

Rapport de projet GES

Intégration d'une toiture en bois et autres éléments combustibles
dans un bâtiment du groupe A2 de 4 étages

Réalisé par

coarchitecture

AFFLECK DELA RIVA

ARUP

Dans le cadre du Programme de vitrine technologique pour les
bâtiments et les solutions innovantes en bois

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Avis de non-responsabilité

Le contenu et les résultats de ce rapport sont produits et présentés par le bénéficiaire de subvention au Programme de vitrine technologique pour les bâtiments et les solutions innovantes en bois (Programme). Le ministère des Forêts, de la Faune et des Parcs (MFFP) ainsi que le Fonds vert ne sont pas responsables du contenu de ce document.

Chacune des sections de ce rapport est expliquée dans le *Protocole de quantification des émissions de gaz à effet de serre attribuables à la fabrication de matériaux de structure pour divers scénarios de bâtiments* (Protocole).

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1. Projet GES

1.1 Parties prenantes du Projet GES

1.1.1 Bénéficiaire de subvention

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1.1.3 Responsable – Rapport du projet GES

Mathieu Castonguay, Ing.

Responsable R&D

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1.1.4 Responsable des estimations de quantités de matériaux

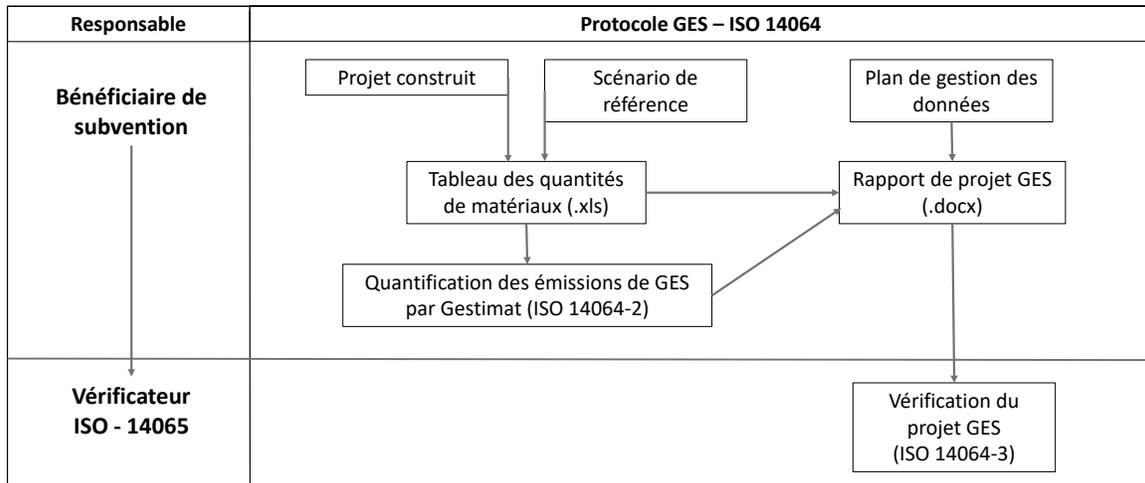
Projet construit	
Structure	Steven Cerri, Ing
Architecture	Christine Laferrière, Arch

Scénario de référence	
Structure	Steven Cerri, Ing
Architecture	Christine Laferrière, Arch

1.1.5 Responsable de la quantification des émissions de GES :

Mathieu Castonguay, Ing., Coarchitecture.

La quantification des émissions a été réalisée à l'aide de GESTIMAT 2.0 conformément aux directives du Protocole¹.



1.2 Titre et lieu de réalisation du projet de construction

Nom du bâtiment	Bibliothèque et espace culturel du Cœur-Nomade
Adresse	3170, Boul. Henri-Bourassa Est, Montréal

1.3 Description du projet de construction

Le Projet consiste à construire un nouveau bâtiment de 4 étages abritant une bibliothèque, des espaces culturels et sociocommunitaires pour desservir la population des arrondissements de Montréal-Nord et Ahuntsic-Cartierville à Montréal. Le concept lauréat du concours d'architecture pluridisciplinaire propose une toiture apparente en bois ainsi un espace ouvert sur tous les niveaux, le jardin d'hiver, comportant une structure de bois apparente.

L'utilisation d'une structure de bois pour la toiture et pour le Jardin d'hiver ont permis de réduire significativement les émissions de GES de pour ces éléments comparativement au scénario de référence. La modélisation du projet et du scénario de référence qui exclut les fondations et la superstructure de béton des deux scénarios permet de mesurer l'impact de l'utilisation du bois en lieu et place des structures incombustibles. La figure 3 présente la réduction des émissions de GES pour ces éléments du projet.

¹ Protocole de quantification des émissions de gaz à effet de serre attribuables à la fabrication de matériaux de structure pour divers scénarios de bâtiment de CECOBOIS, Révision 02

Émissions de GES par système constructif (kg éq. CO₂)

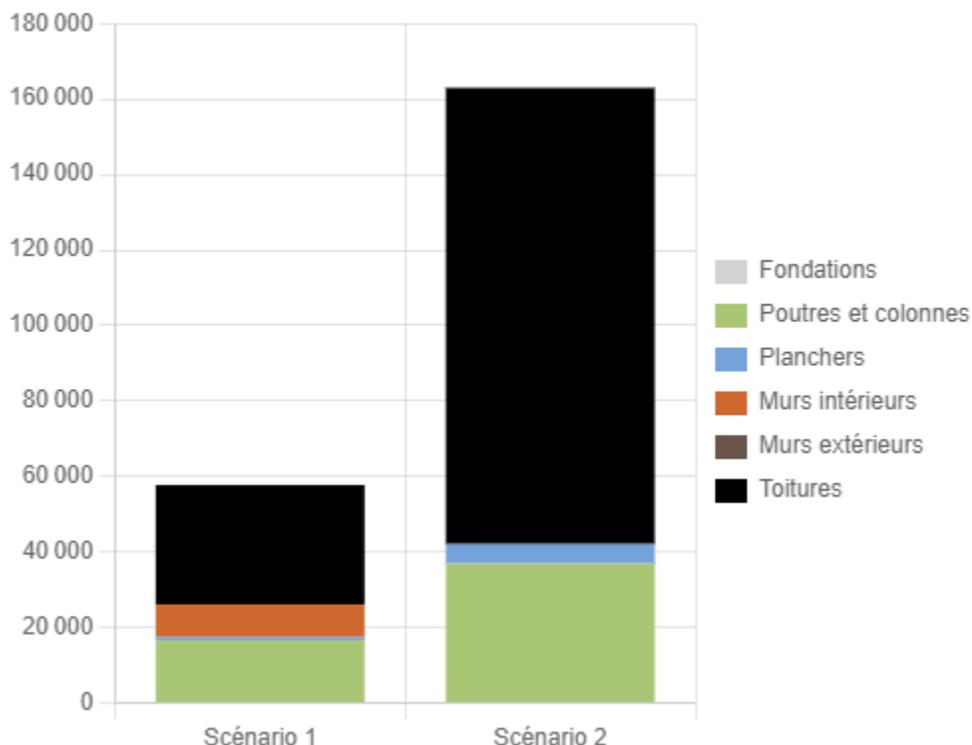


Figure 1 : Comparaison des émissions de GES excluant les fondations et la superstructure

1.4 Description et justification du scénario de référence

Le Code de construction du Québec – Chapitre I, Bâtiment et Code national du bâtiment du Canada 2015 (modifié) (Code) classe le projet dans le groupe A2. Le programme et le site nécessite la construction de quatre étages. Pour ce type de bâtiment, la réglementation applicable permet uniquement la construction de bâtiment incombustible entièrement protégé par gicleurs.

Une demande de mesure équivalente a été présentée et acceptée pour permettre la construction d'une partie de la structure en matériaux combustibles.

Afin de comparer le projet et le scénario de référence, les professionnels ont utilisé les plans de construction du projet et ont simplement remplacé les éléments en matériaux combustibles par les matériaux incombustibles les plus susceptibles qui auraient été utilisés si la solution équivalente avait été refusée par la Régie du bâtiment du Québec (RBQ).

L'architecture, la superficie, géométrie et les aménagements considérés pour le bâtiment de référence sont identiques au projet réalisé. Uniquement les éléments mentionnés dans la décision de la RBQ acceptant la mesure équivalente ont été comparés. Seulement les deux éléments du

projet ayant fait l'objet de la demande de mesure équivalente présentent des différences, à savoir la toiture du niveau 03 et la structure du jardin d'hiver.

Selon toutes probabilité, la structure de la toiture du bâtiment de référence aurait été en béton comme le reste de la structure. Ce type de structure est une solution très courante dans les bâtiments incombustible nécessitant une résistance au feu d'au moins une heure.

Pour sa part, la structure du jardin d'hiver aurait été réalisée de manière similaire à la cage d'escalier attenante. Les colonnes extérieures auraient été en acier supportant des poutres et planchers en béton.

Les éléments identiques qui ne sont pas directement reliés à la structure de bois ont été omis de l'analyse pour les deux scénarios. Le tableau suivant présente tous les éléments tangibles mentionnés dans la décision de la RBQ et décrit comment le Projet et le scénario de référence y répondent.

RBQ	Projet	Référence
Bois massif exposé qui se trouve au niveau 03 de la bibliothèque	Poutres et solives de toit en bois lamellé-collé de dimensions variables : <ul style="list-style-type: none"> • 175 mm x 266 mm, • 265 mm x 684 mm, • 265 mm x 836 mm, • 315 mm x 380 mm, • 315 mm x 950 mm, • 365 mm x 950 mm; le platelage du toit en bois lamellé-croisé (CLT) de 105 mm [trois (3) couches] pour le toit du puits de lumière central et de 175 mm [5 couches] pour le reste de la toiture. Les platelages sont recouverts d'OSB de 12mm ;	Dalle de béton armé de 250 mm. Conception similaire au niveau 2 mais avec des charges réduites. Colonnes de béton de même nombre et taille que le niveau 2 à 3.
Bois massif exposé qui se trouve dans le Jardin d'hiver	Poutres et solives en bois lamellé-collé de dimensions variables : <ul style="list-style-type: none"> • 175 mm x 266 mm, • 315 mm x 684 mm, • 315 mm x 950 mm, • 315 mm x 1 102 mm; les colonnes en bois lamellé-collé de 315 mm x 608 mm;	Dalle de béton armé de 250 mm. Conception similaire au niveau 02 mais avec des charges réduites. Les colonnes en acier de type HS356x245x13

	le platelage du toit en bois lamellé-croisé (CLT) de 175 mm [cinq (5) couches]; les planchers et les plateformes aux 1 ^{er} et 3 ^e étages en bois lamellé-croisé (CLT) de 175 mm [cinq (5) couches].	
Recouvrement des plateformes du Jardin d'hiver :	Seront recouvertes d'un revêtement de finition de lattes de bois; (non inclus aux scénarios)	
Les revêtements combustibles de la bibliothèque :	Aux niveaux 00, 01 et 02 : le plafond des coursives et un secteur du plafond adjacent seront recouverts d'un revêtement de finition en lattes de pin de 25 mm x 55 mm espacés de 50 mm, la surface du plafond recouverte par de lattes de pin sera inférieure à 10 % de la surface totale du compartiment résistant au feu; (non inclus aux scénarios)	
Le mur de l'œuvre d'art prévu au niveau 00	La même œuvre d'art serait installée pour les 2 scénarios. (non inclus aux scénarios)	
soufflage mural au niveau 00	Avec tablettes de bois pour les 2 scénarios.	
finition murale combustible des cloisons au niveau 00	Moins de 5% des surfaces de murs peuvent être en matériaux combustibles autorisés (non inclus au scénario).	Aucune limitation de superficie des murs recouverts de matériaux combustibles autorisés (exclu de l'analyse).
Plafond au sommet de l'escalier central (plafond au-dessus de l'atrium faisant partie des aires communicantes)	Toit en platelage de bois sera apparent;	Toit en béton apparent
Aucun mur dans la bibliothèque du niveau 03 ainsi qu'à l'intérieur du Jardin d'hiver ne sera recouvert d'un matériau de revêtement combustible;	Le recouvrement des murs sera en gypse (non considéré dans l'analyse)	
Colonnes du niveau 03	L'ensemble des colonnes du niveau 03 de la bibliothèque	Colonnes de béton apparent

	seront encapsulées par des panneaux de plaque de plâtre;	
Le Jardin d'hiver sera isolé du reste du bâtiment.	Les cloisons vitrées sont requises à tous les niveaux.	Aucune cloison vitrée ne serait installée aux niveaux 00 et 01 puisqu'elles ne sont pas requises. Les cloisons vitrées des niveaux 02 et 03 sont requises pour éviter l'aire communicante.
Séparation coupe-feu du Jardin d'hiver.	Les gicleurs sont requis aux niveaux 02 et 03 pour que la séparation vitrée forme une séparation coupe-feu de 1 h. Requis mais non inclus à l'analyse.	
Méthode de contrôle de la fumée	Des fenêtres ouvrantes sur batterie et reliées au système d'alarme incendie seront installées au sommet de l'escalier central pour compenser la présence de bois apparent dans cet endroit (aires communicantes). Requis mais non inclus à l'analyse.	Aucune méthode de contrôle de fumée supplémentaire requise. Non inclus à l'analyse.
Bois massif apparent dans les vides de construction;	Afin de recouvrir le bois dans les vides de construction, la structure de bois située au-dessus des plafonds du niveau 03 et les poutres de bois au périmètre de l'enveloppe extérieure sont recouvertes de gypse. Les colonnes situées dans les emboîtements en angle des colonnes du mur sur l'axe 1' (Boulevard Henri-Bourassa Est) sont recouvertes de gypse.	Béton, non requis
Débord de toit	Le pontage de CLT sous le débord de toit est recouvert de gypse.	Aucun recouvrement n'est requis pour la structure du toit en béton
Bâtiment entièrement protégé par gicleurs	Requis pour la classe de bâtiment	Requis pour la classe de bâtiment

Remarques sur les éléments mentionnés dans la réponse de la RBQ à la demande de mesure différentes :

- Pour éviter toute ambiguïté, la description des étages de la décision de la RBQ a été modifiée pour correspondre à la numérotation indiquée aux plans.
- Les dimensions des poutres et colonnes de bois lamellé-collé ainsi que l'épaisseur des différents pontages en CLT mentionnés dans la réponse de la RBQ peuvent différer des éléments correspondants aux plans de structure puisque la décision était basée sur le concept structurel.

• **Tableau 1 : Évaluation des barrières de chaque scénario**

Obstacles	Option 1 Projet de construction (projet GES)	Option 2 Scénario de référence
Règlementaire	Partie de la structure combustible. Nécessite l'approbation d'une mesure équivalente par la RBQ	Structure incombustible, aucun obstacle
Pratique courante	Courant mais moins répandu que le scénario de référence	Courant, aucun obstacle
Financier	Honoraires supplémentaires pour la demande de mesure équivalente, le surcoût de 38% est estimé pour la toiture en bois comparativement à la structure des autres niveaux.	Aucun surcoût de structure
Technologique	Aucun obstacle	Aucun obstacle
Ressources humaines	Aucun obstacle	Aucun obstacle
Infrastructure	Aucun obstacle	Aucun obstacle
Culturel, géographique, climatique	Perception généralement positive du public, contribue à réduire les émissions de GES, offre une meilleure résistance thermique	Aucun obstacle
Marché	Nombre de fournisseurs limité	Aucun obstacle
Institution, perception du public	Programmes de subvention disponibles, perception généralement positive du public.	Aucun obstacle

1.5 Données du projet GES

Le calcul des quantités de matériaux de structure a été effectué par l'ingénieur en structure et sont présentés dans le tableau présenté en annexe.

La description de chaque calcul est présentée dans le tableau suivant :

Élément	Projet	Scénario de référence
Fondations et superstructure	Volume de béton tirées de la maquette REVIT Masse d'acier tiré de la maquette REVIT	
Cloisons du Jardin d'hiver aux niveaux 00 et 01	Superficie tirée de la maquette REVIT le 2023-10-10 Superficie : 78 m ²	Aucune cloison requise.
Recouvrement du soffite en bois	Superficie tirée de la maquette REVIT le 2023-10-10 Superficie : 123 m ²	Aucun recouvrement requis
Recouvrement des colonnes de bois et des vides de construction au niveau 03	Superficie tirée de la maquette REVIT le 2023-10-18 Superficie : 241 m ²	Aucun recouvrement requis

VOLUME TOTAL DE BOIS DANS LE PROJET (m ³)
372,1

Remarque : le volume de bois indiqué ici inclut le bois présent dans le pontage de CLT ainsi que celui de la structure des poutres et colonnes en BLC.

2. Quantification des émissions de GES

Le tableau suivant présente les résultats des émissions de GES tel qu'évalué avec l'outil GESTIMAT 2.0. Le recours à une structure de bois pour la toiture a permis d'éviter l'émission de 94,7 tonnes de GES comparativement à ce qui aurait été émis sans l'approbation de la demande de mesure équivalente.

ÉMISSIONS GES DU SCÉNARIO DE RÉFÉRENCE (kg éq. CO ₂)	ÉMISSIONS GES DU PROJET CONSTRUIT (kg éq. CO ₂)	RÉDUCTION DES ÉMISSIONS GES (kg éq. CO ₂)
1 770 315	1 675 638	94 667

Les coefficients d'émission pour les matériaux personnalisés sont les suivants :

Élément	Coefficient	Source
Meneaux d'aluminium	63,5 kg CO ₂ e/m ²	Utilisation directe du coefficient pour EF30 SW de EPD10684 Annexe E.1
Verre de la cloison du Jardin d'hiver	34,2 kg CO ₂ e/m ²	Coefficient ajusté pour prendre en compte de l'épaisseur différente de l'unité fonctionnelle de ASTM-EPD149. Annexe E.2

- La masse unitaire de 13,4 kg/m² a été utilisé pour le gypse de type X recouvrant les colonnes ainsi que les éléments en bois lamellé-collé situés dans les vides de construction.
- Le coefficient d'émission utilisé par Gestimat 2.0 n'est pas présenté au tableau 2 mais il est estimé à 0,35 kg CO₂e/kg (4,69 kg CO₂e/m²)

Le tableau suivant présente les coefficients d'émission de certains matériaux intégrés à Gestimat 2.0 et utilisés pour produire ce rapport de GES.

Tableau 2 : Extrait de la section 10.1 de Gestimat 2.0

Matériau	Unité	kg éq. CO ₂ par unité
Béton 15 MPa	m ³	168
Béton 20 MPa	m ³	232
Béton 25 MPa	m ³	269
Béton 30 MPa	m ³	320
Béton 35 MPa	m ³	300
Béton 50 MPa	m ³	328
Blocs de béton	m ³	247
Murs en blocs de béton	m ²	38.4
Treillis d'armature métalliques soudés	tonne	1268
Barres d'armature	tonne	1268
Fil machine	tonne	2185
Fibres métalliques	kg	2.23
Fibres synthétiques	kg	2.76
Pontage (acier galvanisé)	tonne	2492
Montants métalliques pour ossature légère	tonne	2492
Profilés extrudés moyens (W,S,C,L)	tonne	1580
Profilés tubulaires d'acier (HSS)	tonne	2024
Tuyaux d'acier	tonne	2319
Poutres à larges ailes (WWF)	tonne	1580
Poutrelles et fermes ajourées en acier	tonne	2492
Bois lamellé-collé (BLC)	m ³	119
Bois lamellé-croisé (CLT)	m ³	70.5
Bois de placages stratifiés (LVL)	m ³	202
Bois à long copeaux parallèles (PSL)	m ³	248
Bois d'oeuvre séché au séchoir	m ³	54.0
Panneaux de lamelles orientées (OSB)	m ³	170
Contreplaqué	m ³	130
Fabrication (poutrelles en I)	m	0.203
Fabrication (poutrelles ajourées et fermes en bois)	m	0.203
Plaques d'acier minces galvanisées	kg	2.49
Plaques d'acier épaisses	kg	2.37
Clous	kg	2.15
Vis, écrous et boulons	kg	3.11

3. Annexes

Liste des annexes :

Annexe	Description
A	Fichier électronique des quantités de matériaux 21-281_TA_quantites_materiaux_Coeur-Nomade.xlsm
A.1	Tableau des quantités de matériaux du bâtiment de référence
A.2	Tableau des quantités de matériaux du projet
B.1	Lettre de confirmation des quantités de matériaux de structure pour le Projet et le scénario de référence
B.2	Lettre de confirmation des quantités de matériaux en architecture pour le Projet et le scénario de référence
C.1	Analyse des émissions de GES du Projet de Gestimat
C.2	Analyse des émissions de GES du Scénario de référence de Gestimat
D	Rapport sommaire de l'analyse comparative des scénarios de Gestimat
E.1	EPD10684 1 m ² of Aluminium Curtain Wall System, Enviro Facades
E.2	ASTM-EPD149 Processed Glass Products, Cardinal Glass Industries
E.3	An Industry Average Cradle-to-Gate Life Cycle Assessment of 1/2" Regular and 5/8" Type X Glass-mat Gypsum Board for the USA and Canadian Markets, Gypsum Association

Annexe A.1

Tableau des quantités de matériaux du bâtiment de référence

COLLECTE DE DONNÉES
- Scénario de référence -

QUANTITÉ DE MATÉRIAUX			INFORMATIONS COMPLÉMENTAIRES	
Matériau	Quantité	Unité	Méthode d'estimation	Commentaires (ex. informations sur le matériau, justification de la précision)
Fondations				
Béton 30 MPa	1358	m ³	Note de calculs	Fondations
Barres d'armature	139	t	Note de calculs	Barres d'armature
AJOUTER				
Poutres et colonnes				
Béton 30 MPa	44,013375	m ³	Note de calculs	Colonnes en béton pour toit
Barres d'armature	4,629555	t	Note de calculs	Armature colonnes en béton
HSS	8,8366	t	Note de calculs	Colonne en acier pour jardin d'hiver
AJOUTER				
Planchers				
Béton 30 MPa	2080	m ³	Note de calculs	Superstructure
Barres d'armature	261	t	Note de calculs	Armature de superstructure
Béton 30 MPa	12,5	m ³	Note de calculs	Dalle jardin d'hiver
Barres d'armature	1,125	t	Note de calculs	Armature jardin d'hiver
AJOUTER				
Toiture				
Béton 30 MPa	291,75	m ³	Note de calculs	Dalle toit
Barres d'armature	26,2575	t	Note de calculs	Armature dalle toit
AJOUTER				
Murs extérieurs				
AJOUTER				
Murs intérieurs				
AJOUTER				

Annexe A.2

Tableau des quantités de matériaux du projet

COLLECTE DE DONNÉES

- Projet -

QUANTITÉ DE MATÉRIAUX			INFORMATIONS COMPLÉMENTAIRES	
Matériau	Quantité	Unité	Méthode d'estimation	Commentaires (ex. informations sur le matériau, justification de la précision)
Fondations				
Béton 30 MPa	1358	m ³	Note de calculs	Fondations
Barres d'armature	139	t	Note de calculs	Barres d'armature
AJOUTER				
Poutres et colonnes				
BLC	20,2	m ³	Note de calculs	Colonnes au niveau 03 / Bois lamellé-collé
BLC	16,52	m ³	Note de calculs	Jardin d'hiver / Colonnes en bois lamellé-collé
BLC	6,82	m ³	Note de calculs	Jardin d'hiver / Poutres en bois lamellé-collé
Plaques d'acier épaisses	527,52	kg	Note de calculs	Jardin d'hiver / Plaques d'assemblage des colonnes
Plaques d'acier épaisses	1537,344	kg	Note de calculs	Colonnes au niveau 03 / plaques d'assemblage
Autres	3229,4	kg	Note de calculs	Colonnes et vides au niveau 03 / recouvrement en gypse type X
BLC	111,84	m ³	Note de calculs	Poutres au toit / Bois lamellé-collé
Plaques d'acier épaisses	670,10112	kg	Note de calculs	Poutres au toit / Plaques d'assemblage
Vis, écrous et boulons	630,318406	kg	Note de calculs	Boulons d'assemblage
AJOUTER				
Planchers				
Béton 30 MPa	2080	m ³	Note de calculs	Superstructure
Barres d'armature	261	t	Note de calculs	Armature de superstructure
CLT	4,53	m ³	Note de calculs	Pontage du Jardin d'hiver - niveau 01
CLT	2,86	m ³	Note de calculs	Pontage du Jardin d'hiver - niveau 03
HSS	0,231	t	Modèle 3D	Acier pour Jardin d'hiver
AJOUTER				
Toiture				
CLT	198	m ³	Note de calculs	Pontage toiture basse
CLT	11,3	m ³	Note de calculs	Pontage toiture haute
WWF	1,7912	t	Modèle 3D	Structure d'acier en toiture
Clous	165,706379	kg	Note de calculs	Clous pour jointage du CLT
Autres	1648,2	kg	Note de calculs	Soffite extérieur / recouvrement en gypse type X
Autres	683,4	kg	Note de calculs	Recouvrement du pontage dans les entre-plafonds
AJOUTER				
Murs extérieurs				
AJOUTER				
Murs intérieurs				
Autres	4953	kg CO2e	Note de calculs	Meneaux d'aluminium (78m ²)
Autres	2667,6	kg CO2e	Note de calculs	Verre trempé 6mm (78m ²)
AJOUTER				

Annexe B.1

Lettre de confirmation des quantités de matériaux de structure pour le Projet et le scénario de référence

31 octobre 2023

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Mathieu Castonguay

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Notre référence 285401-00

Bonjour,

Bibliothèque et centre culturel Cœur-Nomade **Confirmation du calcul des quantités de matériaux pour calcul GES**

Vous trouverez ci-joint l'évaluation des quantités de matériaux de structure évalués dans le cadre du projet de la bibliothèque et centre culturel Cœur Nomade.

Les quantités de matériaux sont estimées aux fins d'évaluation des émissions de GES du projet de bâtiment étudié. Les émissions ont été évaluées selon les recommandations de la section 6.1 du Protocole de quantification des émissions de gaz à effet de serre attribuables à la fabrication de matériaux de structure pour divers scénarios de bâtiment.

Nous avons évalué les quantités de matériaux pour notre projet ainsi qu'un projet de référence. Les quantités évaluées pour le projet ont été déterminées à partir de nos plans émis à niveau de 100% conception. Cette estimation est conforme à la section 6.1 et du *protocole de quantification des émissions de gaz à effet de serre attribuables à la fabrication de matériaux de structure pour divers scénarios de bâtiments*. Nous avons estimé à une précision de 95% les quantités de matériaux utilisés à l'aide des modèles numériques et les plans. Pour le scénario de référence, nous avons effectué un dimensionnement préliminaire de la structure en béton pour faire une estimation avec une précision de 80%.

Je vous prie d'agréer mes salutations distinguées.



Steven Cerri ing.

P.J. Annexe 1 - Tableau calcul GES

Notre référence

285401-00

Date

31 octobre 2023

Annexe 1 - Tableau calcul GES

Projet

QUANTITÉ DE MATÉRIAUX			INFORMATIONS COMPLÉMENTAIRES	
Matériau	Quantité	Unité	Méthode d'estimation	Commentaires (ex. informations sur le matériau, justification de la précision)
Fondations				
AJOUTER				
Poutres et colonnes				
AJOUTER				
Planchers				
AJOUTER				
Toiture				
CLT	11.3	m ³	Modèle 3D	Pontage Toit Haut
CLT	186.7	m ³	Modèle 3D	Pontage Toit
CLT	7.39	m ³	Modèle 3D	Pontage jardin d'hiver
BLC	20.2	m ³	Modèle 3D	Colonne Toit
BLC	16.52	m ³	Modèle 3D	Colonne jardin d'hiver
BLC	111.84	m ³	Modèle 3D	Poutre Toit
BLC	6.82	m ³	Modèle 3D	Poutre jardin d'hiver
Profilé extrudé moyen	1.7912	t	Modèle 3D	Acier Toit
Profilé extrudé moyen (MFCN)	0.231	t	Modèle 3D	Acier jardin d'hiver
Clous	171.963154	kg	Note de calculs	Clous - Toit - CLT et Poutre
Clous	6.85857006	kg	Note de calculs	Clous - Jardin d'hiver- CLT et Poutre
Plaques d'acier minces	2207.44512	kg	Note de calculs	Plaque de base et assemblage toit
Plaques d'acier minces	527.52	kg	Note de calculs	Plaque de base et assemblage jardin d'hiver
Vis, écrous et boulons	630.318406	kg	Note de calculs	Boulon pour assemblage toit
AJOUTER				
Murs extérieurs				
AJOUTER				
Murs intérieurs				
AJOUTER				

Notre référence

285401-00

Date

31 octobre 2023

Scénario de référence

QUANTITÉ DE MATÉRIAUX			Double-cliquez sur AJOUTER pour ajouter une nouvelle ligne d'estimation	INFORMATIONS COMPLÉMENTAIRES
Matériau	Quantité	Unité		Commentaires (ex. informations sur le matériau, justification de la précision)
Fondations				
AJOUTER				
Poutres et colonnes				
AJOUTER				
Planchers				
AJOUTER				
Toiture				
Béton 30 MPa	291.75	m ³	Note de calculs	Dalle toit
Barres d'armature	26.2575	t	Note de calculs	Armature dalle toit
Béton 30 MPa	44.013375	m ³	Note de calculs	Colonne en beton pour toit
Barres d'armature	4.629555	t	Note de calculs	Armature colonne en beton
Béton 30 MPa	12.5	m ³	Note de calculs	Dalle jardin d'hiver
Barres d'armature	1.125	t	Note de calculs	Armature jardin d'hiver
HSS	8.8366	t	Note de calculs	Colonne en acier pour jardin d'hiver
AJOUTER				
Murs extérieurs				
AJOUTER				
Murs intérieurs				
AJOUTER				

Annexe B.2

Lettre de confirmation des quantités de matériaux en architecture pour le Projet et le scénario de référence

Coarchitecture
1195, av. Lavigerie, bureau 50
Québec (Québec) G1V 4N3

Québec, le 31 octobre
2023

À l'attention de M. Mathieu Castonguay

Objet : Évaluation des quantités de matériaux du projet Bibliothèque et espace culturel du Cœur-Nomade

Monsieur,

Vous trouverez ci-joint l'évaluation des quantités de matériaux en architecture tel que prévu aux plans définitifs du projet de bâtiment cité en objet. Le projet est soutenu financièrement par le Ministère de la Forêt, de la Faune et des Parcs, dans le cadre du Programme d'innovation en construction en bois. Les quantités de matériaux sont estimées aux fins d'évaluation des émissions de GES du projet de bâtiment.

Les émissions ont été évaluées selon les recommandations de la section 6.1 du *Protocole de quantification des émissions de gaz à effet de serre attribuables à la fabrication de matériaux de structure pour divers scénarios de bâtiment*. Les matériaux inclus à l'évaluation des quantités sont uniquement constitués des matériaux mentionnés dans la demande de mesures différentes pour le projet.

Nous avons évalué les quantités de matériaux en fonctions des superficies modélisées dans la maquette numérique du projet pour chacun des éléments mentionnés dans le tableau suivant. Aucune quantité de matériau d'encapsulation ou de séparation supplémentaire n'a été ajoutée au projet de référence. Le niveau de précision pour la comparaison entre les 2 bâtiments est supérieur à 80% et est compatible avec les exigences du protocole. Je confirme également par la présente que les renseignements fournis sont complets et exacts.

Espérant le tout satisfaisant, veuillez agréer, Monsieur, mes sincères salutations.



Christine Laferrière, architecte

COLLECTE DE DONNÉES

- Projet -

QUANTITÉ DE MATÉRIEAUX			INFORMATIONS COMPLÉMENTAIRES	
Matériau	Quantité	Unité	Méthode d'estimation	Commentaires (ex. informations sur le matériau, justification de la précision)
Fondations				
AJOUTER				
Poutres et colonnes				
Autres	3229,4	kg	Note de calculs	Colonnes et vides au niveau 03 / recouvrement en gypse type X
AJOUTER				
Planchers				
AJOUTER				
Toiture				
Autres	1648,2	kg	Note de calculs	Soffite extérieur / recouvrement en gypse type X
Autres	683,4	kg	Note de calculs	Recouvrement du pontage dans les entre-plafonds
AJOUTER				
Murs extérieurs				
AJOUTER				
Murs intérieurs				
Autres	4953	kg CO2e	Note de calculs	Meneaux d'aluminium (78m ²)
Autres	2667,6	kg CO2e	Note de calculs	Verre trempé 6mm (78m ²)
AJOUTER				

Annexe C.1

Analyse des émissions de GES du Projet de GESTIMAT

Rapport sommaire de l'analyse comparative des scénarios

Informations du projet

Nom du projet	<u>Coeur-Nomade</u>	Type de projet	<u>Construction neuve</u>
Numéro du projet	<u>21-281</u>	Type de bâtiment	<u>Bibliothèques , salles de spectacle , e</u>
Catalogue	<u>Québec</u>	Nombre d'étages	<u>4</u>
Emplacement	<u>Montréal</u>	Superficie totale (m ²)	<u>4193</u>
Année prévue	<u>2023</u>	Superficie au sol (m ²)	<u>2110</u>
Budget prévu	<u>25782991</u>	Version de l'analyse	<u>Version préliminaire</u>

Description :

Le projet concerne la construction d'une nouvelle bibliothèque de quatre (4) étages. Outre la bibliothèque, le bâtiment comprendra également des espaces culturels et sociocommunautaires. Un espace isolé, désigné comme le Jardin d'hiver, ab...

Scénarios analysés

	Nom	GES totales (kg éq. CO ₂)	Description
Scénario 1	Scénario du projet Coeur- Nomade	1 675 638	Structure de la toiture en bois lamellé-collé. Pontage de toiture en CLT. Structure du Jardin d'hiver en bois lamellé-collé, pontage des plateformes du Jardin d'hiver en CLT.
Scénario 2	Scénario de référence	1 770 315	

Scénario retenu

	Numéro	Type de structure	Émissions GES (kg éq. CO ₂)
Scénario de référence	2	Béton	1 770 315
Scénario retenu	1	Hybride béton-bois	1 675 638

Émissions de GES évitées: 94 677

Rapport sommaire de l'analyse comparative des scénarios

Comparabilité des scénarios

		Scénario 1	Scénario 2
Saisie inclue bâtiment (s) type(s)		Non	Non
Nombre d'éléments modélisés		15	6
Fondations	m ³ béton armé	1 358	1 358
	tonne acier	139	139
Poutres et colonnes	m ³ béton armé		44
	tonne acier		13,5
	m ³ bois	155	
Planchers	m ² de planchers	3 195	3 195
Murs intérieurs	m ² de murs	156	
Toitures	m ² de toitures	1 160	1 167

Superficie totale de plancher: 4193 m²

Superficie au sol: 2110 m²

Validation des scénarios

	Scénario complété	Commentaires sur la comparabilité des scénarios
Scénario 1	Oui	Seuls les éléments différents entre les scénarios sont inclus
Scénario 2	Oui	Structure de béton la plus probable

Rapport sommaire de l'analyse comparative des scénarios

Comparaison des scénarios

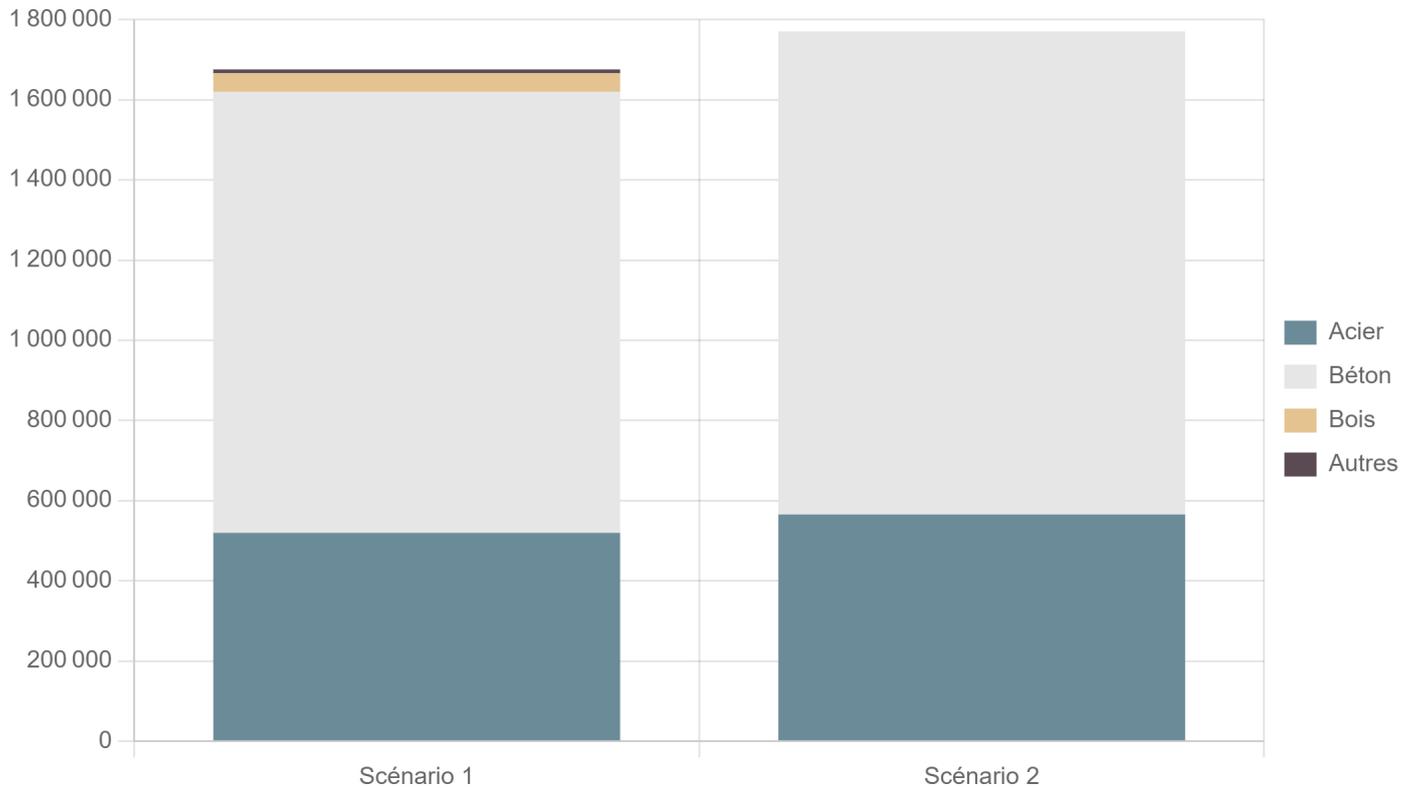
Émissions de GES (kg éq. CO₂)

	Scénario 1	Scénario 2
Nom	Scénario du projet Coeur-Nomade	Scénario de référence
Type de structure	Hybride béton-bois	Béton
Saisie inclue bâtiment (s) type(s)	Non	Non
Par matériau		
■ Acier	519 900	565 676
■ Béton	1 100 160	1 204 639
■ Bois	46 012	0
■ Autres	9 567	0
Par système constructif		
■ Fondations	610 812	610 812
■ Poutres et colonnes	28 062	36 959
■ Planchers	997 427	1 001 725
■ Murs intérieurs	7 621	0
■ Murs extérieurs	0	0
■ Toitures	31 716	120 819
GES totales		
Total	1 675 638	1 770 315
GES par m²	400	422
Choix des scénarios		
Scénario de référence		X
Scénario retenu	X	
Émissions de GES évitées	94 677	-
% de réduction	5,3	-

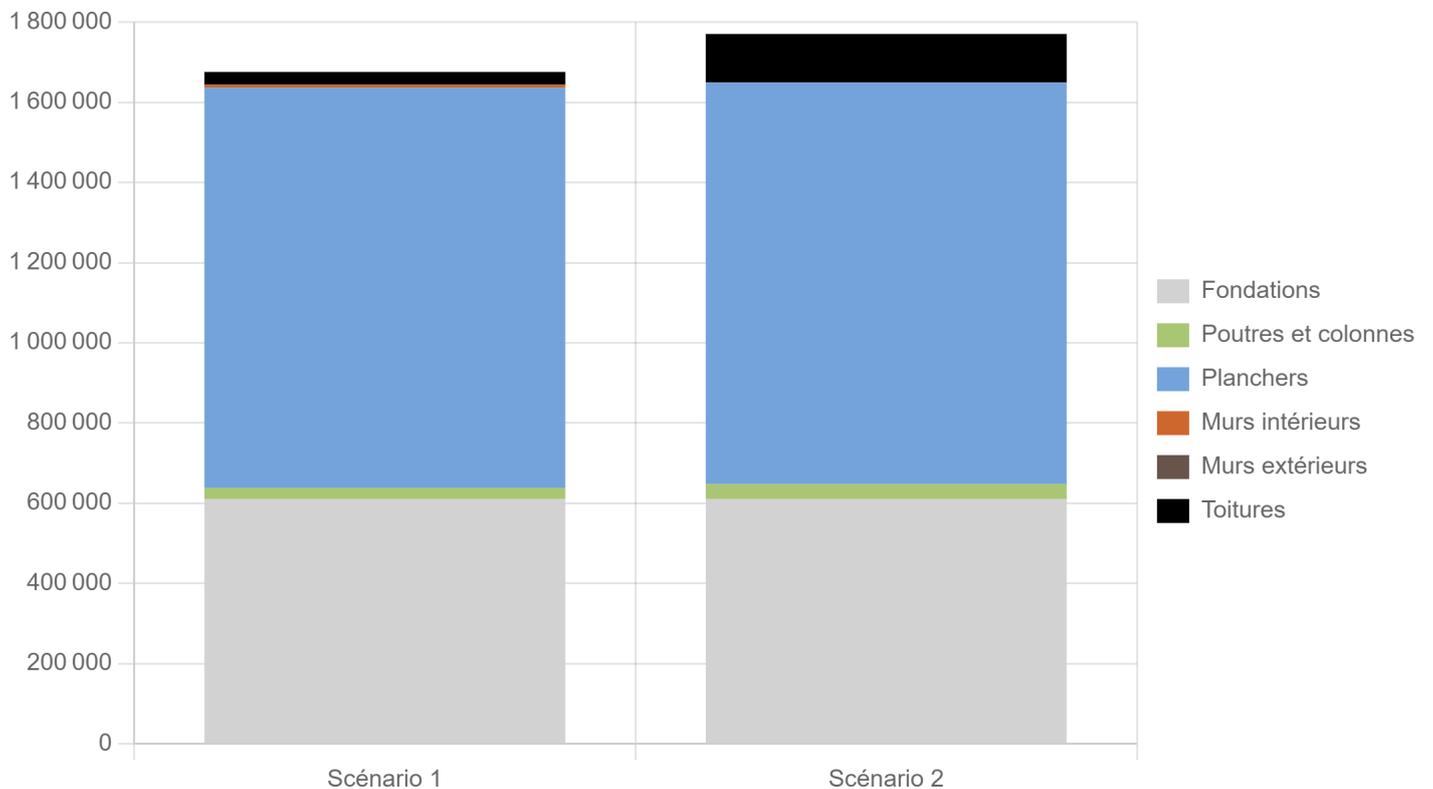
Superficie totale de plancher: 4193 m²

Comparaison des scénarios

Émissions de GES par matériau (kg éq. CO₂)



Émissions de GES par système constructif (kg éq. CO₂)



Annexe C.2

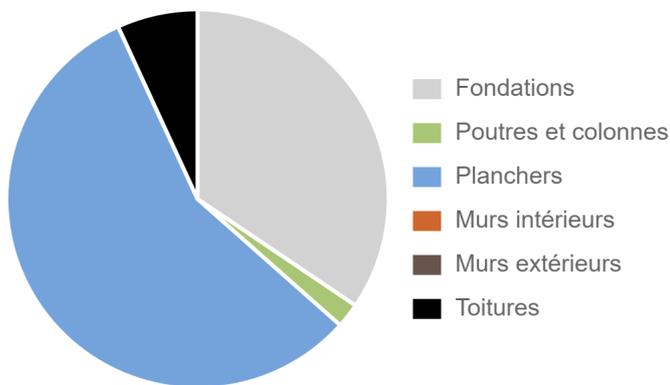
Analyse des émissions de GES du Scénario de référence de GESTIMAT

Analyse des émissions de gaz à effet de serre (GES)

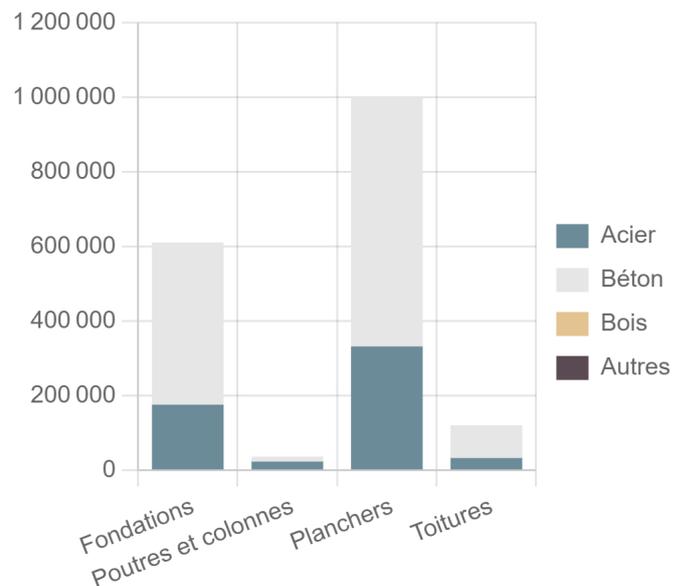
Scénario : Scénario de référence

Nom du projet	<u>Coeur-Nomade</u>
Numéro du projet	<u>21-281</u>
Type de projet	<u>Saisie détaillée</u>
Description	<u>Le projet concerne la construction d'une nouvelle bibliothèque de quatre (4) étages. Outre la bibl</u>

Répartition des émissions de GES



Émissions de GES (kg éq. CO₂)



Émissions de GES (kg éq. CO₂)

	Acier	Béton	Bois	Autres	Total	%
Fondations	176 252	434 560	0	0	610 812	34,5 %
Poutres et colonnes	23 755	13 204	0	0	36 959	2,1 %
Planchers	332 375	669 350	0	0	1 001 725	56,6 %
Murs intérieurs	0	0	0	0	0	0 %
Murs extérieurs	0	0	0	0	0	0 %
Toitures	33 294	87 525	0	0	120 819	6,8 %
Total	565 676	1 204 639	0	0	1 770 315	100 %
GES par m²	135	287	0	0	422	

Superficie totale de plancher: 4193 m²

Annexe D

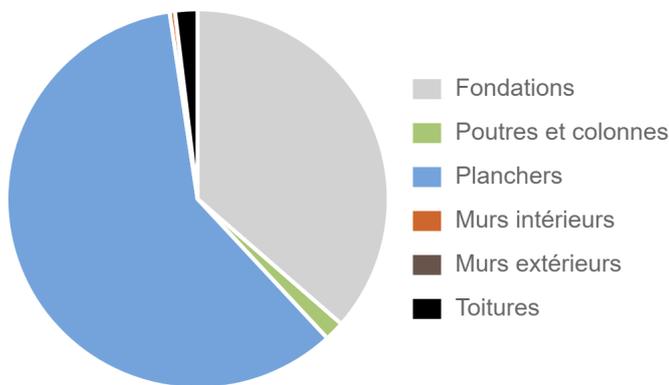
Rapport sommaire de l'analyse comparative des scénarios de GESTIMAT

Analyse des émissions de gaz à effet de serre (GES)

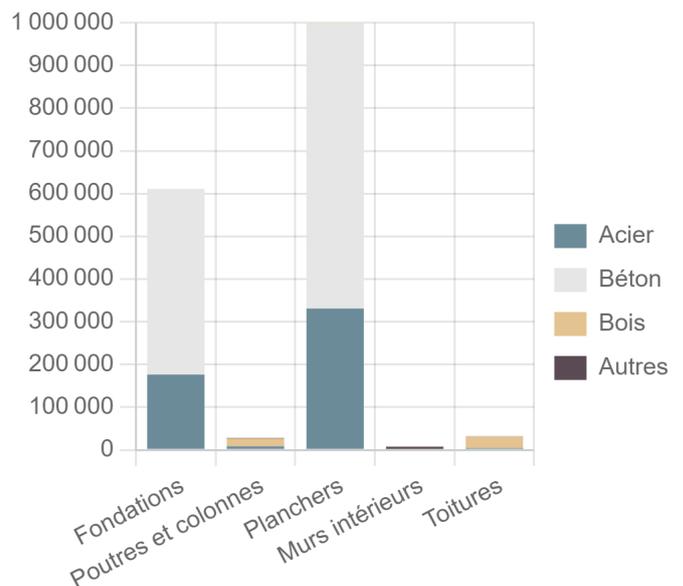
Scénario : Scénario du projet Coeur-Nomade

Nom du projet	<u>Coeur-Nomade</u>
Numéro du projet	<u>21-281</u>
Type de projet	<u>Saisie détaillée</u>
Description	<u>Le projet concerne la construction d'une nouvelle bibliothèque de quatre (4) étages. Outre la bibl</u>

Répartition des émissions de GES



Émissions de GES (kg éq. CO₂)



Émissions de GES (kg éq. CO₂)

	Acier	Béton	Bois	Autres	Total	%
Fondations	176 252	434 560	0	0	610 812	36,5 %
Poutres et colonnes	8 442	0	18 490	1 130	28 062	1,7 %
Planchers	330 948	665 600	879	0	997 427	59,5 %
Murs intérieurs	0	0	0	7 621	7 621	0,45 %
Murs extérieurs	0	0	0	0	0	0 %
Toitures	4 258	0	26 642	816	31 716	1,9 %
Total	519 900	1 100 160	46 012	9 567	1 675 638	100 %
GES par m²	124	262	11	2	400	

Superficie totale de plancher: 4193 m²

Annexe E.1

EPD10684 1 m² of Aluminium Curtain Wall System, Enviro Facades

ENVIRONMENTAL PRODUCT DECLARATION

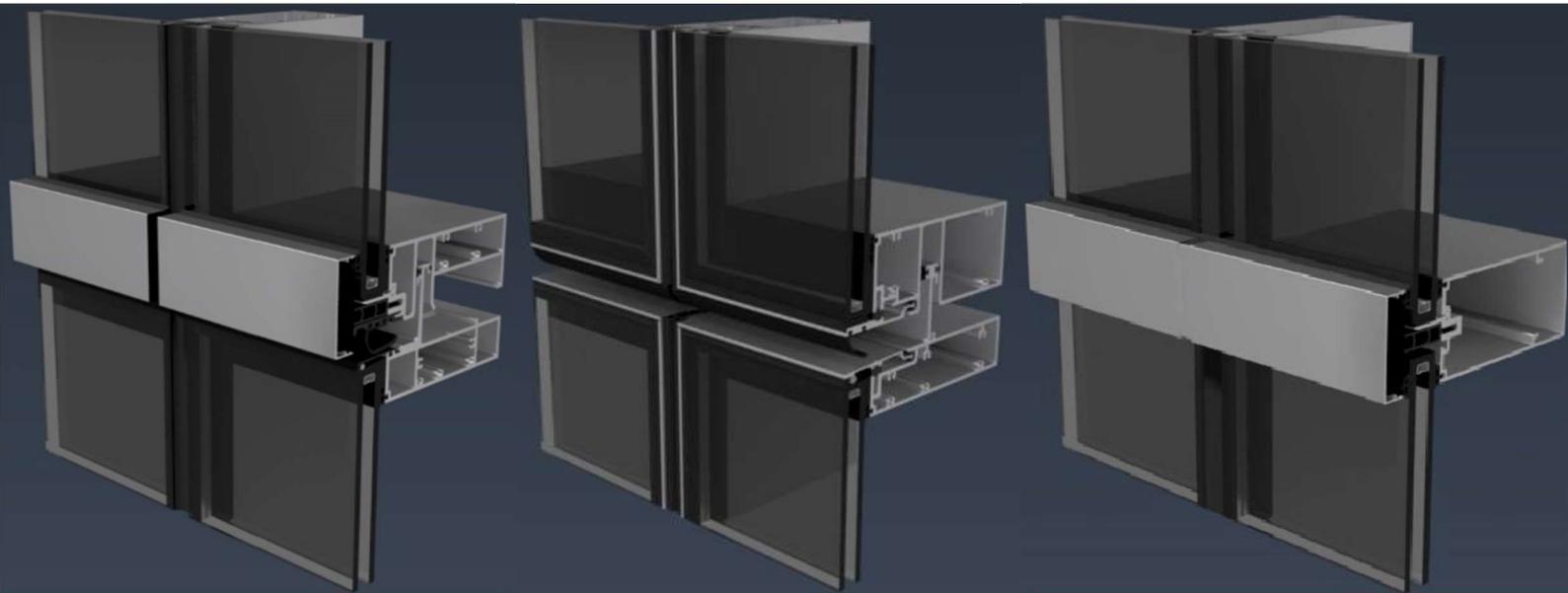


In accordance with ISO 14025:2016 and EN15804+A1 for:

1 m² of Aluminum Curtain Wall Systems

EF30 UW, EF35 UW, EF30 SW

ENVIRO | FACADES®



Program Operator

NSF Certification, LLC
www.nsf.org

EPD Registration Number

EPD10684

Publication Date

2022-01-25

Valid Until

2027-01-24

An EPD should provide current information and may be updated if conditions change. The stated validity is therefore subject to the continued registration and publication at http://info.nsf.org/Certified/Sustain/epd_search.asp

PROGRAM INFORMATION

PROGRAM OPERATOR

NSF Certification LLC
789 N. Dixboro,
Ann Arbor, MI 48105



www.nsf.org

The EPD owner, Erie Architectural, has the sole ownership, liability, and responsibility for the EPD.

DECLARATION HOLDER

Erie Architectural
477 Jutras Dr. South
Lakeshore
Ontario,
N8N 5C4
Canada



www.erieap.com

LCA CONSULTANT

Intertek Deutschland GmbH
Stangenstraße 1
70771
Leinfelden-Echterdingen
Germany



www.intertek.com

PROGRAM DETAILS

Product category rules (PCR): IBU Part A: Calculation Rules for the Life Cycle Assessment and Requirements on the Project Report v.2.0.1. April 2021

IBU Part B: Requirements on the EPD for Curtain Walling, V1.6, Nov 2017

PCR review was conducted by: The Independent Expert Committee
IBU

Independent third-party verification of the declaration and data, according to ISO 14025:2006:

EPD process certification (internal)

EPD verification (external)

Third party verifier:

Jack Geibig, jgeibig@ecoform.com



Tony Favilla, afavilla@nsf.com



Accredited or approved by: NSF Certification, LLC

Procedure for follow-up of data during EPD validity involves third party verifier:

Yes No

GENERAL INFORMATION

COMPANY INFORMATION

Erie Architectural Products are a leading manufacturing company who specialize in the engineering, manufacture and distribution of curtain wall systems across the United States. Erie Architectural Products are the study commissioner and EPD owner. They operate one production site where all the aluminum curtain wall systems were manufactured.

This cradle-to-gate environmental product declaration is for 1m² of the following aluminum curtain wall systems, produced from the locations fully owned and operated by Erie Architectural in Lakeshore, Canada:

- EF30 UW
- EF35 UW
- EF30 SW

Further information regarding Erie Architectural Products can be accessed from www.erieap.com



PRODUCT INFORMATION

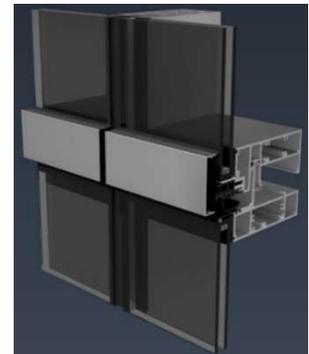
Curtain wall systems clad a building envelope with glass and aluminum to protect the interior from the elements and create a safe and comfortable work environment for the building occupants. Curtain walls are designed to only carry their own weight. The wall transfers wind loads to the main building structure, also known as the main wind force resisting system (MWFRS), at connection points in the floors or columns of the building. A curtain wall is designed to resist air and water infiltration, as well as sway created by wind and seismic forces and its own weight.

Curtain walls may span from floor to floor, used in punched opening applications, or span multiple floors, and take into consideration design requirements such as: thermal expansion and contraction; building sway and movement; water diversion; and thermal efficiency for cost-effective heating, cooling and lighting in the building.

The following curtain wall systems are covered by this LCA study:

- EF30 UW - ENVIRO|FACADES® Unitized Curtain Wall System

A high-performance unitized curtain wall system designed to meet the industry’s most challenging designs. A perfect solution for even the most stringent environmental conditions. The system is designed to be assembled and glazed in a climate-controlled environment for increased quality assurance of critical seals and frame workmanship. Both captured and SSG options are available.



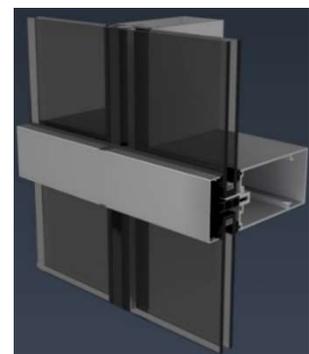
- EF35 UW – ENVIRO|FACADES® Unitized Curtain Wall System

A high-performance unitized curtain wall system designed to meet the industry’s most challenging designs. A perfect solution for large spans and blast/impact mitigation. The system is designed to be assembled and glazed in a climate-controlled environment for increased quality assurance of critical seals. Features 4-sided SSG construction with aluminum trims.



- EF30 SW – ENVIRO|FACADES® Stick-Built Curtain Wall System

A high-performance stick-built curtain wall system designed to meet the industry’s most challenging designs. A perfect solution for even the most stringent environmental conditions. The system is designed to be assembled and glazed in the field. Both captured and SSG options are available.



TECHNICAL SPECIFICATIONS OF PRODUCT

TECHNICAL SPECIFICATION DETAILS FOR EF30 UW

Name	Notes	Value and unit
Thermal Transmittance (U-Factor) AAMA 1503.1, AAMA 507, and NFRC 100	1,2,4	0.38 – 0.40 Btu/hr•ft ² •°F
Solar Heat-Gain Coefficient (SHGC) NFRC 200		Based on glass
Condensation Resistance Factor (CRFf) AAMA 1503.1	1,2,3,4	Minimum of 75
Water Infiltration** ASTM E 331 and AAMA 501.1	2	25 psf
Air Infiltration** ASTM E 283 at 6.24 psf	2	0.01 cfm/ft ²
Impact Resistance ASTM E 1886/1996, Testing Application Standard 201/202/203	2,3,4,5	A,D Missile Type

TECHNICAL SPECIFICATION DETAILS FOR EF35 UW

Name	Notes	Value and unit
Thermal Transmittance (U-Factor) AAMA 1503.1, AAMA 507, and NFRC 100	1,2,4	0.45 – 0.47 Btu/hr•ft ² •°F
Solar Heat-Gain Coefficient (SHGC) NFRC 200		Based on glass
Condensation Resistance Factor (CRFf) AAMA 1503.1	1,2,3,4	Minimum of 73
Water Infiltration** ASTM E 331 and AAMA 501.1	2	25 psf
Air Infiltration** ASTM E 283 at 6.24 psf	2	>0.01 cfm/ft ²
Impact Resistance ASTM E 1886/1996, Testing Application Standard 201/202/203	2,3,4,5	A,D

TECHNICAL SPECIFICATION DETAILS FOR EF30 SW

Name	Notes	Value and unit
Thermal Transmittance (U-Factor) AAMA 1503.1, AAMA 507, and NFRC 100	1,2,4	0.35 – 0.39 Btu/hr•ft ² •°F
Solar Heath-Gain Coefficient (SHGC) NFRC 200		Based on glass
Condensation Resistance Factor (CRFf) AAMA 1503.1	1,2,3,4	Minimum of 78
Water Infiltration** ASTM E 331 and AAMA 501.1	2	20 psf
Air Infiltration** ASTM E 283 at 6.24 psf	2	>0.01 cfm/ft ²

Notes:

- *(1) Calculated based on U (Center of Glass) = 0.29
- (2) Varies by project specific construction
- (3) Dependent on glazing specified
- (4) Based on products tested
- **Predominantly describes the framing

PRODUCT COMPOSITION

The product composition for the three aluminum curtain wall systems is provided in the Tables below. The systems contain 0% bio-based material and does not contain any substances hazardous to health or the environment (in particular carcinogenic, mutagenic, toxic to reproduction, allergic, PBT5 or vPvB6 substances). No substances that are listed in the “Candidate List of Substances of very high concern for authorisation” are contained in the curtain wall systems.

PRODUCT COMPOSITION OF EF30 UW

Material	Mass (kg/m ²)	Percentage (%)
Aluminum	11.55	21.58%
Polyvinyl chloride	0.236	0.44%
Silicone gasket	0.202	0.38%
Insulation (mineral wool)	6.98	13.04%
Backpan	2.69	5.04%
Insulated glass unit	31.66	59.16%

PRODUCT COMPOSITION OF EF35 UW

Material	Mass (kg/m ²)	Percentage (%)
Aluminum	12.65	18.26%
Polyvinyl chloride	0.12	0.17%
Silicone gasket	9.50E-02	0.14%
Insulation (mineral wool)	6.98	10.07%
Backpan	2.89	4.17%
Insulated glass unit	46.56	67.19%

PRODUCT COMPOSITION OF EF30 SW

Material	Mass (kg/m ²)	Percentage (%)
Aluminum	4.27	98.23%
Polyvinyl chloride	2.36E-02	0.54%
Silicone gasket	5.34E-02	1.23%

The curtain wall systems are packaged using crating wood and plastic wrap prior to shipping to installation sites.

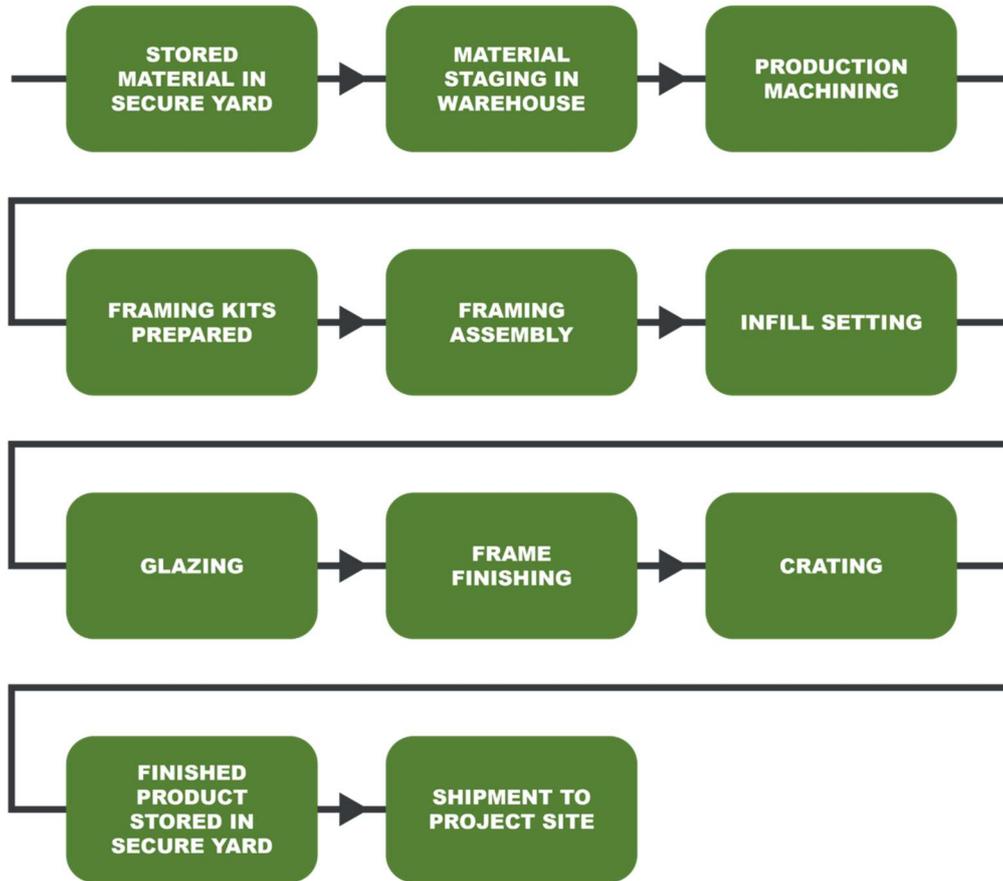
PACKAGING REQUIREMENTS

Material	Mass (lb/m ²)
Crating wood	4.62
Shrink wrap	3.55E-04
Sill wrap	0.439
Silicone block	4.00E-02

MANUFACTURING

All Erie Architectural aluminum curtain wall systems are manufactured, finished and inspected for quality in Erie Architectural facility in Lakeshore, Canada.

The manufacturing process comprises the following production stages:



Materials are received into the production site in Lakeshore, Canada where they are stored prior to going to the production floor where the aluminum is cut, fabricated and assembled into frame units. Glazing is then added. Once the frames are finished, the wall systems are packaged and then stored in the yard prior to shipment.

The aluminum curtain wall systems are not expected to create exposure conditions that exceed safe thresholds for health impacts to humans or flora/fauna under normal operating conditions. Use stage is outside the scope of this EPD.

LCA INFORMATION

LIFE CYCLE ASSESSMENT – PRODUCT SYSTEM AND MODELING

A cradle-to-gate analysis using life cycle assessment (LCA) techniques was conducted for this EPD. The analysis was done according to the product category rule (PCR) for curtain wall and followed LCA principles, requirements and guidelines laid out in the ISO 14040/12044 standards. A comparison or an evaluation of EPD data is only possible if all the data sets to be compared were created according to EN 15804 and the building context, respectively the product-specific characteristics of performance, are taken into account. For calculating the LCA, SimaPro v9 software and ecoinvent 3.6 datasets were used.

DECLARED UNIT

The declared unit for the EPD is one square meter (1m²) of curtain wall product. In line with the PCR, the conversion factor to 1kg of product is provided in the table below.

System	Conversion factor to 1kg
EF30 UW	1/53.5
EF35 UW	1/69.3
EF30 SW	1/4.35

SYSTEM BOUNDARY

This cradle-to-gate analysis provides information on the product stage of the aluminum curtain wall system, comprising modules A1-A3 as shown in the table below.

Upstream	Core		Downstream													Other Environmental Information
			Product Stage			Construction Process Stage		Use Stage						End of Life Stage		
Raw Material Supply	Transport	Manufacturing	Transport	Construction	Use	Maintenance	Repair	Replacement	Refurbishment	Operational Energy Use	Operational Water Use	Demolition	Transport	Waste Processing	Disposal	Future Reuse, Recycling or Energy Recovery Potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND	MND

X = included in LCA; MND = Module not declared

ESTIMATES AND ASSUMPTIONS

This study was performed based on primary production data for the manufacture of the three aluminum curtain wall systems covered by the scope of this EPD.

It has been estimated that the aluminum profiles were composed of a mix of 41% recycled material (20% post-industrial and 21% post-consumer recycled material). This estimate was provided by EAP based on actual data.

Beyond that, no significant assumptions have been made. All of the raw materials and energy inputs were models using processes and flows that closely follow actual production raw materials and processes. All of the raw material and energy flows have been accounted for.

ALLOCATION

No multi-output (i.e. co-product) allocation was performed in this study. In terms of generic data, the main database used, ecoinvent v3.6 (cut-off), defaults to an economic allocation for most processes. However, in some cases a mass-based allocation is used, where there is a direct physical relationship. The allocation approach of specific ecoinvent modules is documented on their website and method reports (see www.ecoinvent.org).

The production plant produced products exclusively during the timeframe for data collection and no co-products were produced, therefore the flow of materials and energy and the associated release of substances and energy into the environment were therefore related exclusively to the aluminum curtain wall systems included within the scope of this LCA

With regard to allocation of recycled content within upstream data, according to the "polluter pays principle" required by EN 15804, in this study the Ecoinvent "cut-off" datasets have been adopted for all the selected items.

CUT-OFF CRITERIA

In case of insufficient input data or data gaps for a unit process the cut-off criteria were 1% of renewable and non-renewable primary energy usage and 1% of the total mass input of that unit process. The total of neglected input flows per module was a maximum of 5% of energy usage and mass.

In practice, all input and outputs, for which data are available, have been included in the calculation. Data gaps have been filled by conservative assumptions with average or generic data. Capital items for the production processes (machines, buildings, etc.) were not taken into consideration.

DATA SOURCES AND QUALITY

Specific data for all core processes were collected from Erie Architectural Products from their site in Lakeshore, Canada for a time period of twelve months from 2019.09.20 to 2020.10.01. Selected generic data were collected for the upstream life cycle stages from the LCI database ecoinvent v3.6 (cut-off).

The data quality can be considered as good. The LCA models have been checked and most relevant flows are considered. Technological, geographical and temporal representativeness is appropriate.

The LCA software SimaPro (version 9) was used to build a model for the product systems under investigation using specific and generic inventory data. In addition, SimaPro was used to apply characterization models and factors from the impact assessment methods to generate results.

ENVIRONMENTAL PERFORMANCE

The environmental performance of the assessed product is declared and reported using the parameters as specified in the PCR. These LCIA results and other environmental results are presented in the table below per declared unit to three significant figures. As additional information, since the products are sold to the North American market, the results have also been reported against the TRACI 2.1 method.

1M² OF EF30 UW

ENVIRONMENTAL IMPACTS: CML 2001 (APR 2013)

Parameter	Unit	A1	A2	A3	A1-A3 (Total)
Parameters describing environmental impacts					
Global warming potential (GWP)	kg CO ₂ equiv.	191	8.62	7.59	207
Ozone Depletion Potential (ODP)	Kg CFC-11 equiv.	8.56E-06	1.50E-06	6.13E-07	1.07E-05
Acidification potential (AP)	kg SO ₂ equiv.	1.14	0.0282	0.0169	1.19
Eutrophication potential (EP)	kg (PO ₄) ₃₋ equiv.	0.276	6.64E-03	0.0123	0.295
Formation potential of tropospheric ozone (POCP)	kg NMVOC equiv.	0.0634	1.17E-03	1.33E-03	0.0659
Abiotic depletion potential – elements (ADPE)	kg Sb equiv.	4.47E-03	2.30E-04	3.58E-05	4.74E-03
Abiotic depletion potential – fossil (ADPF)	MJ, net calorific	1859	127	83.8	2070

ENVIRONMENTAL IMPACTS: TRACI 2.1

Parameter	Unit	A1	A2	A3	A1-A3 (Total)
Parameters describing environmental impacts					
Global warming potential (GWP)	kg CO ₂ equiv.	189	8.61	7.18	205
Ozone depletion potential (ODP)	Kg CFC-11 equiv.	1.12E-05	2.00E-06	7.57E-07	1.40E-05
Acidification potential (AP)	kg SO ₂ equiv.	1.16	0.0316	0.0182	1.21
Eutrophication potential (EP)	kg N equiv.	0.5149	9.52E-03	0.0281	0.5525
Smog Potential (SP)	Kg O ₃ equiv.	13.4	0.667	0.320	14.4
Fossil fuel consumption (FF)	MJ	136	18.1	12.9	167

RESOURCE USE AND OUTPUT / WASTE PARAMETERS

Parameter	Unit	A1	A2	A3	A1-A3 (Total)
Parameters describing use of resources					
Use of renewable primary energy resources – use as energy carrier	MJ, net calorific value	190	1.44	26.3	218
Use of renewable primary energy resources – use as raw materials	MJ, net calorific value	26.5	0.275	0.742	27.5
Use of renewable primary energy resources – total	MJ, net calorific value	217	1.71	27.1	246
Use of non-renewable primary energy resources – use as energy carrier	MJ, net calorific value	2531	128.4	262.4	2922
Use of non-renewable primary energy resources – use as raw materials	MJ, net calorific value	0	0.0	0.0	0
Use of non-renewable primary energy resources – total	MJ, net calorific value	2531	128.4	262.4	2922
Use of secondary material	kg	4.82	0	0	4.82
Use of renewable secondary fuels	MJ, net calorific value	0	0	0	0
Use of non-renewable secondary fuels	MJ, net calorific value	0	0	0	0
Net use of fresh water	m ³	1.19	0.0106	0.535	1.74
Parameters describing waste production					
Hazardous waste disposed	kg	0.0236	1.18E-03	5.31E-03	0.0301
Non-hazardous waste disposed	kg	32.9	6.06	3.63	42.6
Radioactive waste disposed	kg	3.53E-03	8.43E-04	5.12E-03	9.50E-03
Parameters describing outputs flows					
Components for reuse	kg	0	0	0	0
Material for recycling	kg	0	0	6.57	6.57
Materials for energy recovery	kg	0	0	0	0
Export energy, electricity	MJ	0	0	0	0

Note that the LCIA results are relative expressions and do not predict impacts on category end-points, the exceeding of thresholds, safety margins or risks

1M² OF EF35 UW

ENVIRONMENTAL IMPACTS: CML 2001 (APR 2013)

Parameter	Unit	A1	A2	A3	A1-A3 (Total)
Parameters describing environmental impacts					
Global warming potential (GWP)	kg CO ₂ equiv.	221	11.69	6.85	239
Ozone Depletion Potential (ODP)	Kg CFC-11 equiv.	9.93E-06	2.04E-06	5.49E-07	1.25E-05
Acidification potential (AP)	kg SO ₂ equiv.	1.36	0.0383	0.0154	1.42
Eutrophication potential (EP)	kg (PO ₄) ₃ -equiv.	0.316	9.00E-03	1.07E-02	0.336
Formation potential of tropospheric ozone (POCP)	kg NMVOC equiv.	0.073	1.59E-03	1.20E-03	0.076
Abiotic depletion potential – elements (ADPE)	kg Sb equiv.	6.37E-03	3.11E-04	3.30E-05	6.71E-03
Abiotic depletion potential – fossil (ADPF)	MJ, net calorific	2153	172	77.7	2402

ENVIRONMENTAL IMPACTS: TRACI 2.1

Parameter	Unit	A1	A2	A3	A1-A3 (Total)
Parameters describing environmental impacts					
Global warming potential (GWP)	kg CO ₂ equiv.	219	11.7	6.5	237
Ozone depletion potential (ODP)	Kg CFC-11 equiv.	1.32E-05	2.71E-06	6.74E-07	1.66E-05
Acidification potential (AP)	kg SO ₂ equiv.	1.38	0.043	0.016	1.44
Eutrophication potential (EP)	kg N equiv.	0.582	1.29E-02	2.42E-02	0.619
Smog potential (SP)	Kg O ₃ equiv.	15.9	0.905	0.274	17.1
Fossil fuel consumption (FF)	MJ	164	24.5	12.0	201

RESOURCE USE AND OUTPUT / WASTE PARAMETERS

Parameter	Unit	A1	A2	A3	A1-A3 (Total)
Parameters describing use of resources					
Use of renewable primary energy resources – use as energy carrier	MJ, net calorific value	215	1.95	25.0	242
Use of renewable primary energy resources – use as raw materials	MJ, net calorific value	31.4	0.373	0.704	32.5
Use of renewable primary energy resources – total	MJ, net calorific value	246	2.32	25.7	274
Use of non-renewable primary energy resources – use as energy carrier	MJ, net calorific value	2901	174	248	3323
Use of non-renewable primary energy resources – use as raw materials	MJ, net calorific value	0	0	0	0
Use of non-renewable primary energy resources – total	MJ, net calorific value	2901	174	248	3323
Use of secondary material	kg	5.29	0	0	5.29
Use of renewable secondary fuels	MJ, net calorific value	0	0	0	0
Use of non-renewable secondary fuels	MJ, net calorific value	0	0	0	0
Net use of fresh water	m ³	1.29	0.01	0.51	1.81
Parameters describing waste production					
Hazardous waste disposed	kg	2.64E-02	1.60E-03	5.01E-03	3.30E-02
Non-hazardous waste disposed	kg	37.0	8.22	3.09	48.3
Radioactive waste disposed	kg	4.26E-03	1.14E-03	4.85E-03	1.03E-02
Parameters describing outputs flows					
Components for reuse	kg	0	0	0	0
Material for recycling	kg	0	0	4.66	4.66
Materials for energy recovery	kg	0	0	0	0
Export energy, electricity	MJ	0	0	0	0
Export energy, thermal	MJ	0	0	0	0

Note that the LCIA results are relative expressions and do not predict impacts on category end-points, the exceeding of thresholds, safety margins or risks.

1M² OF EF30 SW

ENVIRONMENTAL IMPACTS: CML 2001 (APR 2013)

Parameter	Unit	A1	A2	A3	A1-A3 (Total)
Parameters describing environmental impacts					
Global warming potential (GWP)	kg CO ₂ equiv.	55.67	0.72	7.11	63.5
Ozone Depletion Potential (ODP)	Kg CFC-11 equiv.	1.97E-06	1.26E-07	5.72E-07	2.67E-06
Acidification potential (AP)	kg SO ₂ equiv.	0.305	2.37E-03	0.0158	0.324
Eutrophication potential (EP)	kg (PO ₄) ₃ -equiv.	0.0832	5.59E-04	0.0111	9.48E-02
Formation potential of tropospheric ozone (POCP)	kg NMVOC equiv.	0.019	9.88E-05	1.24E-03	2.00E-02
Abiotic depletion potential – elements (ADPE)	kg Sb equiv.	1.49E-04	1.99E-05	3.43E-05	2.03E-04
Abiotic depletion potential – fossil (ADPF)	MJ, net calorific	530.0	10.63	80.49	621

ENVIRONMENTAL IMPACTS: TRACI 2.1

Parameter	Unit	A1	A2	A3	A1-A3 (Total)
Parameters describing environmental impacts					
Global warming potential (GWP)	kg CO ₂ equiv.	55.3	0.724	6.75	62.8
Ozone depletion potential (ODP)	Kg CFC-11 equiv.	2.63E-06	1.68E-07	7.04E-07	3.50E-06
Acidification potential (AP)	kg SO ₂ equiv.	0.309	2.66E-03	0.0169	0.329
Eutrophication potential (EP)	kg N equiv.	0.161	8.05E-04	0.0251	0.187
Smog Potential (SP)	Kg O ₃ equiv.	3.54	0.056	0.285	3.88
Fossil fuel consumption (FF)	MJ	30.3	1.51	12.4	44.2

RESOURCE USE AND OUTPUT / WASTE PARAMETERS

Parameter	Unit	A1	A2	A3	A1-A3 (Total)
Parameters describing use of resources					
Use of renewable primary energy resources – use as energy carrier	MJ, net calorific value	61.9	0.123	26.2	88.2
Use of renewable primary energy resources – use as raw materials	MJ, net calorific value	6.79	0.024	0.73	7.55
Use of renewable primary energy resources – total	MJ, net calorific value	68.7	0.146	26.9	95.8

Parameter	Unit	A1	A2	A3	A1-A3 (Total)
Use of non-renewable primary energy resources – use as energy carrier	MJ, net calorific value	758	10.8	258	1027
Use of non-renewable primary energy resources – use as raw materials	MJ, net calorific value	0	0	0	0
Use of non-renewable primary energy resources – total	MJ, net calorific value	758	10.8	258	1027
Use of secondary material	kg	1.83	0	0	1.83
Use of renewable secondary fuels	MJ, net calorific value	0	0	0	0
Use of non-renewable secondary fuels	MJ, net calorific value	0	0	0	0
Net use of fresh water	m ³	0.295	8.91E-04	0.532	0.828
Parameters describing waste production					
Hazardous waste disposed	kg	8.21E-03	9.91E-05	5.25E-03	0.0136
Non-hazardous waste disposed	kg	10.6	0.500	3.21	14.3
Radioactive waste disposed	kg	8.33E-04	7.07E-05	5.07E-03	5.98E-03
Parameters describing outputs flows					
Components for reuse	kg	0	0	0	0
Material for recycling	kg	0	0	4.93	4.93
Materials for energy recovery	kg	0	0	0	0
Export energy, electricity	MJ	0	0	0	0
Export energy, thermal	MJ	0	0	0	0

Note that the LCIA results are relative expressions and do not predict impacts on category end-points, the exceeding of thresholds, safety margins or risks

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Intertek is a leading Total Quality, Safety and Sustainability Assurance provider to industries worldwide. Through our network of more than 1,000 laboratories and offices and over 44,000 people in more than 100 countries, we are refining the industry with our innovative and bespoke Assurance, Testing, Inspection and Certification solutions for our customers' operations and value chains.

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Annexe E.2

ASTM-EPD149 Processed Glass Products, Cardinal Glass Industries

ENVIRONMENTAL PRODUCT DECLARATION

According to ISO 14025

PROCESSED GLASS PRODUCTS

CARDINAL GLASS INDUSTRIES



Cardinal Glass Industries is considered one of the world's leading providers of superior quality glass products. From the melting of sand to produce clear float glass to the vacuum sputtering of silver to produce low-emissivity coatings.

With this EPD Cardinal intends to support architects and designers with the information they need about the life-cycle environmental impact of Cardinal glass products.

Issue Date: 05-27-2020

Valid Until: 05-27-2025

Declaration Number: ASTM-EPD149



Declaration Number: ASTM-EPD149

DECLARATION INFORMATION

DECLARATION

Program Operator: ASTM International



Company: Cardinal Glass Industries



www.astm.org

www.cardinalcorp.com

PRODUCT INFORMATION

Product Name: Processed Glass

Product Definition: Coated, tempered, and coated & tempered glass

Cardinal Coated Glass Products	LoE-180 [®]	LoE ² -272 [®]	LoE ² -240 [®]	LoE-x89 [®]
	LoE-180ESC [®]	LoE ³ -366 [®]	LoE ³ -340 [®]	Neat+ [®]
	LoE ² -270 [®]	Quad LoE-452+ [®]	LoE-i89 [®]	

Declaration Type: Business to business

PCR Reference:

- Part A: Calculation Rules for the LCA and Requirements Project Report, (IBU/UL E, V1.2, 06.19.2014)
- Part B: Processed Glass EPD Requirements (UL Environment, 2016)

VALIDITY / APPLICABILITY

Period of Validity: This declaration is valid for a period of 5 years from the date of publication

Geographic Scope: United States

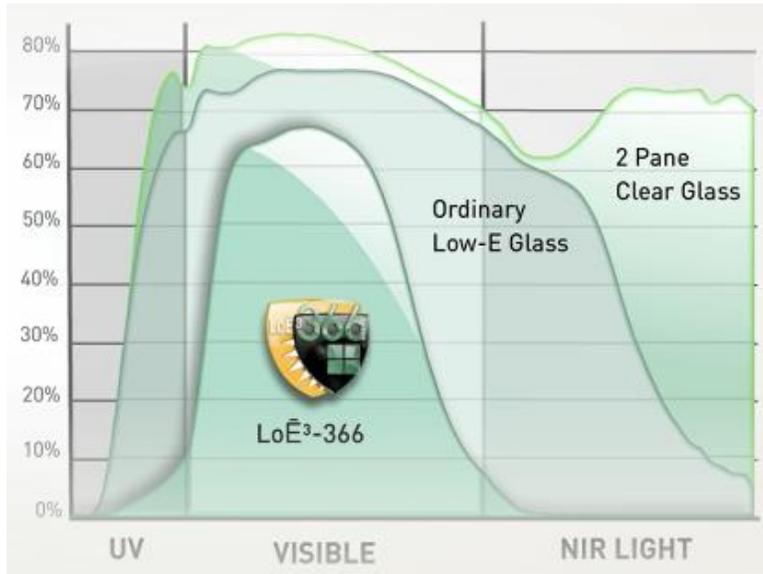
PCR Review was conducted by:

- Thomas P. Gloria, Ph.D., Industrial Ecology Consultants
- Mr. Jack Geibig, Ecoform
- Mr. Bill Stough, Sustainable Research Group

PRODUCT APPLICATION AND / OR CHARACTERISTICS

Coated glass, and in particular low-E coated glass, is used to enhance glazing energy performance.

TECHNICAL DRAWING OR PRODUCT VISUAL



CONTENT OF THE DECLARATION

- Product definition and physical building-related data
- Details of raw materials and material origin
- Description of how the product is manufactured
- Data on usage condition, other effects and end-of-life phase
- Life Cycle Assessment results

VERIFICATION

Independent verification of the declaration and data, according to ISO 21930:2007 and ISO 14025:2006

internal external

This declaration and the rules on which this EPD is based have been examined by an independent verifier in accordance with ISO 14025.

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Date: 05-27-2020

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Industrial Ecology Consultants
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Date: 05-27-2020

EPD SUMMARY

This document is a Type III environmental product declaration by Cardinal Glass Industries (Cardinal) that is certified by ASTM International (ASTM) as conforming to the requirements of ISO 21930 and ISO 14025. ASTM has assessed that the Life Cycle Assessment (LCA) information fulfills the requirements of ISO 14040 in accordance with the instructions listed in the referenced product category rules. The intent of this document is to further the development of environmentally compatible and sustainable construction methods by providing comprehensive environmental information related to potential impacts in accordance with international standards.

No comparisons or benchmarking is included in this EPD. Environmental declarations from different programs based upon differing PCRs may not be comparable. Comparison of the environmental performance of construction works and construction products using EPD information shall be based on the product's use and impacts at the construction works level. In general, EPDs may not be used for comparability purposes when not considered in a construction works context. Given this PCR ensures products meet the same functional requirements, comparability is permissible provided the information given for such comparison is transparent and the limitations of comparability explained. When comparing EPDs created using this PCR, variations and deviations are possible. Example of variations: Different LCA software and background LCI datasets may lead to different results for upstream or downstream of the life cycle stages declared.

Impact Category	Unit per m ² of processed glass	Coated (Total, A1-A3)	Tempered (Total, A1-A3)	Coated & tempered (Total, A1-A3)
TRACI 2.1				
GWP	kg CO ₂ eq.	13.7	17.1	22.3
AP	kg SO ₂ eq.	0.0476	0.0479	0.0641
EP	kg N eq.	0.00295	0.00312	4.21E-03
POCP	kg O ₃ eq.	1.25	1.31	1.63
ADPe	kg Fe eq., per ReCiPe 1.08	0.265	0.110	0.361
ADPf	MJ, surplus	22.8	31.5	38.7

SCOPE AND BOUNDARIES OF THE LIFE CYCLE ASSESSMENT

The Life Cycle Assessment (LCA) was performed according to ISO 14040 (ISO, 2006) and ISO 14044 (ISO, 2006) following the requirements of the ASTM EPD Program Instructions and referenced PCR.

System Boundary: Cradle-to-gate

Allocation Method: No allocation required

Declared Unit: 1 m² (7.5 kg) of processed glass

1 ORGANIZATION, PRODUCT, AND PRODUCT CATEGORY DESCRIPTIONS

1.1 DESCRIPTION OF COMPANY/ORGANIZATION

Cardinal Glass Industries is a management-owned S-Corporation leading the industry in the development of residential glass for windows and doors. We have grown to more than 6,000 employees located at 43 manufacturing locations around the United States.

Cardinal operates (5) divisions:

- Cardinal FG (float glass)
- Cardinal CT (custom tempered glass)
- Cardinal LG (laminated glass)
- Cardinal CG (coated glass)
- Cardinal IG (insulating glass)

1.2 DESCRIPTION AND DEFINITION OF PRODUCTS

Low emissivity (Low-E) coated glass improves the energy efficiency of the window by rejecting ultraviolet and near infrared energy, while allowing visible light from the sun to pass through. It also reflects room temperature radiation to reduce heat transfer providing lower Ufactors.

1.3 PRODUCT USE AND APPLICATION

After fabrication into sealed insulating glass units, the final product is shipped to a customer for installation into a window system.

1.4 TECHNICAL REQUIREMENTS

Primary use is governed by building codes. These codes will layout safety glazing requirements, structural sufficiency needs, and building energy compliance.

1.5 MATERIAL CONTENT

The composition of processed glass products produced by Cardinal is presented in Table 1-1.

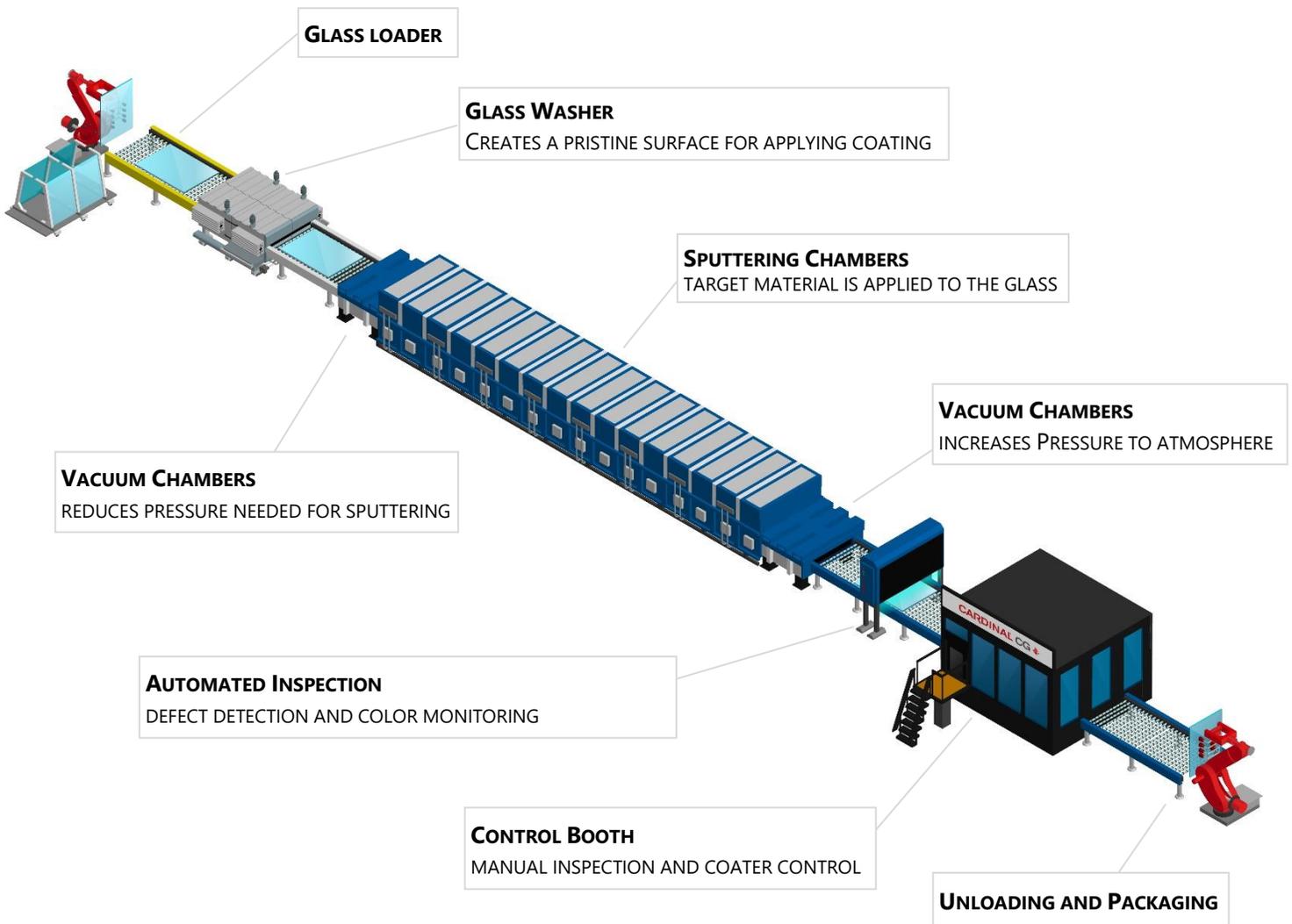
Table 1-1. Processed glass material content

Material inputs	Mass %		
	Coated	Tempered	Coated & Tempered
Glass oxide	99.95%	100.00%	99.95%
Nickel	<0.01%	-	<0.01%
Silicon	<0.01%	-	<0.01%
Silver	<0.01%	-	<0.01%
Tin	<0.01%	-	<0.01%
Titanium	<0.01%	-	<0.01%
Zinc	0.04%	-	0.04%

2 LIFE CYCLE STAGES

2.1 PRODUCTION

Energy efficient Low-E coatings consist of optically transparent nanoscopic layers sputtered onto glass via magnetron sputtering. The layers are deposited onto the glass substrate in sputtering chambers which are under vacuum. A high voltage magnetron ignites a plasma creating energetic ions of inert gases. The energetic ions forcefully collide with the target ejecting target atoms which deposit onto the glass substrate. The coated glass is then packaged and sent to customers to be processed into insulating glass units.



The following life cycle stages are evaluated:

- **Material Extraction and Pre-Processing** - Raw material extraction, pre-processing, and upstream transport for raw substance manufacture, but excludes the inbound transport of materials to the manufacturing facility
- **Transport** - Inbound transport of raw materials from the supplier to the manufacturing facility
- **Manufacturing** - Includes the energy and inputs to manufacturing processed glass products

2.2 PACKAGING

The processed glass product is packaged in cardboard and secured using plastic and steel banding as well as plastic wrap. The processed glass is also supported using wood.

3 LIFE CYCLE ASSESSMENT BACKGROUND INFORMATION

3.1 FUNCTIONAL UNIT

The declared unit for processed glass is 1 m² of glass. Each 1 m² pane weighs 7.5 kg, assuming a glass density of 2,500 kg/m³ and thickness of 3 mm.

3.2 SYSTEM BOUNDARY

The system boundary of the study is cradle-to-gate.

3.3 ESTIMATES AND ASSUMPTIONS

None.

3.4 CUT-OFF CRITERIA

No cut-off criteria had to be applied within this study. The system boundary was defined based on relevance to the goal of the study. For the processes within the system boundary, all available energy and material flow data have been included in the model. In cases where no matching LCI are available to represent a flow, proxy data have been applied based on conservative assumptions regarding environmental impacts.

3.5 BACKGROUND DATA

The LCA model was created using the GaBi ts software system v9.2 for life cycle engineering, developed by thinkstep AG. The GaBi 2019 LCI database provides the life cycle inventory data for several of the raw and process materials obtained from the background system.

3.6 DATA QUALITY

A variety of tests and checks were performed throughout the project to ensure the high quality of the completed LCA. Data included first-hand company manufacturing data in combination with consistent background LCI information from the GaBi 2019 databases.

Primary data represent the production of flat and processed glass at Cardinal facilities located in the United States. As such, the geographical coverage for this study is based on the respective system boundaries for all processes and products produced at each facility. Whenever geographically-relevant background data are not readily available, European or global data are to be used as proxies.

3.7 PERIOD UNDER REVIEW

The primary data collected from Cardinal are intended to represent production within the 2018 calendar year.

3.8 ALLOCATION

No allocation had to be applied.

3.9 COMPARABILITY

A comparison or evaluation of EPD data is only possible if all data sets to be compared are 1) created according to EN 15804 and 2) are considered in a whole building context or utilize identical defined use stage scenarios. Give this PCR is cradle to gate in scope, comparisons of EPD data from one product to another are not allowed. Refer to section 5.3 of EN 15804 for further information.

4 LIFE CYCLE ASSESSMENT RESULTS

Life cycle assessment results for the three types of processed glass covered in this EPD are presented per m² of glass products in this section. The cradle-to-gate impacts have been broken out into production of flat glass input, and processing (coating and/or tempering).

4.1 COATED GLASS

Table 4-1: Resource use LCI results for coated glass products, per declared unit [1 m², 7.5 kg]

Flow	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Renewable primary energy as energy carrier	MJ	5.93	7.54	13.5
Renewable energy resources as material utilization	MJ	0.240	0.174	0.414
Renewable total primary energy demand	MJ	6.17	7.72	13.9
Non-renewable primary energy as energy carrier	MJ	150	35.3	185
Non-renewable energy resources as material utilization	MJ	0.099	0.326	0.424
Non-renewable total primary energy demand	MJ	150	35.7	186
Use of secondary material	kg	-	-	-
Renewable secondary fuels	MJ	-	-	-
Non-renewable secondary fuels	MJ	-	-	-
Recovered energy	MJ	-	-	-
Use of net fresh water resources	m ³	25.6	18.4	44.0

Table 4-2: Wastes and outputs LCI results for coated glass products, per declared unit [1 m², 7.5 kg]

Flow	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Hazardous waste disposed	kg	1.13E-07	5.38E-08	1.67E-07
Non-hazardous waste disposed	kg	0.455	0.0207	0.476
High-level radioactive waste	kg	0.00213	0.00134	0.00347
Intermediate- and low-level radioactive waste	kg	7.24E-05	4.57E-05	1.18E-04
Components for re-use	kg	-	-	-
Materials for recycling	kg	0.0221	-	0.0221
Materials for energy recovery	kg	-	-	-
Exported energy	MJ	-	-	-

Table 4-3: LCIA results for coated glass products per functional unit [1 m², 7.5 kg]

Impact Category [TRACI 2.1]	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Global Warming Potential	kg CO ₂ eq.	11.1	2.67	13.7

Impact Category [TRACI 2.1]	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Ozone Depletion Potential ¹	kg CFC-11 eq.	-	-	-
Acidification Potential	kg SO ₂ eq.	0.0409	0.00669	0.0476
Eutrophication Potential	kg N eq.	0.00246	4.95E-04	0.00295
Photochemical Ozone Creation Potential	kg O ₃ eq.	1.16	0.0846	1.25
Metal Depletion	kg Fe eq., per ReCiPe 1.08	0.0694	0.195	0.265
Resources, Fossil Fuels	MJ	20.2	2.56	22.8

4.2 TEMPERED GLASS

Table 4-4: Energy usage LCI results for tempered glass products, per declared unit [1 m², 7.5 kg]

Flow	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Renewable primary energy as energy carrier	MJ	5.41	6.81	12.2
Renewable energy resources as material utilization	MJ	0.233	0.195	0.428
Renewable total primary energy demand	MJ	5.64	7.00	12.6
Non-renewable primary energy as energy carrier	MJ	156	103.2	259
Non-renewable energy resources as material utilization	MJ	0.107	0.291	0.399
Non-renewable total primary energy demand	MJ	156	103.5	259
Use of secondary material	kg	-	-	-
Renewable secondary fuels	MJ	-	-	-
Non-renewable secondary fuels	MJ	-	-	-
Recovered energy	MJ	-	-	-
Use of net fresh water resources	m ³	23.6	15.4	38.9

Table 4-5: Wastes and outputs LCI results for tempered glass products, per declared unit [1 m², 7.5 kg]

Flow	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Hazardous waste disposed	kg	1.19E-07	8.71E-08	2.06E-07
Non-hazardous waste disposed	kg	0.472	0.0283	0.500
High-level radioactive waste	kg	0.00255	0.00209	0.00464
Intermediate- and low-level radioactive waste	kg	8.68E-05	7.13E-05	1.58E-04
Components for re-use	kg	-	-	-
Materials for recycling	kg	0.0171	-	0.0171
Materials for energy recovery	kg	-	-	-
Exported energy	MJ	-	-	-

Table 4-6: LCIA results for tempered glass products per functional unit [1 m², 7.5 kg]

Flow	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Global Warming Potential	kg CO ₂ eq.	11.1	6.91	17.1
Ozon Depletion Potential ²	kg CFC-11 eq.	-	-	-
Acidification Potential	kg SO ₂ eq.	0.0407	0.0092	0.0479
Eutrophication Potential	kg N eq.	0.00247	7.92E-04	0.00312
Photochemical Ozone Creation Potential	kg O ₃ eq.	1.15	0.21	1.31
Metal Depletion	kg Fe eq., per	0.069	0.0470	0.110

¹ ODP values were originally in the order of magnitude of negative 10⁻¹². The negative values are a result of credits given in the background systems of various GaBi datasets. Since the magnitude of these ODP results is extremely low, the values are read and interpreted as zero.

² ODP values were originally in the order of magnitude of negative 10⁻¹². The negative values are a result of credits given in the background systems of various GaBi datasets. Since the magnitude of these ODP results is extremely low, the values are read and interpreted as zero.

ReCiPe 1.08

Resources, fossil fuels	MJ	20.1	13.1	31.5
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4.3 COATED AND TEMPERED GLASS

Table 4-7: Resource use LCI results for coated tempered glass products, per declared unit [1 m², 7.5 kg]

Flow	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Renewable primary energy as energy carrier	MJ	6.46	19.7	26.1
Renewable energy resources as material utilization	MJ	0.272	0.492	0.763
Renewable total primary energy demand	MJ	6.73	20.2	26.9
Non-renewable primary energy as energy carrier	MJ	177	147.5	324
Non-renewable energy resources as material utilization	MJ	0.120	0.822	0.942
Non-renewable total primary energy demand	MJ	177	148	325
Use of secondary material	kg	-	-	-
Renewable secondary fuels	MJ	-	-	-
Non-renewable secondary fuels	MJ	-	-	-
Recovered energy	MJ	-	-	-
Use of net fresh water resources	m ³	28.1	37.8	65.9

Table 4-8: Wastes and outputs LCI results for coated tempered glass products, per declared unit [1 m², 7.5 kg]

Flow	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Hazardous waste disposed	kg	1.35E-07	1.65E-07	2.99E-07
Non-hazardous waste disposed	kg	0.537	0.0577	0.594
High-level radioactive waste	kg	0.00275	0.00361	0.00637
Intermediate- and low-level radioactive waste	kg	9.38E-05	1.23E-04	2.17E-04
Components for re-use	kg	-	-	-
Materials for recycling	kg	0.0219	-	0.0219
Materials for energy recovery	kg	-	-	-
Exported energy	MJ	-	-	-

Table 4-9: LCIA results for coated tempered glass products per declared unit [1 m², 7.5 kg]

Impact Category [TRACI 2.1]	Unit	Float Glass only (A1)	Processing (A1-A3)	Total (A1-A3)
Global Warming Potential	kg CO ₂ eq.	12.6	9.67	22.3
Ozon Depletion Potential ³	kg CFC-11 eq.	-	-	-
Acidification Potential	kg SO ₂ eq.	0.0463	0.0177	0.0641
Eutrophication Potential	kg N eq.	2.80E-03	1.41E-03	4.21E-03
Photochemical Ozone Creation Potential	kg O ₃ eq.	1.31	0.315	1.63
Metal Depletion	kg Fe eq., per ReCiPe 1.08	0.0788	0.282	0.361
Resources, Fossil Fuels	MJ	22.9	15.8	38.7

5 LCA INTERPRETATION

The analysis results represent the cradle-to-gate environmental performance of processed glass products.

Detailed results are presented for only a select few impact categories, chosen because of their familiarity within the LCA

³ ODP values were originally in the order of magnitude of negative 10⁻¹². The negative values are a result of credits given in the background systems of various GaBi datasets. Since the magnitude of these ODP results is extremely low, the values are read and interpreted as zero.

community (Acidification Potential (AP), Eutrophication Potential (EP), Global Warming Potential (GWP), and Smog Formation Potential (SFP)).

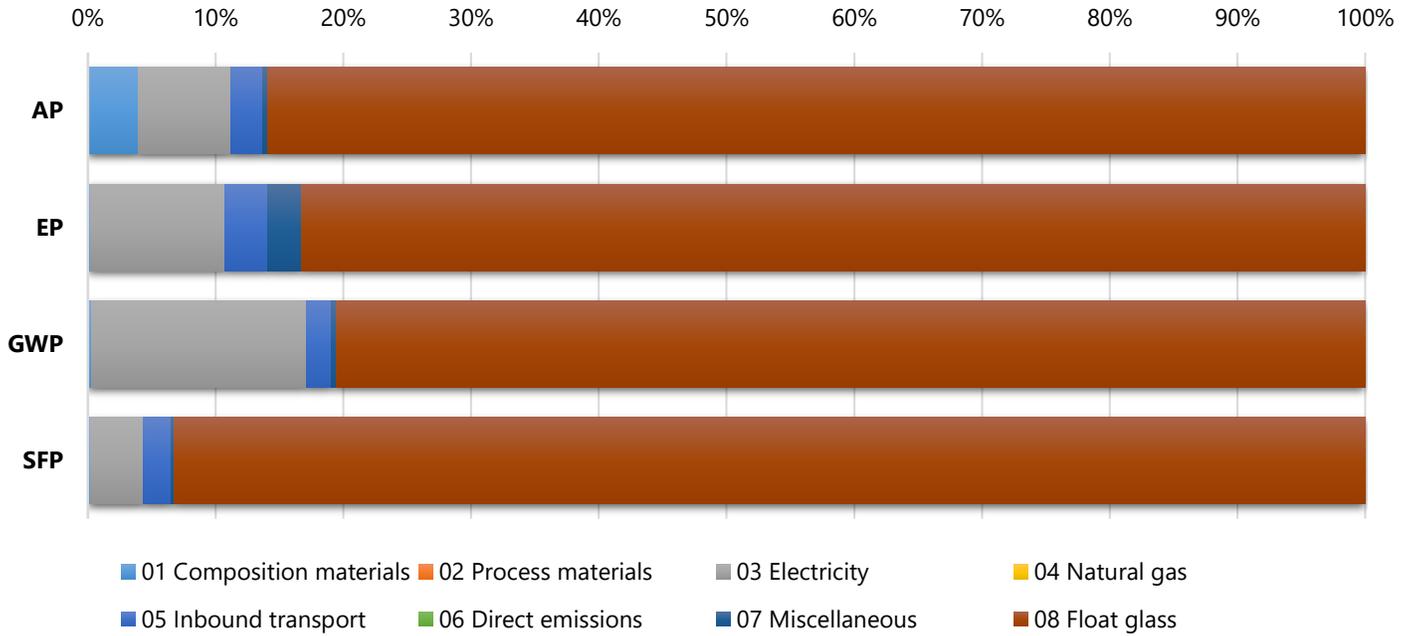


Figure 5-1: Relative contributions of flat glass production and the coating process (TRACI 2.1)

Relative contributions of coated glass manufacturing are broken down in Figure 5-1. The potential impacts of uncoated glass significantly outweigh those of glass coating. The largest category driving the potential impacts of the coating process is the electricity input.

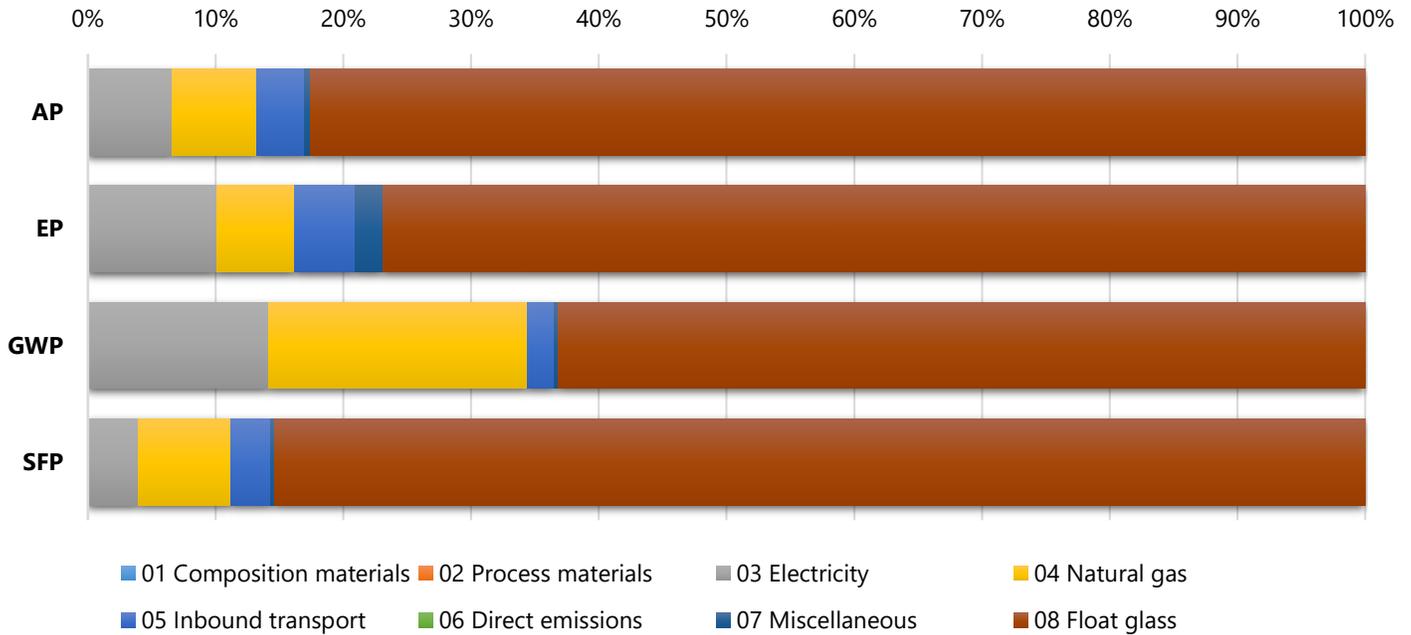


Figure 5-2: Relative contributions of uncoated glass production and tempering (TRACI 2.1)

Relative contributions of tempered glass manufacturing are broken down in Figure 5-2. Compared to coating, tempering has a much higher contribution to the total, though the impacts of uncoated glass are still the most significant. The largest drivers within tempering are the energy inputs – electricity and natural gas.

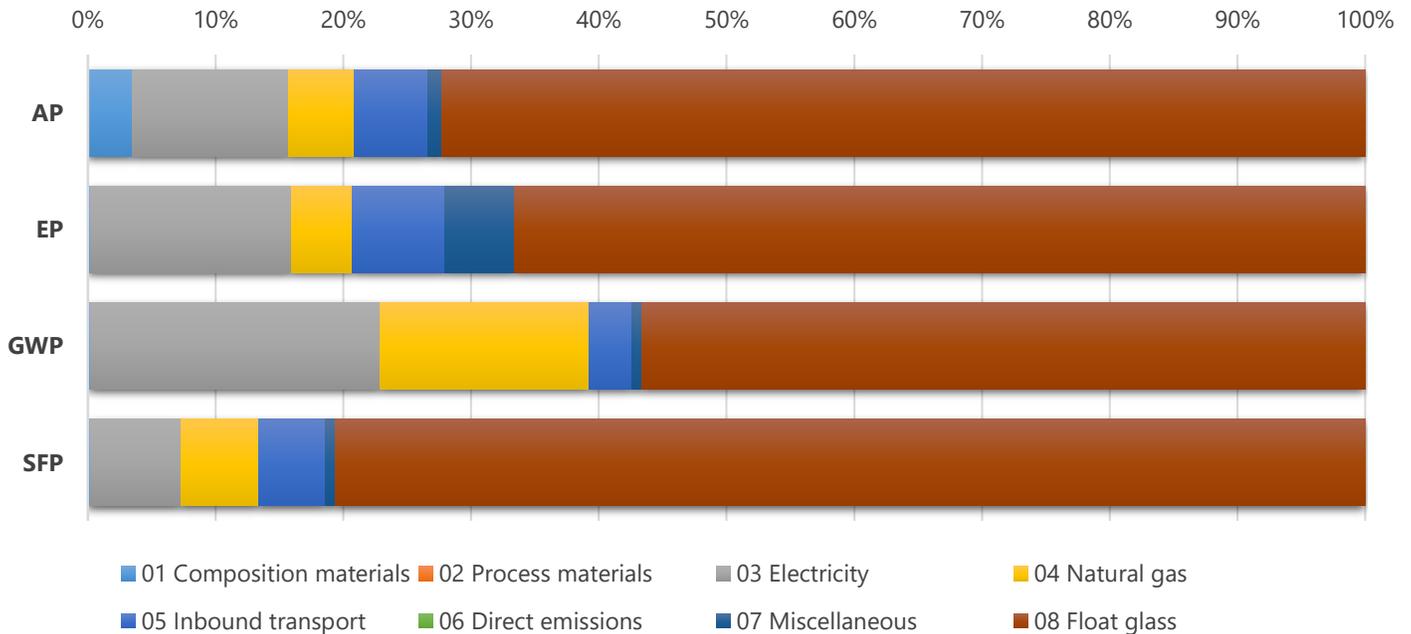


Figure 5-3: Relative contributions of uncoated glass production and coating and tempering combined processes (TRACI 2.1)

Relative contributions of tempered and coated glass manufacturing are broken down in Figure 5-3. Note that coated and tempered products are not necessarily the sum of the two processes, as each of these three products are calculated as a production weighted average of the various facilities. Differences between facilities and their corresponding production

volumes does not allow for a linear relationship.

6 **ADDITIONAL ENVIRONMENTAL INFORMATION**

6.1 **ENVIRONMENT AND HEALTH DURING MANUFACTURING**

Please refer to the Article Data Sheet for flat glass products, which can be found at www.cardinalcorp.com.

6.2 **ENVIRONMENT AND HEALTH DURING USE**

Please refer to the Article Data Sheet for flat glass products, which can be found at www.cardinalcorp.com.

6.3 **EXTRAORDINARY EFFECTS**

Fire / Water / Mechanical Destruction

Please refer to the Article Data Sheet for flat glass products, which can be found at www.cardinalcorp.com.

6.4 **ENVIRONMENTAL ACTIVITIES AND CERTIFICATIONS**

Please refer to the Article Data Sheet for flat glass products, which can be found at www.cardinalcorp.com.

7 **REFERENCES**

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Annexe E.3

**An Industry Average Cradle-to-Gate Life Cycle Assessment of 1/2" Regular and 5/8" Type X
Glass-mat Gypsum Board for the USA and Canadian Markets, Gypsum Association**



An Industry Average Cradle-to-Gate Life Cycle Assessment of 1/2" Regular and 5/8" Type X Glass-mat Gypsum Board for the USA and Canadian Markets

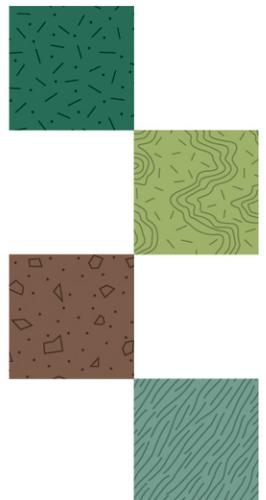
EPD Project Report

This Final Report is an abridged version of the original report whereby possible confidential information has been removed to protect the GA and its members.

Commissioner: Gypsum Association

EPD Program Operator: ASTM International

April 2021



General Summary

This LCA background report presents industry average results for 1/2" Regular and 5/8" Type X glass-mat gypsum boards as produced by Gypsum Association members in the US and Canada. The LCA has been completed to support a Type III Environmental Product Declaration (EPD) for glass-mat gypsum boards conforming to ASTM C1177/C1177M- 17 *Standard Specification for Glass Mat Gypsum Substrate for Use as Sheathing* [1]. Specifically, this industry average LCA background report (named the "*The Project Report*" in ISO 21930:2017 [2]) has been conducted in conformance with ISO 14040/44 standards [3], [4], and according to the requirements of ISO 21930:2017 [2], NSF International product category rules (PCR) for preparing an environmental product declaration for gypsum panel products [5] and ASTM International's EPD program operator rules [6]. This underlying LCA report for EPD development purposes was commissioned by the Gypsum Association and its members and is verified by ASTM International to conform to the requirements of ISO 14040 [3], 14044 [4], 14025 [7], and 21930 [2].

General Summary

Owner of the EPD



Gypsum Association (GA)

962 Wayne Avenue, Suite 620

Silver Spring, MD 20910

Link (URL): www.gypsum.org, info@gypsum.org

The GA is a not-for-profit trade association founded in 1930. Its mission is to promote the use of gypsum while advancing the development growth, and general welfare of the gypsum industry in the United States (U.S.) and Canada on behalf of its member companies. GA members include all the active gypsum panel product manufacturers in the U.S. and Canada.

GA member companies provided both LCI and meta-data for the reference year 2019. GA members, with the inclusion of their Canadian holdings and affiliates, produce and ship over 95% of the glass-mat gypsum boards consumed in the USA and Canada.

The owner of the declaration is liable for the underlying information and evidence.

GA Member Companies Corporate Locations



American Gypsum Company LLC

3811 Turtle Creek Blvd., Suite 1200

Dallas, TX 75219, USA

Member Link (URL):

<http://www.americangypsum.com/>



CertainTeed Gypsum, Inc.

CertainTeed Gypsum Canada, Inc.

20 Moores Road

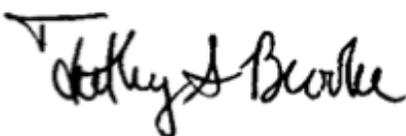
Malvern, PA 19355, USA

Member Link (URL):

<http://www.certainteed.com/gypsum>

In the course of completing this EPD project Continental Building Products (CBP) was acquired by CertainTeed. CBP also provided operational data to support this project.

General Summary	
	<p>Georgia-Pacific Gypsum LLC 133 Peachtree Street NE Atlanta, GA 30303, USA Member Link (URL): http://www.buildgp.com/Georgia-Pacific-Gypsum</p>
	<p>National Gypsum Company 2001 Rexford Road Charlotte, North Carolina 28211, USA Member Link (URL): http://nationalgypsum.com/</p>
	<p>PABCO® Gypsum 10600 White Rock Road, Suite 100 Rancho Cordova, CA 95670, USA Member Link (URL): http://www.pabco gypsum.com/</p>
	<p>United States Gypsum Company 550 West Adams Street Chicago, IL 60661-3676, USA Member Link (URL): https://www.usg.com/content/usgcom/en.html</p> <p>Canadian Gypsum Company (CGC) Inc. 350 Burnhamthorpe Road West 5th Floor Mississauga, ON, L5B 3J1, Canada Member Link (URL): https://www.usg.com/content/usgcom/en_CA_east.html</p>
<p>Product Group and Name</p>	<p>Glass-mat gypsum board</p>
<p>Product Description</p>	<p>Glass-mat gypsum boards are designed to be used as exterior substrate or sheathing for weather barriers. The substrates consist of a non-combustible water-resistant gypsum core, surfaced with glass mat partially or completely embedded in the core.</p>
<p>Product Category Rules (PCR)</p>	<p>NSF International, Product Category Rule for Environmental Product Declarations, PCR for Gypsum Panel Products, April 2020 [5].</p>
<p>Certification Period</p>	<p>05.01.2021 - 05.01.2026</p>
<p>Declared Unit</p>	<p>92.9 m² (1,000 square feet) of glass-mat gypsum board with a nominal finished thickness of ½” and 5/8”.</p>
<p>ASTM Declaration Number</p>	<p>EPD 206</p>

EPD and Project Report Information					
Program Operator	ASTM International				
Declaration Holder	Gypsum Association (GA)				
Declaration Type					
A “cradle-to-gate” EPD for glass-mat gypsum boards manufactured by GA members. Activity stages or information modules covered include production with the product ready for shipment at the manufacturing plant (modules A1 to A3). The declaration is intended for use in Business-to-Business (B-to-B) communication.					
Applicable Countries					
United States and Canada					
Product Applicability					
Glass-mat gypsum boards are typically used as exterior building envelope sheathing providing weather barriers, mold and fire resistance for new construction or renovation work.					
Content of the Declaration					
This declaration follows <i>Section 9; Content of an EPD</i> , NSF International, Product Category Rule for Environmental Product Declarations: PCR for Gypsum Panel Products, April 2020 [5].					
This EPD was independently verified by ASTM in accordance with ISO 14025 and the reference PCR:					
<table border="0"> <tr> <td>Internal</td> <td>External</td> </tr> <tr> <td></td> <td>X</td> </tr> </table>	Internal	External		X	 Tim Brooke, ASTM International
Internal	External				
	X				
The Project Report <i>Note that this Project Report is not part of the public communication (ISO 21930, 10.1).</i>	An Industry Average Cradle-to-Gate Life Cycle Assessment of 1/2” Regular and 5/8” Type X Glass-mat Gypsum Board for the USA and Canadian Markets, April 2021.				
Prepared by	Lindita Bushi, PhD, Mr. Jamie Meil and Mr. Grant Finlayson Athena Sustainable Materials Institute 280 Albert Street, Suite 404 Ottawa, Ontario, Canada K1P 5G8 info@athenasmi.org www.athenasmi.org				
					
This EPD project report was independently verified by in accordance with ISO 14025, ISO 14040/44, and the reference PCR:	Thomas P. Gloria, Ph. D. Industrial Ecology Consultants 35 Bracebridge Rd. Newton, MA				
PCR Information					
Program Operator	ASTM International				
Reference PCR	NSF International, Product Category Rule for Environmental Product Declarations: PCR for Gypsum Panel Products [5].				
Date of Issue	April 2020				
PCR review was conducted by:	Thomas P. Gloria, PhD (Chair), Industrial Ecology Consultants, t.gloria@industrial-ecology.com Mr. Jack Geibig, EcoForm Mr. Bill Stough, Sustainable Research Group				

Terms and Definitions

ISO 14040/Amd1:2020 and ISO 14044:2006/Amd1:2017/Amd2:2020 [3], [4] – Clause 3 Terms and Definition.

Allocation: Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems.

Comparative assertion: environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function.

Life Cycle Assessment (LCA): Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.

Life Cycle Impact Assessment (LCIA): Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product.

Life Cycle Interpretation: Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations.

Life Cycle Inventory (LCI): Phase of Life Cycle Assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle.

Product system: Collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product.

System boundary: Boundary based on a set of criteria specifying which unit processes are part of the system under study.

Uncertainty analysis: Systematic procedure to quantify the uncertainty introduced in the results of a life cycle inventory analysis due to the cumulative effects of model imprecision, input uncertainty and data variability.

Note: Either ranges or probability distributions are used to determine uncertainty in the results.

ISO 14021:2016 [9]- Clause 7.8 Recycled content

Recovered material: Material that would have otherwise been disposed of as waste or used for energy recovery but has instead been collected and recovered as a material input, in lieu of new primary material, for a recycling or a manufacturing process.

Pre-consumer material: Material diverted from the waste stream during a manufacturing process. Excluded is reutilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it.

Post-consumer material: Material generated by households or by commercial, industrial and institutional facilities in their role as end-users of the product that can no longer be used for its intended purpose. This includes returns of material from the distribution chain.

ISO 14025:2006 [7] - Clause 3 Terms and definitions

Type III Environmental Product Declaration (EPD): Providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information

Note 1 the predetermined parameters are based on the ISO 14040 series of standards.

Note 2 the additional environmental information may be quantitative or qualitative.

Product Category Rules (PCR): Set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories.

ISO 21930:2017 [2] - Clause 3 Terms and definitions

Average data: Data based on a fully representative sample for a construction product or construction service, provided by one or more suppliers, either from their multiple plants or based on multiple similar construction products of the supplier(s).

By-product: Co-product from a process that is *incidental or not intentionally* produced and which cannot be avoided.

Co-product: Any of one or more products from the same unit process, but which is not the object of the assessment.

Declared unit: Quantity of a construction product for use as a reference unit in an EPD based on LCA for the expression of environmental information in information modules.

Note 1 to entry: The declared unit is used where the function and the reference scenario for the whole life cycle, on the construction works level, cannot be stated.

Information module: Compilation of data to be used as a basis for an EPD, covering a unit process or a combination of unit processes that are part of the life cycle of a product.

Life cycle: All consecutive and interlinked stages in the life of the object under consideration.

Note 1 to entry: For consideration of environmental impacts and environmental aspects, the life cycle comprises all stages, from raw material acquisition or generation from natural resources to end-of-life.

Based on NSF PCR:2020 [5] - 3 Terms and definitions

Product category: Group of construction products that can fulfill equivalent functions.

Glass-mat gypsum board: the generic name for a family of sheet products consisting of a non-combustible core primarily of gypsum with a nonwoven facing (ASTM C11 – 18b).

Gypsum panel products: The general name for a family of sheet products consisting essentially of gypsum.

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Acronyms and Abbreviations

ADP _f	Abiotic depletion potential for fossil resources
ASCC	Alaska Systems Coordinating Council, NERC
AP	Acidification potential
ASTM	American Society for Testing and Materials
B2B	Business-to-business
BD+C	Building Design and Construction, LEED
CFC-11	Trichlorofluoromethane
CO ₂	Carbon dioxide
CRU	Components for re-use
EE	Recovered energy exported from the product system
EP	Eutrophication potential
EPD	Environmental product declaration
FFD	Fossil fuel depletion
FGD	Flue gas desulfurization, synthetic gypsum
FRCC	Florida Reliability Coordinating Council, NERC
FW	Consumption of fresh water
GA	Gypsum Association
GWP 100	Global warming potential, 100 years' time horizon
LHV	Lower heating value or net caloric value
HICC	Hawaiian Islands Coordinating Council, NERC
HLRW	High-level radioactive waste, conditioned, to final repository
HWD	Hazardous waste disposed
ID+C	Interior Design and Construction, LEED
ILLRW	Intermediate- and low-level radioactive waste, conditioned, to final repository
IPCC	International Panel on Climate Change
ISO	International Organization for Standardization
kg	Kilogram
km	Kilometer
kWh	kilowatt hours
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
LEED	Leadership in Energy and Environmental Design
MC	Moisture content
MER	Materials for energy recovery
MJ	Mega joule
MR	Materials for recycling
MRO	Midwest Reliability Organization, US part only, NERC
MSF	Thousand square feet
N	Nitrogen
NAICS	North American Industry Classification System

NERC	The North American Electric Reliability Corporation
NHWD	Non-hazardous waste disposed
NPCC	Northeast Power Coordinating Council, US part only, NERC
NPRI	Canadian National Pollutant Release Inventory
NRPR _M	Non-Renewable primary energy carrier used as material
NRPR _E	Non-renewable primary energy carrier used as energy
NRSF	Non-renewable secondary fuel
NSF	National Center for Sustainability Standards
O ₃	Ozone
ODP	Ozone depletion potential
O+M	Building Operations and Maintenance, LEED
OSHA	Occupational Safety & Health Administration
PCR	Product category rules
PM	Particulate Matter
RE	Recovered energy,
RFC	Reliability First Corporation, NERC
RPR _M	Renewable primary energy carrier used as material
RPR _E	Renewable primary energy carrier used as energy
RSF	Renewable secondary fuel
SERC	Southeastern Electric Reliability Council, NERC (a.k.a, SERC Reliability Corporation)
SFP	Smog formation potential
SM	Secondary material
SO ₂	Sulfur dioxide
SPP	Southwest Power Pool, NERC
tkm	Tonne-kilometre
TRACI	Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts
TRE	Texas Regional Entity, NERC
TRI	United States Toxics Release Inventory (TRI) Program
UN CPC	United Nations Central Product Classification
US EPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
WECC	Western Electricity Coordinating Council, US part only, NERC.

1 Introduction

The US Green Building Council's *Leadership in Energy and Environmental Design* (LEED) v4 and v4.1 green rating system, reward building projects across the LEED rating systems (BD+C, ID+C, ND, and Homes)¹, for selecting products from manufacturers who have disclosed and verified potential environmental impacts. The intent is to encourage the use of products and materials for which life-cycle information is available and that have environmentally, economically, and socially preferable life-cycle impacts.

This life cycle assessment (LCA) project report supports an *environmental product declaration* (EPD) for the production stage of glass-mat gypsum boards ready for shipment at the plant gate in the USA and Canada and as such has a business-to-business (B2B) focus.

Life cycle assessment is an analytical tool used to comprehensively quantify and interpret the energy and material flows to and from the environment over the entire life cycle of a product, process, or service [3], [4]. Environmental flows include emissions to air, water, and land, as well as the consumption of energy and material resources. By including the potential impacts throughout the product life cycle, LCA provides a comprehensive view of the environmental aspects of the product. An EPD provides quantified environmental data using predetermined parameters and, where relevant, additional environmental information [7]. The predetermined parameters are based on the ISO 14040 series of standards [3], [4] and ISO 21930 [2]. The additional environmental information may be quantitative or qualitative.

This study demonstrates the Gypsum Association (GA) and its members' commitment to transparently sharing the environmental footprint of glass-mat gypsum boards and in support of generating an EPD for users of glass-mat gypsum boards both in the USA and Canada.

In support of this study, primary LCI data were collected from a representative sample of 11 GA members producing glass-mat gypsum boards. This LCA study considered the scale of operations including a mix of small, medium and large facilities, their geographical location by census region and their source of gypsum – adjacent quarry, mine, imported natural gypsum ore and their use of flue gas desulfurized (FGD) synthetic gypsum (both domestic and imported). The study also drew on recent primary data for natural or crude gypsum ore extraction (six quarries and one underground mining site). Lastly, a major glass matting US manufacturer provided confidential LCIA and LCI indicator results for a typical glass mat product used in the manufacturing of glass-mat gypsum boards for production year 2017 to support this project.

¹ *Building Design and Construction (BD+C); Interior Design and Construction (ID+C); Neighborhood Development (ND)*.

LEED v4, MR Credit 2, EPDs- Option 1 applies to BD+C rating system (New Construction, Core & Shell, Schools, Retail, Data Centers, Warehouses & Distribution Centers, Hospitality, and Healthcare: 1 point); ID+C rating system (Commercial Interiors, Retail, and Hospitality: 1 point), ND rating system (new land developments, land redevelopments, residential, mixed use, commercial, and industrial: 1 point); and Homes rating system (Homes, Multifamily Lowrise, Multifamily Midrise: 1 point) [17].

LEED v4.1, MR Credit 2, EPDs- Option 1 (similar to v4): 1 point [18].

2 Study Goals

2.1 Goals of the Study

This is a sector-driven initiative by the Gypsum Association and its members to conduct an LCA to support the development of a Type III EPD according to ISO 14025 [7], the NSF PCR [5], and ISO 21930 [2] for glass-mat gypsum boards, as manufactured and distributed in North America (United States and Canada) by GA members.

2.2 Intended Applications and Audience

This LCA report is intended to support the development of an EPD for use in Business-to-Business (B-to-B) communication. The intended audience for the EPD include GA and its member companies, their suppliers, architectural, engineering, and specifying professionals, LCA practitioners and tool developers, academia, governmental organizations, policy makers and other interested value chain parties who require reliable information on gypsum board products.

2.3 Comparative Assertions

This Project Report (underlying LCA report for EPD) is not a comparative assertion. Only EPDs prepared from cradle-to-grave life cycle results and based on the same function, Reference Service Life (RSL), quantified by the same functional unit, and meeting all the conditions for comparability listed in ISO 14025:2006 and ISO 21930:2017 can be used to compare between products [5].

Per ISO 21930, 10.1 [2], this Project Report shall be made available to the verifier with the requirements on confidentiality stated in ISO 14025 [7]. This Project Report was independently verified by Thomas Gloria PhD, Industrial Ecology Consultants, in accordance with ISO 14025 [7], ISO 14040/44 [3], [4], and the NSF PCR requirements [5].

3 Product Identification

3.1 Product Description

Glass-mat gypsum boards UNSPSC Code 30161500, as defined in ASTM C1177 are designed to be used as an exterior substrate or sheathing for weather barriers [1]. The substrates consist of a non-combustible water-resistant gypsum core, surfaced with a glass mat partially or completely embedded in the core [1]. Typically, glass-mat gypsum boards are 4' wide and 8' length boards (4'x8') produced with a square edge but they may be available in other lengths and can vary in thickness depending on the application.

The focus of this industry average LCA study is on two glass-mat gypsum boards used for *exterior sheathing* applications (walls and soffits).

- 1/2" (12.7 mm) glass-mat gypsum board (Regular core, ASTM C1177), and
- 5/8" (15.9 mm) Type X glass-mat gypsum board (Type X core, ASTM C1177).

The weighted average density of 1/2" Regular glass-mat gypsum board (MC 0%) was determined to be 10.0 kg/m², with a minimum and maximum density value of 8.2 and 12.7 kg/m² (MC 0%), respectively. Similarly, the weighted average density of 5/8" Type X glass-mat gypsum board (MC 0%) was 13.4 kg/m², with a minimum and maximum density value of 10.9 and 15.8 kg/m², respectively.

This study does not cover glass-mat gypsum panels used in *interior wall and ceiling applications* (ASTM C1658). In addition, this study does not cover *glass-mat gypsum roof board* (ASTM C1177), *glass-mat gypsum panel abuse & impact resistant* (ASTM C1629), and *glass-mat gypsum tile backer* (ASTM C1178). Glass-mat gypsum boards are also proprietary products and while they all employ glass matting and a water-resistant gypsum core the panel composition varies across manufacturers. Figure 1 below provides a visual of a glass-mat gypsum board.

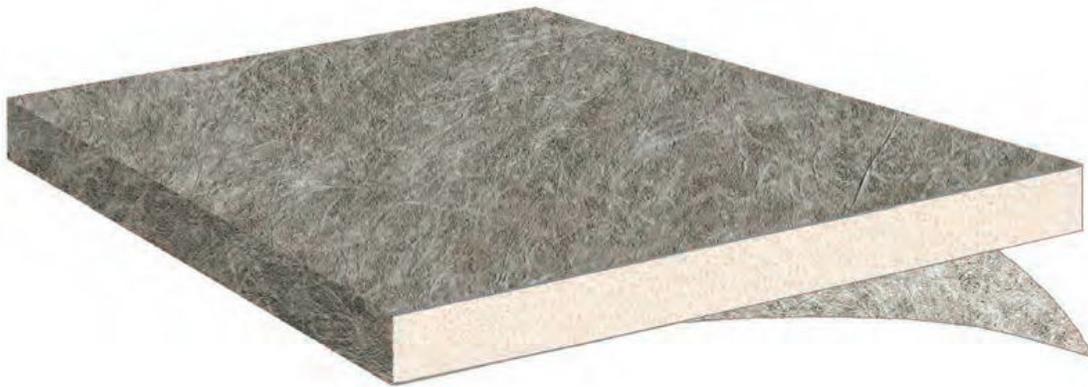


Figure 1 Generic glass-mat gypsum board

3.2 Product Standard

Applicable product standards for glass-mat gypsum boards (UNSPSC Code 30161500) include:

- ASTM C1177/ C1177M–17 *Standard Specification for Glass Mat Gypsum Substrate for Use as Sheathing*
- ASTM C11–18b *Terminology Relating to Gypsum and Related Building Materials and Systems*
- ASTM C22 / C22M–00(15) *Standard Specification for Gypsum*
- ASTM C473–17 *Standard Test Methods for Physical Testing of Gypsum Panel Products*
- ASTM C1264– 19 *Specification for Sampling, Inspection, Rejection, Certification, Packaging, Marking, Shipping, Handling, and Storage of Gypsum Panel Products*
- ASTM E119–18ce1 *Test Methods for Fire Tests of Building Construction and Materials*
- ASTM E2921–16a *Standard practice for minimum criteria for comparing whole building LCAs for use with building codes, standards, and rating systems.*

3.3 Material Content

Table 1 below presents the weighted average composition by input material for 92.9 m² (one thousand square feet, 1 MSF) of glass-mat gypsum boards as derived from the GA member facilities LCI data collection for the reference year 2019. The final weight of each glass-mat gypsum board includes chemically bounded water.

Table 1 Weighted average material content for 92.9 m² (1 MSF) of glass-mat gypsum boards by thickness

Inputs	1/2" Regular glass-mat gypsum board	5/8" Type X glass-mat gypsum board	Units
Natural gypsum ore	1,458.4	1,890.8	lbs
FGD synthetic gypsum	355.4	509.9	lbs
Post-consumer gypsum ¹⁾	3.24	2.06	lbs
Glass matting	113.4	116.9	lbs
Starch	1.59	1.06	lbs
Continuous filament glass fiber	2.44	3.61	lbs
Dispersant	4.00	5.90	lbs
Retarder	0.16	0.45	lbs
Potassium Sulfate	1.43	1.48	lbs
Boric Acid	0.076	0.096	lbs
Land Plaster	0.60	0.33	lbs
Foaming agent (soap)	0.26	0.33	lbs
Ball mill accelerator (BMA)	3.97	2.83	lbs
Edge Paste	2.68	3.66	lbs
Fly ash	1.42	1.11	lbs
Other Chemicals ²⁾	2.47	6.78	lbs
Silicone products	7.18	7.16	lbs
Wax	7.26	11.43	lbs
Other (MgO, Portland cement)	0.14	0.21	lbs
Water	1,355.2	1,788.0	lbs
<i>Final weight, with MC%/ MSF</i>	<i>2,078.9</i>	<i>2,784.4</i>	<i>lbs</i>
Final moisture content	1.40%	1.66%	%
<i>Final weight, with 0% MC/ MSF</i>	<i>2,048.7</i>	<i>2,735.9</i>	<i>lbs</i>

Notes:

¹⁾ Post-consumer gypsum includes on-site construction off-cuts and recovered gypsum material collected from demolition sites.

²⁾ It consists of biocide, sodium omadine, sodium trimetaphosphate, barium metaborate monohydrate (Busan) and emulsion solids. LCI data have been rolled up to protect confidential/proprietary information.

4 Scope of the Study

4.1 Declared Unit

The *declared unit* is defined as the quantity of a construction product for use as a reference unit in an EPD based on LCA for the expression of environmental information in information modules [2], [5].

Per NSF PCR, Section 7.1.4 [5], the declared unit for this LCA study is defined as 92.9 m² (1 MSF) of glass-mat gypsum boards with a nominal finished thickness of 1/2" and 5/8" (see Table 2). A declared unit is defined for EPDs covering the cradle-to-gate *Production stage* which consists

of three alpha-numeric modules: A1 Extraction and upstream production; A2 Transport to factory; and A3 Manufacturing [2].

Table 2 Declared unit definition

Item	1/2" Regular glass-mat gypsum board	5/8" Type X glass-mat gypsum board	Units
Declared unit	92.9	92.9	m ²
Mass	943	1263	kg
Thickness	12.7	15.9	mm
Final MC	1.4	1.7	%
Core type	Regular	Type X	n/a

Note:

¹⁾ Data are rounded to three significant digits.

4.2 System Boundary

For this Project Report, the boundary is “cradle-to-gate” or the *Production stage*, which includes extraction of raw materials (cradle) through the manufacture of glass-mat gypsum boards ready for shipment (gate). Downstream activity stages - *Construction, Use, End-of-life*, and *Optional supplementary information beyond the system boundary* - are excluded from the system boundary (see Figure 2). Figure 3 presents the *Production stage* system boundary for the declared glass-mat gypsum board product system. Per ISO 21930, 7.1.7.2.1 [2], the system boundary with nature includes those technical processes that provide the material and energy inputs into the system and the subsequent manufacturing and transport processes up to the factory gate, as well as the processing of any waste arising from those processes. Per NSF PCR, Section 7.1.7.2 [5], the Production Stage includes the following processes:

A1, Extraction and upstream production

This information module includes:

- A1 extraction and processing of raw materials (natural gypsum ore) including the production of inputs where they are used (see Figure 3);
- A1, treatment of secondary materials used as input for manufacturing the product (flue gas desulfurization (FGD) synthetic gypsum, de-watering at coal-power plants), but not including those processes that are part of the waste processing in the previous product system;
- A1, cradle-to-gate production of glass matting, and formulation materials (a.k.a, formulation additives);
- A1, cradle-to-gate generation of electricity used for extraction and processing of natural gypsum ore, and processing of FGD synthetic gypsum to make it usable as material input (de-watering process);
- A1, cradle-to-gate process fuel supply (diesel, gasoline, and propane) used for extraction and processing of natural gypsum ore, including on-site fuel combustion;
- A1, waste management from natural gypsum ore wastage including transport up to the disposal.

A2, Transport to factory

This information module includes weighted average transportation data of all input materials (raw gypsum, synthetic gypsum, glass matting, formulation materials, secondary, ancillary, and shipping & packaging materials) from extraction site or source to glass mat panel manufacturing site, and including empty backhauls and transportation to interim distribution centers or terminals.

A3, Manufacturing

This information module includes:

- A3, cradle-to-gate production of *ancillary materials* (lubricants, process aids);
- A3, cradle-to-gate production of *shipping and packaging materials*;
- A3, any on-site treatment for *FGD synthetic gypsum*, such as additional drying;
- A3, any on-site treatment for *post-consumer gypsum* to make them usable as a product input, such as secondary crushing and/or screening;
- A3, cradle-to-gate generation of *electricity, steam and heat* used in manufacturing;
- A3, cradle-to-gate *fuel supply* for mobile plant support equipment (diesel, gasoline, and propane) used in manufacturing, including on-site fuel combustion;
- A3, manufacturing of glass-mat gypsum boards and co-products (see Figure 3);
- A3, waste management from manufacturing packaging and manufacturing wastage including weighted average transportation data up to the recycler or disposal.

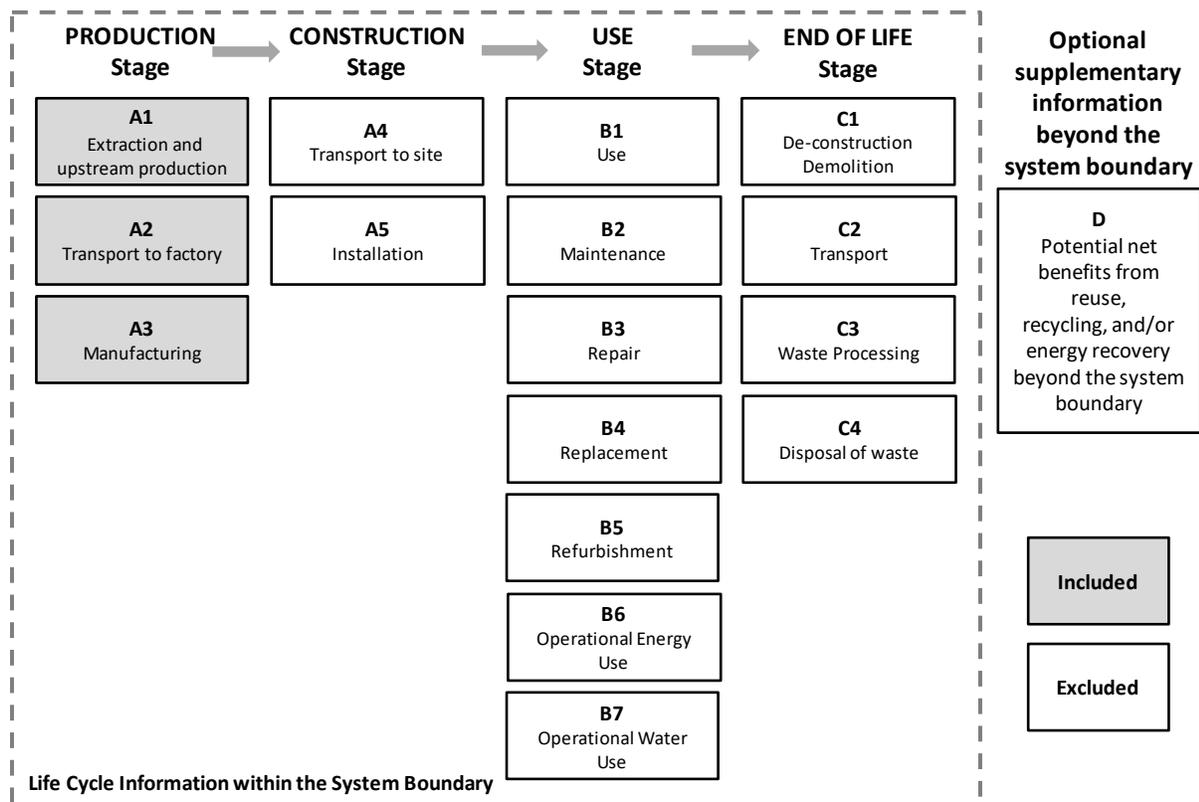


Figure 2 Common four life cycle stages and their information modules for construction products and the optional supplementary module [2]

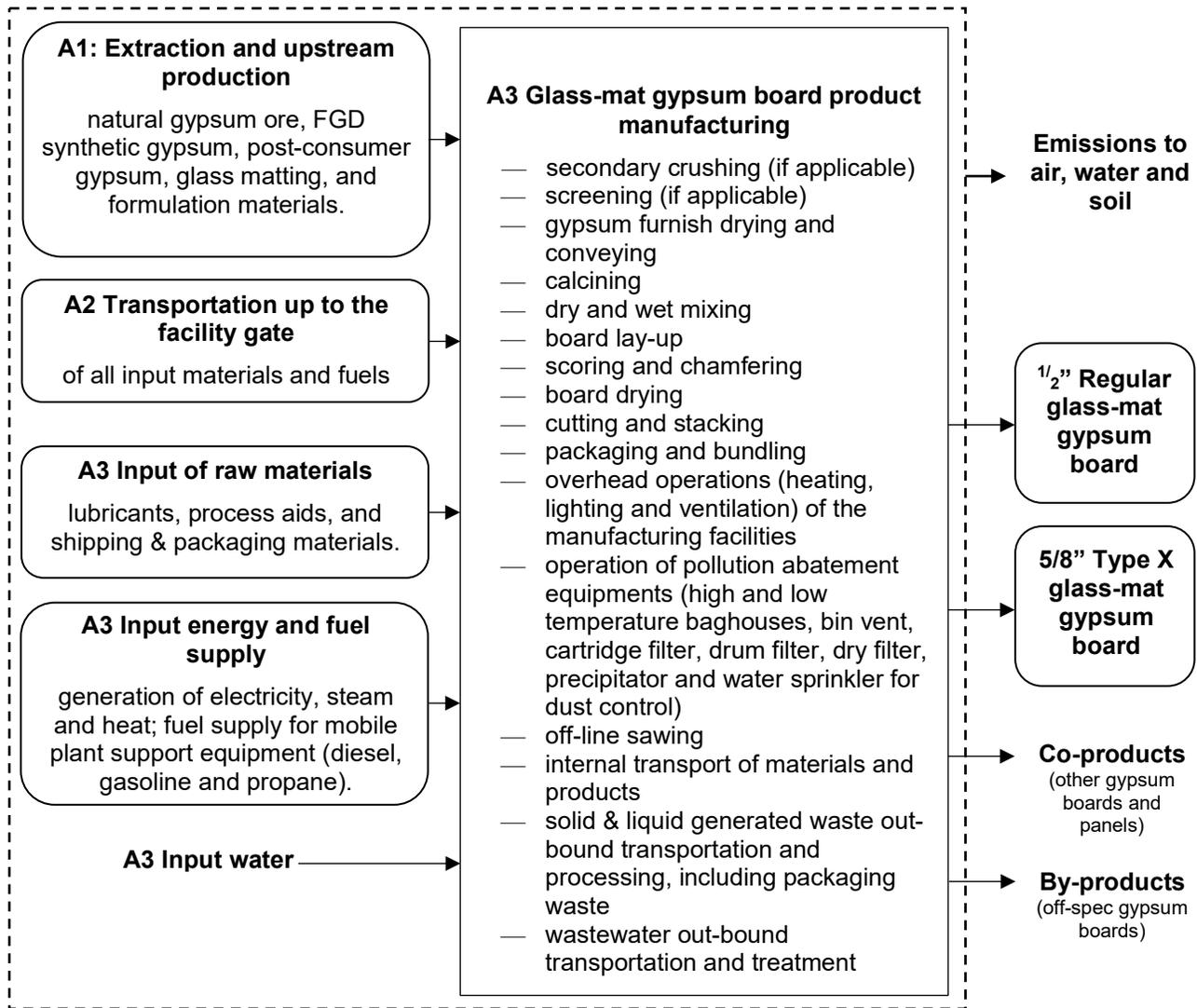


Figure 3: Production Stage (Modules A1 to A3) System Boundary

4.3 Cut-off Criteria

The cut-off criteria as per NSF PCR, Section 7.1.6 [5] and ISO 21930, 7.1.8 [2] were followed for this Project Report. Per ISO 21930, 7.1.8 [2], all input/output data required were collected and included in the LCI modelling (see Annexes A, B and C). No substances with hazardous and toxic properties that pose a concern for human health and/or the environment were identified in the framework of this EPD. Any plant specific data gaps for the reference year 2019 e.g., hydraulic fluids, lubricants, oils, packaging materials or transportation were filled in with plant generic data from previous years or industry average data. Material Safety Data Sheet (MSDSs) were confidentially provided by GA plants per each chemical class e.g., dispersant, retarder chemicals, etc. Any data gaps in the MSDS are filled in with two (proxy) generic LCI datasets, as appropriate (*conservative* assumptions): *Chemical, organic {GLO} production | Cut-off, U*; *Chemical, inorganic {GLO} production | Cut-off, U- see Annex C, Table C1 for details*.

Per NSF PCR, Section 7.1.6 [5], the Production Stage *excludes* the following processes:

- Capital goods and infrastructure;
- Human activity and personnel related activity (travel, furniture, office operations and supplies); and
- Energy and water use related to company management and sales activities that may be located either within the factory site or at another location.

4.4 LCA Software

The LCA model was developed using SimaPro v.9.1.1.1 2021 (<https://simapro.com/>), an LCA software used by industry and academics in more than 80 countries for 25 years [14]. SimaPro LCA software contains recognized databases (e.g., U.S. LCI database and ecoinvent v3.6 database, Allocation, Cut-off by classification) that provide LCI datasets for upstream, core, and downstream material and processes. It also contains the U.S. EPA TRACI 2.1 LCIA methodology and the Cumulative Energy Demand, LHV version 1.0 which are used for this LCA study for EPD.

5 Life Cycle Inventory

5.1 Data Collection, Representativeness, Sources, and Calculations

Data collection was based on an initial survey of all GA member facility operations. GA members operate 51 facilities in the USA and Canada producing various gypsum board and panel products. Some facilities are 100% dedicated to the production of glass-mat gypsum boards while others may produce glass-mat gypsum boards as well as other gypsum panel products. In total 11 facilities operated by the seven (7) GA company members (American Gypsum Company LLC, CertainTeed Gypsum, Inc., CertainTeed Gypsum Canada, Inc., Continental Building Products, Georgia-Pacific Gypsum LLC, National Gypsum Company, PABCO® Gypsum, United States Gypsum Company and CGC Inc.) completed LCI data collection questionnaires representing 35% of all GA member facilities producing glass-mat gypsum boards.

The study LCI data collected from the GA member companies was done with the expressed intent of attaining an acceptable representation of the US industry average technology mix. A representative sample of glass-mat gypsum board plants within its membership was identified based on technical attributes, production scale and geographic location to arrive at a *representative* sample of glass-mat gypsum board manufacturing plants.

Described below is the well-defined plant selection platform for inclusion in the industry-average study sample.

- 11 glass-mat gypsum board manufacturing plants were selected to adequately represent:
 - GA's membership production volume (including having at least *one plant* from *each GA member company* participate in the study);
 - the scale of plant operations including *a mix of small, medium and large* operations;
 - the geographical representation of the participating facilities included facilities from three discrete regions (East, Midwest and Western US).
- To approximate the gypsum source ratio, a mix of plants processing either natural gypsum rock or flue gas desulfurized (FGD) synthetically derived gypsum or a blend of both these two major inputs was selected.
- A mix of plants using *locally derived natural gypsum* ore (adjacent quarry operation) versus imported natural gypsum ore transported by various modes and distances were included (natural gypsum ore imports include Canada or Spain depending on plant location).

This project draws on foreground gate-to-gate LCI data collected for natural gypsum ore extraction (six quarries and one underground mining site) for the reference year 2017. In addition, a major glass matting US manufacturer provided confidential LCIA and LCI indicator results for a typical glass mat product used in the manufacturing of glass-mat gypsum boards for production year 2017 (see Table B1, Annex B).

LCI data collection was based on a customized LCI survey for the GA glass-mat gypsum board manufacturing facilities. The LCI survey covered the following *primary data* for each facility for the 2019 reference year:

- Total manufactured products, and co-products (by-products);
- Main unit processes;
- Excluded processes;
- Pollution abatement equipment;
- Raw materials;
- Secondary materials (if applicable);
- Pre- and post-consumer materials (if applicable);
- Ancillary materials;
- Packaging materials;
- Electricity and fuel consumption;
- Water consumption (fresh and recycled);
- Inbound transportation distances and modes for all inputs;
- Emissions to air, water and land (if applicable);

- Solid waste;
- Wastewater and other liquid waste; and
- Waste outputs and their respective outbound transportation distances and modes.

Source of data is specified as (see Annex A, Table A1):

Direct (D) *based on measurements or purchasing/selling records of the surveyed facilities;*
Indirect (I) *based on calculations made by the personnel of the surveyed facilities;*
Estimated (E) *based on the industry average data and/or expert judgment;*

Annex A, Table A1 summarizes the weighted average LCI data for the glass-mat gypsum board product system by thickness. Annex A, Table A2 and A3 present the transportation modes and weighted average distance (in ton-mile or t-km) for all inputs and outputs for each product thickness, respectively. Transportation activities are included consistently in the respective life cycle module (A1, A2, A3).

Per NSF PCR, Section 5.3 [5] and ISO 21930, 5.3 [2], all facility specific LCI data were weighted based on total annual production to calculate the weighted average LCI profile for glass-mat gypsum boards (per MSF)- see Annex A, Table A5. Table A6 summarizes the product packaging waste data at the installation site (NSF PCR, Section 7.1.7.3.2 [5]. All LCI data (including meta-data) were verified and benchmarked with 2013 plant specific and/or GA industry average LCI data for each product system by the Athena Institute. Note that the [minimum; maximum] range data are also calculated for each LCI flow (but not reported due to confidentiality reasons) to facilitate Monte Carlo uncertainty analysis (see Annex D).

This LCA study draws on appropriate LCI datasets provided by (see Annexes A, B and C):

- Gypsum Association and its members on glass-mat gypsum board manufacturing data (2019) and natural gypsum ore extraction (2017)- see Annex A;
- A major glass matting US manufacturer on a typical glass mat product used in the manufacturing of glass-mat gypsum boards for production year 2017 (see Annex B);
- North American and global LCI databases such as the U.S. National Renewable Energy Laboratory LCI database, September 2015 (<http://www.nrel.gov/lci/>), and ecoinvent 3.6, allocation, cut-off database, December 2019 (<http://www.ecoinvent.org/>). Both are included in the LCA software SimaPro v.9.1.1.1 2020 (see Annex C for details).

Data calculation procedures follow ISO 14044 [4], and NSF PCR for Gypsum Panel Products [5]. The same calculation procedures are applied throughout this LCA study for EPD. Per ISO 21930, 7.2.2 [2], when transforming the inputs and outputs of combustible material into inputs and outputs of energy, the *net calorific value (lower heating value)* of fuels is applied according to scientifically based and accepted values specific to the combustible material.

Per NSF PCR, Section 7.1.10 [5], SI units are used for the LCA data and results. Other units commonly used in the market are also included in addition to the required SI units (see Annex A, Tables A1 to A4).

5.2 Data Quality Requirements and Assessments

Per NSF PCR, Section 7.1.9 [5], and ISO 21930, 7.1.9 [2], appropriate activity and LCI primary and secondary data shall be used to model glass-mat gypsum board product systems. LCI data should be as representative (technologically, geographically, and time-specific), complete, consistent, reproducible and transparent as possible with regards to the goal and scope of the study [3], [4]. A detailed description of collected data and the data quality assessment regarding the NSF PCR requirements [5] and ISO 14044 [4] is provided in Annex C, Tables C1 to C3. Data quality is assessed based on its representativeness (technology coverage, geographic coverage, time coverage), completeness, consistency, reproducibility, transparency and uncertainty (see Table 3).

Table 3 Data Quality Requirements and Assessments

Data Quality Requirements	Description
Technology Coverage	Data represents the prevailing technology in use in U.S. and Canada. Whenever available, for all upstream and core material and processes, North American typical or average industry LCI datasets were utilized (see Annex C, Tables C1 to C3). <i>Technological representativeness is characterized as “high”.</i>
Geographic Coverage	The geographic region considered is U.S. and Canada. The geographic coverage of all LCI databases and datasets is given in Annex C, Tables C1 to C3. <i>Geographical representativeness is characterized as “high”.</i>
Time Coverage	Activity data are representative as of 2017-2019 (see Annex A, Tables A1 to A3). - Glass-mat gypsum board manufacturing process- primary data collected from 11 facilities: reference year 2019 (12 months); - In-bound/ out-bound transportation data- primary data collected from 11 facilities: reference year 2019 (12 months); - Natural gypsum ore – primary data collected from six quarries and one gypsum ore underground mine: reference year 2017 (12 months); - Glass mat manufacturing- cradle-to-gate LCIA and LCI indicator results per ISO 21930:2017 provided by a major glass matting US manufacturer to support this project: reference year 2017 (12 months); - Generic data: the most appropriate LCI datasets were used as found in the US LCI Database, ecoinvent v.3.6 database, December 2019. <i>Temporal representativeness is characterized as “high”.</i>
Completeness	All relevant, specific processes, including inputs (raw materials, energy and ancillary materials) and outputs (emissions and production volume) were considered and modeled to provide an industry average for the glass-mat gypsum board products of interest. The relevant background materials and processes were taken from the US LCI Database, ecoinvent v 3.6 LCI database, and modeled in SimaPro v9.1.1.1, 2021. The completeness of the cradle-to-gate process chain in terms of process steps is rigorously assessed for both glass-mat gypsum boards and documented in Section 4.2.

Data Quality Requirements	Description
Consistency	To ensure consistency, the LCI modeling of the production weighted input and output LCI data for the glass-mat gypsum board product of interest used the same LCI modeling structure across the selected GA member facilities, which consisted of input raw, secondary, glass matting, ancillary and packaging materials, energy flows, water resource inputs, product outputs, co-products, by-products, emissions to air, water and soil, and solid and liquid waste disposal. Crosschecks concerning the plausibility of mass and energy flows were continuously conducted. The LCA team conducted mass and energy balances at the facility level and selected process levels to maintain a high level of consistency.
Reproducibility	Internal reproducibility is possible since the data and the models are stored and available in <i>GA Athena Glass-mat gypsum boards LCI database</i> developed in SimaPro, 2021. A high level of transparency is provided throughout the report as the weighted average LCI profile is presented for each of the declared products as well as major upstream inputs. Key primary (manufacturer specific) and secondary (generic) LCI data sources are summarized in Annex C. External reproducibility is also possible as a high level of transparency is provided throughout the Project Report and LCI data and sources are summarized in Annexes A, B and C.
Transparency	Activity and LCI datasets are transparently disclosed in the project report, including data sources (see Annexes A, B and C).
Uncertainty	A <i>sensitivity check</i> was conducted to assess the reliability of the EPD results and conclusions by determining how they are affected by uncertainties in the data or assumptions on calculation of LCIA and energy indicator results. The sensitivity check includes the results of the <i>sensitivity analysis</i> and <i>Monte Carlo uncertainty analysis</i> (see Section 7 and Annex D).

5.3 Allocation Rules

Per NSF PCR, Section 7.2.3 and 7.2.6 [5], *allocation, if required, shall follow the requirements and guidance of ISO 14044, Section 4.3.4 and shall be based on the mass of gypsum panel products produced. Allocation related to transport shall be based on the mass of the transported product.*

Per ISO 21930, 7.2.4, *Consistent allocation procedures shall be uniformly applied to similar inputs and outputs of the system under consideration. For example, the approaches of allocation to co-products or to secondary materials crossing the system boundary between product systems should use the same procedure used for co-products or to secondary material flows entering the product system.*

The GA glass-mat gypsum board manufacturing facilities typically produce other co-products besides selected products of interest and as such allocation based on the mass of products was necessary. Per ISO 21930, 3 [2], *co-product* is defined as any of one or more products from the same unit process, but which is not the object of the assessment. As a result, plant specific generic formulations for 1 MSF (92.9 m²) of the two glass-mat gypsum board products of interest were used to model and calculate the required input raw materials (both primary and secondary) and water input (see Table 1). As specified in the NSF PCR, Section 7.2.3 to 7.2.6 [5], “*mass*” was used as the physical parameter for allocating flows between the products of interest and other co-products to calculate the input energy flows (electricity, natural gas, propane, etc.), shipping and packaging materials, lubricants, hydraulic fluid, greases, and oils, total water consumption, process emissions to air, water and land and waste flows. LCI modeling accounts for the plant specific fabrication yields in accordance with ISO 14044, 4.3.4.2, “*Some outputs may be partly co-products and partly waste. In such cases, it is necessary to identify the ratio between co-products and waste since the inputs and outputs shall be allocated to the co-products part only*”.

Per ISO 21930, 3 [2], *by-product* is defined as co-product from a process that is incidental or not intentionally produced and which cannot be avoided. No burden is allocated to any of the by-products of the selected product systems such as off-spec gypsum boards (used as dunnage/bunks/sleuters), see Figure 3, and Annex A, Table A1.

Per NSF PCR 7.1.7.2.5 and 7.2.3 [5], flue gas desulfurized synthetic gypsum is considered a recovered “waste” material and is used burden free; other than those burdens necessary to use it as an input in the manufacture of glass-mat gypsum boards. FGD synthetic gypsum is a by-product of coal-fired power generation process – a result of SO₂ scrubbing of stack emissions enforced by the US EPA Clean Air Act – and a major raw material used in the production of glass-mat gypsum board products [10], [11]. For FGD synthetic gypsum to be a saleable product for use in glass-mat gypsum board manufacturing it needs to undergo de-watering process to reduce the moisture content to around 10% [11], [12], [13], and transport to the glass-mat gypsum board manufacturing facility. As a result, the dewatering of sludge by vacuum filtration and transport of FGD synthetic gypsum is included within the Production stage system boundary [12], [13]. It should be mentioned that saleable FGD synthetic gypsum has the same molecular composition

as raw gypsum [11]. Typically, FGD synthetic gypsum undergoes additional secondary drying at the glass-mat gypsum board plant; this drying is included in the A3 Manufacturing information module. In addition, per NSF PCR, Section 7.2.3 to 7.2.6 [5], allocation related to transport is based on the mass of transported inputs and outputs.

5.4 Glass-mat gypsum board Manufacturing

Glass-mat gypsum board is manufactured in a two-step process. In the first step finely crushed and ground gypsum, calcium sulfate dihydrate ($\text{CaSO}_4 \times 2\text{H}_2\text{O}$), is heated and partially dehydrated (calcined) to calcium sulfate hemihydrate ($\text{CaSO}_4 \times 1/2\text{H}_2\text{O}$), called stucco in the industry, also popularly known as “Plaster of Paris”. A unique characteristic of stucco is that when mixed with the proper amount of water, it forms a smooth plastic mass that can be molded to various shapes. When hardening is complete, the mass has been chemically restored to its rock like state – calcium sulfate dihydrate. In the second step of the manufacturing process the stucco is mixed with a number of additives. A foaming agent and an excess amount of water is also added to prepare a gypsum slurry which is extruded on a fast moving, board production line between two layers of glass matting. The “raw” glass-mat gypsum board is then allowed to fully hydrate – calcium sulfate hemihydrate is converted back to dihydrate – before it is cut to the desired size and before it enters a heated kiln, where at elevated temperatures excess water is driven off. The glass-mat gypsum board is then packaged and stacked, ready to be shipped.

Figure 3 shows all unit processes and pollution abatement equipment included in the gate-to-gate system boundaries for glass-mat gypsum board manufacturing process. The production weighted average LCI data for glass-mat gypsum board manufacturing are reported in Annex A, Table A1. Inbound and outbound transportation data for glass-mat gypsum board manufacturing are provided in Annex A, Tables A2 to A3.

Purchased electricity and natural gas were reported to be the primary manufacturing energy inputs (A3). While the electricity is used at all production stages most of the natural gas is used during the drying of gypsum, calcining or stucco production and drying the final glass-mat gypsum board products. Diesel is used at plant for on-site equipment (not transportation). Gasoline and propane are typically used to operate the on-site mobile equipment (e.g., forklifts, small engine vehicles) within and around the facility. Gate-to-gate emissions to air were measured and reported at the stack after the utilization of pollution abatement equipment. Total suspended solids (TSS) and lead were the two emissions to water reported by the surveyed facilities. Lead and mercury were the two emissions to land reported by the reporting facilities.

6 Life Cycle Impact Assessment

6.1 Impact assessment indicators describing main environmental impacts derived from LCA

Per NSF PCR, Section 7.3 [5], the following impact assessment indicators are reported as described in Table 4.

Table 4 LCIA category indicators

Impact category	Category indicator	Unit (per Declared Unit)	Source of the characterization method	Level of site specificity selected	Environmental media
Climate change	Global warming potential (GWP 100) ¹⁾	kg CO ₂ – equiv.	TRACI 2.1, July 2012 /with IPCC 2013, AR5 ¹⁾	Global	Air
Ozone depletion	Depletion potential of the stratospheric	kg CFC-11 equiv.	TRACI 2.1, July 2012/WMO:2003	Global	Air
Acidification	Acidification potential (AP)	kg SO ₂ equiv.	TRACI 2.1, July 2012	North America	Air, Water
Eutrophication	Eutrophication potential (EP)	kg N equiv.	TRACI 2.1, July 2012	North America	Air, Water
Smog	Smog formation potential (SFP)	kg O ₃ equiv.	TRACI 2.1, July 2012	North America	Air
Abiotic depletion potential (ADP), fossil	ADP surplus	MJ, surplus	TRACI 2.1, July 2012	Global	Resource use

Note:

¹⁾ 100-year time horizon GWP factors (a.k.a, GWP 100a) are provided by the IPCC 2013 Fifth Assessment Report (AR5). GWP 100 indicator results *exclude* biogenic CO₂ removal and emissions associated with biobased products such as starch and dextrose (see Table 8 for details). GWP 100a indicator results, IPCC 2007 Fourth Assessment Report (AR4) are presented in Section 8.

6.2 Inventory indicators describing resource use, waste categories and output flows

Per NSF PCR, Section 7.2.10, 7.2.13, 7.2.14 [5], the following mandatory resource use, waste categories and output flows are reported as described in Table 5.

Table 5 Parameters describing resource use, waste categories and output flows

Parameter	Unit (per Declared unit)
Resource Use	
RPR _E : Renewable primary resources used as energy carrier (fuel)	MJ, LHV
RPR _M : Renewable primary resources with energy content used as material	MJ, LHV
NRPR _E : Non-renewable primary resources used as an energy carrier (fuel)	MJ, LHV
NRPR _M : Non-renewable primary resources with energy content used as material	MJ, LHV
SM: Secondary materials	kg
RSF: Renewable secondary fuels	MJ, LHV
NRSF: Non-renewable secondary fuels	MJ, LHV
RE: Recovered energy	MJ, LHV
FW: Consumption of freshwater	m ³
Waste Categories	
HWD: Hazardous waste disposed	kg
NHWD: Non-hazardous waste disposed	kg
HLRW: High level radioactive waste, conditioned, to final repository	kg
ILLRW: Intermediate and low-level radioactive waste, conditioned, to final	kg
Output Flows	
CRU: Components for re-use	kg
MR: Materials for recycling	kg
MER: Materials for energy recovery	kg
EE: Exported energy	MJ, LHV

6.3 LCA results for EPD

This section summarizes the production stage life cycle impact assessment (LCIA) results including resource use and waste generated metrics based on the cradle-to-gate life cycle inventory inputs and outputs analysis. The results are calculated based on 92.9 m² (1 MSF) of 1/2" and 5/8" glass-mat gypsum boards. (Tables 6 and 7). *It is noted that LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins or risks [3], [4].*

Table 6 Production Stage (A1-A3), EPD Results – 92.9 m² (1 MSF) of 1/2” Regular glass-mat gypsum products

Impact category and inventory indicators ¹⁾	Unit	A1, Extraction and upstream production	A2, Transport to factory	A3, Manufacturing	Total
Global warming potential, GWP 100 ²⁾ , AR5	kg CO ₂ eq	207.0	25.5	204.9	437.4
Ozone depletion potential, ODP ²⁾	kg CFC-11 eq	0.0	0.0	0.0	7.2E-05
Smog formation potential, SFP ²⁾	kg O ₃ eq	12.6	10.9	6.4	29.9
Acidification potential, AP ²⁾	kg SO ₂ eq	0.8	0.5	0.3	1.6
Eutrophication potential, EP ²⁾	kg N eq	0.7	0.0	0.3	0.95
ADP surplus, TRACI ³⁾	MJ surplus	407.9	52.0	449.7	910
Renewable primary resources used as an energy carrier (fuel), RPR _E ⁴⁾	MJ LHV	97.6	0.2	61.7	160
Renewable primary resources with energy content used as material, RPR _M ⁴⁾	MJ LHV	0.0	0.0	0.0	0
Non-renewable primary resources used as an energy carrier (fuel), NRPR _E ⁵⁾	MJ LHV	3,336	347.9	3,122	6,806
Non-renewable primary resources with energy content used as material, NRPR _M ⁵⁾	MJ LHV	0.0	0	0.0	0
Secondary materials, SM ⁶⁾	kg	162.5	0	0.0	163
Renewable secondary fuels, RSF ⁷⁾	MJ LHV	0	0	0	0
Non-renewable secondary fuels, NRSF ⁸⁾	MJ LHV	0	0	0	0
Recovered energy, RE ⁹⁾	MJ LHV	0	0	0	0
Consumption of freshwater, FW ¹⁰⁾	m ³	1.3	0	0.8	2.1
Hazardous waste disposed, HWD ¹¹⁾	kg	0.024	0	0.013	0.037
Non-hazardous waste disposed, NHWD ¹²⁾	kg	8.3	0	11.1	19.4
High-level radioactive waste, conditioned, to final repository, HLRW ¹³⁾	m ³	2.0E-08	1.7E-10	1.2E-07	1.4E-07
Intermediate- and low-level radioactive waste, conditioned, to final repository, ILLRW ¹⁴⁾	m ³	1.8E-06	1.1E-06	1.8E-06	4.7E-06
Components for re-use, CRU ¹⁵⁾	kg	0	0	0	0
Materials for recycling, MR ¹⁶⁾	kg	0	0	26.1	26.1
Materials for energy recovery, MER ¹⁷⁾	kg	0	0	0.0	0
Recovered energy exported from the product system, EE ¹⁸⁾	MJ LHV	0	0	0.0	0

Table 7 Production Stage (A1-A3), EPD Results – 92.9 m² (1 MSF) of 5/8" Type X glass-mat gypsum boards

Impact category and inventory indicators ¹⁾	Unit	A1, Extraction and upstream production	A2, Transport to factory	A3, Manufacturing	Total
Global warming potential, GWP 100 ²⁾ , AR5	kg CO ₂ eq	220.4	33.0	250.5	503.9
Ozone depletion potential, ODP ²⁾	kg CFC-11 eq	0.0	0.0	0.0	8.3E-05
Smog formation potential, SFP ²⁾	kg O ₃ eq	13.9	14.4	7.4	35.7
Acidification potential, AP ²⁾	kg SO ₂ eq	0.9	0.7	0.4	2.0
Eutrophication potential, EP ²⁾	kg N eq	0.7	0.0	0.3	1.05
ADP surplus, TRACI ³⁾	MJ LHV	456.1	67.0	548.4	1,072
Renewable primary resources used as an energy carrier (fuel), RPR _E	MJ LHV	99.1	0.3	79.8	179
Renewable primary resources with energy content used as material, RPR _M ⁴⁾	MJ LHV	0.0	0.0	0.0	0
Non-renewable primary resources used as an energy carrier (fuel), NRPR _E	MJ LHV	3,693	447.7	3,817	7,958
Non-renewable primary resources with energy content used as material, NRPR _M ⁵⁾	MJ LHV	0.0	0	0.0	0
Secondary materials, SM ⁶⁾	kg	232.3	0	0.0	232
Renewable secondary fuels, RSF ⁷⁾	MJ LHV	0	0	0	0
Non-renewable secondary fuels, NRSF ⁸⁾	MJ LHV	0	0	0	0
Recovered energy, RE ⁹⁾	MJ LHV	0	0	0	0
Consumption of freshwater, FW ¹⁰⁾	m ³	1.3	0	1.0	2.3
Hazardous waste disposed, HWD ¹¹⁾	kg	0.030	0	0.018	0.048
Non-hazardous waste disposed, NHWD ¹²⁾	kg	8.6	0	14.0	22.5
High-level radioactive waste, conditioned, to final repository, HLRW ¹³⁾	m ³	2.4E-08	2.4E-10	1.4E-07	1.7E-07
Intermediate- and low-level radioactive waste, conditioned, to final repository, ILLRW ¹⁴⁾	m ³	2.6E-06	1.5E-06	2.3E-06	6.4E-06
Components for re-use, CRU ¹⁵⁾	kg	0	0	0	0
Materials for recycling, MR ¹⁶⁾	kg	0	0	41.3	41.3
Materials for energy recovery, MER ¹⁷⁾	kg	0	0	0.0	0
Recovered energy exported from the product system, EE ¹⁸⁾	MJ LHV	0	0	0.0	0

Notes to Tables 6 and 7:

¹⁾ Note that data may not add up to totals due to rounding. Data are rounded to an appropriate number of significant digits (2 to 4).

²⁾ Calculated as per U.S. EPA TRACI v2.1, with IPCC 2013 (AR 5), SimaPro v 9.1.1.1 [14].

GWP 100, excludes biogenic CO₂ removals and emissions associated with biobased products such as starch and dextrose (see Table 8 for details); 100-year time horizon GWP factors are provided by the IPCC 2013 Fifth Assessment Report (AR5), TRACI v2.1 with AR5, v1.05 [14].

³⁾ ADP surplus, TRACI v2.1 (a.k.a Fossil fuel depletion, FFD) is required in LEED V4.1 MR Credit: Building Product Disclosure and Optimization – Environmental Product Declarations [18].

⁴⁾ Calculated as per ACLCA ISO 21930 Guidance [15], 6.2 *Renewable primary resources with energy content used as a material, RPR_M*. Not applicable for the glass-mat gypsum boards (NA).

- 5) Calculated as per ACLCA ISO 21930 Guidance [15], 6.4 *Non-renewable primary resources with energy content used as a material, NRPR_M*- N/A.
- 6) Calculated as per ACLCA ISO 21930 Guidance [15], 6.5 Secondary materials, SM; it includes post-consumer gypsum and synthetic gypsum (FGD) used in manufacturing.
- 7) Calculated as per ACLCA ISO 21930 Guidance [15], 6.6 *Renewable secondary fuels, RSF*- N/A.
- 8) Calculated as per ACLCA ISO 21930 Guidance [15], 6.7 *Non-renewable secondary fuels, NRSF*- N/A.
- 9) Calculated as per ACLCA ISO 21930 Guidance [15], 6.8 *Recovered energy, RE*- N/A.
- 10) Calculated as per ACLCA ISO 21930 Guidance [15], 9 *Inventory indicators describing consumption of freshwater*. It's calculated from 2017 and 2019 industry average primary data for consumption of freshwater based solely on the foreground system (raw gypsum extraction, glass mat, and glass-mat gypsum boards manufacturing processes).
- 11) Calculated as per ACLCA ISO 21930 Guidance [15], 10.1 *Hazardous waste disposed*. It's calculated from 2017 and 2019 industry average primary data for hazardous waste disposed based solely on the foreground system (raw gypsum extraction, glass mat, and glass-mat gypsum boards manufacturing processes).
- 12) Calculated as per ACLCA ISO 21930 Guidance [15], 10.2 *Non-hazardous waste disposed*. It's calculated from 2017 and 2019 industry average primary data for non-hazardous waste disposed based solely on the foreground system (raw gypsum extraction, glass mat, and glass-mat gypsum boards manufacturing processes).
- 13) Calculated as per ACLCA ISO 21930 Guidance [15], 10.3 *High-level radioactive waste, conditioned, to final repository*. It should be noted that glass-mat gypsum board foreground system (raw gypsum extraction and glass-mat gypsum board manufacturing processes) does not generate any HLRW. High-level radioactive waste, e.g., when generated by electricity production, consists mostly of spent fuel from reactors." (ISO 21930:2017, clause 7.2.14).
- 14) Calculated as per ACLCA ISO 21930 Guidance [15], 10.4 *Intermediate- and low-level radioactive waste, conditioned, to final repository*. It should be noted that glass-mat gypsum board foreground system (raw gypsum extraction and glass-mat gypsum board manufacturing processes) does not generate any ILLRW. Low- and intermediate-level radioactive wastes, e.g., when generated by electricity production, arise mainly from routine facility maintenance and operations (ISO 21930:2017, clause 7.2.14).
- 15) Calculated as per ACLCA ISO 21930 Guidance [15], 10.5 *Components for re-use*- N/A.
- 16) Calculated as per ACLCA ISO 21930 Guidance [15], 10.6 *Materials for recycling*, i.e. secondary material used in the next product system.
- 17) Calculated as per ACLCA ISO 21930 Guidance [15], 10.7 *Materials for energy recovery*, i.e. secondary fuels used in the next product system- N/A.
- 18) Calculated as per ACLCA ISO 21930 Guidance [15], 10.8 *Recovered energy exported from the system*- N/A.

Per NSF PCR, 7.2.7 [5], for glass-mat gypsum board products, starch and dextrose are counted as biogenic carbon. Table 8 shows the cradle-to-gate biogenic CO₂ removals associated with bio-based products used in the glass-mat gypsum board system.

Table 8 Production Stage (A1-A3), Biogenic CO₂ removals – 92.9 m² (1 MSF) of 1/2” Regular and 5/8” Type X glass-mat gypsum boards

Inputs	Chemical formula	C-Content (in %)	Biogenic CO ₂ removals (in kg CO ₂ / MSF)	
			1/2” Regular glass-mat gypsum board	5/8” Type X glass-mat gypsum board
Starch	(C ₆ H ₁₀ O ₅) _n	44%	- 2.6 = -1.59 kg × 0.44 × (44/12)	- 1.7 = -1.06 kg × 0.44 × (44/12)
Dextrose	C ₆ H ₁₂ O ₆	40%	- 0.87 = -0.60 kg × 0.40 × (44/12)	- 0.62 = -0.42 kg × 0.40 × (44/12)

Notes:

- 1) 44 and 12 is the molar mass of CO₂ and C (in g/mol), respectively.
- 2) It includes the amount of dextrose mixed with landplaster to produce BMA (a.k.a, heat resistant accelerator, HRA). The weighted average amount of dextrose in BMA resulted to 15%.
- 3) Data are rounded to an appropriate number of significant digits (2 to 3).

7 Interpretation

Interpretation is the phase of LCA in which the findings from the inventory analysis and the impact assessment are brought together and significant issues are identified and considered in the context of the *study goal and scope* [3]. In addition, the study's completeness, consistency of all applied information, and sensitivity to key assumptions or parameters as they relate to *the goal and scope of the study* are evaluated. Lastly, the interpretation phase ends by drawing conclusions, stating the study's limitations, and making recommendations [4].

7.1 Identification of the Significant Issues

ISO 14044 recommends several possible methods to identify significant issues in an LCA study. Based on established LCA practices, the following analytical techniques were applied for the interpretation phase of this LCA study [4]:

- *Contribution Analysis*, in which the contribution of *information modules* and *processes* to the cradle-to-gate EPD results are examined; and
- *Dominance Analysis*, in which *significant* contributions are examined.

Figures 6 and 7 present the impact assessment and energy indicator results for 92.9 m² (1 MSF) of 1/2" Regular and 5/8" Type X glass-mat gypsum boards, by *information module*, percent contribution basis, respectively.

The cradle-to-gate manufacture of 92.9 m² of 12.7 mm (1 MSF of 1/2") glass-mat gypsum board embodies about 7.0 GJ of primary energy (LHV) and emits 437 kg CO₂ eq of greenhouse gases. Around 98% of the total primary energy is derived from non-renewable primary energy resource.

Across the three production information modules, *Module A1 extraction and upstream production* contributes *the largest share* of the LCIA and energy indicator results – accounting for between 42% (smog) and 69% (eutrophication) of the potential environmental burdens. The glass matting production is the primary contributor to *Module A1 Extraction and upstream production*. *Module A3 Manufacturing* is the second largest contributor (<50%) to the overall potential environmental impacts of 1/2" Regular glass-mat gypsum board manufacture. Except for acidification (31%) and smog potential impacts (37%), *Module A2 Transportation* is generally a minor contributor (<10%) to the overall potential environmental impacts of 1/2" Regular glass-mat gypsum board manufacture.

The cradle-to-gate manufacture of 92.9 m² of 15.9 mm (1 MSF of 5/8") glass-mat gypsum board embodies about 8.1 GJ of primary energy (LHV) and emits 504 kg CO₂ eq of greenhouse gases. Around 98% of the total primary energy is derived from non-renewable primary energy resource.

Across the three production information modules, *Module A1 extraction and upstream production* contributes *the largest share* of the LCIA and energy indicator results – accounting for between 39% (smog) and 65% (eutrophication) of the potential environmental burdens. The glass matting production is the primary contributor to *Module A1 Extraction and upstream production*. *Module A3 Manufacturing* is the second largest contributor (<50%) to the overall potential environmental

impacts of $\frac{5}{8}$ " Type X glass-mat gypsum board manufacture. Except for acidification (35%) and smog potential impacts (40%), *Module A2 Transportation* is generally a minor contributor (<10%) to the overall potential environmental impacts of $\frac{5}{8}$ " Type X glass-mat gypsum board manufacture.

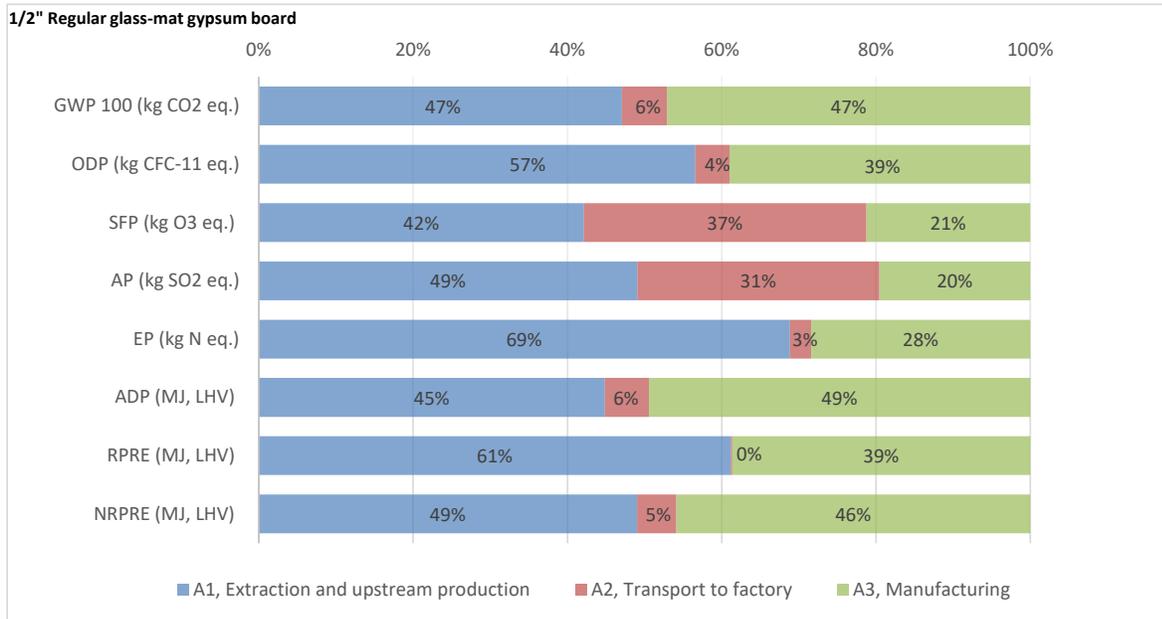


Figure 4 Impact assessment and energy indicator results by information module – 92.9 m² (1 MSF) of 1/2" Regular glass-mat gypsum board – % Basis

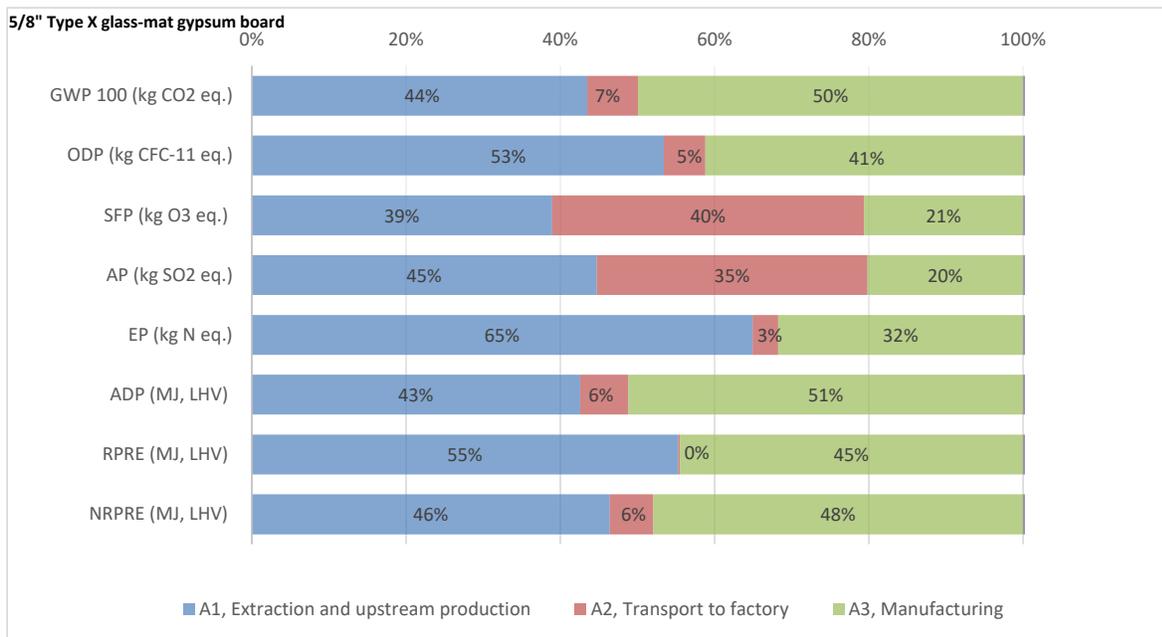


Figure 5 Impact assessment and energy indicator results by information module – 92.9 m² (1 MSF) of 5/8" Type X glass-mat gypsum boards – % Basis

Table 8 presents a dominance analysis, indicating the top four inputs or processes contributing to the global warming potential (GWP₁₀₀) result. In descending order, the upstream manufacture of glass mat, on-site natural gas and electricity consumption during manufacturing, followed by the transportation of inputs are the four major GWP₁₀₀ sources – accounting for over 90% of the greenhouse gases emitted during the production stage.

Table 9 Production Stage (A1-A3), GWP₁₀₀ dominance analysis – 92.9 m² (1 MSF) of 1/2" Regular and 5/8" Type X glass-mat gypsum boards

Production Stage (A1 to A3)	1/2" Regular glass-mat gypsum board		5/8" Type X glass-mat gypsum board	
	kg CO ₂ eq.	%	kg CO ₂ eq.	%
Glass matting production, A1	176	41%	182	36%
On-site natural gas consumption (natural gas processing and combustion), A3	162	37%	198	39%
On-site electricity consumption (electricity generation and transmission), A3	36	8%	45	9%
Transportation, A2	26	6%	33	7%
Rest of processes, A1 to A3	35	8%	44	9%
Total	437	100%	504	100%

7.2 Completeness, Consistency, and Sensitivity Checks

Evaluating the study's completeness, consistency and sensitivity helps to establish and enhance confidence in, and the reliability of, the results of the LCA study, including the significant issues identified in the first element of the interpretation [4].

The objective of the **completeness check** is to ensure that all relevant information and data needed for the interpretation are available and complete [4]. Both 1/2" Regular and 5/8" Type X glass-mat gypsum board systems were checked for data completeness. All input and output data were found to be complete, and no gaps were identified at information modules A1, A2 and A3 (see Annex A, B and C).

The objective of the **consistency check** is to determine whether the assumptions, methods, models and data are consistent with the goal and scope of the study [4]. Through a rigorous process, consistency was ensured between the two glass-mat gypsum board product systems in terms of calculation rules, methods, models, and data quality, including data source, time-related coverage, technology, and geographical coverage (see Sections 5, and Annex B, Tables B1, B2, and B3). Table 3 summarizes the data quality assessment conducted in the framework of this LCA study.

To assess how factors such as *uncertainties in data*, and assumptions would affect the reliability of the results and conclusions, a **sensitivity check** was conducted. The sensitivity check includes the results of the *sensitivity analysis* and *uncertainty analysis* [4].

The procedure of **sensitivity analysis** is a comparison of the LCA results obtained using certain given assumptions, methods, or data, with the LCA results obtained using altered assumptions, methods, or data [4]. ISO 14044 Clause B.3.3 states: “Sensitivity can be expressed as the *percentage of change* or as the absolute deviation of the results. On this basis, *significant changes* in the results (e.g., larger than 10%) can be identified” [4].

As shown in Tables C2 and C3, Annex B, US Electricity grid mix (*Electricity, medium voltage {US} market group for | Cut-off, U*) and US Natural gas mix (*Heat, district or industrial, natural gas {US} market for heat, district or industrial, natural gas | Cut-off, U*) LCI datasets are consistently used for all *foreground* (natural gypsum extraction and glass-mat gypsum board manufacturing) and *background* LCI datasets listed in Annex C, Table C1, as applicable.

Table B1, Annex B and Tables C2 and C3, Annex C, are provided for transparency, to allow for *consistent and transparent industry wide comparability and benchmarking of EPDs*, while maintaining *data confidentiality* (GA plant/site specific market share data) [16]. This allows GA manufactures to accurately meet the LEED v4 and/or v4.1, MR Credit: Building Product Disclosure and Optimization – Environmental Product Declarations, *Option 2 Multi-attribute optimization* (1 point) [17], [18].

Scenario analysis was conducted to illustrate the consequences of replacing US electricity grid and natural gas mix (see above) with the *weighted average* electricity grid and natural gas LCI profiles for natural gypsum extraction and glass-mat gypsum board manufacturing (foreground processes only). *It should be noted that the GA plant/site names and locations are known to all GA members, as a result of the GA LCA team discussions on the industry wide plant sample representativeness*. To protect GA plant/site specific market share data, the *weighted average LCI profiles* for electricity grid and natural gas for natural gypsum extraction and glass-mat gypsum board cannot be presented in the project report, but it is calculated and used for the purposes of the scenario analysis.

The scenario analysis results are presented in detail in Tables 10 and 11 for both ½” Regular and 5/8” Type X glass-mat gypsum board systems. The positive (+) or negative (-) signs of deviation (in %) depend on the mathematical signs (+/-) of both the value of base case and the deviation of the LCIA and energy indicators (see Tables 10 and 11). For example, the influence of this scenario to GWP₁₀₀ of the 5/8” Type X glass-mat gypsum board compared to the base case is positive (+0.6%) and indicates a 0.6% higher GWP compared to the base case. *The scenario analysis shows that the weighted average LCI profiles for electricity grid and natural gas (for foreground processes only) were deemed not significant sensitivity scenario (less than 1% change, except for RPR_E (2%) and EP (5%) for the LCIA and energy indicators for both ½” Regular and 5/8” Type X glass-mat gypsum board systems.*

Table 10 Scenario analysis results (*Production stage*)- 92.9 m² (1 MSF) of ½” Regular glass-mat gypsum board

LCIA and energy indicators	Base case	Scenario case	Deviation-in absolute basis	Deviation-in %
GWP (kg CO ₂ eq.)	437.4	439.8	2.3	0.5%
ODP (kg CFC-11 eq.)	7.19E-05	7.21E-05	2.1E-07	0.3%
SFP (kg O ₃ eq.)	29.9	29.8	-0.1	-0.3%
AP (kg SO ₂ eq.)	1.6	1.6	-0.004	-0.2%
EP (kg N eq.)	1.0	1.0	0.044	4.6%
ADP (MJ surplus)	910	917	7.5	0.8%
RPR _E (MJ, LHV)	160	157	-3.0	-1.9%
NRPR _E (MJ, LHV)	6,806	6,831	25	0.4%

¹⁾ Data are rounded to an appropriate number of significant digits (2 to 4).

Table 11 Scenario analysis results (*Production stage*)- 92.9 m² (1 MSF) of 5/8” Type X glass-mat gypsum board

LCIA and energy indicators	Base case	Scenario case	Deviation-in absolute basis	Deviation-in %
GWP (kg CO ₂ eq.)	503.9	506.8	2.9	0.6%
ODP (kg CFC-11 eq.)	8.30E-05	8.33E-05	2.5E-07	0.3%
SFP (kg O ₃ eq.)	35.7	35.6	-0.1	-0.3%
AP (kg SO ₂ eq.)	2.0	1.9	-0.005	-0.2%
EP (kg N eq.)	1.1	1.1	0.055	5.2%
ADP (MJ surplus)	1,072	1,081	9.3	0.9%
RPR _E (MJ, LHV)	179	175	-3.7	-2.1%
NRPR _E (MJ, LHV)	7,958	7,988.4	31	0.4%

¹⁾ Data are rounded to an appropriate number of significant digits (2 to 4).

A **Monte Carlo uncertainty analysis** was also conducted to assess the combined uncertainty effect of the data variability on the LCIA and energy indicator results (see Annex D).

Based on the industry sample data, [minimum; maximum] range data was calculated per each input/output flow for the two selected foreground product systems (natural gypsum extraction and glass-mat gypsum board manufacturing). These data are used in the Monte Carlo uncertainty analysis. *This uncertainty analysis assesses the combined uncertainty effect of the inventory data (both foreground and background)-see Annexes A to C. It should be noted that U.S. EPA TRACI v2.1 methodology has not specified any uncertainty information of the characterization factors per impact category.*

As a statistical method to process data uncertainty, Monte Carlo analysis is used to establish the uncertainty range, which expresses the variance between the upper and lower confidence limit [97.5%, 2.5%], in the calculated LCA results (Figures D1 and D2, Annex D). *Based on 1,000 runs, such information provides a quantitative indication of the range of results that are likely for the*

manufacturer's specific products covered by the industry average EPD for two selected glass-mat gypsum board products.

7.3 Conclusions, Limitations and Recommendations

Based on the goal and scope of this LCA, life cycle inventory, impact assessment, and interpretation phases, the following **conclusions** can be reached:

- The use of *FGD synthetic gypsum* is beneficial for the glass-mat gypsum board industry as it reduces the dependency on primary material resources (natural gypsum ore).
- Across the three production stage information modules, *Modules A1 and A3*, contribute the largest share of the LCIA category and energy indicator results – together accounting for between 60% (smog) and 97% (eutrophication) of the potential environmental burdens for both ½” Regular and 5/8” Type X glass-mat gypsum board systems.
- Over 98% of the total primary energy is derived from *non-renewable primary energy resource* for both ½ Regular and 5/8” Type X glass-mat gypsum board systems.
- On-site *natural gas and electricity consumption* (Module A3) accounted for greater than 45% of the GWP₁₀₀ indicator results. Glass matting production (Module A1) accounted for around 40% of the GWP₁₀₀ indicator results.

For best interpretation and appropriate use of the LCA results for EPD, it is important to state the inherent **limitations** and assumptions of the LCA technique. *LCA addresses “potential environmental impacts” and does not predict absolute or precise environmental impacts due to (a) the relative expression of potential environmental impacts to a reference unit, (b) the integration of environmental data over space and time, (c) the inherent uncertainty in modeling of environmental impacts, and (d) the fact that some possible environmental impacts are clearly future impacts* [3].

The GA gypsum board manufacturing facilities produce other co-products besides selected glass-mat gypsum boards and as such allocation based on the mass of gypsum board products was necessary. This methodological approach is expected to be “conservative” for 5/8” Type X glass-mat gypsum board products.

Based on the EPD results “on-site” energy conservation efforts at glass-mat manufacturing facilities are strongly recommended. The EPD study results indicate that “on-site” energy use is the single largest contributor to the cradle-to gate EPD results. More specifically, efforts to reduce natural gas use offer the most immediate opportunity to improve the environmental performance of glass-mat gypsum board plants and products.

8 Additional Environmental Information

- *GWP 100a indicator results per IPCC 2013 AR5 and IPCC 2007 (AR4)*

TRACI v2.1 was originally based on IPCC 2007 AR4 GWP 100a factors. IPCC 2013 AR5 is the successor of the IPCC 2007 AR4 method. Table 12 shows cradle-to-gate GWP 100a indicator results per IPCC 2013 AR5 and IPCC 2007 AR4 for 92.9 m² (1 MSF) of ½” Regular and 5/8” Type X glass-mat gypsum boards.

Table 12 Product Stage (A1-A3), GWP 100a indicator results per IPCC 2013 (AR5) and 2007 (AR4) – 92.9 m² (1 MSF) of ½” Regular and 5/8” Type X glass-mat gypsum boards

GHGs	Unit	1/2" Regular glass-mat gypsum board		5/8" Type X glass-mat gypsum board	
		GWP 100a IPCC 2013 (AR5) ¹⁾	GWP 100a IPCC 2007 (AR4) ²⁾	GWP 100a IPCC 2013 (AR5) ¹⁾	GWP 100a IPCC 2007 (AR4) ²⁾
GWP 100a	kg CO ₂ eq.	437.4	431.7	503.9	497.2

Note:

¹⁾ The GWP 100a per IPCC 2013 AR5 (in kg CO₂ eq.): CO₂=1; CH₄, fossil=30; CH₄, biogenic=28; N₂O=265.

²⁾ The GWP 100a per IPCC 2007 AR4 (in kg CO₂ eq.): CO₂=1; CH₄, fossil =25; CH₄, biogenic=22.25; N₂O=298.

³⁾ Data are rounded to four (4) significant digits.

- **Health Protection Manufacture**

The OSHA standards are applicable and followed.

- U.S. Department of Labor, Occupational Safety & Health Administration (OSHA), 29 CFR, PART 1910 Occupational Safety and Health Standards.

https://www.osha.gov/pls/oshaweb/owasrch.search_form?p_doc_type=STANDARDS&p_toc_level=1&p_keyvalue=1910, accessed 30-03-2021.

No additional health protection measures extending beyond mandatory occupational safety measures for commercial operations are required.

- **Environmental Protection Manufacture and Equipment**

The GA member manufacturing facilities comply with the regional (U.S. and Canadian) environmental protection requirements, monitor and report the emissions to air during the manufacturing process as per the following:

- EPCRA Section 313 Toxic Release Inventory reporting (U.S)

<https://www.epa.gov/toxics-release-inventory-tri-program>, accessed 30-03-2021.

- The Canadian National Pollutant Release Inventory (NPRI) reporting

<http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=4A577BB9-1>, accessed 30-03-2021.

Pollution abatement equipment typically used in the glass-mat gypsum board manufacturing facilities are as follows: fabric filter – high temperature (baghouse), fabric filter- low temperature (baghouse), bin vent filter, drum filter, dry filter, cartridge filter, precipitator and water sprinkler for dust control.

9 Declaration Type and Product Average Declaration

The type of EPD based on this Project Report is defined as:

- A “Cradle-to-gate” EPD for ½” Regular and 5/8” Type X glass-mat gypsum boards covering the *Production stage* (information modules A1 to A3) and is intended for use in *Business-to-Business* communication.

GA EPD of glass-mat gypsum boards UNSPSC Code 30161500 falls under the description:

- An average product EPD, as an average from several GA manufacturers’ facilities (in this case, GA member manufacturers as listed under “GA Member Companies Corporate Locations”, see pg. 2).

10 Declaration Comparability Limitation Statement

The following ISO 21930 statement indicates the EPD comparability limitations and intent to avoid any market distortions or misinterpretation of EPDs based on the NSF PCR for Gypsum Panel Products [5]:

- Only EPDs prepared from cradle-to-grave life cycle results and based on the same function, RSL, quantified by the same functional unit, and meeting all the conditions for comparability listed in ISO 14025:2006 and ISO 21930:2017 can be used to comparison between products.

11 EPD Explanatory Material

For any explanatory material, regarding the GA EPD for glass-mat gypsum boards based on this Project Report, please contact the program operator.

ASTM International
Environmental Product Declarations
100 Barr Harbor Drive,
West Conshohocken,
PA 19428-2959, <http://www.astm.org>

12 References

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