scenario analysis possible	Information is reported in a simplified way	Web interface, import/export of design and LCA information is possible using independent software formats
EIME Commercial price Demo, long-distance training, helpdesk offered	- Allows assessment of A1-A5, B1-7, C1-4, D - Database developed over more than 20 years, updated at least once per year - Available in English	Full coverage of indicators set in EN 15978 + reporting of extracted materials + additional PEF indicators	Sensitivity analysis (e.g. check influence of parameters and datasets on results) and scenario analysis (e.g. check of alternative options) possible	Sources of information and key data and modelling assumptions are reported but are not systematically trackable and verifiable nor can they be documented in detail inside the software	Web interface, import/export of design and LCA information is possible using independent software formats
ELODIE Commercial price Aftersales support offered	- Allows assessment of A1-A5, B1-7, C1-4, D - Available in French and English	Full coverage of indicators set in EN 15978 + reporting of extracted materials + additional PEF indicators	No data quality assessment offered	Information is reported in a simplified way	Web interface, import/export of design and LCA information is possible using independent software formats
EQUER Commercial price Demo, initial training, and aftercare support offered	- Allows assessment of A1-A5, B4, B6, B7, C1-4, D - INIES and ecoinvent are used as databases - Available in French	Full coverage of indicators set in EN 15978 + reporting of extracted materials + additional PEF indicators	Sensitivity analysis, uncertainty analysis and scenario analysis possible	Sources of information and key data and modelling assumptions are reported but are not systematically trackable and verifiable nor can they be documented in detail inside the software	Software to install on computer, import/export of design and LCA information is possible using BIM
VIZCAB Commercial and free version Demo offered	- Allows assessment of A1-5, B1-7, C1-4, D - INIES and ecoinvent are used as databases - Available in English	Full coverage of indicators set in EN 15978	Parametric analysis possible	Parametric visualization	Software to install on server, import/export of design and LCA information is possible using BIM
TEAM Commercial version Training offered	- Allows assessment of A1-5, B1-7, C1-4, D - TEAM allows the building of large databases by the user - Available in English	Full coverage of indicators set in EN 15978 + PEF indicators	Reliability assessment, sensitivity analysis, scenario analysis is possible.	Sources of information and key data and modelling assumptions are systematically trackable and verifiable and they can be documented in detail inside the software	Software to install on computer, import/export of design and LCA information is possible using independent software formats
ETOOL Commercial and free version Demo, long-distance training, aftercare support offered	- Allows assessment of A1-5, B1-7, C1-4, D - Available in English	Full coverage of indicators set in EN 15978	Reliability assessment, sensitivity analysis and scenario analysis possible.	Sources of information and key data and modelling assumptions are systematically trackable and verifiable and can they be documented in detail inside the software	Web interface, import/export of design and LCA information is possible using independent software formats

Overview of existing tools for LCA + CO_2 score

EMBODIED CARBON COEFFICIENTS (ECC)

The definition of ECC is an important and complex matter. The ECC can vary significantly depending on strength, composition, location (production/application) and time (as production methods become more environmentally friendly). The values given below are to be considered as indicative, and where regionally verified EPDs are available, these should be prioritized.

MATERIAL QUALITY		GLOBAL WARMING POTENTIAL kgCO_2eq/kg
CONCRETE	CEM I C30/37	0.131
	CEM I C50/60	0.168
	CEM III C30/37	0.061
	CEM III C50/60	0.072
REBAR	BE500	1.990
STRUCTURAL STEEL	S235	1.300
	S355	1.400
	S460	1.500
TIMBER	Engineered	0.580
	Sawn	0.180
ALUMINIUM	Standard	6.670
	Recycled (> 75%)	2.300

NOTES

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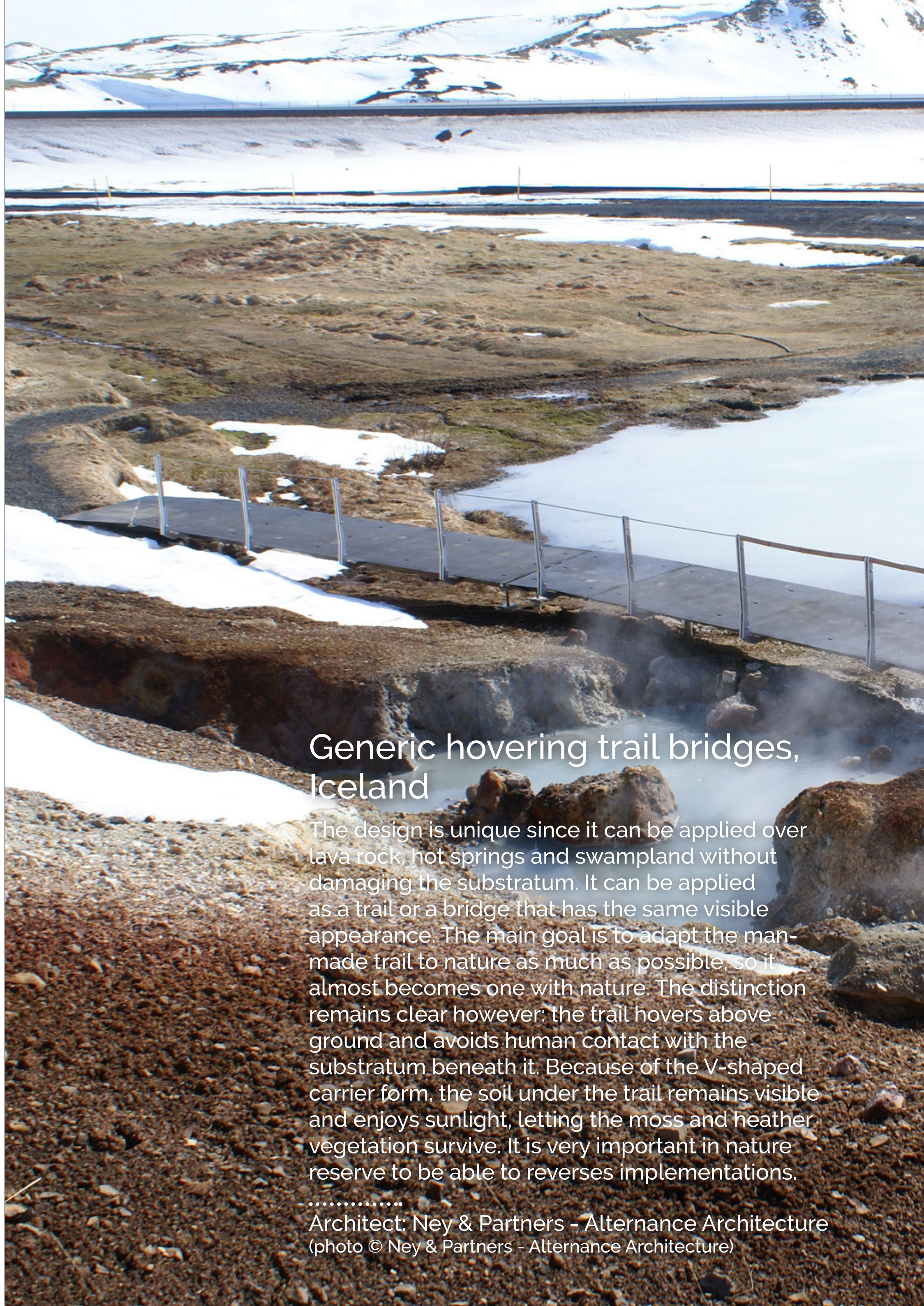
17 https://codde.fr/en/our-software/eime-en/eime-presentation
18 https://logiciels.cstb.fr/batiments-et-villes-durables/performances-environnementales/elodie/
19 https://www.izuba.fr/logiciels/outils-logiciels/pleiades-acv/
20 https://vizcab.io/en/accueil
21 https://ecobilan.pwc.fr/en/team.html
22 https://www.dubocalc.nl
23 https://simapro.com
24 http://etoolglobal.com

Text: Jean-Didier Steenackers, Catherine De Wolf, Jeroen Vander Beken
Credits: Ney & Partners - Alternance Architecture (back cover).
Book design: Jessika L'Ecluse



Generic hovering trail bridges, Iceland

The design is unique since it can be applied over lava rock, hot springs and swampland without damaging the substratum. It can be applied as a trail or a bridge that has the same visible appearance. The main goal is to adapt the man-made trail to nature as much as possible, so it almost becomes one with nature. The distinction remains clear however: the trail hovers above ground and avoids human contact with the substratum beneath it. Because of the V-shaped carrier form, the soil under the trail remains visible and enjoys sunlight, letting the moss and heather vegetation survive. It is very important in nature reserve to be able to reverses implementations.

Architect: Ney & Partners - Alternance Architecture
(photo © Ney & Partners - Alternance Architecture)

NEY & PARTNERS BXL
Terhulpsesteenweg 181
B-1170 Brussels
Belgium
T +32 (0)2 643 21 80
ney@ney.partners
www.ney.partners

NEY & PARTNERS WOW TIMBER STRUCTURES
Rue de la Montagne 2
B-5000 Namur, Belgium
T +32 (0)81 414 899
wow@ney.partners
www.ney.partners

NEY & PARTNERS FRA
4A 1 Place de la Liberté
33600 Pessac (Bordeaux), France
T +33 (0)9 75 30 69 81
fra@ney.partners
www.ney.partners

NEY & PARTNERS VNM
Comatce Tower
61 Nguy Nhu Kon Tum
Hanoi, Vietnam
T (+84) 24 2283 9922 – 0989 345 716
vnm@ney.partners
www.ney.partners

T6 – NEY & PARTNERS LUX
Rue du Fort Bourbon 3
L-1249 Luxembourg
Grand Duchy of Luxembourg
T +352 78 81 31
lux@ney.partners
www.ney.partners

NEY & PARTNERS JPN
3-15-6-601 Higashi Shibuya-ku
Tokyo 150-0011
Japan
T +81 3 6427 5603
jpn@ney.partners
www.ney.co.jp

NEY & PARTNERS NL
Westvest 149
2611AZ Delft, The Netherlands
T +31 15 799 8300
nl@ney.partners
www.ney.partners

NEY
+PARTNERS