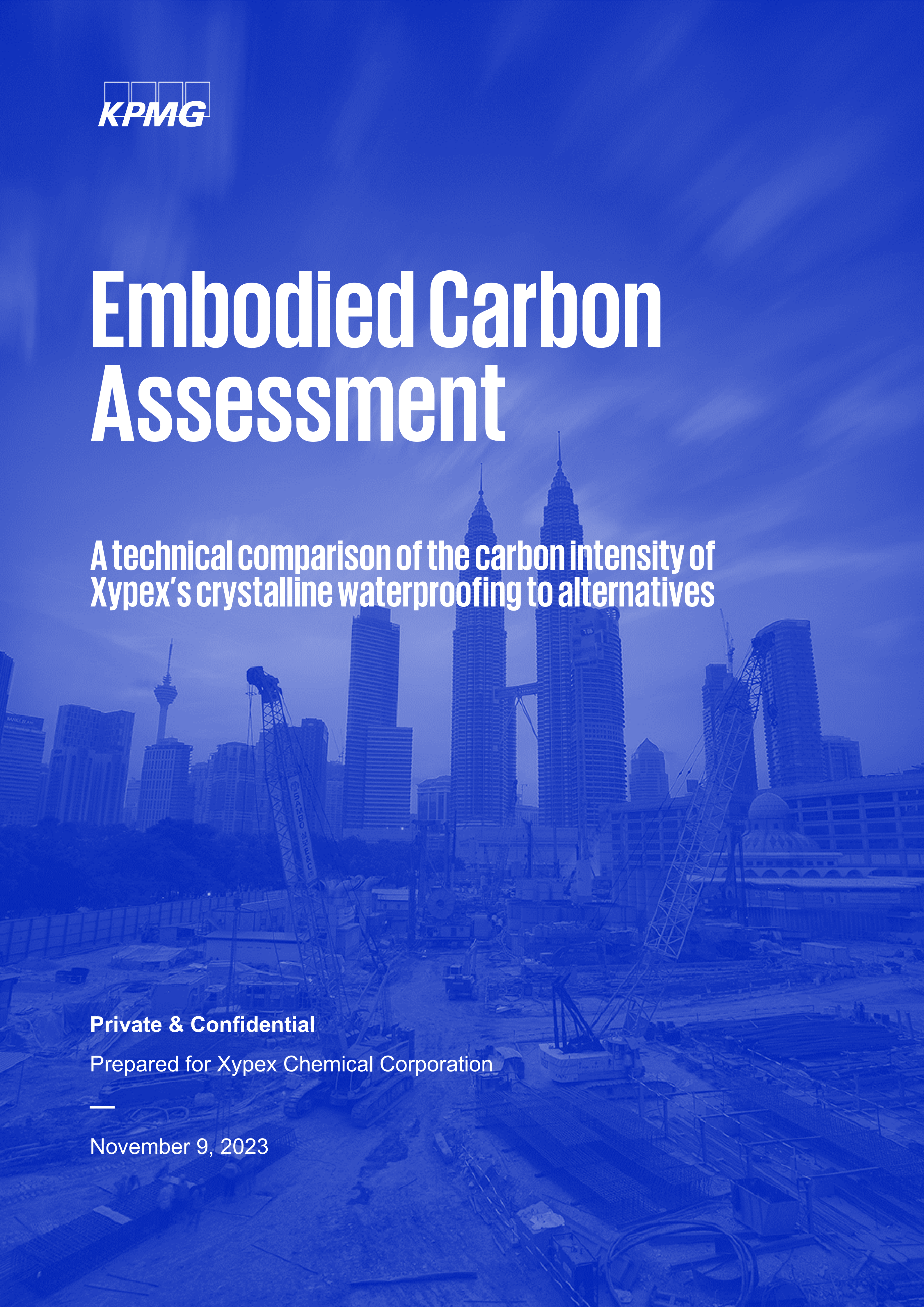

Embodied Carbon Assessment

A technical comparison of the carbon intensity of Xypex's crystalline waterproofing to alternatives

Private & Confidential

Prepared for Xypex Chemical Corporation

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November 9, 2023

Disclaimer

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Our methodology consisted of research, analysis and comparison of information obtained both from publicly available sources, which are cited herein, and Client-provided data related to its crystalline technology. KPMG has relied on Client for the completeness, accuracy, appropriateness and reliability of the information provided and, given the proprietary nature of such information, did not independently verify the data.

The services provided in connection with this engagement comprise an advisory engagement, which is not subject to assurance or other standards issued by the Canadian Auditing and Assurance Standards Board and, consequently, no opinions or conclusions intended to convey assurance have been expressed.

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1 Executive Summary

Introduction and Background

Construction and the built environment contribute to approximately 37% of global greenhouse gas (GHG) emissions.[1] As a result, project developers and asset owners are increasingly investigating innovative opportunities to limit the GHG emissions required to produce the materials used in their projects — towards the objective of reducing emissions and transitioning to a lower-carbon economy. GHG emissions required to make building materials are often referred to as “embodied carbon”.

Xypex, a provider of a proprietary crystalline waterproofing technology, engaged KPMG to assess the embodied carbon of its crystalline technology, as well as those of two generic, commonly used market alternatives for waterproofing concrete. This report presents the results of KPMG’s research and analysis. In consultation with Xypex, KPMG selected comparable alternatives and used an illustrative case study for waterproofing a 10,000 ft^2 (929 m^2) concrete foundation of a new commercial building. The four waterproofing technologies selected for comparison were the following:

(i) **Hot-applied rubberized asphalt**: A material that combines the waterproofing qualities of traditional asphalt with the rubber properties of styrene-butadiene-styrene (SBS) elastomer;

(ii) **High density polyethylene (HDPE) sheeting**: A synthetic peel-and-stick waterproofing membrane that integrates the flexible characteristics of plastic with its non-reactive properties;

(iii) **Xypex crystalline admixture**: A blend of chemicals and minerals added to ready-mix concrete prior to a pour that grow within the capillary pores and cracks of concrete; and,

(iv) **Xypex crystalline concentrate surface-applied waterproofing**: A blend of chemicals and minerals applied to a cured concrete surface that grow within the capillary pores and cracks of concrete.

KPMG's research and analysis were guided by the ISO 14064-2:2019 framework for the quantification, monitoring and reporting of GHG emissions reductions or removal enhancements. This approach comprised data collection to identify suitable comparators, emissions quantification across specific areas of the product lifecycle, and presentation of results. The analysis focused on quantifying emissions across four key stages of the product lifecycle:

(A) **Raw material extraction and manufacturing:** Emissions associated with extracting and manufacturing the individual materials that typically constitute each type of technology;

(B) **Installation:** Emissions associated with installing each technology during the construction stage;

(C) **Repair and maintenance:** Emissions associated with repair and maintenance activities;[2] and,

(D) **End-of-life:** Emissions associated with demolition, transport and disposal of materials.

To account for potential variations in manufacturing processes among products of the same technology, the methodology used for Stage A evaluates the individual materials themselves that typically constitute each technology. This approach enables a meaningful, technology-focused, and “like for like” comparison, rather than seeking to assess the specific manufacturing processes of individual products. Where possible, KPMG compared its calculations to available Environmental Product Declaration (EPD) reports.[3] Where necessary, KPMG adapted its methodology to simplify the analysis and safeguard the confidential nature of Xypex’s proprietary chemicals. For example, Xypex provided KPMG with Stage A emissions calculations for its crystalline technology.

[1] United Nations Environmental Programme (November 2022).

[2] Repair and maintenance needs depend on numerous potential factors beyond the waterproofing technology selected, such as quality of workmanship, detailing quality, and structural movement. Given these reasons, among others, KPMG applied a qualitative approach to assessing the inherent renewal requirements of each technology, as opposed to quantitative methods.

[3] Although EPD reports use a different methodology to calculate emissions factors, they are a valuable source of related data, including the raw material extraction and manufacturing emissions values of individual materials.

Summary of Results

The table below summarizes the results of the analysis.

	Hot-Applied Rubberized Asphalt	HDPE Membrane Sheeting	Xypex Crystalline Admixture	Xypex Crystalline Concentrate
Raw material extraction & manufacturing stage	1,724 $kgCO_{2eq}$	1,750 $kgCO_{2eq}$	967 $kgCO_{2eq}$	885 $kgCO_{2eq}$
Installation stage [4]	208 $kgCO_{2eq}$	0 $kgCO_{2eq}$	0 $kgCO_{2eq}$	18 $kgCO_{2eq}$
Repair & maintenance stage [5]	Potential additional carbon	Potential additional carbon	Potential carbon savings	Potential carbon savings
End-of-life stage	685 $kgCO_{2eq}$	545 $kgCO_{2eq}$	10 $kgCO_{2eq}$	10 $kgCO_{2eq}$
Totals	**2,617 $kgCO_{2eq}$**	**2,295 $kgCO_{2eq}$**	**977 $kgCO_{2eq}$**	**913 $kgCO_{2eq}$**

Results indicate that Xypex's Crystalline Admixture technology contains approximately:

— 63% less embodied carbon than hot-applied rubberized asphalt, and

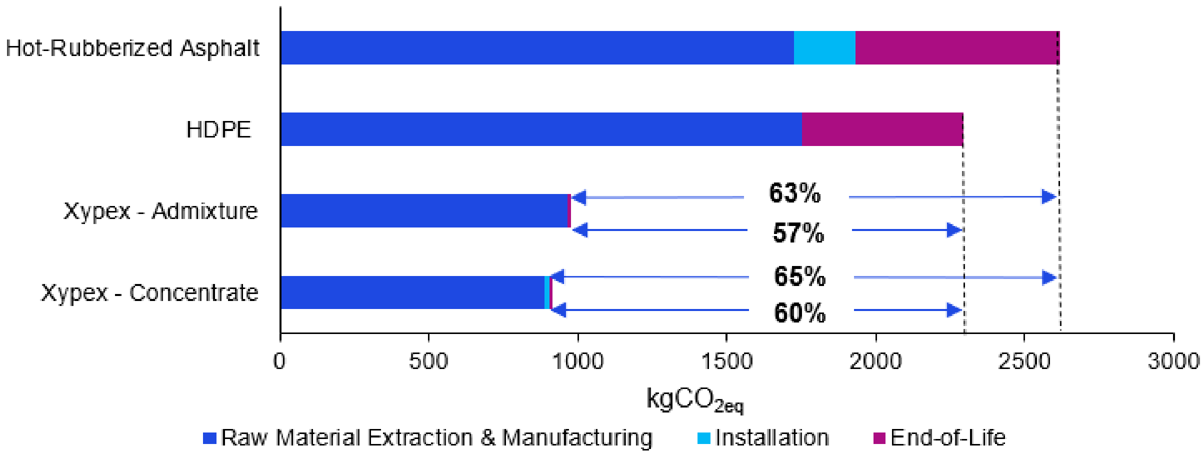
— 57% less embodied carbon than HDPE membrane sheeting over its lifecycle.

Results indicate that Xypex's Crystalline Concentrate technology contains approximately:

— 65% less embodied carbon than hot-applied rubberized asphalt, and

— 60% less embodied carbon than HDPE membrane sheeting over its life cycle.

The figure below presents a graphic representation of the embodied carbon of the four comparators across the product lifecycle.



[4] Assessment of the installation stage for HDPE membrane sheeting does not include incidental emissions, such as torching of the seams, which are not deemed to be material for the purposes of this analysis.

[5] Repair and maintenance of hot-applied rubberized asphalt membrane requires the combustion of propane, potentially leading to additional carbon emissions to address. In addition, HDPE membrane sheeting may experience water seepage from potential adhesive failures and detailing at joints, potentially leading to additional carbon emissions to address. While more difficult to quantify, Xypex's crystalline technology likely leads to additional—potentially material—carbon savings during the repair and maintenance stage, relative to the comparators selected, due to its self-healing properties. Unlike waterproofing technologies that act as adhered barriers, Xypex's crystalline technology integrates deep into the porous matrix of concrete, able to self-heal cracks over time and allow concrete to remain watertight. This property enables Xypex's crystalline technology to reduce future waterproofing repairs in many cases, resulting in lower embodied carbon relative to the comparators.

2 Introduction

Given its share of global GHG emissions, the construction industry faces increased pressure to address the impacts of climate change, particularly through the carbon intensity of the sector's building materials. In response, project developers and asset owners are proactively exploring opportunities to reduce the carbon emissions associated with these materials (i.e., "embodied carbon"). Over time, this will require additional data, measurement, and technical analyses to understand more clearly the environmental impacts of various materials and related construction practices. This research report seeks to contribute to those strategic objectives.

2.1 Research Project Objective

Xypex engaged KPMG to conduct targeted research and analysis to evaluate the embodied carbon of its crystalline technology compared to two generic, commonly used market alternatives for waterproofing concrete.

2.2 Illustrative Case Study Approach

In consultation with Xypex, KPMG used an illustrative case study approach to quantify the embodied carbon of each comparator. The case study involves waterproofing the concrete foundational walls of a building with the following characteristics:

- **Building Type:** Commercial;
- **Geographic Location:** North America;
- **Waterproofing Area:** 10,000 ft^2 (~929 m^2) of foundation vertical walls;[6]
- **Wall Thickness:** 8" (~200 mm)

Using the case study, KPMG analyzed the embodied carbon of the following four waterproofing technologies:

(i) Hot-applied rubberized asphalt (base case scenario #1);

(ii) HDPE membrane sheeting (base case scenario #2);

(iii) Xypex crystalline admixture (project case scenario #1) and

(iv) Xypex crystalline concentrate (project case scenario #2).

Table 1 on the next page provides an overview of each technology, their inherent properties, and reasons for selection.

[6] The selection of 10,000 ft^2 as the area and 8" wall thickness for the case study are arbitrary and serve as a practical benchmark to analyze the waterproofing technologies.

Table 1: Overview of waterproofing technologies

	Hot-Applied Rubberized Asphalt	HDPE Membrane Sheeting	Xypex Crystalline Admixture & Concentrate
Scenario	Base case #1	Base case #2	Project case #1 – Admixture Project case #2 – Concentrate
Description	SBS hot-applied rubberized asphalt is a type of asphalt that combines the waterproofing qualities of traditional asphalt with the rubber properties of the SBS synthetic elastomer.	HDPE membrane sheeting is a synthetic peel-and-stick waterproofing membrane that integrates the flexible characteristics of plastic with its non-reactive properties.	Xypex's crystalline technology utilizes a proprietary blend of chemicals that react with moisture and alkaline earth compounds to form insoluble crystals which grow within the capillary pores and cracks of concrete.
Material Composition	Typically composed of: • SBS modified asphalt (90%) • Polystyrene protection board (10%)	Typically composed of: • High-density polyethylene (70%) • Additive plastics: Combination of polystyrene, polypropylene and LDPE (20%) • Petroleum hydrocarbons - olefins (10%)	Composed of: • Portland cement • Sand • Alkaline earth compounds • Proprietary materials
Installation process	(i) Heat rubberized asphalt to 180ºC to 200ºC using a propane kettle (ii) Apply liquid rubberized asphalt by squeegee (iii) Overlay protection board	(i) Release disposable plastic liner and apply peel-and-stick membrane.	Two methods for installation: (i) Admixture: Mixed directly into concrete within concrete truck during time of pour (ii) Concentrate: Apply slurry mix of concentrate using a spray
Recyclability with concrete	Concrete cannot be directly recycled with rubberized asphalt. To facilitate concrete recycling, the rubberized asphalt must be separated from the concrete.	Concrete cannot be directly recycled with HDPE membrane sheeting. To facilitate concrete recycling, the HDPE sheeting must be separated from the concrete.	Directly recyclable with concrete.
Reasons for inclusion	Widely recognized waterproofing technology known for its versatility across various applications. It is sometimes favoured for its rapid drying capabilities and ability to resist cracking and scaling caused by building movement.	Widely recognized waterproofing technology known for its puncture resistance as well as peel-and-stick sheeting, which allows for quick and uniform application on a wide variety of surfaces.	Waterproofing technology with inherent properties that contribute to lower embodied carbon. Additional properties include material composition, installation during concrete batching, self-healing capabilities and recyclability.

3 Methodology

KPMG's methodology comprised the following three phases:

1. Phase I: Data collection;
2. Phase II: Emission quantification; and,
3. Phase III: Presentation of results.

Each phase is described below.

Phase I: Data collection

In the first phase, KPMG reviewed waterproofing technologies commonly used by the market based on their ability to waterproof the illustrative case study and versatility. KPMG's review included assessing the following hot- and cold-applied waterproofing technologies, which Xypex confirmed were potential comparators:

- Hot-applied rubberized asphalt;
- HDPE membrane sheeting;
- Polyurethanes; and,
- Elastomers.

In the next stage, KPMG conducted research to assess data availability for each technology. The assessment included researching the following sources to assess data availability and quality:

- Technical and safety product datasheets;
- Public disclosures of companies producing these technologies;
- Industry associations;
- EPD reports; and,
- LCI databases recognized by the GHG Protocol.

The assessment identified hot-applied rubberized asphalt and HDPE membrane sheeting as applicable comparators with sufficient data available to conduct the analysis. Xypex confirmed that the selected comparators would provide valuable insights into understanding how the embodied carbon of Xypex's crystalline technology compares to its alternatives.

Phase II: Emission quantification

The calculation methodology is divided into four stages, (A) raw material extraction and manufacturing, (B) installation, (C) repair and maintenance, and (D) end-of-life. Table 2 outlines the product lifecycle for a waterproofing technology.

Table 2: Product Lifecycle

Stage	Raw material extraction and manufacturing			Installation		Repair & maintenance				End-of-life			
	RRM 1	RRM 2	RRM 3	I1	I2	R&M 1	R&M 2	R&M 3	R&M 4	EOL 1	EOL 2	EOL 3	EOL 4
Component	Raw Material	Transport	Manufacturing	Transport	Installation	Use	Maintenance	Repair	Refurbishment	Demolition	Transport	Waste Processing	Disposal

The calculation methodology for each stage is described below. Appendix B – Data Quality summarizes the assumptions used to complete the calculations.

Raw material extraction and manufacturing (RRM1 – RRM3): Recognizing the inherent variations in manufacturing processes among different products within the same technology, as well as limitations in understanding the full manufacturing process of Xypex's proprietary chemicals, a more general quantification approach was taken. The approach involves quantifying the raw material extraction and manufacturing process emissions of the specific materials typically constituting each technology, allowing for a general comparison.

The following three-step approach quantifies the emissions associated with the raw material extraction and manufacturing processes of specific materials:

(i) Material analysis: Identify the specific materials typically constituting each technology;

(ii) Mass analysis: Quantify the amount of material required to waterproof the case study; and,

(iii) **$kgCO_{2eq}$ analysis:** Multiply each mass with its corresponding cradle-to-gate emissions factor.[7]

Given the confidential nature of Xypex's proprietary chemicals, KPMG could not quantify Stage A emissions factors for its crystalline technology directly and independently. To address this limitation, which was discussed with Xypex prior to commencing the project, KPMG provided Xypex with publicly available emissions factors derived from a range of materials that it understood to be relevant to the chemical composition of Xypex products. This enabled Xypex staff to review the emissions factors of the specific (confidential) raw materials that materially comprise its proprietary chemicals, engage with its suppliers to address data requirements, and calculate Stage A emissions factors itself. KPMG answered Xypex's questions as they arose. While KPMG did not conduct the calculations itself, Xypex described its approach in sufficient detail that KPMG believes the measurements were completed to an appropriate level of rigour for the purposes of this report.

Installation (I2): This stage involves quantifying emissions associated with installing each technology in the case study. The boundary of this stage includes the arrival of materials on-site to the completion of installation (I2). Emissions related to the transportation of product delivery (I1) are not quantified, as they are assumed to be equal for all technologies.

The following three-step approach calculates the emissions associated with installing each technology:

[7] A cradle-to-gate emissions factor refers to the amount of greenhouse gas emissions associated with a unit product or material from the extraction of raw materials (cradle) to the point of leaving the manufacturing facility (gate).

(i) **Energy analysis:** Identify equipment necessary to install each technology that requires fuel and/or electricity;

(ii) **Mass analysis:** Quantify fuel and/or electricity consumption required to install each technology; and,

(iii) **$kgCO_{2eq}$ analysis:** Multiply fuel and/or electricity consumption amounts with their corresponding emissions factor.

For this stage, KPMG utilized a proxy process to estimate the amount of fuel consumed through equipment during installation. KPMG selected proxies to align with the specific characteristics and requirements of each waterproofing technology, ensuring an accurate estimation of the equipment usage time and fuels consumed.

Repair and maintenance (R&M1 – R&M4): Numerous potential factors can lead to repair and maintenance needs, such as quality of workmanship, improper detailing, and structural movement of the building. In commercial buildings, internal repairs are typically prioritized over excavation due to cost, feasibility, and site-specific factors. As a result, accurately quantifying emissions related to repair and maintenance throughout the lifecycle of the case study presents challenges, as it depends on various site-specific factors in addition to the waterproofing technology.

Therefore, the analysis of repair and maintenance focuses on a qualitative assessment rather than a quantitative measurement. It evaluates the inherent properties of each technology that have an impact on the need for repair and maintenance.

End-of-life (EOL1 – EOL4): The final stage quantified emissions associated with separating the waterproofing substrate from the concrete foundation to enable concrete recycling, as well as the emissions associated with transporting and disposing each waterproofing technology.

The following four-step approach calculates the emissions associated with the end-of-life stage:

(i) **Energy analysis:** Identify equipment requiring fuel and/or electricity to separate waterproofing substrate from concrete;

(ii) **Mass analysis:** Quantify amount of fuel and/or electricity required to separate waterproofing substrate from the concrete;

(iii) **$kgCO_{2eq}$ analysis:** Multiply fuel and/or electricity consumption amounts with their corresponding emissions factors; and,

(iv) **Disposal analysis:** Calculate transport, recycling and landfilling emissions of waterproofing materials using the US Environmental Protection Agency (EPA) Waste Reduction Model (WARM Model).

For this stage, KPMG utilized a proxy process to estimate the amount of fuel consumed through equipment to separate the waterproofing substrates from concrete. KPMG selected proxies to align with the specific characteristics and requirements of each waterproofing technology, ensuring an accurate estimation of the equipment usage time and fuels consumed.

Phase III: Presentation of Results

The final phase involved presenting the results for each stage using the principles outlined in the ISO 14064-02 framework. The emission calculations, along with their associated assumptions, are presented in a manner that facilitates understanding and thorough assessment. By adhering to the ISO 14064-2 framework and presenting the results in a clear and concise manner, this report aims to provide complete and easy understanding of the emissions associated with each stage of the product lifecycle.

Data Quality

The field of emissions factors is continuously evolving and selecting representative emissions factors requires careful consideration. KPMG based the emissions factors presented in this report on information available at the time of the analyses. Over time, emissions factors may change, and the changes may have a material impact on the accuracy of the calculations presented herein.

This paper uses a data management procedure when selecting emissions factors. Table 3 outlines considerations impacting the data quality of emissions factors and best practices undertaken when selecting them. Appendix B – Data Quality summarizes the data quality ratings of the emissions factors used.

Table 3: Data Management Procedure

	Description	Management Procedure
Source	Emissions factors may vary across reporting organizations. As a result, there may be more than one emissions factor value available for a specific material or process.	Emissions factors are only sourced from Environmental Product Declaration (EPD) reports, industry associations and lifecycle databases recognized by the GHG Protocol.
Date	Emissions factors are continuously refined and updated as new research and data become available.	Emissions factors are sourced from the most recent reports and databases available.
Geography	Emissions factors may be specific to a country or region based on local processes, environmental standards and regulations.	North American-specific sources are prioritized, and European emissions factors are only utilized if data is unavailable from a reliable North American source.

4 Emissions Quantification

4.1 Raw material extraction and manufacturing

This section quantifies the emissions associated with the raw material extraction and manufacturing of the typical materials constituting each waterproofing technology.

4.1.1 Hot-Applied Rubberized Asphalt

Hot-applied rubberized asphalt is typically applied at a rate of 5 kg/m^2 on a concrete surface. The table below presents the emissions resulting from extracting and manufacturing the materials typically composing hot-applied rubberized asphalt to waterproof the case study.

Raw material	Composition (%)	Qty (kg)	Cradle-to-gate Emissions Factor	$kgCO_{2eq}$
	A	B=A*Coverage*Area	C	D=B*C
Polystyrene	10	464	3.24	1,506
SBS Asphalt	90	4,181	0.052	218
Totals		4,645		1,724

4.1.2 HDPE Membrane Sheeting

HDPE membrane sheeting is typically applied at a rate of 1 kg/m^2 on a concrete surface. The table below presents the emissions resulting from extracting and manufacturing the materials typically composing HDPE membrane sheeting to waterproof the case study.

Raw material	Composition (%)	Qty (kg)	Cradle-to-gate Emissions Factor	$kgCO_{2eq}$
	A	B=A*Coverage*Area	C	D=B*C
Olefins	15	139	1.22	170
Polyethylene	65	604	1.90	1,146
Additive plastic	20	186	2.33	434
Totals		929		1,750

4.1.3 Xypex Crystalline Technology

The percent composition of Xypex's crystalline technology as well as the contents of its proprietary chemicals could not be provided to KPMG as part of this analysis. To complete this calculation, KPMG provided Xypex with the emissions factors of its known material contents (portland cement, sand and alkaline earth compounds). Xypex then inputted the percent composition of each raw material to calculate the emissions factor for the known portion of its proprietary materials.

For materials that are proprietary, KPMG provided Xypex with various databases of emissions factors and a calculator to input material composition and emissions factors. Xypex then computed the raw material extraction and manufacturing emissions for its admixture and concentrate product and shared the computed output with KPMG for the purpose of the analysis. The outputs provided to KPMG are as follows:

Total emissions – Admixture ($kgCO_{2eq}$)	967
Total emissions – Concentrate ($kgCO_{2eq}$)	885

4.2 Installation

This section quantifies the emissions associated with installing of each technology to waterproof the case study.

4.2.1 Hot-Applied Rubberized Asphalt

Rubberized asphalt arrives to site in solid blocks. Blocks are heated into a liquid form prior to application using a propane-fuelled kettle. The tables below calculate the emissions related to the use of propane in the kettle.

A. Energy required to heat of rubberized asphalt blocks

As per Section 4.1.1, waterproofing the case study will require approximately 4,181 kgs of rubberized asphalt. The table below calculates the energy required to heat the mass to its liquid temperature.

	Reference	Value	Unit
Mass	A	4181	kg
Specific heat capacity of asphalt	B	900	J/kg*K
Temperature difference	C	180	K
Efficiency factor	D	80	%
Heat energy (J)	**E=(A*B*C)/D**	**846,578,588**	**J**
Heat energy (MJ)	**$E/10^6$**	**846.6**	**MJ**

B. Propane volume required to heat rubberized asphalt

The table below presents the amount of propane fuel required to heat the rubberized asphalt to its application temperature:

	Reference	Value	Unit
Heat energy in Megajoules	A	846.6	MJ
Propane mass	B=A/E	16.8	kg
Volume of propane required		**7.6**	**gallons**

C. Emissions associated with use of propane

The table below presents the emission related to the use of propane to heat the rubberized asphalt:

GHG	Emissions Factor (per gallon)	Global Warming Potential (GWP)	Emissions Factor	Propane volume (gallons)	$kgCO_{2eq}$
	A	B	C=A*B	D	E=B*C
CO_2	5.72	1	5.72	7.6	43
CH_4	0.27	25	6.75		51
N_2O	0.050	298	14.9		114
Emissions from propane consumption for heating ($kgCO_{2eq}$)					**208**

Note: Emissions factors are retrieved from the US EPA Emissions Factors Hub 2023.

4.2.2 HDPE Membrane Sheeting

HDPE membrane sheeting utilizes a disposable plastic release liner removed by hand during installation. Since the product is installed without equipment requiring fuels or electricity, embodied carbon during installation is considered to be zero (~0 $kgCO_{2eq}$).

4.2.3 Xypex Crystalline Technology

Xypex crystalline waterproofing is installed in one of the following two ways:

(i) **Admixture:** Directly inserting the product into the concrete truck prior to a concrete pour. Since the product is blended into the concrete truck without fuels or electricity, embodied carbon during installation is considered to be zero (~0 $kgCO_{2eq}$).

(ii) **Concentrate:** Mixing the powder with water to make a slurry paste and spray applying the product onto the cured concrete surface.

The use of water to create the slurry and equipment requiring electricity result in embodied carbon during installation. The tables below calculate the emissions related water supply and electricity.

A. Emissions related to mixing:

The desired proportion of water to create a slurry is 5 parts of powder to 3 parts of water. The slurry is created by mixing the powder and water using an electric concrete mixer.

Tabulated below are the emissions associated with utilizing an electric mixer to create the slurry.

GHG	Emissions Factor (lb/MWh)	Global Warming Potential (GWP)	Emissions Factor	Energy consumption (MWh)	lbsCO_{2eq}
	A	B	C=A*B	D	E=B*C*D
CO_2	852.3	1	852.3	0.0225	19.2
CH_4	0.071	25	1.78	0.0225	0.04
N_2O	0.010	298	2.98	0.0225	0.07
Emissions from electricity usage (lbsCO_{2eq})					**19.3**
Emissions from electricity usage (kgCO_{2eq})					**8.75**

Note: Emissions factors are National United States Electricity Averages retrieved from the US EPA Emissions Factors Hub 2023.

B. Emissions related to water usage:

Tabulated below are the emissions associated with supplying water to create the slurry.

	Emissions Factor (kgCO_{2eq}/m^3)	Water quantity (m^3)	Emissions from water usage (kgCO_{2eq})
	A	B	C=A*B
Water	0.149	0.770	0.11
Emissions from water usage (kgCO_{2eq})			**0.11**

Note: Emissions factors are National United Kingdom averages retrieved from the DEFRA GHG Emission Database 2021.

C. Emissions related to spray:

Tabulated below are the emissions associated with utilizing an electric spray to apply the slurry onto the concrete surface.

GHG	Emissions Factor (lb/MWh)	Global Warming Potential (GWP)	Emissions Factors	Energy consumption (MWh)	lbsCO_{2eq}
	A	B	C=A*B	D	E=D*C
CO_2	852.3	1	852.3	0.0225	19.2
CH_4	0.071	25	1.78	0.0225	0.04
N_2O	0.010	298	2.98	0.0225	0.07
Emissions from electricity usage (lbsCO_{2eq})					**19.3**
Emissions from electricity usage (kgCO_{2eq})					**8.75**

Note: Emissions factors are United States National Electricity Averages retrieved from the US EPA Emissions Factors Hub 2023.

Combining the above steps, the table below summarizes the embodied carbon emissions associated with installing Xypex's crystalline concentrate during construction:

Installation stage	Emissions (kgCO_{2eq})
Emissions from electricity usage – Preparation of mixture	8.75
Emissions from water usage – Preparation of mixture	0.11
Emissions from electricity usage – Application of mixture	8.75
Total	**17.6**

4.3 Repair and Maintenance

The need for remediating a waterproofing system and concrete is affected by factors beyond the waterproofing technology itself, such as workmanship, detailing and structural movement of the building. In addition, concrete deteriorates and undergoes shrinkage over time, which can lead to cracking and water seepage. Since factors impacting the need for repair and maintenance are not solely dependent on the waterproofing technology itself, this section provides a qualitative analysis assessing the inherent properties each technology possesses that may impact emissions in this stage.

4.3.1 Hot-applied Rubberized Asphalt

Below are inherent properties of hot-applied rubberized asphalt that may impact repair and maintenance and its associated emissions:

— **Membrane flexibility**: Rubberized asphalt exhibits flexibility and can bridge over cracks that may occur in concrete over time. This property allows the waterproofing system to remain intact even if the underlying structure experiences slight movements that cause a crack; and,

— **Fuel and equipment**: When repairs are required, they are associated with higher embodied carbon when compared to alternative methods during installation.

4.3.2 HDPE Membrane Sheeting

Below are inherent properties of HDPE membrane sheeting that may impact the need for repair and maintenance and its associated emissions:

— **Adhesives:** The peel-and-stick application method of HDPE membrane sheeting requires minimal equipment to install the technology. However, this technology does require the application of an adhesive. These adhesives demand thorough surface preparation and specific concrete moisture levels, otherwise, they may exhibit subpar performance, potentially leading to increased repair and maintenance requirements; and,

— **Installation detailing:** Due to the overlapping nature of the membrane at details such as joints, upturns and downturns, this technology is more prone to create water seepage channels at details than its comparators. This characteristic can contribute to increased repair and maintenance requirements throughout its lifecycle.

4.3.3 Xypex Crystalline Technology

KPMG conducted interviews with Xypex and reviewed case studies to understand the repair and maintenance properties of its crystalline technology. Below are the outputs from the review:

— **Self-healing:** The formulation of Xypex's proprietary chemicals enables the technology to react with both the porous concrete matrix and water. This reaction triggers a continuous crystallization process within the concrete, sealing existing cracks and capillaries while preventing seepage of water over time. As a result, the Xypex crystalline technology enables the concrete to repair itself over time, unlike other technologies.

Xypex's crystalline technology has a unique advantage during this stage from comparators, which lies in its self-healing ability. Unlike current waterproofing technologies that act as an adhered barrier, the crystalline technology integrates deep within the porous matrix of the concrete, able to fill cracks over time and allow the concrete to renew itself. This property enables it to become a part of the concrete structure, potentially further decreasing the probability of repair and maintenance related emissions when compared to alternatives.

As evidence for the increased longevity of Xypex's crystalline technology is gathered and quantified, future studies may want to quantify the carbon benefits from avoided repair and maintenance as compared to other technologies.

4.4 End-of-life

This section quantifies the embodied carbon associated with each waterproofing technology during the end-of-life stage.

4.4.1 Hot-applied Rubberized Asphalt

Concrete cannot be recycled with bonded rubberized asphalt. To recycle the concrete foundation, the waterproofing substrate must be separated. A common technique for separating adhered materials from concrete is concrete sawing.

A. Emissions separating substrate to concrete

The table below calculates the emissions associated with utilizing a concrete saw to separate the rubberized asphalt from concrete.

GHG	Fuel carbon content (kg/gallon)	Carbon content (kg/hour)	GWP	Length of time to remove substrate from concrete (hour)	$kgCO_{2eq}$
	A	B=A*Fuel Rate	C	D	E=B*C*D
CO_2	8.780	2.634	1	40	105
CH_4	0.380	0.114	25		114
N_2O	0.080	0.024	298		286
Total					**505**

Note: Emissions factors are United States National Electricity Averages retrieved from the US EPA Emissions Factors Hub 2023.

B. Emissions related to transport and landfill

Once separated, the concrete foundation can be recycled. However, hot-applied rubberized asphalt will contain concrete contamination and is unable return to a natural state suitable for recycling, requiring the technology to be disposed of in landfills.

Using the EPA WARM Model, emissions relating to the transport and landfill of this technology is below.

Material composition	Composition (%)	Mass (kg)	Emissions ($kgCO_{2eq}$)
Polystyrene	10	464	**180**
Asphalt	90	4181	

Combining the above steps, the table below presents the total embodied carbon emissions associated with the end-of-life stage of rubberized asphalt:

End-of-life Stage	Emissions ($kgCO_{2eq}$)
Separating substrate to concrete	505
Transport and landfill	180
Total	**685**

4.4.2 HDPE Membrane Sheeting

Similar to hot-applied rubberized asphalt, facilitating the recycling of concrete will require the waterproofing substrate to be separated using a concrete saw.

A. Emissions from separating substrate to concrete

The table on the next page calculates the emissions associated with utilizing a concrete saw to separate the HDPE membrane sheeting from concrete.

GHG	Fuel carbon content (kg/gallon)	Carbon content (kg/hour)	GWP	Length of time to remove substrate from concrete (hour)	$kgCO_{2eq}$
	A	B=A*Fuel Rate	C	D	E=B*C*D
CO_2	8.780	2.634	1		105
CH_4	0.380	0.114	25	40	114
N_2O	0.080	0.024	298		286
Total					**505**

Note: Emissions factors are United States National Electricity Averages retrieved from the US EPA Emissions Factors Hub 2023.

B. Emissions related to disposal

Once separated, the concrete foundation can be recycled. However, similar to rubberized asphalt, the HDPE sheeting will contain concrete contamination and is unable to return to a natural state suitable for recycling, requiring the technology to be disposed of in landfills.

Using the EPA WARM Model, emissions relating to the transport and landfill of this technology is below.

Material composition	Composition (%)	Mass (kg)	Emissions ($kgCO_{2eq}$)
High Density Polyethylene	75	697	**40**
Mixed plastics	25	233	

Combining the above steps, the table below presents the total embodied carbon emissions associated with the end-of-life stage of HDPE membrane sheeting:

End-of-life Stage	Emissions ($kgCO_{2eq}$)
Separating substrate to concrete	505
Transport and landfill	40
Total	**545**

4.4.3 Xypex Crystalline Technology

Xypex's crystalline technology, unlike other waterproofing technologies, is fully recyclable with concrete. This unique characteristic allows the waterproofing substrate to be recycled while still being bonded to the concrete.

The embodied carbon associated with the recycling of the Xypex crystalline technology is quantified as follows:

Material composition	Composition (%)	Emissions ($kgCO_{2eq}$)
Concrete	100	10

5 Summary of Results

The analysis presented herein indicates that Xypex’s crystalline admixture and concentrate technologies offer substantially lower embodied carbon for concrete waterproofing when compared to current waterproofing technologies, such as hot-applied rubberized asphalt and HDPE membrane sheeting, over the asset lifecycle.

Specifically, the findings indicate that Xypex’s crystalline admixture technology contains approximately:

- 63% less embodied carbon than hot-applied rubberized asphalt, and
- 57% less embodied carbon than HDPE membrane sheeting over its lifecycle.

Xypex’s crystalline concentrate technology contains approximately:

- 65% less embodied carbon than hot-applied rubberized asphalt, and
- 60% less embodied carbon than HDPE membrane sheeting.

In addition, Xypex’s crystalline technology can potentially generate additional carbon savings relative to comparators due to its self-healing ability. Unlike generic waterproofing technologies that act as an adhered barrier, Xypex’s crystalline technology integrates deep within the porous matrix of the concrete, able to fill cracks over time and allow the concrete to renew itself. This property enables Xypex’s crystalline technology to become a part of the concrete structure, potentially further decreasing the probability of repair and maintenance related emissions compared to alternatives.

5.1 Green Building Certifications

As a result of the comparatively lower embodied carbon in Xypex’s crystalline technology, Xypex provides an additional sustainability value to customers by supporting their potential objectives to pursue and obtain a range of green building certifications. Examples include:

- Leadership in Energy and Environmental Design (LEED);
- Building Research Establishment Environmental Assessment Method (BREEAM);
- WELL Building Standard;
- Built Green; and,
- Building Owners and Managers Association (BOMA) Best.

The purpose of green building certifications is to identify buildings that meet defined sustainability requirements or standards. These certifications help developers and building owners demonstrate their commitment to conscious sustainable design and development of infrastructure. They generally score or award points/credits on parameters such as air quality, energy, pollution, and, more specifically in this context, the use of more sustainable construction materials. Examples include:

- The LEED certification awards 5 credits for the indicator ‘Building Life-cycle impact reduction’ under the parameter Materials and Resources;
- The BREEAM evaluation framework evaluates sustainable construction practices through the parameters of resilience, materials, waste and innovation;
- The WELL Building Standard has an innovation parameter that encourages organizations to address GHG emissions as an integral part of their broader focus on promoting health and well-being;

- The Built Green certification rewards points for innovation in sustainable construction. Specifically, reporting on embodied carbon, which relates to the total carbon emissions associated with construction materials, can earn innovation points; and,
- The BOMA Best certification assesses real estate on six comprehensive parameters, one of which is the overall carbon emissions throughout the building's lifecycle.

Table 3: Summary of Results populated in ISO 14064-02 Requirements

		Hot Rubberized Asphalt	HDPE Membrane Sheeting	Xypex Crystalline Admixture	Xypex Crystalline Concentrate
Describe the project		Please refer to Section 2.			
SSRs relevant		Please refer to Section 3.			
Determine baseline		Base case #1	Base case #2	Project case #1	Project Case #2
SSRs relevant to baseline		Baseline and project SSRs are the same.			
Quantified emissions	Extraction & manufacturing	1,724 $kgCO_{2eq}$	1,750 $kgCO_{2eq}$	967 $kgCO_{2eq}$	885 $kgCO_{2eq}$
	Installation	208 $kgCO_{2eq}$	0 $kgCO_{2eq}$	0 $kgCO_{2eq}$	18 $kgCO_{2eq}$
	End-of-life	685 $kgCO_{2eq}$	545 $kgCO_{2eq}$	10 $kgCO_{2eq}$	10 $kgCO_{2eq}$
	Totals	**2,617 $kgCO_{2eq}$**	**2,295 $kgCO_{2eq}$**	**977 $kgCO_{2e}$**	**913 $kgCO_{2e}$**
Data Quality[8]	Extraction & manufacturing	Moderate	Moderate	Moderate to Advanced	Moderate to Advanced
	Installation	Moderate	Moderate	Not applicable	Minimum[9] to Moderate
	End-of-life	Moderate	Moderate	Moderate	Moderate
Monitor emissions		Not applicable.			
Document project		Please refer to Section 4.			
Validated or verified		Not verified.			
Report project		Please refer to Section 5.			

[8] References regarding data quality levels of minimum, moderate and advanced are described om Appendix B – Data Quality.

[9] Minimum data quality rating pertains to the use of the DEFRA emissions factor database for water supply.

Appendix A – Glossary

Embodied carbon: The total amount of greenhouse gas emissions produced throughout the lifecycle of a product or technology, including raw material extraction, manufacturing, transportation, installation, use, maintenance, and end-of-life stages.

ISO 14064-2 framework: A structured approach outlined by the International Organization for Standardization (ISO) for quantifying and examining greenhouse gas emissions. It provides guidelines for conducting a lifecycle assessment and calculating carbon footprints.

SSRs: Areas within the project boundary that are emission sources, sink or reservoirs (SSRs).

Baseline Scenario: The baseline scenario refers to the reference condition against which the project scenario is compared. It represents the business-as-usual or existing conditions without any specific interventions or changes.

Project Scenario: The project scenario, also known as the alternative scenario or intervention scenario, represents the conditions with the proposed project or activity in place. It includes the changes, measures, or interventions implemented to achieve specific environmental objectives, such as reducing greenhouse gas emissions or minimizing environmental impact.

EPD Report: A document providing transparent and standardized information about the environmental impacts of a product throughout its lifecycle.

Emissions Factor: Factors used to quantify greenhouse gas emissions associated with specific materials or processes, typically expressed as CO_2 equivalent (CO_{2eq}) emissions per unit of a material or activity.

GHG Protocol: The Greenhouse Gas Protocol, a widely used accounting framework for quantifying and managing greenhouse gas emissions.

US EPA: United States Environmental Protection Agency. A federal agency in the United States responsible for environmental protection and regulation.

US EPA WARM Model: US Environmental Protection Agency Waste Reduction Model (WARM Model) is a tool developed by the US EPA to estimate greenhouse gas emissions from various waste management practices.

DEFRA: Department for Environment, Food and Rural Affairs (DEFRA) is a United Kingdom government department responsible for environmental protection, food production, agriculture, fisheries, and rural communities.

Cradle-to-gate: A lifecycle assessment boundary that includes all stages from raw material extraction to the point of product leaving the factory gate.

GWP Potential: A measure of how much a given greenhouse gas contributes to global warming over a specific time period, relative to carbon dioxide. It is used to compare the warming effects of different gases and guide climate change mitigation strategies.

HDPE: High-density polyethylene (HDPE) membrane sheeting, a flexible synthetic material used for waterproofing.

SBS: Styrene-Butadiene-Styrene (SBS) is a synthetic elastomeric polymer composed of styrene and butadiene units, commonly used in the production of modified asphalt materials for various applications, including waterproofing.

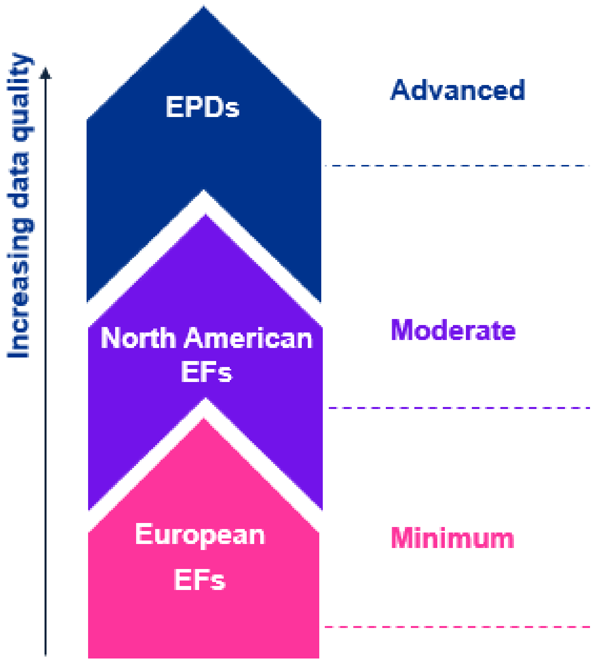
Olefins: Unsaturated hydrocarbon compounds characterized by the presence of one or more carbon-carbon double bonds. They are commonly used as feedstocks in the production of plastics, synthetic fibres, and other chemical products.

VOCs: Volatile Organic Compounds (VOCs) are organic chemicals that have a high vapor pressure at room temperature, which causes them to readily evaporate into the air.

Appendix B – Data Quality

Below is a framework to rank the data quality of emissions factors.

- **Advanced:** Emissions factors provided by suppliers through EPD reports.
- **Moderate:** Emissions factors provided through North American Industry associations or North American LCI databases recognized by the GHG Protocol.
- **Minimum:** Emissions factors provided through European Industry associations or European LCI databases recognized by the GHG Protocol.



Below are assumptions utilized in the calculations:

Stage	Assumption
Raw material extraction and manufacturing	**Hot-applied rubberized asphalt:** • Assumed polystyrene protection board accounts for 10% of coverage by weight. **HDPE Membrane sheeting:** • Composition percentage between polyethylene, additive plastics and olefins depends on products. Assumed a 70%, 20%, and 10% composition based on sample products.
Installation	**Xypex crystalline technology:** • Assumed power load of 0.75 W for concrete mixer and electric spray. • Assumed waterproofing duration of 30 hours.
Repair & maintenance	Not applicable.
End-of-life	**Hot-applied rubberized asphalt:** • Assumed concrete saw fuel consumption rate of 0.3 gallons/hour of gasoline. • Assumed length of time for substrate separation to be 40 hours (5 days). • Assumed to be landfilled as asphalt concrete. **HDPE membrane sheeting:**

Stage	Assumption
	• Assumed concrete saw fuel consumption rate of 0.3 gallons/hour of gasoline. • Assumed length of time for substrate separation to be 40 hours (5 days). • Assumed to be landfilled as HDPE (75%) and mixed plastics (25%).