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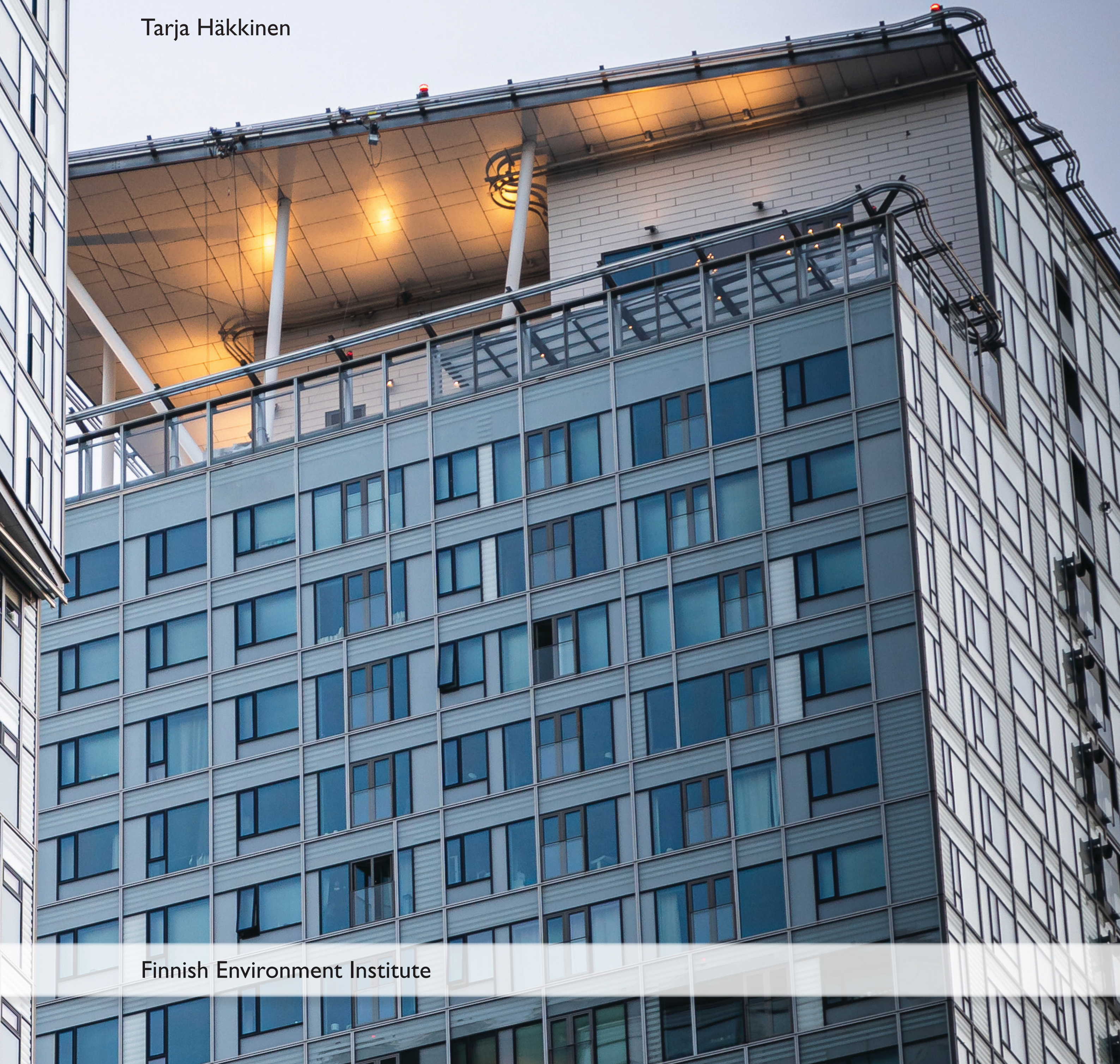
LCA database for building products, services, and systems

Description of the content and working methods

Tarja Häkkinen



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Abstract

LCA database for building products, services, and systems

The emission database for building products and services – CO2DATA – was developed at the Finnish Environmental Institute (SYKE) by the request of the Ministry of the Environment and in collaboration with specialists of Life Cycle Assessment (LCA) for building products and buildings.

The main target of the database is to support the design for low carbon and resource-efficient building by providing typical environmental data for products, services, and systems to be used in the assessment of alternative design solutions.

An essential function of the CO2DATA database is to enable the preparation of climate reports for building designs. Climate reports will be required in the building permissions processes for new building and deep renovation in accordance with the new Government's proposal for Building Act. Climate reports can be calculated and formulated by combining the emission data based on CO2DATA with the information about the energy consumption and energy sources, and the information based on the bill of quantities.

The purpose of this report is to explain how the environmental data of the database was developed and introduce what kind of sources were used. The purpose is also to give information about the structure and coverage of data and to support the correct use of data in the environmental assessment of buildings and building designs.

The main indicator of the database is global warming potential (GWP). The database defines GWP values for products, services, and systems. The indicator is called as carbon footprint and defined as the total amount of greenhouse gases induced during the life cycle of the building, expressed as the weight of carbon dioxide equivalents.

For all building products, the GWP is expressed in terms of kg CO_2e per kg of product. Additional information – such as weight per m, m^2 or m^3 – is typically also given to help the conversion of the mass-based value. The specific GWP values of energy services are given in kg CO_2e in relation to the energy unit of the service (kWh), and those of transportation services are defined in kg CO_2e per load unit (ton) and the unit of transportation distant (km). The GWP values for construction and deconstruction of buildings are mostly given in terms of kg CO_2e per building area unit (m^2).

Keywords: Building, construction, building product, life cycle, LCA, carbon footprint, database, energy, environmental product declaration

Sammandrag

LCA-databas för byggprodukter, processer och system

Utsläppsdatabasen för byggprodukter, energi och transport – CO2DATA – har utvecklats vid Finlands miljöinstitut (SYKE) på uppdrag av Miljöministeriet och i samarbete med specialister på livscykelanalys (Life Cycle Assessment, LCA) för byggprodukter och byggnader.

Huvudmålet med databasen är att stödja designen för lågkoldioxid och resurseffektivt byggande genom att tillhandahålla typiska miljödata för produkter, transport och energitjänster och system som ska användas vid bedömning av alternativa designlösningar.

En väsentlig funktion för CO2DATA-databasen är att möjliggöra utarbetande av klimatrapporter för byggnadsdesign. Det kommer att krävas klimatredovisningar i bygglovsprocesserna för nybyggnation och omfattande renoveringar enligt den nya regeringens förslag till bygglag. Klimatrapporter kan beräknas och formuleras genom att kombinera utsläppsdata baserade på CO2DATA med informationen om energiförbrukning och energikällor samt informationen baserad på mängdförteckningen.

Syftet med denna rapport är att förklara hur databasens miljödata har utvecklats och presentera vilken typ av informationskällor som använts. Syftet är också att ge information om datas struktur och täckning samt att stödja korrekt användning av data vid miljöbedömning av byggnader och byggplaner.

Databasens huvudindikator är global uppvärmningspotential (GWP). Databasen definierar GWP-värden för produkter, tjänster och system. Indikatorn kallas för koldioxidavtryck och definieras som den totala mängden växthusgaser som induceras under byggnadens livscykel, uttryckt som vikten av koldioxidekvivalenter.

För alla byggprodukter uttrycks GWP i termer av kg CO_2e per kg produkt. Ytterligare information – såsom vikt per m, m^2 eller m^3 – ges vanligtvis också för att underlätta omvandlingen av det massbaserade värdet. De specifika GWP-värdena för energitjänster anges i kg CO_2e per energienhet (kWh), och de för transporttjänster definieras i kg CO_2e per last (ton) och resans längd (km). GWP-värdena för konstruktion och dekonstruktion av byggnader anges oftast i kg CO_2e per byggnadsarea (m^2).

Nyckelord: Byggnad, konstruktion, byggprodukt, livscykel, LCA, koldioxidavtryck, databas, energi, miljödeklaration

Tiivistelmä

LCA-tietokanta rakennustuotteille, palveluille ja järjestelmille

Rakennustuotteiden ja -palvelujen päästötietokanta – CO2DATA – on kehitetty Suomen ympäristökeskuksessa (SYKE) ympäristöministeriön tilauksesta ja yhteistyössä rakennustuotteiden ja rakennusten elinkaariarvioinnin (Life Cycle Assessment, LCA) asiantuntijoiden kanssa.

Tietokannan päätavoitteena on tukea vähähiilisen ja resurssitehokkaan rakentamisen suunnittelua tarjoamalla tyypillistä ympäristötietoa tuotteille, palveluille ja järjestelmille vaihtoehtoisten suunnitteluratkaisujen arviointiin ja vertailuun.

CO2DATA -tietokannan olennainen tehtävä on myös mahdollistaa rakennussuunnitelmien ilmastoselvitysten laatiminen. Uudisrakentamisen ja peruskorjauksen rakennuslupaprosesseissa tullaan vaatimaan ilmastoselosteiden laatimista Valtioneuvoston uuden rakentamislakiehdotuksen mukaisesti. Ilmastoselvitys voidaan laskea ja muotoilla yhdistämällä CO2DATA -pohjaiset päästötiedot energiankulutusta ja energialähteitä koskeviin tietoihin sekä rakennussuunnitelman määräluetteloon perustuviin tietoihin.

Tämän raportin tarkoituksena on selittää, miten tietokannan ympäristödata on kehitetty ja millaisia lähteitä tietojen valinnassa on pääosin käytetty. Tarkoituksena on myös antaa tietoa tietokannan rakenteesta ja kattavuudesta sekä tukea tiedon oikeaa käyttöä rakennusten ja suunnitelmien arvioinnissa.

Tietokannan pääindikaattori on ilmastonlämpenemispotentiaali (GWP). Tietokanta määrittelee GWP-arvot tuotteille, palveluille ja järjestelmille. Tunnuslukua kutsutaan hiilijalanjäljeksi, ja se annetaan rakennuksen elinkaaren aikana syntyneiden kasvihuonekaasujen kokonaismääränä, ja sen yksikkönä käytetään kilogrammaa hiilidioksidiekvivalentteja (kg CO_2e).

Kaikille rakennustuotteille GWP ilmaistaan kilogrammoina hiilidioksidiekvivalentteja tuotekiloa kohden (kg CO_2e/kg). Massaperusteisen arvon muuntamisen avuksi annetaan tyypillisesti myös lisätietoa – kuten tuotteen paino per m, m^2 tai m^3. Energiapalveluiden GWP-arvot annetaan energiayksikköä (kWh) kohden ja kuljetuspalveluiden arvot kuormayksikköä (tonnia) ja kuljetusetäisyyden yksikköä (km) kohden. Rakennusten rakentamisen ja purkamisen GWP-arvot annetaan pääosin rakennuksen pinta-alayksikköä (m^2) kohti.

Asiasanat: Rakennus, rakentaminen, rakennustuote, elinkaari, elinkaariarvio, hiilijalanjälki, tietokanta, energia, ympäristöseloste

Foreword

Carbon footprints for buildings have been calculated for years and standards for life cycle assessment are in place. However, the comparability of such evaluations has been poor. Two separate calculations of a same building may have given very different results.

Defining right actions to reach ambitious carbon neutrality targets requires the ability to measure and compare different plans and designs. This can only be achieved if indicators and methods used to calculate the carbon footprint are the same.

Carbon footprint assessment of a building requires information on both operational and embodied emissions, but the availability of freely accessible and adequate environmental information of products and services has been lacking. Regulatory control of building-related emissions, however, requires that sufficiently good-quality and comprehensive information is available for use is building design processes.

The national emissions database for building products and services has been created to ensure the comparability and availability of data for assessment.

New green construction products and services are constantly being developed and taken into wider and wider use. This is good news, but adds another demand on the database, requiring continued maintenance of indicator values and ability to openly indicate the status of each indicator.

Open documentation like this description of the content and working methods is a corner stone for enabling openness and comparability, but also for enabling discussion and gathering development ideas from the industry experts. The database is still being developed to add new data and ensure compatibility with related tools and systems. Much of this development work will be Nordic in scope and target common methods while most indicator values remain national due to market differences. All these changes will most likely require updating the database but updates to this document will probably also be necessary within a couple of years.

Common, open, and up-to-date information is an important enabler of a greener future.

Janne Pesu and Tarja Häkkinen

Contents

1 Purpose and main content of the database

The emission database for building products and services – CO2DATA – was developed at the Finnish Environmental Institute (SYKE) by the request of the Ministry of the Environment and in collaboration with specialists of life cycle assessment (LCA) for building products and buildings.

The work was also supported by close co-operation and exchange of information with Sweden and other Nordic countries. Concurrent development of similar type of databases in Sweden by Boverket[1] and IVL[2] and in Finland helped both in solving problems and finding solutions. The Finnish project is related to the three-stage roadmap for low-carbon building published by the Ministry of the Environment (YM 2022a).

The main idea of the database is to support the design for low carbon and resource-efficient building. With regard to this, an important purpose of the database is to enable the assessment of the global warming potential (GWP) and material use of buildings in accordance with the procedures included in the planned new building regulations. Two essential planned decrees are the regulations on climate declaration and material report, which are planned to be required in the building permission process (YM 2022b, 2022c).

To fulfil this need, the database provides typical GWP data for

- building products and building services systems
- transportation, construction, deconstruction, and waste management services
- fuels and energy services.

The database covers a major share of different kinds of building products and services.

The database also supports the consideration of potential carbon benefits of the building and benefits beyond the building's life. In accordance with the draft for the new Building Act (VN 2022), the benefits are potential avoided emissions called as carbon handprints, which are divided to five parts covering avoided emissions because of:

- recycling or reuse of materials and products
- energy recovery, or use as energy source in power plant with efficiency ≥65 percentage
- surplus renewable energy
- biogenic or technological carbon storage
- carbonation of cement-based products after service life.

The database will be later supplemented by adding data of urban trees to support the carbon footprint and carbon handprint assessment also for the building plot.

In addition, the database supports the reporting of the content and the origin of materials. The building materials and products are described by information about the types of main materials contents, harmful substances contents, and information about the origin in terms of renewability of materials and secondary materials.

The purpose of this report is to introduce how the environmental data of the database was developed and what kind of sources were used. The purpose is also to give information about the structure and coverage of data and to support the correct use of data in the environmental assessment of buildings and building designs.

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[1] The Swedish National Board of Housing, Building and planning

[2] Swedish Environmental Research Institute

2 Contents of CO2DATA

The database includes roughly 250 products and services (Table 1). The building products of the database include insulation and waterproofing products, building boards, concrete products, other mineral materials and glass, steel and metals, wood products, floorings and surface materials, and HVAC products and electrical installations. Services include energy services, transportation services and construction and demolition services. In addition, the database provides emission values for building services systems.

Table 1. Description of the contents of the database. The list of included products is indicative as the database is updated when necessary

Products (Life-Cycle ModulesA1 – A3, C3 and B4)	**Insulation and water proofing**
	Mineral, plastic, and cellulose based insulations, water vapour barriers, and bitumen roofing
	Building boards
	Wood and mineral-materials based boards including particle boards, fibre boards, plywood, OSB, gypsum boards, and fibre cement boards
	Concrete
	Ready mixed concrete products, precast concrete products, and other products such as blocks and roofing tiles
	Steel and metals
	Steel, stainless steel, copper and aluminium products including load bearing structures, lightweight profiles, sheets, pipes, rebars, and wires
	Solid wood
	Sawn and planed timber, LVL, GLT, CLT, heat treated, and impregnated timber
	Mineral materials and glass
	Bricks, calcium silicate bricks and blocks, masonry mortars, autoclaved aerated concrete products, float glass and other glass types, natural stone products, aggregates
	Floorings and surface materials
	Ceramic tiles, wood and polymer-based floorings, plastering mortar and screed, and paints
	HVAC products and electrical installations
	Pipes, ducts, tubes, cables, wires, pumps, heat exchanger, radiator, exhaust ventilation system, elevator, solar panel and collector, electrical group center, faucets and other items and devices
	Supplementary products
	Doors, windows, partition walls, cabinets, chimneys, and staircases
	Infra, yard and foundations products
	Natural stone products, aggregates, piles, pipes, well elements, asphalt concrete, geotextile, stabilizers, insulations, impregnated timber, and other timber products
Services	Energy services (module B6)
	Electricity, district heat, district cooling, fossil fuels
	Transportation services (modules A4 and C2)
	Semi-trailers, heavy delivery lorries and earth movers Container train Container ship, bulk carrier
	Construction service (module A5)
	Construction, earthwork, and stabilization
	Demolition (modules C1 and C4)
	Deconstruction, disposal
Systems	Building services (modules A1 – A3, C3 and B4)
	Heating, cooling, ventilation, water and sewerage system, electricity, and systems related to sprinkler, dry ascent, and radon

The life-cycle modules are structed in accordance with EN 15804 (2019) as follows.

Table 2. Life cycle modules

Abbreviation	Module
A	Product stage
A1	Raw material extraction and processing, processing of secondary material input
A2	Transport to the manufacturer
A3	Manufacturing
A4	Transport to the building site
A5	Installation into the building
B1	Use of application of the installed product
B2	Maintenance
B3	Repair
B4	Replacement
B5	Refurbishment
B6	Operational energy use
B7	Operational water use
C1	De-construction, demolition
C2	Transport to waste processing
C3	Waste processing for reuse, recovery and/or recycling
C4	Disposal
D	Benefits and loads beyond the system boundary, information module*

*Called as carbon handprint in accordance with (VN 2022) and (YM 2022b) and further structured as explained in Section 4.2.

3 Typical values and conservative values

The idea of *the typical values* for different building products is to represent average values for different product types when considering the most significant manufactures from the viewpoint of the Finnish construction market. Because of lack of comprehensive information, the typical data values are not mean values calculated on the basis of market shares.

CO2DATA defines two kinds of GWP values for building products. In addition to the typical values, *conservative values* are provided. Conservative values are calculated by multiplying the typical GWP value by a chosen factor. By searching information about the range of GWP values of similar product types with the help of environmental product declarations (EPDs), a factor of 1.2 was chosen though the range varies much, and the differences may be significantly bigger for some products.

Conservative values are only defined for GWP (fossil) regarding the first life cycle modules (A1 – A3 including extraction of raw materials, transportation, and manufacturing). Those are not defined for potential carbon benefits (carbon handprints as called in VN 2022) nor material data.

The assessed typical emission values for energy, transportation and construction and demolition services are also not multiplied by the factor 1.2 though those are called as conservative values in the database.

Conservative factor was used for GWP (A1-A3) (fossil) values mainly because those are based on environmental product declarations. The idea was to hinder unjustified application of results and to encourage for doing more EPDs. However, conservative factors were not used for other values because of their much more generic nature.

4 Indicators

4.1 **Global warming potential**

4.1.1 Phases and units of GWP indicator

The selection of indicators, the outline of the stages of building's life cycle, and the required methods for assessing the global warming potential (GWP) in different stages follow the basic principles stated in EN 15804 (2019). However, the scope of the indicators is more limited.

The main indicator of the database is global warming potential. The database defines GWP values for products, services, and systems. The indicator is called as carbon footprint and defined as the total amount of greenhouse gases induced during the life cycle of the building, expressed as the weight of carbon dioxide equivalents.

For all building products, the GWP is expressed in terms of kg CO_2e per kg of product. Additional information – such as weight per m, m^2 or m^3 – is typically also given to help the conversion of the mass-based value.

The specific GWP values of energy services are given in kg CO_2e in relation to the energy unit of the service (kWh), and those of transportation services are defined in kg CO_2e per load unit (ton) and the unit of transportation distant (km).

The GWP values for construction and deconstruction of buildings are mostly given in terms of kg CO_2e per building area unit (m^2). Emissions from waste processing and waste disposal are given per kg of material.

Table 3. Carbon footprint indicators

NOTE: Only emissions from product stage and waste processing and disposal (i.e. stages A1 - A3 and C3 and C4) are given in relation to the products in question.

Stage	Unit	Comment
Product stage (A1–A3)	kg CO_2e/kg	Conversation with the help of weight per m, m^2, m^3, or unit.
Transportation (A4)	kg CO_2e/ton km	Data given different transportation services.
Construction (A5)	kg CO_2e/m^2	Data given for construction of buildings of different use purposes.
Use (B6)	kg CO_2e/kWh	Data given related to consumption of different energy services.
Deconstruction (C1)	kg CO_2e/m^2	Data given for deconstruction of buildings of different use purposes.
Transportation (C2)	kg CO_2e/ton km	Data given for different transportation services.
Waste processing (C3)	kg CO_2e/kg	Data given related to different groups of materials. Conversation with the help of weight per m, m^2, m^3, or unit.
Waste disposal (C4)	kg CO_2e/kg mixed waste	Data given related to the total assessed amount of mixed waste.

4.1.2 Selection of biogenic and luluc related GWP values

The following principles were followed in the selection of the typical value for GWP biogenic and GWP luluc values:

- Based on the review of the environmental declarations, wood products have a low GWP (biogenic) value, when carbon dioxide binding to the growing wood and release in the C phase of the product (Table 2) are not taken into account. In Finland, in the manufacture of wood products in sawmills, the burning of wood-based fuel does not produce methane, but some carbon monoxide (emission factor of 1.57) is induced. The released nitrous oxide is attributed to fossil emissions. Thus, the GWP (biogenic) share caused by wood-based fuels is largely compensated to zero within the A phase (Table 2), and it can be left out of consideration in the typical values of the emission database. Also, the GWP (biogenic) values, which are caused by, for example, packaging materials, are typically very small compared to the GWP (fossil) value. In summary, it can be concluded that GWP (biogenic) can be ignored without making a significant assessment error when choosing typical values, except for the carbon bound to and released from sawn timber.

- The sum of GWP (biogenic) values in modules A and C in environmental declarations for sawn timber is usually zero or almost zero. According to the standard, the procedure is such that the value of bound CO_2 is negative in A1 phase and the value of CO_2 is positive when carbon is released from the system either during combustion or when the product moves from one product system to the next. In the selection of the typical values, it was decided to proceed in such a way that the same value is used for organic bound carbon as for the carbon storage in D phase, which indicates the amount of stored carbon as carbon dioxide. The same value is taken into account in phase A as negative and again in phase C as positive (i.e. emission). It is also assumed that the products are made from timber harvested from a sustainably managed forest. GWP (biogenic) values are not multiplied by a conservative factor.
- Regarding other materials and based on a small review of environmental declarations, GWP (biogenic) emission values are low. The typical order of magnitude is smaller than two percentage compared to GWP (fossil). The current version of the database does not take into account GWP (biogenic) emissions for any other materials than wood, but those are marked as zero.
- The GWP (luluc) values of construction products as presented in environmental product declarations are also very small compared to the GWP (fossil) values. In general, construction materials and fossil fuel inputs contribute with insignificant share to land-use impacts in the life cycle of Finnish buildings, as mineral and fossil raw materials and fuels have low embodied land-use needs (Häkkinen et al. 2013). For these reasons, the values are now ignored in the typical values, and marked as zero.

In Finland, a total of 419,000 hectares of forest land has been transferred to the other land use category between 1990 and 2017. A total of 243,000 hectares has been used for construction, roads, and transmission lines, 117,000 hectares for farmland and 30,000 hectares for peat production. If greenhouse gas emissions are taken as a perspective instead of surface area, the share of construction is 23 percentage, farmland 57 percentage and peat production 11 percentage (Timonen 2020, p. 36). Emissions from areas that have been converted from forest land to built-up areas were 0.7 Mt CO_2 in 2017 (Timonen 2020, p. 32). Although the effect of mineral materials on GWP (luluc) values are small compared GWP (fossil) values, the impact assessment of buildings should cover land use and land use change related emissions caused by construction and by the use of wood. Although these aspects are not considered in the current version of CO2DATA, those must be further studied and possibly added to the database in the next update phase.

As described above, it was assumed that wooden products are made from timber harvested from a sustainably managed forest. The principles for dealing with the biogenic carbon has a significant effect on the emission data of wooden products as the carbon uptake is considered for products originating from sustainably managed forests. Overall principles would require further research and sharpening but one of the aspects that need to be considered is growth. Now, the carbon data for wooden products was formulated based on the assumption of sustainably managed forests. The selection was based on the current growth statistics in Finland.

The removal from the forest rose to 91.6 million cubic meters in 2021 in Finland. In addition to the trunk wood harvested for use, the removal includes a total of 15.3 million cubic meters of naturally dead trunk wood and felling residues remaining in the forest. 103 million cubic meters of new trunk wood grew in the whole country, so the living standing trees in the Finnish forests increased by about 12 million cubic meters. (LUKE 2022a)

On the other hand, according to the latest measurements of trees, the amount of tree stand in Finland has continued to increase, but at a slower rate than before. The growth of trees has decreased. Growth has decreased in pine, and the decrease in growth is especially visible in northern Finland. The estimate of the annual growth of the tree stand is now (2014–2020) 103.5 million cubic meters, which is 4.3 million cubic meters less than the previous growth estimate (for the years 2009–2018). The growth of the tree stand is measured for the five years preceding the inventory years. (LUKE 2021)

In addition, according to the information by the Yearbook of natural resources (LUKE 1029) the wood imports to Finland in 2018 was 11.6 million cubic meters of which 63 percentage pulpwood, 27 percentage wood chips, and 10 percentage logs, firewood, impregnated wood, and waste wood. However, the imports have decreased significantly in 2022, as 2.71 million cubic meters of wood were imported to Finland in January-June. The amount of wood imported decreased by 58 percent compared to the same time previous year. Of the imported wood, only three percent was log wood. 55 percent of the amount of wood imported in January-June 2022 came from Russia. 19 percent of wood came from Estonia and 14 percent from Latvia. (LUKE 2022b)

However, the current interpretation of sustainable forestry criteria does not consider the effect of levels of harvesting on the net carbon sink. According to the report by The Finnish climate change panel (Seppälä et al. 2022) permanently increasing levels of harvesting from the current average annual level of 72 million m^3 will decrease the carbon sink of forests each year for at least the rest of this century, if compared to a scenario where harvesting is kept at the current level. Alternatively, if harvesting levels were decreased, this would increase the carbon sinks of Finland during this century.

The increased felling of trunk trees in recent years has meant that the net sink of the LULUCF sector has been annually (2016–2019 excluding 2018) on average approximately 5 Mt CO_2 less than what the EU has obliged Finland to do in 2021–2025 (EU 2021) and where Finland has set the target level of the net sink in order to achieve carbon neutrality in 2035. The annual variation of the net sink in the LULUCF sector in Finland is explained almost exclusively by the variation in the amount of felling of forests. The net sink of the LULUCF sector can be strengthened by reducing emissions from peatland fields and forests in particular and by increasing the carbon sequestration and storage of fields and forests. However, the large-scale and rapid implementation of emission reduction measures in the LULUCF sector can be challenging and finding out the possibilities also requires research. The amount of felling affects the carbon store and carbon sink of forests the most.

Because of these reasons, the overall calculation rules and principles regarding land use, forestry and wood related emissions require more research and discussion. This is planned to take place within an ongoing Nordic project (Nordic Sustainable Construction 2022).

4.2 **Potential GWP benefit**

The database gives data for potential GWP benefit.

The aspect of potential benefits is included because the draft for new Building Act (VN 2022) includes the carbon handprint aspect defined as benefits that slow down climate change, and which would not have arisen without the building project, expressed as weight of carbon dioxide equivalents.

The following aspects are considered.

Table 4. Different product-related aspects related to potential GWP benefit

Phase	Unit
Potential benefit because of reuse and recycling (D1)	kg CO_2e/kg
Potential benefit because of energy recovery (D2)	kg CO_2e/kg
Potential benefit because of use in power plant with energy efficiency ≥ 65 percentage (D2)	kg CO_2e/kg
Potential benefit because of carbon storage (D4)	kg CO_2e/kg
Potential benefit because of carbonation (D5)	kg CO_2e/kg

The values of potential benefits are not multiplied with the conservative factor (1.2) that is used for the carbon footprint values. However, whenever there are more options, a conservative approach is chosen in the scenario selection. The applied typical scenario – as based on the conservative approach – for wood products is energy recovery and for mineral products landfilling. The applied typical scenario for metals is recycling.

The consideration of potential benefits mainly corresponds to the idea of benefits beyond the system boundary as defined in EN 15804 (2019). However, the benefit because of carbon storage is an additional aspect. The consideration of this aspect is related to VN (2022), and also to the inclusion of carbon storage aspect in the proposal for a new energy performance directive (Article 7 in COM 2021)[3]. Carbon storage of wood is also considered in the method according to the standardization, but EN 15804 directs to report it as carbon instead of carbon dioxide.

The justification for the consideration of potential benefit because of carbon storage is related to the arguments explained in Section 4.2 regarding the effect of harvesting levels. According to the report by The Finnish climate change panel (Seppälä et al. 2022), the emissions reduction due to the carbon stored in wood-based products and the substitution effects of wood-based products and fuels compared to fossil-based options are not enough to compensate for the loss of forest carbon sinks in at least 150 years' time if levels of harvesting are permanently increased to supply these products. However, wood-based building materials currently provide higher climate benefits than pulp-based products. If increased production of wood-based building materials can be achieved without increasing levels of harvesting, climate benefits can be gained even in the short term compared to the current situation.

4.3 Type and origin of materials

The type of material contents and origin of materials are outlined in accordance with the draft for the Decree of building material report (YM 2022b). The used data structure is as follows (Table 5).

[3] " Member States shall also address carbon removals associated to carbon storage in or on buildings" as sated in Article 7 in Proposal for a directive of the European Parliament and of the Council on the energy performance of buildings (recast).

Table 5. Type and origin of materials

Indicator	Unit
Origin of materials	
Share of renewable materials	%(a
Share on non-renewable materials	%
Share of reused products	%
Share of recycled materials	%
Share of substances of very high concern (SVHC)	%
Type of materials	
concrete, brick, ceramic material, natural stone	%
wood, natural fibre	%
glass	%
plastics, rubber	%
bitumen, bituminous mix	%
metal	%
heat insulation material	%
machine, appliance	%
other	%
soil and aggregate	%
planted tree	%

[a)] the percentages are expressed as mass-%

4.4 Waste factor and service life

The CO2DATA database gives a waste factor which represents the assessed typical amount of waste of products at building site. The factors are not based on statistical information but represent general understanding and were formulated with the help of discussions together with construction and manufacturing industry experts.

The waste factor is expressed with the help of the value that expresses the total need of the product considering the waste and the product itself (relative value with no unit, Table 6). However, regarding sawn and planed timber, the factor also covers waste at prefabrication site. This is because there are no separate GWP values for example for pre-cut timber products.

The waste factors are rough estimates and vary between 1.01 and 1.10. The value 1.01 is used for many supplementary and HVAC units. The value 1.03 is used for most of the metal products, GLT, vertical CLT, glass, most of the insulation products, precast concrete, some supplementary products, plumbing products, ducts, and pipes. Factor 1.05 is used for most of the mineral based products, building boards and floorings. Factor 1.1 is for water proofing, bitumen roofing, paints, plasters, geotextiles, ceramic tiles, and sawn timber.

Service life values consider the general service life information given in environmental declarations. The values are not based on statistical information but aim to represent general understanding. The values do not take into account different environmental or use conditions but refer to technical service life in relation to normal and short expectancy. The product-based data does not take into account service life values that are more than 50 years. This is because the draft for the decree that describes the assessment method to be used for the formulation of climate declarations applies the value 50 years for the service life of a building.

CO2DATA also provides a separate table for building-part specific service life values. Values are defined for site elements, building elements, internal space elements and building services. The building parts are structured and named in accordance with the Finnish TALO 2000 (Rakennustieto 2000) construction classification system. The service life assumptions do not extend beyond 50 years but in the case of expected long service life this marked as ReqSLB = Required Service Life of Building. The service life assumptions consider typical service life data according to EU Level(s) (JRC 2020) and aim to represent typical values divided to two classes: short expectancy and normal expectancy.

Table 6. Service life and waste factor units

Indicator	Unit
Service life (if ≤ 50 years)	years
Waste factor	-

5 Data collection procedures and sources of data

5.1 Introduction

The types of different building products included in the CO2DATA were selected and defined to cover a major share of all materials and products used in different building parts and to represent a major share of the carbon footprint of a building.

The naming of the selected products was made utilising the terms used in harmonised standards (EU 2011) and TALO 2000 classification system (Rakennustieto 2000).

The selected terms and outlines were discussed together with representatives of building industry.

The global warming values and the values of other indicators are based on publicly available information, in practice mostly on relevant environmental product declarations. When assessing the relevance of information, the following order of importance was considered:

- domestic results – as the domesticity rate of building is usually high
- Nordic results – as manufacturing processes, methods and markets are often similar although the energy sources for electricity differ
- results from countries that export building products to Finland as some products – like for instance -MDF and OSB boards – are not manufactured in Finland
- generic results in foreign databases – as those represent average values.

The results were searched especially from databases such as:

- RTS EPD (Rakennustieto 2022)
- EPD Norway (2022)
- Environdec (2022)
- ÖkobauDat (2022)
- IBU (2022)
- ICE (2022).

The main sources of information were environmental product declarations (EPDs) based on the European standard EN 15804 *Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction* (2019).

At present the EPDs published in different databases can be based on either of the two versions of the standard. EN 15804:2012+A1:2013 says[4] that that the global warming potential (GWP) shall be calculated based on Global Warming Potential for a 100-year time horizon as in IPCC: Climate Change 2007[5] (AR4). However, the current version of EN 15804 + A2 2019 refers[6] to the IPCC 2013 (AR5). The GWP values for 100-year time horizon for greenhouse gases are somewhat different in accordance with AR4 and AR5 as presented in the following table for carbon dioxide, methane, and nitrogen oxide. At this stage there are still many EPDs available that follow the previous version. The difference in the calculation of the GWP values (see e.g. Table 7) was ignored. However, more attention should be paid to this issue, when the CO2DATA will be updated.

[4] Annex C Normative. Table C.8 Sources for life-cycle impact assessment (LCIA) models

[5] The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment

[6] Annex C. Normative. Table C1

Table 7. Example of difference in the calculation of GWP values based on AR4 and AR5

Chemical formula	GWP values for 100-year time horizon	
	AR4	AR5
CO_2	1	1
CH_4	25	28
N_2O	298	265

In addition to environmental product declarations, the generic environmental reports published by associations representing different industries on European or international level were used as sources of information. Thus, for example reports and the data by the following organisations were made use of:

- Plastics Europe (2022)
- European Aluminium (2021)
- Copper Alliance (2022)
- LVL Handbook (2020).

The results were also compared to the former databases collected by VTT (published in the connection of different research reports and by Green Building Council). An essential point of comparison was the database collected by IVL and published by Boverket (2022) (Climate database from Boverket).

5.2 Building products and installations

GWP data for building products in CO2DATA database covers the phases A1 – A3 (extraction of raw materials, transportation, and manufacturing) and C3 or B4 (waste management) in accordance with EN 15804 (2019). In addition, the database provides estimates for potential benefits (D). The database also defines a default value for material loss at building site. The overall need of material is calculated with the help of this factor.

The following working process was carried out for most of the building products (Table 8).

Table 8. Working process in the formulation of data for building products

	Steps of the working process
I	Search for data from different databases and other sources.
II	Comparison of data from different sources.
III	Assessing the relevance of data from different sources paying attention to the degree of domestic manufacturing and market shares.
IV	Selection of data assessed as most relevant, or calculation of average values based on different relevant sources.
V	In few cases, modification of values with the help of defined assumptions to improve the relevance of values (An example of the modification, is the application of Swedish data for crushed aggregate and the modification of results based on different energy sources).
VI	Definition of types of the product when relevant from the viewpoint environmental impacts. An example is the division of plywood into product the following types: uncoated birch plywood, coated birch plywood, uncoated spruce plywood, and coated spruce plywood.
VII	Defining all indicator values based on searched information for the product types.
VIII	Writing a background report that lists the standard(s) and classification, shortly describes the product and current market, presents the collected information, and explains the selections made.
IX	Contacting representatives of manufacturers to hear their comments.
X	Formulating the final version of the background report and providing the data for the database.

The formulation of environmental data for heating, ventilation, and air conditioning (HVAC) related products, for electrical installations and for supplementary products was based on rough modelling. The main steps of the process are presented in Table 9. The GWP data is typically given in terms of kg CO_2e per unit together with the weight value.

The formulation of typical data for all products of this group is difficult. The main reasons for the difficulty are:

1. The lack of environmental product declarations.
2. The lack of such grouping and naming system that supports reasonable approach in the consideration and assessment of GWP of HVAC[7] and electrical products. The number of items in classification systems (such as LVI2010 and S2010) is very high but many of the products are insignificant from the viewpoint of weight and GWP impact on the building level.

When relevant EPDs were not available to be used as data sources, the following rough modelling process was followed (Tale 9).

Table 9. Modelling process for the establishment of typical GWP values for HVAC products, electrical installations, and supplementary products

	Process steps
I	Selection of the product types to be modelled based on their assessed significance from the viewpoint of weight and volume of use in buildings.
II	Identifying the typical composition and typically used materials of the selected product types. Modelling the product "recipe".
III	Roughly assessing the use of energy in manufacturing process and other issues that might significantly affect the GWP of the product under scrutiny.
IV	Calculating the GWP of the modelled products based on the defined composition and the GWP values of corresponding materials. These are in most cases steel, other metals, and plastics. The GWP values of these materials were mainly based on CO2DATA database.
V	Writing background reports for all product types. The report shortly describes the modelled product, market in the Finnish construction (when information was available), presents one or few examples of GWP and other environmental values for similar types of products based on EPDs (if available), and defines the proposed values for the CO2DATA database.

5.2.1 Raw materials and manufacturing (A1 – A3)

The GWP values for the phases A1 – A3 (as defined in Table 2) were always defined for each product covering fossil and biogenic emissions. GWP (luluc) values were not considered as explained in Section 4.1.

In most cases, the availability of applicable data was rather good. There were some difficulties in defining the GWP(A1 – A3) values for wooden products when the available EPDs were written without making a difference between fossil and biogenic GWP. In few cases the comparison of GWP values between similar types of products raised doubts about the correctness of results and led to the exclusion of some results otherwise seen relevant.

An ideal approach for calculating the typical value would be to calculate the average value of different products in the market considering the market shares. However, this is not possible because of the lack of data. In practice, all available EPDs for each product type in the Finnish market were considered. In addition, relevant other product specific data, as given in EPDs, and generic data, as defined in generic databases, were collected. Relevant generic databases include for example the Swedish Boverket's Klimatdatabas (Boverket 2022) and German Ökobaudat (2022). In most cases it was possible to define the GWP values with the help of adequately representative Finnish data. However, the overall collected data formulated an important material with the help of which the credibility of the values could be assessed.

GWP values of building products formulate the main part of the CO2DATA database. Due to the large amount of data collected for the definition of GWP values regarding the modules A1 – A3, the selected values as well the references (mainly EPDs) are given in separate background reports available on the CO2DATA (2022).

[7] HVAC heating, ventilation, and air conditioning

5.2.2 Waste management (C3 and B4)

The European standard EN 15643 (2021) defines secondary materials as materials recovered from previous use or from waste which substitute primary materials. Examples for secondary materials (to be measured at the system boundary) are recycled metal, crushed concrete, glass cullet, recycled wood, and recycled plastic granulates. On the other hand, waste is defined as a substance or object which the holder discards or intends or is required to discard. The following four criteria are defined for the end-of-waste (EN 15804. 2019):

- used for specific purposes
- a market or demand exists
- lawful and specific requirements
- fulfills limit values for SVHC.

If the material is waste, it is disposed of in a landfill or by burning. Backfilling is defined as a recovery operation where suitable non-hazardous waste is used for purposes of reclamation in excavated areas or for engineering purposes in landscaping. Non-hazardous waste used for backfilling substitutes non-waste materials, is suitable for the afore-mentioned purposes, and is limited to the amount strictly necessary to achieve those purposes (EN 15643. 2021).

Waste processing may partly happen already at demolition site. The environmental impact of waste processing depends on the type and quantity of demolition waste and on the aimed use of the processed waste. The effect of the aimed use purpose of the material on the emissions in C3 phase can be significant; thus, the definition of a representative values for typical C3 data is somewhat problematic.

Regarding multi-storey buildings, the main share of emissions in C3 phase comes from crushing and possible pulverizing of concrete, which is the main building material of these buildings.

The typical GWP values for phase C3 were not defined product-specifically but for the same groups of materials as listed in the proposed regulation on material reports (YM 2022c):

1. concrete, brick, ceramic, and natural stone materials
2. wood and materials based on natural fibres
3. glass
4. plastics and rubber
5. metals
6. heat insulation materials
7. gypsum
8. machinery and equipment
9. other materials
10. soil materials
11. planted trees.

However, regarding:

- groups 1 and 7, a separate value was defined for concrete and all other mineral materials
- groups 4, 6, and 9, a common value was defined
- groups 5 and 8, a common value was defined
- group 10, the value zero (0) was selected for use, and
- for group 11, no value was defined.

Typical values were defined mainly with the help of environmental product declarations.

Concrete

In accordance with (Elementtisuunnittelu 2020) crushed concrete can be used either as crushed stone in road construction or in the production of new concrete. If crushed concrete is used in the manufacture of concrete up to about 20 percentage of the total amount of aggregate, the properties of the concrete will remain almost the same as in concrete made with normal aggregates. However, the largest area of use for crushed waste concrete is in earth construction as filling in the construction of roads, streets, and courtyards and parking areas. There are more than 20 collection points for waste concrete in different parts of Finland. The Government Decree on the Utilization of Certain Wastes in Civil Engineering (VN 2017) allows the use of crushed concrete through a notification procedure without an environmental permit. Quality assurance has been arranged for the concrete crushed stone, in which the concentration and solubility of possible harmful substances in the environment are examined periodically.

Crushing is in practice the only option for the processing of ready mixed concrete structures for recycling. Regarding concrete elements, also the use elements would be possible in theory but is very rare in practice. However, there are experiences in other countries, for example in Germany (Mäkelä 2013).

The GPW values for C3 of concrete products was selected as an average value (0.006 kg CO_2e/kg) based on relevant collected EPDs (Table 10):

Table 10. GPW values for concrete products in C3 in accordance with EPDs and German generic values

Product type	GWP(C3) kg CO_2e/kg	Source of data
Concrete column	0.002	RTSEPD 30-19 / (Rakennustieto 2022)
Hollow core slab	0.006	RTSEPD 28-19 / (Rakennustieto 2022)
Prefabricated reinforced massive wall	0.0074	NEPD-2062-930 / (EPD Norge 2022a)
Prefabricated reinforced massive slab	0.0076	NEPD-2062-930 / (EPD Norge 2022a)
Prefabricated reinforced balcony	0.0076	NEPD-2062-930 / (EPD Norge 2022a)
Precast slab	0.007	Precast slab (20cm; 504 kg/m^2) / (Ökobaudat 2022)
Precast wall	0.007	Precast wall (12cm; 291.3 kg/m^2) / (Ökobaudat 2022)
Ready mixed concrete (C30/37)	0.007	Ready mixed concrete (C30/37) / (Ökobaudat 2022)

Timber and engineered wood products

The waste processing scenario for timber and engineer products is chipping. According to the RTS EPD for CLT, wood materials finally typically end up incinerated (99 percentage). Emissions values for waste management of timber and engineered wood products are based on data collected from environmental product declarations. Table 11 summarises the converted data (per kg instead of declared unit) and considering the release of carbon in wood in module C3 in accordance with EN 15804 (2019)). When specified to two decimal places, the values vary between 0.01 and 0.04. The variation is big, but the values are small compared to GWP(A1 – A3)(fossil). The average value 0.02 was selected for CO2DATA as representative typical value.

Table 11. GPW values for wooden products in C3 in accordance with EPDs and German generic values

Product type	GWP (C3) fossil kg CO_2e/kg	Source of data
Sawn and planed timber	0.005	RTS EPD-124-21 (Rakennustieto 2022)
CLT	0.027	RTS EPD-110-21 (Rakennustieto 2022)
Cross laminated timber	0.0087	Environdec (2022b)
Wooden cladding	0.0090	NEPD 1691 (EPD Norway 2022)
Glued laminated timber structure	0.0250	NEPD 1576 (EPD Norway 2022)
Cross laminated timber system	0.0360	NEPD 1269 (EPD Norway 2022)

Steel and other metals

Steel scrap is assumed to reach the end-of-waste status once it is shredded and sorted, thus becomes input to the product system in the inventory. Emissions values for waste management of steel are based on data collected from environmental product declarations. Table 12 summarises Nordic EPDs published for steel structures for C3 phase:

Table 12. GPW values for steel products for module C3 in accordance with relevant EPDs

Product	GWP(C3) kg CO_2e/kg	Source of data
Prefabricated steel structure, Sweden	0.0010	NEPD-1928-851(EPD Norway 2022)
Load bearing steel structures, Finland	0.0600	NEPD 1905-832 (EPD Norway)
Steel beams, Norway	0.0002	NEPD-2409-1210 (EPD Norway 2022)
Steel structures, Finland	0.0024	RTS EPD 67-20 (Rakennustieto 2022)
Steel structures, Finland	0.0028	RTS EPD Nro 9 (Rakennustieto 2022)

The values vary very much. If the lowest and highest values are excluded, the average is 0.002 kg CO_2e/kg. The building-scale impact is rather low as also the share of metals in demolition waste is typically low.

Bricks, gypsum, and other mineral products

Relevant Finnish and German sources give the following values for the C3 module (Table 2) of bricks:

Table 13. GPW values for mineral products in C3 in accordance with EPDs and German generic values

Product	GWP(C3) kg CO_2e/kg	Other information	Source of data
Light and red brick, Finland	0.00496	58% collected with mixed construction waste, 42% separately for recycling	RTS EPD 46-19 and 47-19 (Rakennustieto 2022)
Clay-based facing bricks, Germany	0.00734	Represent the country specific situation in Germany, focusing on the main technologies.	Facing brick 2018 (ÖkobauDat 2022)
Clay-based bricks, Germany	0.000263	For recycling	EPD-ZWM-20160126-ICG1-EN (IBU 2022)
Clay-based bricks, Germany	0	For landfilling	EPD-ZWM-20160126-ICG1-EN (IBU 2022)
Lime sand bricks, Finland	0.00031	For material recycling	NEPD-2831 (EPD Norway 2022)
Lime sand bricks, Germany	0.00627	Country specific values focusing on main technologies	Sand-lime brick, 2018 (ÖkobauDat 2022)
Gypsum boards, Finland	0.00397	Average of four types of boards, recycling scenario	ECO EPD 00001313 (EnvirondecC 2022)
Gypsum boards, Sweden	0.00017	85% landfilled and 15% recycled	S-P-00388 (Environdec 2022)

Based on the collected results, emission value 0.005 kg CO_2e/kg was selected as a conservative value to represent all mineral materials except concrete.

Glass

Euroglas (2017) reports the value 0.017 kg CO_2e/kg for C3 module for flat glass, toughened glass and laminated safety glass based on the assumption that 70 percentage of glass is landfilled, and 30 percentage recycled. Ökobaudat (2022) (Insulated glazing, double pane; double glass, 2018) presents the value 0.074 kg CO_2e/kg for C3 module for insulation glass unit. The result represents the country specific situation in Germany focusing on the main technologies. In Finland, RTS EPD 36–19 (Rakennustieto 2022) gives the value 0.018 kg CO_2e/kg for C3 for wood framed window unit with aluminium cladding (share of glass

56.5%), (37% for material recycling, 21% for energy use, and 42% for final disposal). A Norwegian manufacturer reports the GWP value 0.033 kg CO_2e/kg for C3 phase for wood framed window without aluminium cladding (share of glass 80%) (NEPD-2996 of the source EPD Norway 2022).

The GWP value 0.02 kg CO_2e/kg was selected for C3 in accordance with the Finnish EPD for windows. All collected values are roughly of the same order of magnitude.

Plastics

In accordance with Finnfoam (2021), all PIR polyurethane insulation boards can be assumed to be recycled as it is easy to collect and to be qualified for recycling. The given values for module C3 phase for three PIR products are 0.619, 0.618 and 0.624 kg CO_2e/kg. In each case, polyurethane is the main material of the product. ÖkobauDat (2022) (PIR high-density foam) presents the result 2.6 kg CO_2e/kg for waste processing (C3) of PIR high-density foam without information about the scenario. The result represents the country specific situation in Germany. German EPDs of the source (IBU 2022) also define the following values: C4 value 2.0 kg CO_2e/kg for energy recovery scenario for PIR insulation boards and the value 2.1 kg CO_2e/kg for energy recovery scenario for PU thermal insulation boards with 50 µm aluminium facing (EPD-UNI-20140123-IBA1-EN (valid to 2019) and EPD-UNI-20140123-IBA1-EN).

Table 14 lists emission values for C3 and C4 modules for EPS insulation boards.

Table 14. GPW values for EPS products in C3/C4 module in accordance with EPDs

Product	Emission (kg CO_2e/kg)	Source
EPS, Finland	2.4 (C3) for energy recovery scenario	RTS EPD 19-1-2017 (Rakennustieto 2022)
EPS, Norway	1.88 (C3), 50% energy recovery and 50% recycled	NEPD 1236-244 (EPD Norway 2022)
EPS, Germany for walls and with the density of 18 kg/m³	3.3 (C3) for energy recovery scenario	EPS-Hartschaum, Styropor (Ökobaudat 2022)
EPS density 15 kg/m³	0.725 (C3) for recycling scenario and 3.37 (C4) for energy recovery scenario	EPD-EUM-20160273-IBG1-EN ECO, EPD-EUM-20160272-IBG1-EN (IBU 2022)
EPS density 20 kg/m³ (region Scandinavia)	0.07(C3) for landfilling scenario and 3.45 (C3) for energy recovery scenario	
EPS density 30 kg/m³	0.725 (C3) for recycling scenario and 3.37 (C4) for energy recovery scenario	

The EPD by The European Plastics Pipes and Fittings Association (TEPPFA 2018) presents the average end-of-life GWP value 0.07 kg CO_2e/kg for PVC pipes based on the scenario that 80 percentage goes for landfilling, 15 percentage for incineration, and 5 percentage for mechanical recycling. Correspondingly TEPPFA defines for PP pipes that the GWP for end-of-life is 0.02 if 80 percentage is left in ground, 15 percentage for incineration, and 5 percentage for mechanical recycling. ÖkobauDat (2022) presents the following values for C3 for polymer-based pipes (representing the country specific situation in Germany):

- PP pipes 3.22 kg CO_2/kg (Polypropylene pipe; PP)
- PEX water pipes 3.77 kg CO_2e/kg (Drinking water pipe PE-X; PE-X)
- Polybutadiene pipes 3.22 kg CO_2/kg (Polybutadiene pipe; PB)
- PVC rain drainpipes 3.01 kg CO_2/kg (Rain drainpipe PVC; PVC pipe).

The scenario-based study by Kinnunen and Kupiainen (2019) assessed the emission related to two different waste processing scenarios for plastics. Regarding the incineration scenario, the assessed emissions were 1.9 kg CO_2e/kg or 2.0 kg CO_2e/kg (two cases), and regarding the recycling scenario the assessed emissions were 1.32 kg CO_2e/kg (both cases). In accordance with Punkkinen et al. (2011)[8] (53), the GWP of incineration of mixed plastics waste is 2.2 CO_2e kg/kg.

Based on the collected data, the selected rounded average GWP values for waste processing for polymer-based insulation boards and pipes are:

- 3.0 kg CO_2/kg for energy recovery scenario
- 0.7 kg CO_2/kg for recycling scenario.

The same value is selected also for bitumen roofings regarding the recycling scenario. For example, Katepal (2022) gives GWP values for C3 module for bitumen roofings that are somewhat smaller but of the same order of magnitude, namely 0.4 kg CO_2e/kg.

Summary of selected values

The following values were selected as representative for waste processing in phase C3 for different material types:

- concrete materials 0.006 kgCO_2e/kg (mainly because of crushing)
- bricks, gypsum, lime sand bricks (and other mineral materials excluding concrete) 0.005 kgCO_2e/kg (mainly because of crushing)
- glass 0.02 kg CO_2e/kg
- wooden materials (not impregnated) 0.02 kg CO_2e/kg
- metals 0.002 kg CO_2/kg
- plastics 3.0 kg CO_2e/kg for energy recovery scenario
- plastics 0.7 kg CO_2e/kg and bitumen roofings for recycling scenario.

The calculation method on building scale is to assess the amount of demolition waste divided to the above-mentioned groups and calculate the building scale value with using the typical values for these groups.

Material waste also occurs in building construction phase. However, the emission values for A5 module do not include waste processing. Estimated at the level of the entire building, the significance of waste processing in A5 module is small compared to waste processing after demolition, because the loss of materials is few percentages of used materials in construction phase but the waste processing after deconstruction applies to the entire amount of materials in the building.

5.2.3 Potential benefits (D module)

A conservative approach was applied for the assessment of potential benefits. The applied typical scenario for wood products is energy recovery and for mineral products landfilling. In the case of landfilling and other similar (low-value) recycling methods, the potential benefit is considered zero. This scenario was applied for all mineral products. The applied typical scenario for metal-based products is recycling. For plastics both energy recovery and recycling scenarios were considered.

The chosen (typical) end-of-life scenario for wood and engineered wood products is energy recovery. The saved emissions were assessed by using the value 12 MJ/kg as effective (lower) heat value in operating mode in accordance with Fuel classification 2022[9]. The saved emissions are calculated assuming an efficiency of 80 percentage and by using the assumed emission values for district heat after 50 years as presented in CO2DATA.fi (emission value 0.021 kg CO_2e/kWh):

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[8] The report assesses the emissions from the incineration of wood and plastic waste. The assessed quantity is 83 340 t/a of which 42 590 t/a plastics and 40 750 t/a wood. As a result of the burning of plastic and wood, an estimated 122 700 t/a of CO_2 is released from the boiler of which 29 900 t/a is bio-based and therefore not considered. Thus, the emission from plastics equals (122700-29900)/43590, i.e. 2.2 kg/kg (page 41 in the report).

[9] Polttoaineluokitus 2022. Tilastokeskus. stat.fi/tup/khkinv/khkaasut_polttoaineluokitus.html

$$0.8 * 12\ MJ/kg * 0.27778\ kWh/MJ * 0.021\ kg\ CO_2e/kWh = 0.06\ kg\ CO_2e \qquad (Eq.\ 1)$$

Steel scrap is assumed to reach the end-of-waste status once it is shredded and sorted, thus becomes input to the product system in the inventory. A credit is given for the net scrap that is produced at the end of a final products life. This net scrap is determined as follows:

$$\text{Net scrap} = \text{Amount of steel recycled at end-of-life} - \text{Scrap input} \qquad (Eq.\ 2)$$

For example, the EPDs published by SSAB (such as RTS_48_20, Rakennustieto 2022), the impact of recycling is calculated using World Steel Association's (2017) method. The compensation is calculated as the difference between the primary and secondary production of a steel perceived with the acquisition of the recycling process. In addition, the ratio of the need of recycled steel to produce 1 kg of steel in secondary production is considered as well as the use of scrap steel in steel production. If the recycling rate is 0.9, the need of scrap is assumed to be 1.1 in relation to the amount of steel produced, by assuming no scrap use in primary production, and by using emission values 2.5 and 0.9 kg CO_2e/kg for primary and scrap-based steel in accordance with Boverket (2022), the benefit beyond the life cycle becomes -1.3 kg CO_2e/kg.

Correspondingly, we can calculate the potential benefit for aluminium (-3.5 kg CO_2e/kg) by using emission values 6.0 and 1.7 kg CO_2e/kg for products based on virgin raw materials or scrap, and for copper (-3 kg CO_2e/kg) by using emission values 4.0 and 0.5 kg CO_2e/kg (CO2DATA).

The current recycling rate of plastics from building demolition waste is roughly 25 percent (EURIC 2020). Most of the types of plastics used in buildings are recyclable in principle but there are difficulties in collection, separation, and management. For example, recycling of PVC is limited due to the presence of additives. EPS is generally recyclable, but its low density makes is difficult to process through conventional recycling processes. The assumption used in the calculation of GWP benefits in module D in published EPDs vary very much. Typically, the assumed benefits for PVC pipes are zero or close to zero (EPD Norway 2022). The EPDs by Uponor present that the GWP benefit in D module for PP-based pipes is less than 5 percentage compared to impacts in A1 module (Rakennustieto 2022). However, for example the EPD by Pipelife (2022) presents that the benefit of PP pipes in D module because of recycling and incineration is 64 percentage compared to A1 emissions. Finnfoam presents that the D phase benefits regarding EPS are based on energy recovery and regarding PIR on recycling. In the latter case, GWP benefit in D module is almost 80 percentage compared to GWP impact in A1 module.

In conclusion, the recycling of plastics from building demolition waste is still low, and the benefits of recycling are often thus excluded in the EPDs of plastic building products. If the benefit is assessed only on the basis of incineration, a similar approach needs to be used as regarding wood products. By assuming an efficiency of 80 percentage, LHV of 42 MJ/kg, and by using the assumed emission values for district heat after 50 years as presented in CO2data.fi (emission value 0.021 kg CO_2e/kWh):

$$0.8 * 42\ MJ/kg * 0.27778\ kWh/MJ * 0.021\ kg\ CO_2e/kWh = 0.20\ kg\ CO_2e \qquad (Eq.\ 3)$$

The recycling potential of bitumen roofings can be assessed to be rather good. Recycled bitumen roofing can be used as direct replacement for virgin bitumen in asphalt. Potential savings have been assessed to be roughly 0.2 kg CO_2e/kg (Katepal 2022). The value 0.1 kg CO_2e/kg was selected assuming that half of deconstruction waste is recycled in asphalt.

Carbonation of concrete is a natural chemical reaction by which CO_2 in the ambient air penetrates the concrete and reacts with hydration products in the concrete. Thus, part of the carbon dioxide emitted during cement production is rebound to the concrete during use and end of life stages. However, according to the proposed regulation (YM 2022b) the consideration of the carbonation is limited to the reaction that happens during a maximum of one hundred years period after the cement-based building material is removed from use (2 §). In addition, the evaluation of the carbon handprint of carbonation must be based on the same types of cement that have been used in the evaluation of the carbon footprint. The standard says EN 5676 (2017) (Annex BB) that although pozzolanic binders and latent hydraulic binders could contain reactive CaO, the calculation of uptake of CO_2 should only consider the materials that have allocated emissions. The standard EN 16757 (2017) provides a method to assess the CO_2 absorbed through carbonation of concrete. Based on the general principles presented in the informative Annes, significant carbon uptake could happen in C phase after crushing in favorable conditions due the influence of CO_2 in the ambient air. However, when used in new concrete products as aggregate materials, the phenomenon proceeds very slowly, and its share of the overall possible carbon uptake is small. The same is probably true, when crushed concrete is utilized in landfilling (in land restoration). According to the standard, in Module D, carbonation may be taken into account up to the point of functional equivalence.

The typical value presented in the CO2DATA database, is calculated assuming that the proportion of lime exposed to carbonation in the cement-based material (out of the total amount of lime) could be in maximum 50 percentage considering that a significant share of maximum carbonation has already taken place during B and C phases and considering the maximum time period 100 years in D phase. Also, by using the weight 2400 kg/m3 for concrete, a kind of maximum value 400 kg/m3 for cement content, assuming a 65% CaO content in cement, and using the mole ratio 44/56=0,786 for CO2 and CaO, the following upper value was calculated:

$$0.786 \text{ kg } CO_2e/kg * 0.65 * (400 \text{ kg} /2400 \text{ kg}) * 0{,}5 = 0.043 \text{ kg } CO_2e/kg \qquad \text{(Eq. 4)}$$

The lowest value could - on the other hand - be zero or almost zero in earth conditions, where the penetration of air would be almost negligible, and when cement content is low, and carbonation has already taken place during earlier phases.

A value in the middle of these two values was chosen as the typical value for the database for all concrete types.

The typical emission values for concrete products in the database do not consider carbonation although EN 16757 (2017) presents that when the CO_2 uptake due to the carbonation of concrete is taken into account, it shall be included in the respective modules in which it occurs. Thus, the emission values of concrete products may need to be modified, if the same approach was also included in the later/final version of the climate declaration.

Summary of selected D module values

The following values were selected as representative for potential benefits because of landfilling, recycling, energy recovery, carbon storage, or carbonation:

- concrete, other mineral materials, and glass: 0 kgCO_2e/kg (landfilling)
- concrete: -0.022 kg CO_2e/kg (carbonation in D module)
- wooden products: -0.060 kg CO_2e/kg (energy recovery)
- wood: -1.6 kg CO_2e/kg (carbon storage)
- steel: -1.3 kg CO_2e/kg (recycling)
- aluminium: -3.5 CO_2e/kg (recycling)
- copper: -3.0 kg CO_2e/kg (recycling)
- plastics: -0.20 kg CO_2e/kg (energy recovery)
- bitumen roofing -0.10 kg CO_2e/kg (recycling).

Discussion

As explained in chapter 8 of this report, the emission values of district heating and electricity are assumed to decrease rapidly within the next 50 years. The CO2DATA database provides both current average emission values and gradually decreasing emission values for the next decades. This decarbonization of energy services is taken into account in the building's emission calculation in accordance with the draft regulation (YM 2022b). On the other hand, no similar scenarios have been made regarding the emission development of product manufacturing. This causes an apparent problem for the calculation of the potential savings beyond the life cycle.

Because of different approaches, the potential greenhouse gas savings due to recycling become significant while those from energy recovery are very small. The approach favors especially steel and other metals. The current emission when manufacturing metal products from virgin-based raw materials are high and the difference compared to recycling-based manufacturing is big. The recycling practices also exist, and the recycling rates are very high. Thus, recycling needs to be considered also when using a conservative approach.

The purpose of the assessment of climate impacts is to support low carbon future. Naturally also, the rules of assessment should support this goal. The life-cycle methodology ensures the consideration of all phases but at the same time the focus needs to be on today's emissions because of the urgency of the climate measures.

The methodology should reflect the reality correctly, but it should also support decision making toward low-carbon choices. The consideration of decarbonation of energy probably describes the future well. However, this approach provides less support to efforts toward zero-energy building. The consideration of decarbonation in manufacturing industry would also probably describe the future well, but – correspondingly - it would create less pressure for the industry to hasten the implementation of solutions for low-carbon industry.

Because of this dilemma, the suitability of GWP (fossil) indicator to describe potential benefits is questionable. It is important to be able to assess and consider the future benefits and problems of different selections, but it is not reasonable to make these comparisons with the help of an indicator that deals with emissions that should be almost zero after 50 years from this day. Although the current measures – including limit values for buildings' emissions – will hopefully be able to end GWP (fossil) emissions, there will very probably be shortage of available material and energy resources.

Although GWP (fossil) is the key indicator just now, the role and significance of other key indicators should be discussed. Especially, the importance of indicators that describe the use of material and energy resources and also GWP(lulucf) and GWP(biogenic) need to be discussed.

6 GWP data for building services systems

The database also includes information for selected building services systems.

The main steps of the working process were as follows:

- collection of information of the bill of quantities with the help of reference projects,
- selection and defining the building services systems to be considered,
- investigation to define typical quantities and product types in different systems separately for different kinds of buildings when relevant, and
- use of product level data to define GWP values for systems.

GWP data is be given in terms of kg CO_2e/m^2.

The selection of the systems and assessment of the bills of quantities and finally the calculation of the results with the help of product-based values included in the CO2DATA were carried out at Sweco design and consulting office (Sweco 2021).

The assessment of bill of quantities (BOQ) of heating, water and sewage and ventilation systems was mainly based on the IFC models of these systems. In addition, lists of equipment were made use of. The BOQ based data was changed to mass-based data with the help of manufacturers' product information. Such components that are modelled only as space reservations as for example heat pumps were not taken into account. Small components like meters, water pumps, shower basins, and cabinets were also excluded (Sweco 2021).

Regarding electrical systems, the quantities were assessed with the help of building designs. Small components like socket centres were not considered. The electric heating systems were minor or those were not used at all in the reference cases (Sweco 2021).

Emissions data from the CO2DATA database and EPDs were used to calculate the emissions on the basis of products' mass-based data.

The reference cases were two office buildings, two blocks of flats, one retail building and one hotel. The heating system in reference buildings was district heating except the retail building where it was air-water heat pump and electric boiler. The energy class was B in the reference office and residential buildings.

The renewal periods of products and installations were taken inti account. The use purpose of the building was considered when defining the typical periods of renewals.

More detailed information about the reference buildings, calculation principles and results is presented in the report (Sweco 2021).

The system specific results are given for different building types as presented in Table 15.

Table 15. Building types and life cycle modules considered in the determination of emission values for building services systems.

Building type	Life cycle modules
Accommodation / hotel	A1 – A3 and B3 – B4
Apartment building	A1 – A3 and B3 – B4
Cooling system for apartment buildings	A1 – A3 and B3 – B4
Cooling system for educational buildings	A1 – A3 and B3 – B4
Educational building	A1 – A3 and B3 – B4
Fire extinguishing system, sprinkler (for apartment building)	A1 – A3 and B3 – B4
Office	A1 – A3 and B3 – B4
Other retail building	A1 – A3 and B3 – B4
Shopping centre	A1 – A3 and B3 – B4

The emission values of modules A and B for seven building types, classified according to purpose of use, are presented in the CO2DATA database.

7 GWP data for construction and demolition

7.1 Construction (A5 module)

The typical emission values for construction services of different kinds of buildings was developed with the help of information collected from research studies based on real construction cases. However, the number of relevant studies is quite small and most of the available studies focus only on residential buildings.

The main steps of working were as follows (Table 16). Table 17 presents the considered case studies and the assessed emissions because of construction in each case.

Table 16. Main process steps in defining typical values for construction services

	Process steps
I	Searching research reports and other sources that report information about the use of energy in different phases of construction process regarding different types of buildings.
II	Collecting, calculating, and comparing data.
III3	Selecting the values interpreted most relevant representing typical values.
IV4	Calculating the results in terms of kg CO_2e/m^2 for different building types.

Table 17. Emissions caused by building construction according to different case studies

	Source	Building data	Emission kg CO_2e/m^2	Remarks
1	Hämäläinen (2012)	Block of flats, concrete building Location Tampere Volume 22500 m^3 Area Gross 6467 m^2 Area Net 5830 m^2	31	Emissions calculated based on energy consumption * (covering framework and inner work phases) Excluding earth work
2	Hämäläinen (2012)	Block of flats, concrete building Location Tampere Volume 14161 m^3 Area Gross 3797 m^2 Area Net 3417 m^2	43	Emissions calculated based on energy consumption* (covering framework and inner work phases) Excluding earth work
3	Pöyry et al. (2015)	Block of flats, concrete building Location Tampere Volume 9645 m^3 Area Gross 3085 m^2 Area Net 2777 m^2	41	Emissions data based on the reported values Excluding site clearing, excavation and construction of the outdoor area.
4	Ahola and Liljeström (2015)	Block of flats, concrete building Location Vantaa Volume - Area Gross 8830 m^2 Area Net 8029 m^2	46	Emissions data based on the reported values Earth work included
5	Ahola and Liljeström (2015)	Block of flats, concrete building Location Vantaa Volume - Area Gross 6224 m^2 Area Net 5670 m^2	63	Emissions data based on the reported values Earth work included

	Source	Building data	Emission kg CO_2e/m^2	Remarks
6	Ahola and Liljeström (2015)	Block of flats, concrete building Location Vantaa Volume - Area Gross 11675 m^2 Area Net 10697 m^2	55	Emissions data based on the reported values Earth work included
7	Ahola and Liljeström (2015)	Block of flats, concrete building Location Vantaa Volume - Area Gross 8842 m^2 Area Net 7553 m^2	47	Emissions data based on the reported values Earth work included
8	Rintamäki (2016)	Retail building, Building extension Location Tampere Volume - Area Gross 401 m^2 Area Net 361 m^2	20	Emissions calculated based on energy consumption*

*Emissions were calculated based on the following emission data:
Emission value for electricity: 139 g CO_2e/kWh.
Emission value for district heating: 149 g CO_2e/kWh.
Emission value for fossil fuels: 85 g CO_2e/MJ or 306 g CO_2e/kWh.

The values presented in Table 17 indicate significantly higher emissions than the Swedish results reported by Larsson et al. (2016). They present results of monitored electricity and district heat consumption during construction phase in five Swedish construction cases (Table 18). The corresponding average carbon footprint of these cases would be 17 kg CO_2e/m^2 by calculating with Finnish emission values for electricity and district heat.

Table 18. Energy consumption in 5 Swedish building cases in phase A5 as reported by Larsson et al. (2016)

	Case 1	Case 2	Case 3	Case 4	Case 5
Electricity kWh/net area m^2	90	53	56	77	135
District heat kWh/net area m^2	0	28	43	96	13
Total kWh/net area m^2	80	91	99	173	148

The seasonal timing of construction has a significant effect on heating and lighting needs on construction site (Heinänen 2016, Karhunen 2011). This may also partly explain the differences in the Finnish and Swedish case-specific results. In accordance with Heinänen (2016), the share of heating energy consumption is around 70 percentage of total energy consumption of construction work. Heating may be needed also in in the phases of earth work and foundations for melting of ice and snow and for accelerating the hardening of concrete. However, seasonal effect on energy consumption was not considered here, because of lack of sufficient data. Furthermore, construction usually occurs throughout the year encompassing all seasons as the duration of the construction of a multi-story building is typically around or more than 1 year.

According to the Finnish statistics (Tilastokeskus 2022), the ratio of building volume (m^3) to net area (m^2) in different building types is as follows (average of all buildings in years 2020 and 2021):

- blocks of flats (group 012) 3.6
- attached and detached buildings (group 011) 3.6
- commercial buildings (group 03) 6.0
- office buildings (group 04) 4.6
- traffic buildings (group 05) 5.0
- nursing buildings (group 06) 4.4
- public buildings (group 07) 7.9
- educational buildings (group 08) 4.9.

The ratio is in average 1.5 times bigger in other buildings compared to residential buildings. Because of the significant share of heating, room height affects the energy demand to some degree though not linearly. Here, the factor 1.2 was chosen to be used for construction-phase emissions for all other building compared to residential buildings.

There is lack of data also regarding the energy demand and emissions caused by earth work. Rintamäki (2016) gives an estimate of 0.4–0.8 l fuel per building cubic meter because of earthwork. When using the factor 3.6 as a ratio between volume and net building area, this corresponds to 1.4–2.9 l/m^2 (net area). By using the emission factor 3225 g CO_2e/l, the average emission value for earth work becomes 7 kg CO_2e/m^2.

The typical value for emissions in construction phase excluding earth work was calculated based on Table 17 cases 1–7. By assuming that the share of earth work in cases 4–7 is 7 kg CO_2e/m^2, the average excluding earth work becomes 43 kg CO_2e/m^2.

In addition, the emission value of 0.039 kg CO_2e/kg stabilizer was selected for general column and mass-stabilization work (based on information by Sirje Vares, VTT, calculated in the context of Malmi airport environmental analysis).

Alternatively, the energy consumption and related emissions at construction site can also be assessed more specifically, when relevant earlier information is available about the consumption of electricity, district heat and fuels. Emission values for electricity and district heat are given in Table 19, and more detail explanation is given in Section 8. Emission values for working machines in terms of fuel amount and working hours are also given in Table 19.

Table 19. Emissions values defined in terms of energy consumption and working hours of working machines

Description of the parameter	Emission value	Remarks and source of information
Electricity	0.153 g CO_2e/kWh	Section 8 of this report
District heat	0.147 g CO_2e/kWh	Section 8 of this report
Emission because of the use of working machines (in terms of fuel amount)	2673 g CO_2e/l	Average as defined by VTT (2021)
Emissions because of the procurement of fuels (in terms of fuel amount)	552 g CO_2e/l	As defined by JRC (2014) By using the following values: density 0.832 kg/k LHV 43.2 MJ/kg
Total emission because of the use of working machines and procurement of fuels (in terms of fuel amount)	3225 g CO_2e/l	
Emission because of the use of working machines (in terms of working hours)	Drivable diesel machines 21.3 CO_2e kg/h Main working machines (excavators, loaders, bulldozers): 26.4 kg CO_2e kg/h	Average as defined by VTT (2021)
Total emission because of the use of working machines and procurement of fuels (in terms of working hours)	Drivable diesel machines 27.2 kg CO_2e kg/h Main working machines (excavators, loaders, bulldozers) 32.6 kg CO_2e kg/h	

Table 20 and 21 summarize the defined grouping and selected emission values.

Table 20. GWP values for construction process at building site

Scope	GWP	Units	Remarks
A 5 residential building	43	kg CO_2e/m^2 (net)	Emission value per building area excluding earth work
A 5 other buildings	52	kg CO_2e/m^2 (net)	Emission value per building area excluding earth work
A 5 earth work	7	kg CO_2e/m^2 (net)	Emission value per building area
A 5 stabilization	0.04	kg CO_2e/kg stabilizer	General column and mass-stabilization when relevant Note, the value is given per the amount of stabilizer

Table 21. Alternative GWP values for construction process at building site when reliable predicted values are available about the consumption of electricity and district heat and use of working machines

Description of the parameter	Emission value
Electricity	0.153 kg CO_2e/kWh
District heat	0.147 kg CO_2e/kWh
Working machines (in terms of fuel amount)	3225 g CO_2e/l
Drivable working machines (in terms of working hours)	27.2 kg CO_2e kg/h
Main working machines (excavators, loaders, bulldozers) (in terms of working hours)	32.6 kg CO_2e kg/h

7.2 Demolition and waste management (C module)

The typical GWP values for building demolition were assessed with the help of research reports, data collection from few real deconstruction cases and few environmental product declarations. However, because of low availability of good-quality basic data, the quality of results is assessed to be inadequate and should be improved in the future with the help of more data and more accurate data.

The main steps of working were as follows.

Table 22. Main process steps in defining typical values for end-of-life services

	PROCESS STEPS
I	Searching research reports and other sources that report information about the use of energy in different phases of demolition (module C in accordance with EN 15804) regarding different types of buildings.
II	Collecting, calculating, and comparing data.
III	Defining the structure for the data and selecting the most relevant results representing typical values.

In accordance with EN 15804 (2019), the end-of-life phase consists of four modules, which are deconstruction (C1), transportation (C2), waste processing (C3), and final waste disposal (C4).

7.2.1 Deconstruction

Deconstruction phase is usually small in comparison to that of the production and assembly phases of products (Gustavsson et al. 2010). Gustavsson et al. (2010) estimate that the energy need for wooden building is 10 kWh/m^2. The case study by Bozdağ and Seçer (2008) also presents that the average energy consumption for demolition is 10 kWh/m^2. They investigate the life cycle of three buildings, which were 5, 6 or 10 storey residential buildings; the main building material was concrete. 10 kWh/m^2 equals to 3.2 kg CO_2e/m^2 calculated with the help of values for diesel fuel (Table 19). The theoretical study by Coelho and Brito (2012) proposes a value of 2.62 kg CO_2/m^2 for demolition. Vainio et al. (2018) estimate that emissions because of demolition are 10 kg CO_2/m^2. Vares (2020) have assessed the consumption of energy in the demolition of five storey concrete residential building in Finland. The assessment focused on the fuel consumption of working machines used for the demolition of the building frame. Based on the reported results for working hours and fuel consumption (in total 2 960 l for 5 700 m^3 building), the emission from mechanical demolition is 1.54 kg CO_2e/m^3. By using the ratios 3–4 for building volume and floor area, this makes 4.6–6.2 kg CO_2e/m^2.

The Finnish concrete element manufacturer Parma presents that a typical emission value for deconstruction is 0.0041 kg CO_2e/kg for concrete columns and 0.0100 kg CO_2e/kg for hollow core slabs (Rakennustieto 2022). By using the average of these values and assuming that the amount of concrete waste for a residential building is 1,000 kg/gross m^2 (based on Ruuska and Häkkinen 2013), we get the emission 7 kg CO_2e/m^2. This value should be close to but somewhat smaller compared to the building-scale value because the share of concrete of demolition waste is typically high. The value is close to the values based on literature and described above (same order of magnitude).

Delete Ltd has collected deconstruction emission values on the basis of recent demolition cases. The average emission value of 6 office buildings was 14.6 kg/m^2. However, the differences between cases are significant and the emissions are typically lower for bigger building sizes (Figure 1).

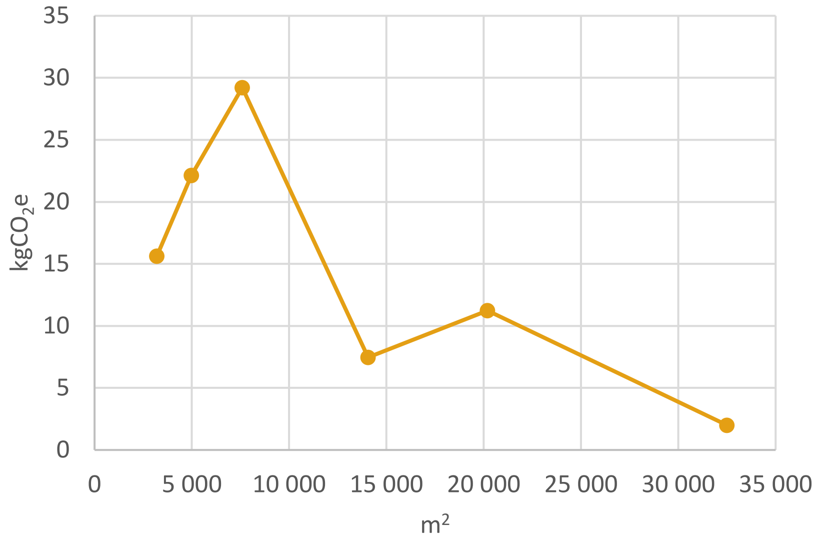

Figure 1. Carbon footprint (kg CO_2e/m^2) of demolition for 6 office building cases in relation to building size (m^2) (reported by Delete Ltd).

The energy consumption because of deconstruction depends on several issues including the type of the construction system and building material, number of floors and floor height. All collected emission values for the deconstruction phase are of the same order of magnitude (around 10 kg CO_2e/m^2). As the ratio between building volume and area is typically bigger in other building types than in residential buildings, the emission value may also be typically bigger for example for offices than for blocks of flats. However, there is lack of adequate data that would enable the formulation of justified specific values for different building types, and value 10 kg CO_2e/m^2 was selected for all building types.

7.2.2 Transportation

The GWP of phase C2 depends on the quantities of waste, transportation distances, load sizes, means of transportation and types of fuels. Demolition wastes are transported by lorries. The load sizes and load factors vary and those can be small for some waste fractions. The typical waste volume regarding residential concrete buildings is around 1 200 kg/m^2, and transportation distances roughly 50–100 km.

When the typical values of CO2DATA database is used for phase C2, the approach is:

1. to apply default values for emissions of transportation by lorry (given in the CO2DATA database),
2. to apply a default value 100 km for transportation distance and load sizes (to 100% and back 0%) or define case-specific values if known
3. to assess the quantities of waste always on building scale (considering the overall weight of the building).

7.2.3 Waste management

GWP data for waste processing was collected and formulated for building products as explained in Section 5.2.

7.3 Disposal

Landfilling of organic material is restricted under the Government Decree on Landfills (331/2013). The aim is to steer biodegradable waste or other waste containing organic material away from landfills to be used as material or energy and to reduce the adverse impacts of waste management to the environment.

The main part of mixed waste assessed by weight - consists of concrete and other mineral materials. Mixed waste from building sites is not applicable for combustion. The different fractions need to be separated on buildings sites, or at latest on waste separation plants.

Statistics Finland has published emission values for different kinds of fuels. The value for recovered fuels is 0.57 kg CO_2/kg (Tilastokeskus 2020).

The selected approach for phase C4 is:

- to provide a generic emission value regarding the building-scale amount of combustible waste generated at demolition site
- to use a value given for recovered fuels by Statistics Finland (0.57 kg CO_2/kg)
- When the share of combustible waste fraction cannot be assessed a default value or 10% can be used[10] which leads to the emission value of 0.057 kg CO_2/kg of all mixed waste.

7.4 Summary

The structure of end-of-life services related data in the CO2DATA database is described in Table 23.

Table 23. Structure of end-of-life services data in the CO2DATA database

Scope	Unit	Remark
C 1 Deconstruction (all building types)	kg CO_2e/m^2	
C 2 Transportation	kg CO_2e/ton km	The final result is calculated in terms of kg CO_2e/m^2 based on the case specific volumes of demolition waste and with the help of CO2DATA for transportation
C 3 Waste processing of materials	kg CO_2e/kg of waste	Defined as product group specific data (Section 5.2)
C 4 Disposal	kg CO_2e/kg	Based on the assumed share of combustible waste in mixed waste and the value for recovered fuels according to the Statistics Finland (Tilastokeskus 2020).

[10] as proposed by Tuuli Myllymaa SYKE

8 Transportation

Emission data for transportation services are mainly based on LIPASTO database. VTT LIPASTO[11] has been an open license traffic unit emission database for Finland but at present it is not available. The unit emission database included emission factors for road, rail, and waterborne as well as working machines. Unit emissions mean the amounts of emissions emitted during operation of vehicles, measured in mass units and allocated to tonne of freight transported over one kilometre (g/tonne kilometre).

The results for road transportation service (for modules A4 and C2 in accordance with EN 15804 (2019)) are based on the former LIPASTO database published and maintained by VTT and the database for transport by Finnish Transport Infrastructure Agency. Values included the common fuel types and those were in accordance with EEA Guidebook 2019. LIPASTO provided values for the calculation of the emissions for different loads and for different capacity trucks. The emission database by Finnish Transport Infrastructure Agency has also used LIPASTO for earth moving truck emission factor as well as their own default speed values for the trucks in highway and urban driving (Aulakoski et al. 2014).

LIPASTO emission factors for shipping are based on MEERI-calculation system for shipping for the year 2016. CO2DATA uses average emissions and energy use of maritime freight transport. Port emissions are included in the emission factors. Values include the common fuel types and are in accordance with EEA Guidebook 2019. The selected ship types are the types that were considered relevant for calculating the emissions of waterborne freight transport used in construction process. Return trip does not need to be calculated separately as it was included in the emission factors in LIPASTO.

Emission values for rail transport are based on RAILI calculation model of LIPASTO Unit Emissions database. LIPASTO database provided average rail transport emission values for the year 2016. Unit emission factors for diesel trains were based on measurements by VR Group, measurements commissioned by VR and information from producers of locomotives. Values are in accordance with EEA Guidebook 2019 (EEA 2019). The selected train type was the one considered relevant for calculating the emissions of rail freight transport used in construction process. Backhaul does not need to be considered separately.

The working steps were as in Table 24.

Table 24. Main process steps in defining typical values for transportation services

	Process steps
I	Studying the available and relevant databases for transportation.
II	Selecting transportation parameters applicable for use for modules A4 and C2 (according to EN 15804) in CO2DATA.
III	Adding the impact of procurement on GWP values.

JRC Well-to-tank JEC v4.a report (JRC 2014) describes processes of producing, transporting, manufacturing, and distributing fuels and gives emission factors for different types of fuels, production routes and transport methods. JEC well-to-tank values were added to LIPASTO emission values to represent the actual values of the whole transportation process. JEC-values were added to emission factor by multiplying the share of well-to-tank process of diesel to the whole emission factor including combustion.

Recently a new version (Prussi 2020) has been published by JRC for the inclusion of procurement related emissions of fuels. This new version was not considered. However, the recommendation is to recalculate values based on the newer version in the next update of the database.

More detailed information about the calculations is given in the background reports written by Ismo Hämäläinen (Finnish Environment Institute) available on (CO2DATA 2022).

The database provides GWP values for the transportation alternatives shown in table 25.

[11] information available on lipasto.vtt.fi/yksikkopaastot/ (Accessed 3.1.2023)

Table 25. The list of transportation services included in the database. The unit for the emissions is kg CO_2e/ton km

Transportation services for freight transport	
Road	Earth moving trucks 32t highway driving
	Earth moving trucks 32t urban driving
	Heavy delivery lorry highway driving
	Heavy delivery lorry urban driving
	Semi trailer light highway driving
	Semi trailer light urban driving
Waterborne	Container ship, 1 000 TEU
	Bulk carrier, medium
Rail	Container train, diesel (Net Load 686t):

9 Energy services

The CO2DATA database provides emission factors for fuels, renewable energy technologies, and for electricity, district heat, and district cooling. The results are based on extensive statistical data and research results. The details are explained in the background report for energy services written by Sampo Soimakallio (Finnish environment Institute) and available on the CO2DATA (2022). The following text summarises the main principles and information sources on the bases of the background report.

The emission factors were defined for the following fuels and renewable energy technologies to calculate the GWP of electricity, district heat and cooling:

- heavy fuel oil
- coal
- natural gas
- peat
- wood chips
- waste
- nuclear power
- wind power
- solar power and
- hydro power.

The specific emissions from the use of electricity, district heat, and district cooling by buildings were calculated for years 2020–2120. The results are given for each decade. The specific emissions were defined on the basis of GHGs from yearly domestic production and considering the net import of electricity.

The specific GHG emissions from electricity and district heat production were estimated considering CO_2, CH_4, and N_2O emissions from the combustion and procurement of fuels (except CO_2 from combustion of biomass-based fuels), and the construction of the capacity infrastructure for fuel supply and heat and power generation.

Specific emissions were calculated per energy content of the fuel with regard to the production based on fuel combustion, while regarding nuclear, water, wind and solar power, the emissions were calculated in relation to the produced electricity.

The CO_2 emissions from the combustion of fuels are based on the Finnish Statistics (Tilastokeskus 2018).

The specific CH_4 and N_2O emissions from the combustion of fuels were assessed on the basis of total CH_4 and N_2O emissions from public sector heat and power generation in 2018 and on the basis of the energy content of fuels used for the generation of heat and power (SVT 2021).

The CO_2 emissions from the combustion of biomass were calculated as zero emissions. The influence of harvesting of biomass on carbon sinks of forests or soil was not considered. The method follows the calculation principles based on sustainability criteria of the EU directive on the promotion of renewable energy sources (EU 2009, EU 2018).

The emissions because of procurement of fuels are based on the 4th version of Well to tank report by JRC (2014). As the 5th version has already been published, the recommendation is to recalculate pre-combustion values in the next update of the CO2DATA database.

The benefit allocation method was applied to allocate the consumption of fuels for power and heat in combined heat and power (CHP) generation. In this method the consumption of fuels is allocated for heat and power based on the same assumed efficiencies as in separate production. The efficiency of 39% was used for electricity and 90% for heat.

The CO2DATA database provides emission values for energy services also for coming decades considering the targeted decarbonization of energy services. The applied assumptions are based on the basic scenario (the so-called WEM scenario) for 2020–2050 presented by VTT and SYKE in PITKO project (Long-term emission trends) documentation (Koljonen et al. 2017a, b, Koljonen et al. 2019).

The WEM scenario does not specify district cooling. The specific emissions from district cooling have been defined by assessing the required electricity and district heat for production and delivery of district cooling and by applying for these the specific emissions of heat.

The GHG emissions of fossil fuels for building heating in decentralized systems were assessed for light heating oil considering the emissions caused by procurement and construction of infra in addition to combustion. The precombustion emissions and the CH_4 and N_2O emissions of combustion were assumed to be the same as those assumed for heavy fuel oil in the connection of emission-assessment of electricity and district heat. The specific emissions for biofuels (wood briquettes, pellets, and bio-oils) were formulated by using the same factors as was used for chips for in the connection of emission-assessment of electricity and district heat. The assessed emissions because of transportation and manufacturing were added following the principles of EU REDII Directive (EU 2018). The specific emission factors for fossil fuels and biofuels for decentralized heating of buildings were assumed to remain unchanged throughout the period considered.

10 The use of GWP values in life-cycle assessment of buildings

One of the main ideas of the CO2DATA is to provide GWP information that enables the consideration of the entire life cycle of buildings in the design process. The following table summarises the availability of data in CO2DATA suitable for different life cycle modules in accordance with EN 15804 and other standards prepared by CEN TC 350 *Sustainability of construction works*.

Table 26. Building life cycle modules and corresponding GWP data in CO2DATA

Life cycle module	GWP data of CO2DATA
Product stage (A1–A3)	GWP for building products
Transport to the building site (A4)	GWP for transportation services
Construction / Installation into the building (A5)	GWP for construction services (also waste factors for materials)
Operational energy use (B6)	GWP for energy services (considering decarbonization in coming decades)
Replacement (B4)	GWP for building products + service life values for products (when <50years)
Deconstruction (C1)	GWP for demolition services
Transport (C2)	GWP for transportation services
Waste processing (C3)	GWP for waste processing of building products
Disposal (C4)	GWP for waste disposal
Benefits beyond life cycle (D)	Carbon handprint estimates for recycling, energy recovery, carbon storage, carbonation

11 Terms and definitions

The following table defines or explains the most essential terms used in this report.

Table 27. Definitions and explanations for essential terms used in the report

Term	Definition / explanation
Carbon footprint	Global warming potential (GWP) in kg CO_2e/kg The value is given for products considering the life cycle modules A1 – A3 (as defined in EN 15804). The other phases (modules) of life cycle are considered with the help of carbon footprint values defined for transportation, construction, energy, deconstruction, waste processing, and disposal services.
Typical value	GWP (A1–A3) value that represents an average value for a product type when the most significant manufactures from the viewpoint of the Finnish construction market are considered NOTE: The typical data value is not mean a value or weighted mean value calculated based on market shares.
Conservative value	GWP (A1–A3) value calculated by multiplying the typical value by a factor of 1.2.
Product specific value	GWP (A1–A3) value of a specific product presented in its EPD.
Mean value / Weighted mean value	GWP value calculated as an arithmetic mean considering all manufactures of the product type in the market / value calculated as an arithmetic mean and weighted by market shares of all manufactures of the product type in the market.
Service life	Period of time after installation during which a facility or its component parts meet or exceed the performance requirements (ISO 15686-1, 2011) Service life value based on the general service life information given in environmental declarations. Does not take into account different environmental or use conditions but refer to technical service life in normal or easy conditions. NOTE: The calculation method provides a more specific table for service life values to be used in the calculations to be required in building permission process. These values consider the purpose of use and divides the values into two categories (short/normal expectancy).
Waste factor	Estimated value for typical amount of waste at building site. The factor is given as the ratio of the weight of procured product at site per weight of product in building. Regarding sawn and planed timber, the factor also covers waste at prefabrication site.
Carbon handprint	Assessed potential GWP benefit beyond the system boundary because of recycling, energy recovery, carbon storage, or carbonation. The term used in (VN 2022) and (YM 2022b).
End of life scenario	Assumed way of utilization or disposal of the product after deconstruction. The values are given in assumed percentages broken down to reuse, recycling, energy recovery, disposal in earth construction, and hazardous waste to be removed from use.

11.1 Abbreviations

Abbreviation	Explanation
BOQ	Bill of quantitatives
CLT	Cross laminated timber
EPD	Environmental product declaration
EPS	Expanded polystyrene
GLT	Glued laminated timber
GWP	Global warming potential
HVAC	Heating, ventilation and air conditioning
IFC	Industry Foundation Classes (a common standard for data exchange)
LCA	Life cycle assessment
LULUCF	Land use, land use change and forestry
LVL	Laminated veneer lumber
PB	Polybutadiene
PEX	Cross-linked polyethylene
PP	Polypropylene
PUR and PIR	Polyurethane based insulation panels
PVC	Polyvinyl chlorine

12 Development and supplemental needs

The main target of CO2DATA database is to support the design for low carbon and resource-efficient building by providing typical environmental data for products, services, and systems to be used in the assessment of alternative design solutions. The aim of this report is to explain how the environmental data of the database has been developed and what kind of sources has been used. The purpose is also to give information about the structure and coverage of data and to support the correct use of data in the environmental assessment of buildings and building designs.

The database will be further developed by adding new data and by proving more accurate and relevant values for existing products and services from time to time when necessary. Also, the methodological approach needs to be developed and revised in the future.

"Databases and management of data" is one part of the joint Nordic project (Nordic sustainable construction. 2022) which aims at developing harmonised practices for building LCA. The main objective of this task is to seek for common Nordic understanding for the establishment and maintenance of databases that serve for environmental assessment of buildings. The task will start in 2023 and it will develop common processes for the collection and development of typical data for databases.

Today, the most important approach for the development and choice of emission values is to collect available data mainly based on environmental product declarations and to assess the relevance and validity of this data with the help of expertise and by considering the market conditions. In most cases, reasonably representative data can be developed with the help of this approach. Lacks in the availability of EPDs and accurate information about markets probably hinder the possibilities to calculate real average values also in the near future.

However, there are some important methodological aspects that need further consideration. One of the important needs of development is to clarify the consideration of climate benefits from long-term storages of carbon in relation to different forest use. The overall calculation rules and principles regarding land use, forestry and wood related emissions require more research and discussion.

The overall methodological rules for the development of carbon handprint data (or data for module D, benefits beyond the life cycle) also require research and serious consideration. The definition of rules for the reasonable selection of end-of-life scenarios is an important issue. Besides, the consideration of decarbonation of energy should be consistent, and common principles should be defined.

Eventually, the suitability of GWP (fossil) indicator to describe potential benefits should be discussed. It may not be reasonable to use an indicator that describes impacts of emissions that should be almost zero after 50 years from this day. Although GWP (fossil) is the key indicator just now, the role and significance of future key indicators should be discussed.

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LCA database for building products, services, and systems –
Description of the content and working methods

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