Opportunities for reducing climate impact through the circular use of plastic in the construction and demolition sector

State of knowledge in the field

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REPORT 7077 | MAY 2020

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Internet: www.naturvardsverket.se

ISBN 978-91-620-7077-9
ISSN 0282-7298

Translation: Accent Språkservice
Print: Arkitektkopia AB, Bromma 2022
Cover photos: Lena Granefelt, Johnér Bildbyrå

MILJÖMÄRKT
3041 0843
TRYCKSAK

Preface

Used correctly, plastic is very valuable and provides great benefits to society. Plastic has many good properties that make it a suitable building material as it is dense, light and cheap, and has high moisture resistance and good insulating properties. In certain contexts, plastic can help save energy and reduce greenhouse gas emissions. But today's production and use of plastics also pose major challenges.

Like other materials, plastic needs to be adapted for use in a circular economy, so that we can minimise environmental and climate impacts and reduce litter and emissions of plastic and hazardous substances into nature.

The construction and demolition sector is the second largest user of plastic after the packaging sector and consumes approximately 21 per cent of all plastic in Sweden.

Do you want to know more about the use of plastic and the climate impact of plastic and plastic waste from the construction and demolition sector? And read about specific examples and recommendations on how different stakeholders in the construction and demolition sector can contribute to more sustainable use of plastic? In that case, we hope that you will find this report to be useful.

The report has been prepared by IVL and was commissioned by the Swedish Environmental Protection Agency. The Swedish Environmental Protection Agency has not taken a position on the content of the report. The authors from IVL are responsible for the report's content and its conclusions.

The Swedish Environmental Protection Agency's work with plastics is based on its role as Sweden's expert authority in the environmental field. We have been tasked by the government's to be responsible for national plastic coordination. Our work is focused on gathering, building and disseminating knowledge and coordinating and pursuing issues with a view to contributing to sustainable plastic use. We do this in conjunction with relevant authorities and other stakeholders. Our work with plastic aims at ensuring that the material is used in a sustainable way.

Stockholm, May 2020

Martin Eriksson
Head of Department, Department for Project Development

Innehåll

Summary

Used correctly, plastic is very valuable and provides clear benefits to society. In some contexts, plastics can help to save energy and reduce greenhouse gas emissions. Plastic has many good properties that make it a suitable building material as it is dense, light and cheap, and has high moisture resistance and good insulating properties. Plastic also requires little maintenance and has a long service life, between 30 and 50 years But today's production and use of plastics also pose major challenges. To conserve the earth's resources and achieve sustainable use, the plastic lifecycle needs to work.

This report summarises what is currently known about the use of plastic in the construction and demolition sector. It provides an indication of the climate impact of plastic, gives specific examples and makes recommendations for what different stakeholders in the construction and demolition sector can do to contribute to a more sustainable use of plastic.

The construction and demolition sector is a large user of plastics

The construction and demolition sector is the second largest user of plastic after the packaging sector and consumes approximately 21 per cent of all plastic in Sweden. PVC, polyethylene and polystyrene are the most common types of plastic and are used in such products as floor and wall mats, pipes, building membranes, thermal insulation, cable insulation and profiles.

Circular use of plastic is key to reducing climate impact

The climate impact of plastic use in the construction and demolition sector can be reduced by increasing circular use of this material. This can be done by using as little material as possible, using it for a long time (e.g., reuse), recycling the plastic material as many times as possible and using recycled or bio-based plastic raw material in the manufacture of new products.

Based on existing knowledge, recommendations and good examples from various studies, this report recommends a series of measures that contribute to circular use of plastic in the construction and demolition sector. The measures are addressed to the following stakeholders:

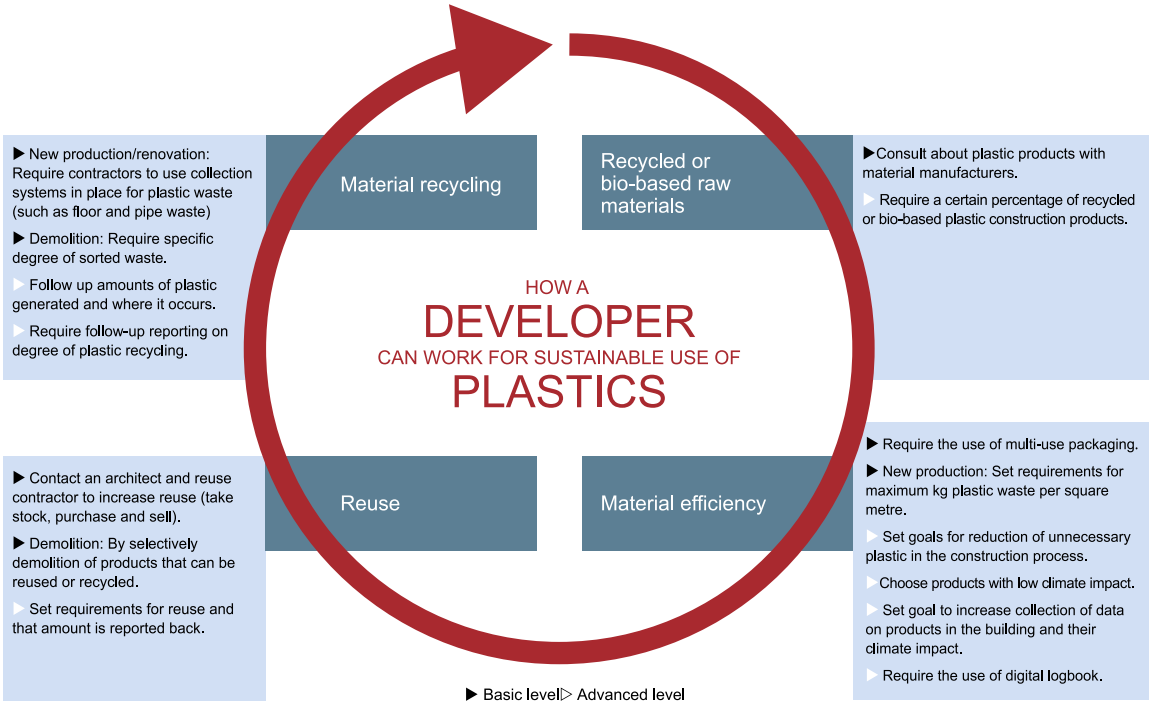
- Developers
- Materials manufacturers
- Architects and technical consultants
- Building contractors
- Waste and reuse contractors.

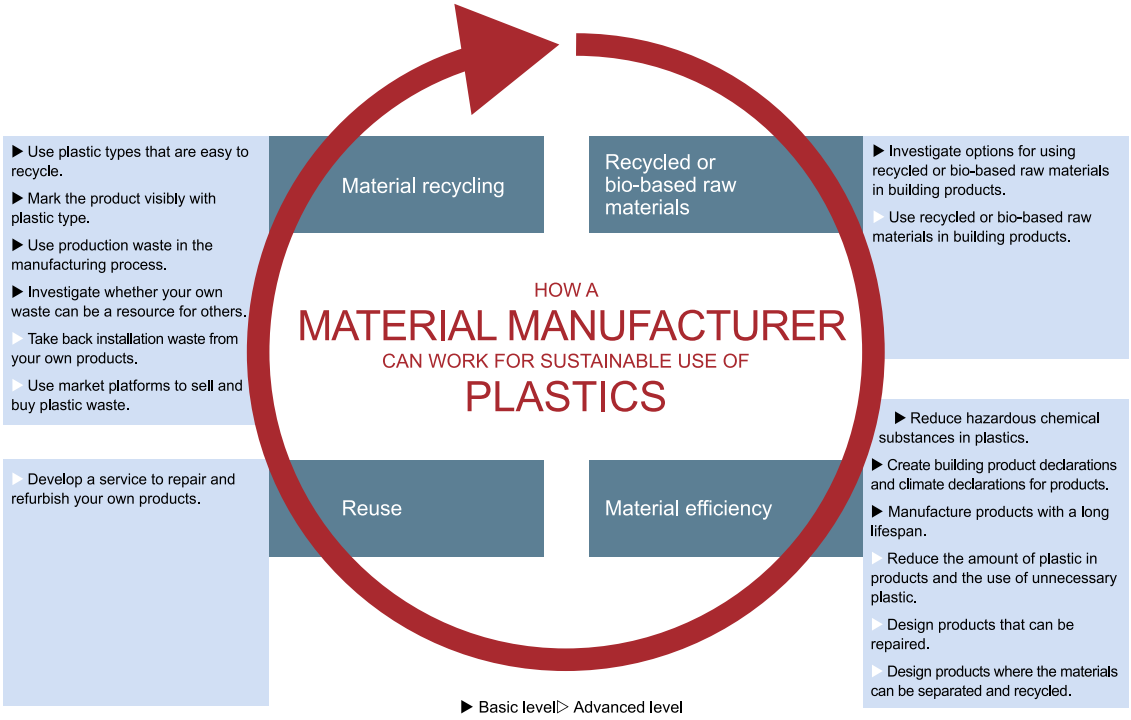
The measures are based on the principle that reducing production and use of fossil virgin raw materials will reduce climate impact. The exact climate impact of the various measures depends on many factors, such as the amount of material used, the type of raw material, the manufacturing process and transports. There is currently insufficient data to quantify the impact of individual measures. For this reason, the report suggests that stakeholders in the construction and demolition sector consider the recommended measures to be a source of inspiration and use their own life cycle analyses to identify the measures to implement in their organisations.

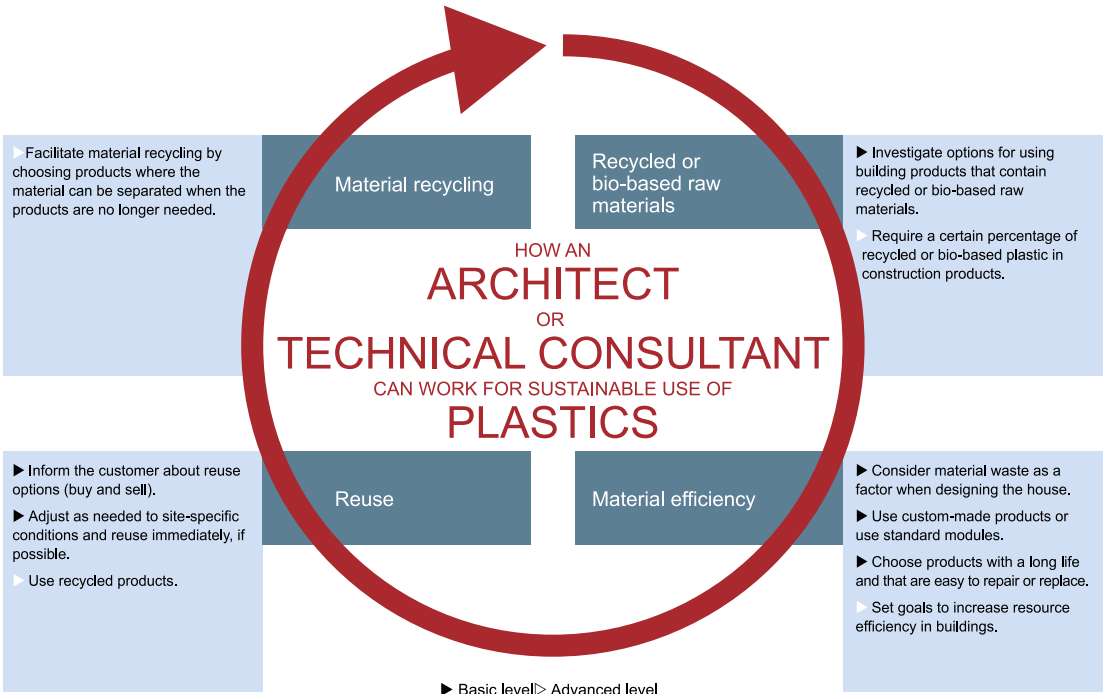
Proposed measures are divided into two levels:

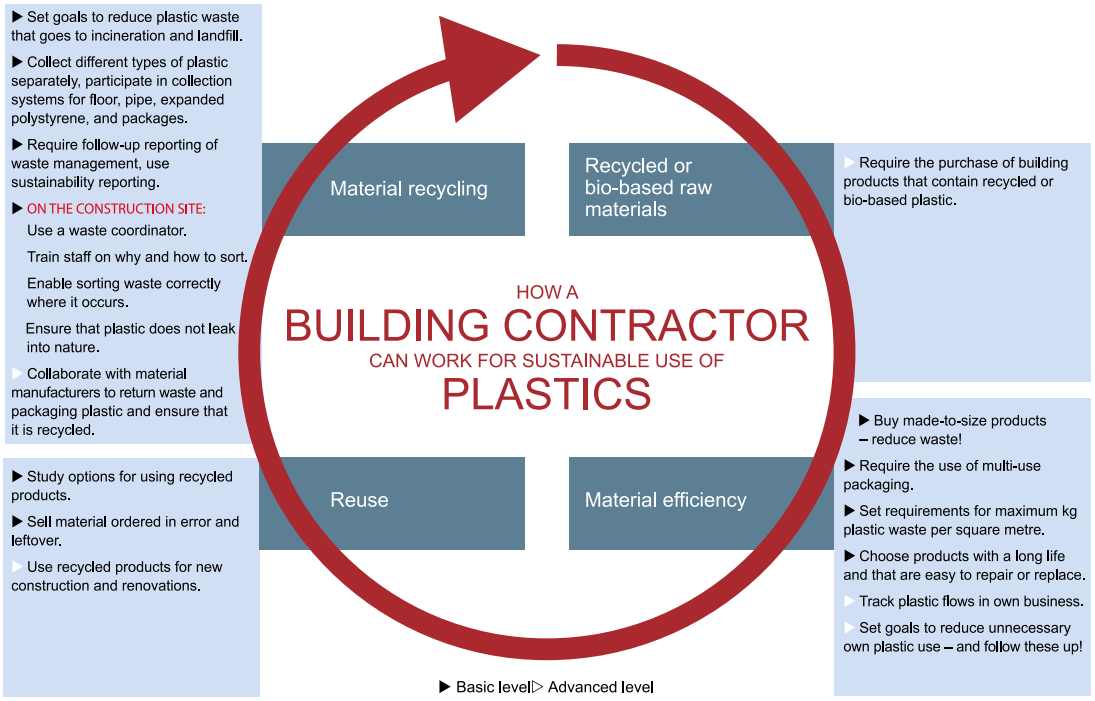
- *Basic level:* This means that there are logistics solutions, information and tools to be able to implement the measure.
- *Advanced level:* This means that a specific area is less developed and can contribute to development when it is implemented.

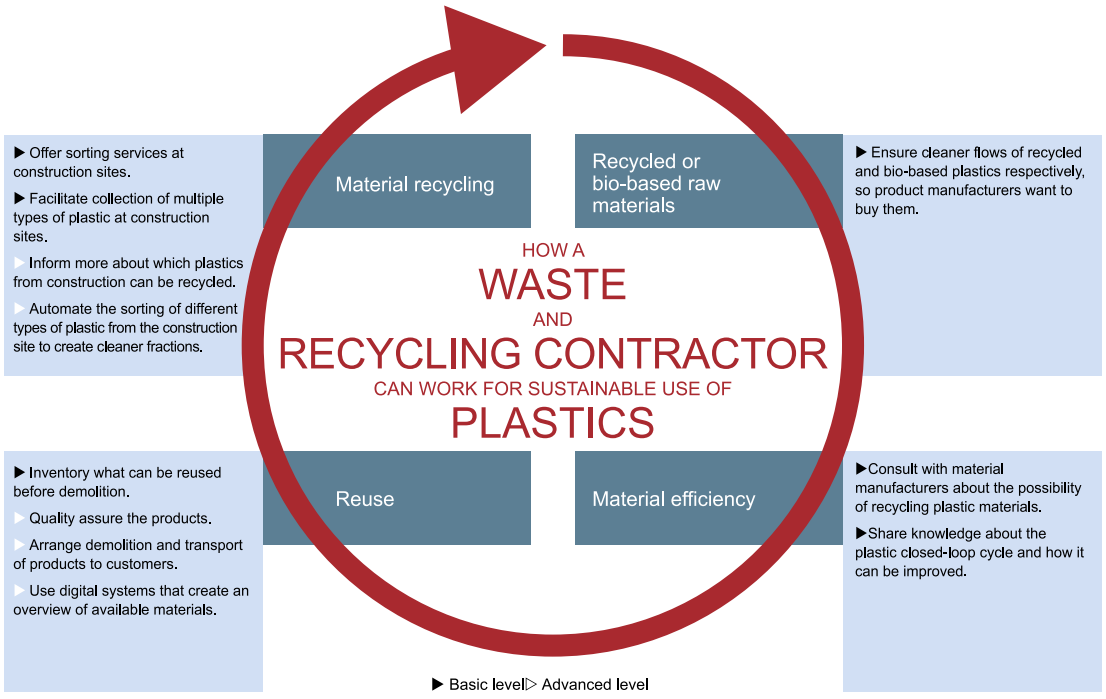
Measures for the different stakeholder groups are summarised in the illustrations below.




▶ Use plastic types that are easy to recycle.
▶ Mark the product visibly with plastic type.
▶ Use production waste in the manufacturing process.
▶ Investigate whether your own waste can be a resource for others.
▶ Take back installation waste from your own products.
▶ Use market platforms to sell and buy plastic waste.
Material recycling
Recycled or bio-based raw materials
▶ Investigate options for using recycled or bio-based raw materials in building products.
▶ Use recycled or bio-based raw materials in building products.
HOW A
MATERIAL MANUFACTURER
CAN WORK FOR SUSTAINABLE USE OF
PLASTICS
▶ Develop a service to repair and refurbish your own products.
Reuse
Material efficiency
▶ Reduce hazardous chemical substances in plastics.
▶ Create building product declarations and climate declarations for products.
▶ Manufacture products with a long lifespan.
▶ Reduce the amount of plastic in products and the use of unnecessary plastic.
▶ Design products that can be repaired.
▶ Design products where the materials can be separated and recycled.
▶ Basic level▷ Advanced level


▶ Facilitate material recycling by choosing products where the material can be separated when the products are no longer needed.
Material recycling
Recycled or bio-based raw materials
▶ Investigate options for using building products that contain recycled or bio-based raw materials.
▶ Require a certain percentage of recycled or bio-based plastic in construction products.
HOW AN
ARCHITECT
OR
TECHNICAL CONSULTANT
CAN WORK FOR SUSTAINABLE USE OF
PLASTICS
▶ Inform the customer about reuse options (buy and sell).
▶ Adjust as needed to site-specific conditions and reuse immediately, if possible.
▶ Use recycled products.
Reuse
Material efficiency
▶ Consider material waste as a factor when designing the house.
▶ Use custom-made products or use standard modules.
▶ Choose products with a long life and that are easy to repair or replace.
▶ Set goals to increase resource efficiency in buildings.
▶ Basic level▷ Advanced level


▶ Set goals to reduce plastic waste that goes to incineration and landfill.
▶ Collect different types of plastic separately, participate in collection systems for floor, pipe, expanded polystyrene, and packages.
▶ Require follow-up reporting of waste management, use sustainability reporting.
▶ ON THE CONSTRUCTION SITE:
Use a waste coordinator.
Train staff on why and how to sort.
Enable sorting waste correctly where it occurs.
Ensure that plastic does not leak into nature.
▷ Collaborate with material manufacturers to return waste and packaging plastic and ensure that it is recycled.
▶ Study options for using recycled products.
▶ Sell material ordered in error and leftover.
▷ Use recycled products for new construction and renovations.
Material recycling
Recycled or bio-based raw materials
Reuse
Material efficiency
▷ Require the purchase of building products that contain recycled or bio-based plastic.
▶ Buy made-to-size products – reduce waste!
▶ Require the use of multi-use packaging.
▶ Set requirements for maximum kg plastic waste per square metre.
▶ Choose products with a long life and that are easy to repair or replace.
▷ Track plastic flows in own business.
▷ Set goals to reduce unnecessary own plastic use – and follow these up!
HOW A
BUILDING CONTRACTOR
CAN WORK FOR SUSTAINABLE USE OF
PLASTICS
▶ Basic level ▷ Advanced level


▶ Offer sorting services at construction sites.
▶ Facilitate collection of multiple types of plastic at construction sites.
▷ Inform more about which plastics from construction can be recycled.
▷ Automate the sorting of different types of plastic from the construction site to create cleaner fractions.
▶ Inventory what can be reused before demolition.
▷ Quality assure the products.
▷ Arrange demolition and transport of products to customers.
▷ Use digital systems that create an overview of available materials.
Material recycling
Recycled or bio-based raw materials
Reuse
Material efficiency
▶ Ensure cleaner flows of recycled and bio-based plastics respectively, so product manufacturers want to buy them.
▶ Consult with material manufacturers about the possibility of recycling plastic materials.
▶ Share knowledge about the plastic closed-loop cycle and how it can be improved.
HOW A
WASTE
AND
RECYCLING CONTRACTOR
CAN WORK FOR SUSTAINABLE USE OF
PLASTICS
▶ Basic level ▷ Advanced level

The report concludes with some examples of obstacles, needs and gaps in knowledge. Above all, the stakeholders in the construction and demolition sector need to work together to create a circular flow of plastic. Some of the most important measures apply to all stakeholder groups and are based on interaction throughout the whole value chain:

Need for more data: There is no data on the climate impact of plastic in the construction and demolition sector. Information is available on the climate impact of the construction and demolition sector in general and on the climate impact of plastic, but the combination needs to be investigated. Producing this data is essential for our prioritisation of future measures.

Overview leads to development: We need an overview, partly of what plastic flows in the construction and demolition sector look like and partly of the opportunities for material recycling and reuse that are available for different types of plastic – from technical, commercial and sustainability perspectives. This overview should highlight several prioritised plastic flows and work to ensure that they function so that all the stakeholders in the construction and demolition sector can work together to create a circular flow of plastic.

Support for product selection: The construction and demolition sector requires assistance in selecting products on the basis of different aspects: climate impact, opportunities for recycling and reuse, etc. One way would be to create a guide to which materials and products should be chosen from different perspectives, another would be to produce key figures that make the selection easier.

Digital information flows: A fundamental requirement for the creation of a sustainable circular plastic flow is that digital information about the products' content is available, updated and linked to the building and position where the products are installed. At present, a lot of information is collected and processed manually and in an analogue way, which is both resource-intensive and precarious from a quality point of view. The further development of digitisation in the construction and demolition sector is also important from a circular perspective.

1. How much plastic is used in the construction and demolition sector?

Plastic began to be used as a building material in the 1960s, and its use has increased steadily since then. In 2017, the construction and demolition sector was estimated to account for 21 per cent of total plastic use in Sweden[1]. This corresponds to approximately 262,000[2] tonnes of plastic, as shown in Figure 1.

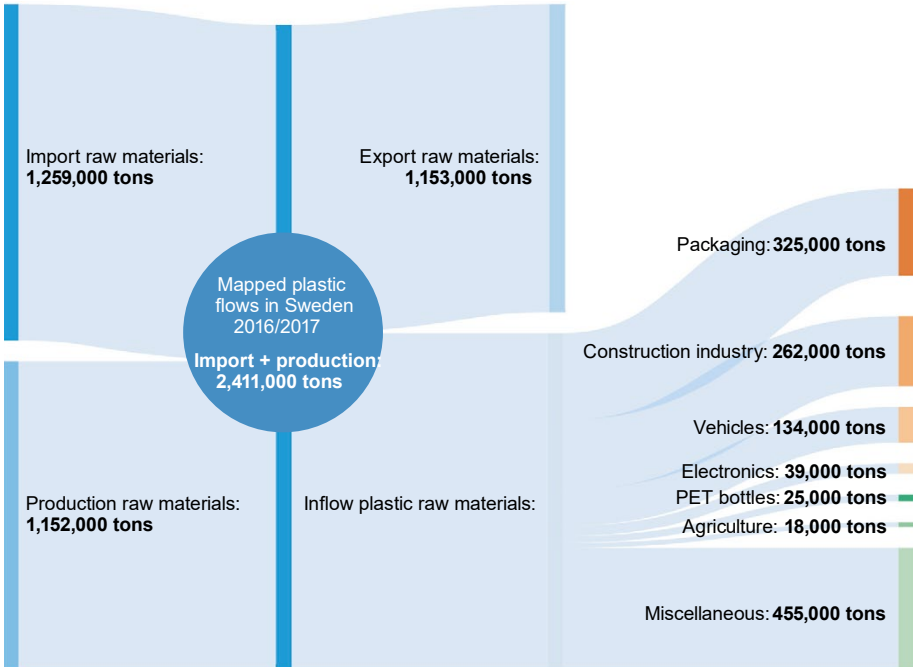


Figure 1. Plastic flows surveyed in Sweden in 2017.[3]

There are no general figures for how much plastic is used in the construction of buildings today, nor are there industry-wide studies. To try to give a picture of how much plastic is built into a building, Vasakronan has mapped out the materials used in a specific building, the 12,500 square metre Uppsala Science Park, containing offices, laboratories, restaurants and conference facilities.[4]
All materials used at the construction site (both used for the building and waste) were accounted for by a total of 36 contractors using a digital tool. The survey showed that 11 kg of polypropylene and 5 kg of cellular plastic were used per square metre of the total gross area. These were the only types of plastic included in the survey,

[1] (SMED, 2019)
[2] The estimate is based on the demand with plastic-processing companies
[3] (SMED, 2019)
[4] (Vasakronan, 2019)

so, unfortunately, it did not provide any information about other plastic products used in the building.[5]

There is also a lack of precise figures on how much plastic is present in Sweden's current total property stock. The use of plastic has varied considerably over time, and this affects the proportion of plastic in demolition rubble. A study investigating demolition waste from flats between 1964 and 1974 showed a sharp increase from 8 kg to 67 kg of plastic material per flat during that period.[6] Two case studies examined demolition waste from the nursing home Sävegården (built in the 1950s) and the rebuild of the school, Nödingeskolan (built in the 1980s). A total of 9,220 kg of plastic was sorted out from the two projects, which corresponds to approximately 18 kg per square metre.[7]

1.1 Plastic as building material and packaging

Plastic has many good properties that make it suitable as a building material. It is impermeable, light and cheap, has high moisture resistance and provides good insulation. Plastic also requires little maintenance and has a long service life, between 30 and 50 years

More than 50 types of plastic are used in the construction and demolition sector.[8] In addition to variations in their chemical structure, added substances, such as antioxidants, pigments, plasticisers, oils, fillers, and reinforcing fibres, can give them different properties.[9]

Many parts of a building contain plastic products or small plastic elements. The largest groups of plastic construction products are shown in Figure 2.

The following types of plastic are mainly used in the construction and demolition sector:

- PVC (polyvinyl chloride) is mainly used in pipes and pipe fittings, interior profiles and floor and wall mats. PVC can be both rigid (in tubes and profiles) and soft (in carpets). Approximately 80 per cent of all PVC produced today is used in the construction and demolition sector.[10]
- Building foil, cable insulation and pipes are made from PE (polyethylene). There is High Density Polyethylene (HDPE), which is hard, and Low Density Polyethylene (LDPE), which is soft.
- PS (polystyrene) is used primarily as an insulation material in the form of expanded polystyrene (EPS) or extruded polystyrene (XPS), often also known as Styrofoam or cellular plastic.
- PP (polypropylene) is used in the construction and demolition sector as a component in water and wastewater pipes, in electrical components and as a textile flooring support material.[11]

[5] (Vasakronan, 2018)
[6] (Yarahmadi, 2013)
[7] (Elander & Sundqvist, 2015)
[8] (Plastics Europe, 2012)
[9] (Jansson, Boss, & Lundberg, 2019)
[10] (Byggmaterialindustrierna, 2019)
[11] (Sundqvist, Fråne, & Hemström, 2013).

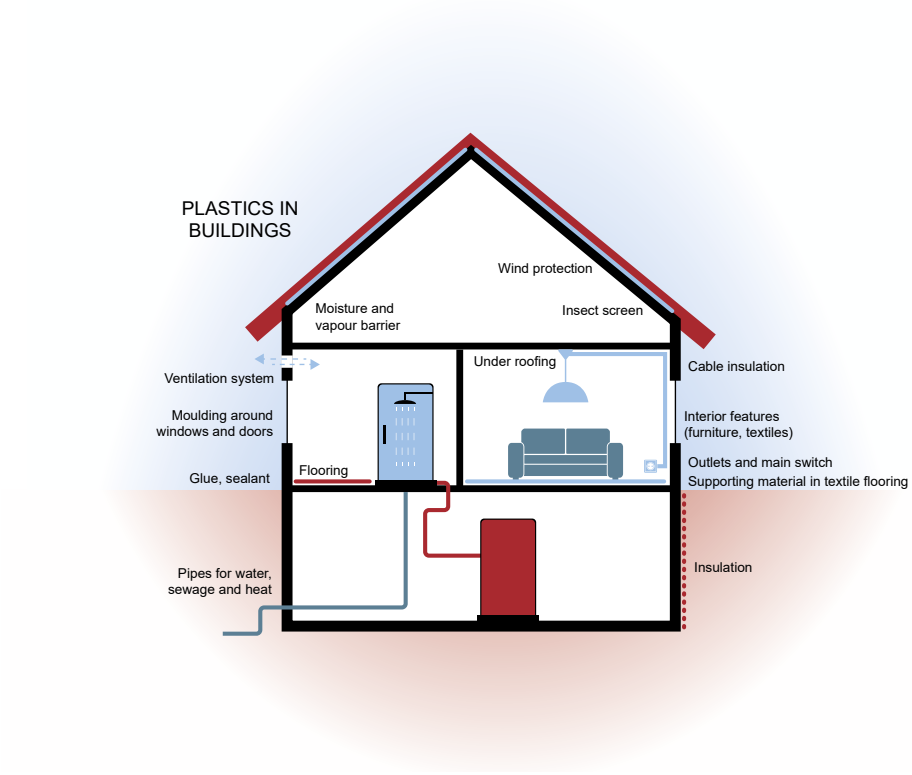


Figure 2. Construction products and interior fittings containing plastic.

Plastic floors and wall mats

Every year, approximately 6.3 million square metres of plastic flooring is laid in Sweden,[12] which is roughly equivalent to 18,000-20,000 tonnes of plastic material. Plastic flooring is the single largest plastic product (calculated in weight percentages) in a building and is usually made from PVC. PVC mats can also be used as moisture barriers in walls and on floors in bathrooms or other wet areas.[13] Plastic flooring is installed in large quantities in hospitals, schools, commercial kitchens and other institutional settings.

Plastic roofing sheets

Roofs are protected from moisture using an impermeable layer of bitumen on a plastic fabric base.[14] There is also entirely plastic roofing sheeting, for which PVC is currently the most commonly used material. Roofing sheets also use other polymers, such as chlorinated polyethylene (CPE), thermoplastic or flexible polyolefin (TPO or FPO).[15] Estimates indicate that there are approximately 25 million square metres of low-slope roofs coated with rubber or plastic in Sweden.[16]

[12] (Golvbranschen, 2019a)
[13] (SMED, 2019)
[14] (SMED, 2019)
[15] (Takdukproducenternas Förening, 2019a)
[16] (Takdukproducenternas Förening, 2019c)

Other plastic membranes

Various types of plastic membranes are built into walls and floors to seal out air, moisture, cold and heat. For example, building foils are installed in outer walls to prevent damage caused by a building's internal moisture moving into the cold parts of the building. Wind shields (usually made from polypropylene laminated with a polyethylene foil) are placed behind the outer wall façade material. Polypropylene matting is used under floors to create air gaps, insulate against moisture and drain foundations.[17]

Plastic insulation

Building insulation made from plastic (EPS or XPS, often called Styrofoam or cellular plastic) has become popular in recent years, but other insulation materials are used, including mineral wool and glass wool. The purpose of the insulation is to insulate a building against both temperature and noise.

Plastic piping and pipe fittings

About 100,000 tonnes of plastic pipes are manufactured in Sweden each year.[18] They have a long lifespan and are widely used for water and wastewater, heating and ventilation, as well as for installation ducting for electrical, telecom and data cables.[19]

Windows, doors and mouldings

Although wooden-framed windows and doors have traditionally been primarily used in Sweden, the proportion of plastic doors and windows is increasing. Plastic-framed windows and doors have the advantage that they offer less maintenance than wood, are lighter in weight and have a long service life.[20]

Cables and electrical installations

Plastic is used as insulation material around the conductors in cables and other electrical installations.

Shrink and stretch film

Shrink and stretch film is used in the construction and demolition sector to protect against dust, moisture, water and smoke for products that are stored outdoors or transported by rail, sea, air or road. Shrink film is made from PE that shrinks when heated. Its uses include protecting prefabricated building elements while being transported from the factory to the construction site. Stretch film, also made from PE, can be used to protect goods on pallets, to stabilise goods, and to protect and hold them together. Packing strapping, made from PP or PET, is used to secure goods to pallets.

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[17] (SMED, 2019)
[18] (Boss, 2018)
[19] (SMED, 2019)
[20] (SMED, 2019)

EPS Packaging (Styrofoam)

Various types of packaging materials made from EPS are used to protect electronic products, tools and machine parts and other products during transport. EPS is made up of 98 per cent air, which means that the material has high moisture resistance and provides good insulation.[21]

1.2 Plastic as a waste flow

National statistics from 2016 show that the construction and demolition sector generates over 60,000 tonnes of plastic waste. This refers only to sorted quantities, not to plastics included in mixed waste fractions.[22] It has been estimated that a further 89,000 tonnes of plastic waste end up in mixed waste from the construction and demolition sector and is sent for incineration. This means that the construction and demolition sector generates approximately 150,000 tonnes of plastic waste each year. Only 0.8 per cent of this plastic waste is currently recycled.[23]

There is a difference between plastic in waste from construction and from demolition. In the case of new construction, the contents of the plastic waste are known and are often more homogeneous, making them relatively easy to recycle. They can consist of soft PE packaging plastics, insulation made from cellular plastic or pipe lengths made from PE, PP or PVC.

Studies on mixed construction waste from new production from 2018–2019 show that nearly 30 per cent is plastic.[24] Of this plastic waste, almost half is soft plastic packaging, as shown in Figure 3. Sweden has a producer responsibility scheme for plastic packaging and a system for collecting it for recycling.[25] This makes sorting out the waste at construction sites and sending it to recycling relatively simple.

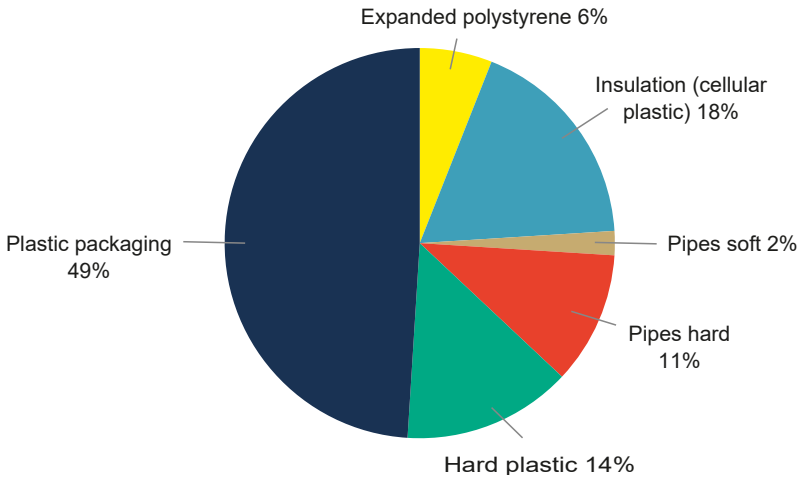

Figure 3. Average composition of the plastic fraction in combustible construction waste.[26]

[21] (SMED, 2019)
[22] (Stenmarck et al., 2018)
[23] (SMED, 2019)
[24] (Edo et al., 2019),
[25] (Sahlin, Edo, & Johansson, 2019)
[26] (Sahlin, Edo, & Johansson, 2019)

Plastic is more difficult to recycle from demolition waste. Most buildings have a long service life, which means that demolition waste can contain older plastics like PVC pipes, cables, profiles and plastic mats. There will be no information about the products in the building and the substances they contain[27]. To avoid the risk of recirculating substances regulated as hazardous to the environment or to health, energy recovery is considered to be the most appropriate measure for demolition waste rather than recycling.[28]

Although it is difficult to recycle demolition waste, some projects have investigated recycling plastic from it. A 2015 project shows that it is possible to separate plastic waste during demolition and that about a quarter of it could be recycled, including plastic carpets, roof and wall cloths, electrical ducting, other pipes and hoses, and mouldings made from PVC, PE, PP, PS, PET, PMMA and PC. However, a selective demolition process in which plastic is sorted out for recycling would today result in higher costs from the processing than the revenue it can be expected to generate. This situation could change if demand for granules from recycled plastic waste increases.[29]

1.3 Discharge of plastic to nature from the construction and demolition sector

Plastic ending up in nature is a problem for society. Disposable products, such as packaging and packaging, are the primary cause of discharges to nature.[30] Accidental discharge of packaging and building materials into the environment can be a source of microplastic in nature.

No data is currently available that shows how much of this litter comes from the construction and demolition sector, but the following risks have been identified:

a) **Use of products outdoors.** The greatest risk of litter is from product groups that are handled outdoors, a common occurrence on construction sites. One hazard is when material is taken out of its transport packaging, because packaging materials are relatively light and in some cases brittle, which increases the risk of the plastic blowing off and becoming litter.
b) **Outdoor storage and disposal of waste.** If the waste is stored in containers outside, as on construction sites, it is important that the container is covered or otherwise protected from the weather to prevent the waste from spreading to the surrounding environment. The risk of creating litter varies from project to project and stakeholders, but the better the conditions for waste management where waste occurs, the lower the risk of littering.
c) **Waste transport.** The risk of littering during transport depends on how the load is covered. Drivers for the company transporting the waste are responsible for covering the load. In general, nets or tarpaulins are used on containers for transport. The meshes on the covering nets are quite coarse, and EPS (expanded polystyrene or Styrofoam), in particular, can blow off, creating litter.[31]

[27] (SMED, 2019)
[28] (SOU 2018:84)
[29] (Elander & Sundqvist, 2015)
[30] (Addamo & Laroche, 2017)
[31] (SMED, 2019)

2. What is the climate impact of the construction and demolition sector and how does plastic contribute?

'Climate impact' can be described as the amount of greenhouse gases generated when manufacturing a product or performing an activity. Climate impact is quantified in CO_2 equivalents (CO_2e) calculated in a life cycle analysis (LCA).

Total greenhouse gas emissions from the construction and real estate sector (domestic emissions and imported goods) in 2017 amounted to approximately 18.1 million tonnes of CO_2e.[32]

When erecting a new building, about 84 per cent of the emissions come from the production of the material and the products that are built in.[33] The climate impact varies depending on how energy-intensive manufacturing is, how the energy is produced and how much of the material is used in a building.

There are studies showing the size of the climate impact that specific buildings have and what the main sources of the impact are.[34] However, these studies focus primarily on materials like concrete and steel that are used in large quantities in the construction and demolition sector and they do not quantify the climate impact of plastics.

The use of plastic in buildings has increased significantly over recent years, making it also relevant to examine how much of the building's climate impact comes from its plastic. As only one per cent of the bio-based plastics produced today are used in the construction and demolition sector globally[35], the climate impact calculations in this chapter assume that 100 per cent of the plastics used in the construction and demolition sector in Sweden are of fossil origin.[36]

As described in the previous chapter, Vasakronan's project 'Hubben' is the only construction project in Sweden, at the time of writing, for which plastic use has been tracked. The Hubben project used 16 kg of plastic per each of its 12,500 square metres, which means that approximately 200 tonnes of plastic is in the building.

Hubben can be used as an example when estimating the climate impact of plastic, but it is important to note that this is a rough estimate and not based on a life cycle analysis. Life cycle analyses are recommended for stakeholders in the construction

[32] (Boverket, 2019)

[33] (Liljenström et al., 2015)

[34] (Liljenström et al., 2015)

[35] (IfBB, 2018)

[36] The world's first bio-based PVC has been launched at the time of writing in October 2019 by InnoVyn, but no products are available on the market yet.

and demolition sector when quantifying the actual climate impact of plastics from their own buildings.

Each metric tonne of plastic produced produces an average of 2.3 tonnes of CO_2e[37]. The main sources of emissions are refining, steam cracking and other processes in polymer production. Applying these figures to the Hubben project shows that the plastic in the building has generated approximately 460 tonnes of CO_2e.

However, the manufacturing process only accounts for part of the total climate impact of the plastic. An even greater amount of carbon is embedded in the product itself, about 2.7 tonnes of CO_2e for each tonne of plastic. If the plastic is incinerated, the entire amount of carbon will be released as emissions to air. So if the plastic is made of new fossil material that is then incinerated as waste, the total fossil carbon dioxide load for one tonne of plastic amounts to as much as 5 tonnes of CO_2e.[38]

As described in Chapter 1, it is estimated that the construction and demolition sector generates more than 150,000 tonnes of plastic waste each year.[39] If this plastic is of fossil origin and goes to incineration, it produces emissions in the order of 750,000 tonnes of CO_2e.

This represents just over 4 per cent of the total climate impact from the construction and property sector. However, it should be stressed that better basic data about plastic use in buildings is required if we are to be able to respond satisfactorily to the climate impact of plastic in the construction and demolition sector.

[37] (Material Economics, 2019)
[38] (Material Economics, 2019)
[39] (SMED, 2019)

3. How can the climate impact of plastic in the construction and demolition sector be reduced?

Circular use of plastic in the construction and demolition sector and the transition from fossil to bio-based plastics contribute to reducing the climate impact of plastic. Circular use involves the use of materials that already exist and the recycling of materials and using less virgin fossil plastics in new construction products.

There are several products, initiatives and projects in Sweden that contribute to more circular use of plastic in the construction and demolition sector. This chapter presents some of these, divided into the following four main categories:

- Recycled or bio-based raw materials
- Material efficiency
- Reuse
- Recycling[40]

3.1 Recycled or bio-based raw materials

One way to reduce the climate impact of plastic is to use recycled or bio-based raw materials. Manufacturing that uses recycled plastic has about 3.5 times lower climate impact than virgin plastic. As noted above, the average climate impact from the production of virgin plastic raw material is about 2.3 kg CO_2e/kg material. The climate impact of recycled plastics is approximately 0.7 kg CO_2e/kg material, as also shown in Figure 4.[41]

[40] These groups are equivalent to potential measures that can reduce greenhouse gas emissions from the construction and property sector listed by the Swedish National Board of Housing and the Swedish Environmental Protection Agency (2019) climate scenarios for the construction and property sectors

[41] (Stenmarck et al., 2018)

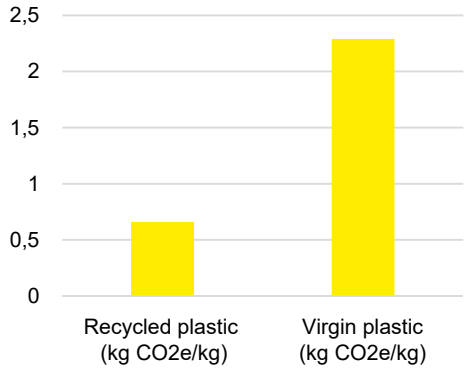

Figure 4. Average greenhouse gas emissions from the production of recycled plastics (secondary production) and virgin (primary production). The unit is kg CO_2e/kg material.[42]

The quality of the plastic decreases when recycled. The extent of the reduction depends on the type of polymer involved. Some polymers retain their quality longer and can withstand several recycling rounds. Companies that use recycled raw materials generally add a certain amount of virgin raw materials to ensure that the products have the desired properties.

There are already some plastic products on the market that have recycled plastics. To find out whether a product contains recycled raw material, refer to the product's construction product declaration[43]. It includes information about the materials and substances that the product is made from and their climate impact.

Recycled raw materials can originate from waste generated during manufacture and installation, and plastic collected from demolition waste that has been cleaned and pelleted. By far the most common way source of recycled raw materials is waste from the company's own production.

Renewable raw materials are raw materials that will not run out in the foreseeable future. For plastic, this mainly refers to bio-based raw material, but research is also under way into the extraction of raw material from carbon dioxide.[44] Bio-based plastics are mainly produced from starch-rich crops, such as maize and sugar cane, but also from cellulose from forestry and plant-based oil.[45] Bio-based plastics account for only about 1 per cent of the annual production of plastic in the world. However, increased demand and several new areas of application contribute to the growth of the market for bio-based plastic plants.[46]

Replacing fossil raw materials with bio-based raw materials can reduce the climate impact but also presents a number of challenges. The land used to grow crops for bio-based raw materials requires water, fertiliser and pesticides that can have an adverse effect on the environment. More energy is needed in the production of bio-based plastics than in recycling fossil plastics. The recycling of bio-based plastics is also different from bio-based plastic compared to fossil plastic, so today's facilities need to be adapted and developed.[47]

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[42] (Stenmarck et al., 2018)
[43] (Byggvaruindustrierna, 2019)
[44] (SOU 2018:84)
[45] (SOU 2018:84)
[46] (European Bioplastics, 2017)
[47] (SOU 2018:84)

Below are some examples of products or materials that contain recycled or bio-based raw materials.

Floors

The Tarkett company manufactures various types of PVC-based floors in Sweden. Tarkett has developed solutions that recover waste from production and installation. In 2018, the company launched a solution that enables recycling of plastic floors laid after 2011.[48] The company estimates that their plastic floors contain, on average, approximately 23 per cent recycled plastics from both production and installation waste.[49]

EPS insulation

In 2019, the Use Re-Use initiative enabled the BEWiSynbra company to collect and recycle EPS (expanded polystyrene, also known as Styrofoam), something that had not previously taken place in Sweden. The initiative allows EPS waste from building sites to be collected, compressed and sent to the production of new EPS blocks.[50] BEWiSynbra reports that 100 per cent of the EPS can be recycled, and the company has recently launched the world's first insulation material made from 100 per cent recycled EPS.[51]

Cable ducts and cable drums

In partnership with polymer manufacturers, recycling companies and cable manufacturers, RISE IVF has run a research programme focusing on the recycling of plastics in cables. They have also developed methods for sorting, separating and recycling various cable plastics.[52] One result is that recycled cross-linked polyethylene (PEX) from cables is currently used for the production of cable drums produced by Axjo AB. The ambition is to use 100 per cent recycled plastics (PEX and PP) in cable drums.

Plastic recovery trials in the Constructivate project

The 'Constructivate' research project was funded by Mistra Closing the Loop and was carried out between 2016 and 2019 with the aim of increasing recycling of construction and demolition waste.[53] Two laboratory and material manufacturer trials were conducted to show that construction materials containing recycled plastics meet existing product marketing requirements.

The trials were conducted on two product groups:

- Collated nail strips and plasterboard scrim tape made from recycled plastics from HDPE pipes and from halogen-free cable plastics, HFFR (the product is shown in Figure 5).

[48] (Tarket, 2019)
[49] (Almasi & Zhang, 2019)
[50] (BEWiSynbra, 2019b)
[51] (BEWiSymbra, 2019a)
[52] (Jansson, Boss, & Lundberg, 2019)
[53] (Mistra Closing the Loop, 2019)

- Boards made from composite materials. Approximately two tonnes of PE plastic packaging from two of NCC's construction sites were sorted separately and used by Polyplank to manufacture plastic/wood composite boards. The experiment showed that the recycled plastic had the same physical characteristics as virgin plastic in this product.

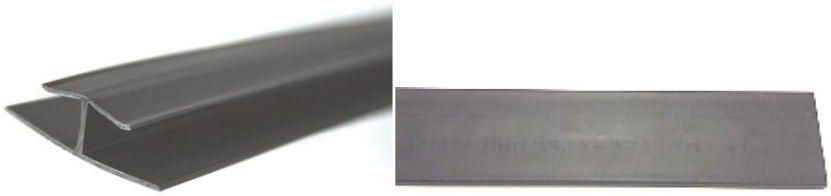

Figure 5. Plaster board scrim tape made from 100 per cent recycled material; 50 per cent HFFR and 50 per cent HDPE on the left and a collated nail strip on the right made from the same material.

Bio-based PVC

The world's first bio-based PVC was launched by Inovyn in October 2019. The material has been developed in cooperation with the floor manufacturer Tarkett. The product is not yet on the market.[54]

3.2 Material efficiency

Material efficiency is an important strategic effort at both EU and national level to reduce the climate impact of the construction and demolition sector.[55] [56]

Material efficiency means reducing the amount of material used in products, processes and buildings. This can be done in different ways: either by using less virgin material, reducing discards and waste, or by using a product for a long time to avoid the need to produce new material.

It is important to have access to information about the products and materials in a building to have efficient material handling during construction and future renovations and demolition. Information about the product content, dimensions, quantity and position in the building provides a list of what can be reused or recovered in the future.

The following are some general examples of material efficiency for building materials. It has not been possible to find examples that illustrate how effective this use of plastic is, so they should be regarded as inspiration for future development. The examples also include tools that facilitate the sharing of information during the construction process, as this is an important basis for future material efficiency improvements through reuse and material recovery.

[54] (Hållbar Kemi 2030, 2019)
[55] (SOU 2018:51)
[56] (European Commission, 2014)

BREEAM

The Swedish version of the international environmental rating system, BREEAM, provides an indicator of material efficiency. This includes using less material, re-using existing demolition waste, and purchasing more recycled materials.[57] The purpose of this indicator is to minimise the climate impact of material use and waste without compromising building design stability, durability or service life.[58]

LEED

The LEED environmental rating system focuses mainly on energy efficiency but also includes requirements for reduced waste volumes. A premium is placed on the recycling and recovery of materials in the assessment.[59]

Modular design using standard products

BoKlok is an example of an industrial builder that manufactures housing units from standardised modular systems. They have managed to achieve waste volumes below 10 kg/gross tonne area, which is considered to be a low amount in the construction and demolition sector.[60]

Customised products and standard modules

Customised products can help improve material usage by reducing installation waste on the construction site. The waste produced by the material manufacturer can be recycled back into production as a raw material. Products adapted to standard modules can also be used to contribute to more efficient material use. No matter which option is chosen, it is a decision that needs to be made at the drawing board stage.

To give examples of the potential savings for plaster waste, it should be mentioned that when the Nattugglan block in Stockholm was being rebuilt, Vasakronan ordered customised plaster boards from the factory, which reduced the amount of gypsum waste by 20 per cent.[61]

Construction product declarations

The construction product declaration is a Swedish industry agreement on how a product's environmental performance is declared. It includes a declaration of contents of materials and substances, the origin of raw materials, whether any raw material is recycled, whether the product can be reused, and how to handle the product when it has become waste.

EPD

The Environmental Product Declaration (EPD) is an independently verified and registered document that provides transparent and comparable information on a product's environmental impact from a life cycle perspective.

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[57] (Sveriges Byggindustrier, 2019)
[58] (BREEM-SE, 2017)
[59] (Sveriges Byggindustrier, 2019)
[60] (Ejlertsson, Loh Lindholm, Green, & Ahlm, 2018)
[61] (Ejlertsson, Loh Lindholm, Green, & Ahlm, 2018)

Logbook

The Swedish National Board of Housing proposes that a logbook, a list of the materials in a building, be drawn up at the time of construction and kept up-to-date throughout the life of the building. The developer must ensure that this is done and that the logbook shows all construction products that are included in the building, with the exception of devices, electrical cables and mountings. The proposal is for the legislation to come into force on 1 January 2021.

There are several ways of creating a logbook. One example is to use the BASTA self-declaration system to record what registered products are contained in a building.

3.3 Reuse

At present, plastic products are rarely reused. Plastics and plastic products, as well as products containing several materials in addition to plastics, need to be designed for reuse and recycling to a greater extent.[62] However, some stakeholders in the construction and demolition sector have started to investigate reuse of interior construction materials and furniture containing plastics, among other things. This is why the following shows some general examples of the reuse of interior building materials and furniture.

The construction industry's circular marketplace

Centrum för Cirkulärt Byggande [*The Centre for Circular Construction Methods*] has developed a digital marketplace for reuse building materials, furniture and furnishings. Stakeholders from throughout the industry can use the digital tool to list, purchase and sell materials and products.[63]

Guidance and tools for reuse in the construction and demolition sector

White Arkitekter has developed a guide to assist architects, clients and project managers with reuse projects. The guide suggests that buildings should be seen as resource banks and that the stakeholders involved should create the vision for a new project based on the materials and products that can be reused.[64]

IVL Swedish Environmental Research Institute has published a guide to ways of working that can increase reuse when refurbishing premises. The aim is to provide support and knowledge for property owners and other stakeholders who want to work towards increased reuse of interior construction products.[65]

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[62] (SOU 2018:84)
[63] (Centrum för Cirkulärt Byggande, 2019)
[64] (White Research Lab, 2018)
[65] (Gerhardsson, Lindholmen Loh, & Ahlm, 2019)

Reuse operators

CS Riv is a demolition company that sells products and materials that can be reused through its subsidiary Brattöns Återbruk before a building is demolished. Most of the products are sold to customers on a subscription basis.[66]

Another reuse option is provided by Kompanjonen, which checks the inventory premises to enable reuse and brokers reused products between sellers and buyers.[67]

3.4 Recycling

As noted earlier, plastics are a collective name for a large group of polymeric materials that have different properties and therefore are suitable for recycling. If a circular plastic flow is to be created, possibilities for future recycling need to be considered at the design stage. Avoiding the use of plastics with chemical additives hazardous to human health and the environment enables the potential for future recycling of the material.

Material recycling is made more complicated if bio-based raw materials are used in the plastic. These are so-called 'replacement plastics', with physical and chemical properties differing from those of today's fossil-based plastics. They can be either biodegradable or non-biodegradable. One problem with biodegradable replacement plastics is that they do not fit into today's recycling system. In addition, industrial composting is usually required to decompose them. Sweden currently has no composting on an industrial scale. This makes these biodegradable replacement plastics problematic when they end up in waste.[68] But there are also bio-based so-called 'drop-in plastics', which have the same chemical and mechanical properties as the corresponding fossil plastics and are therefore easier to recycle. They can be recycled into existing systems without any impact on the quality of the recycled material.[69]

For this reason, separated collection of different types of plastic waste is a prerequisite for good recycling. A well-considered system and a functioning logistics chain from the construction and demolition site to the next links of the chain are required to collect the materials in a controlled manner and pass them on to operators who sort, wash and create granulate. Equally important is that there is a demand for recycled materials.[70] Transparent recycled plastic generally has a higher market value than coloured because it is easier to manufacture more types of products from it.

It is important to keep the plastic free of dirt and other contaminants when it is collected for recycling.[71] The industry has a few voluntary initiatives for a return system for installation waste from plastic, such as from plastic flooring[72] and plastic pipes[73]. They have their own sorting and logistics systems and a method for quality assurance of the returned material so that it can be re-introduced to production as a raw material.[74]

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[66] (Brattöns Återbruk, 2019)
[67] (Kompanjonen, 2019)
[68] (SOU 2018:84)
[69] (SOU 2018:84)
[70] (Jansson, Boss, & Lundberg, 2019)
[71] (Fråne, Andersson, & Lassesson, 2017)
[72] (Golvbranschen, 2019b)
[73] (NPG Nordic, 2019)
[74] (SOU 2018:51)

Sweden has producer responsibility for packaging, including plastic packaging. This means that manufacturers who sell packaging on the market are responsible for its collection and recycling.

The following are some examples of separate collection of plastic waste and recycling of plastics in the construction and demolition sector.

Industry system for returning installation waste from plastic flooring

Golvbranschens Riksförbund [*The Swedish Flooring Trade Association*] has a collection system for waste from installation of plastic flooring (made of PVC and polyolefin). It is estimated that up to 10 per cent waste is generated when plastic flooring is laid, creating approximately 1,800–2,000 tonnes of waste each year. The waste should be collected separately at the construction sites for it to be collected through this dedicated system.[75]

Industry system and project for return of plastic piping installation waste

In Sweden, the Nordic Plastic Pipe Group (NPG) has employed a system for collecting plastic pipe waste from new builds and old pipes from demolition or renovation since 1996. The system is used for pipes and pipe fittings made of PVC, PE and PP. Until recently, there were only seven sites for collection in Sweden, and the share collected was far less than the potential.[76] NPG is now participating in a development project, Repipe Demo, led by RISE, aimed at upgrading the collection system and increasing rates of waste collection and recycling at installation sites. It is estimated that 5,000 tonnes of waste are generated from installation of pipes in Sweden annually and that 10,000 tonnes of CO_2 equivalent would be saved by recycling it.[77]

International industry system for the collection of PVC roofing sheets

Ten international manufacturers of PVC roofing sheets are members of the international RoofCollect collection and recycling system.[78] Three of them market their products in Sweden, and they can probably assist customers in recycling their old PVC roofing sheets.[79]

The construction industry's Resource and Waste Guidelines for Construction and Demolition

Byggföretagen, the Swedish Construction Federation (formerly Sveriges Byggindustrier) has developed guidelines to improve waste management and increase resource efficiency in the construction and demolition industry. It publishes regularly updated

[75] (Golvbranschen, 2019b)
[76] (NPG Nordic, 2019)
[77] (RISE, 2019)
[78] (Roof Collect, 2019)
[79] (Takdukproducenternas Förening, 2019b)

versions intended to help the industry meet the requirements of the Environmental Code's general precautionary regulations and waste hierarchy, contribute to the achievement of Sweden's environmental goals, and to meet society's expectations of introducing circular flows for materials and waste. The guidelines provide guidance on how different waste fractions, including plastic waste, should be handled at a construction site. In the latest version, published in 2019, the guidelines now include materials inventories, intended to increase reuse.[80]

Nudging at construction sites

The concept of nudging is about giving people, companies and organisations a helpful push in the right direction. In cooperation with Beteendelab, the construction contractor Wästbygg has been running a pilot project aimed at changing behaviour at construction sites to increase sorting of construction waste.[81]

The project included:

- waste sorting containers at the site where the waste was produced
- clear feedback on how well the workplace sorted the waste
- new four-language signs with clear symbols for correct sorting

After a year, the result was a 10 per cent increase in sorting for recycling.[82]

[80] (Sveriges Byggindustrier, 2019)
[81] (Fastighetstidniningen, 2019)
[82] (Wästbygg, 2019)

4. Guidance and advice for the construction and demolition sector stakeholders

Construction projects are usually carried out by project organisations with a large number of stakeholders who interact and change from project to project. Construction, maintenance and renovation are a partnership between builders, property owners, architects, technical consultants, construction companies and building materials' manufacturers, but also wholesalers and retailers.[83] All of these stakeholders have an impact on the use of plastic in a construction project.

This part of the report presents how climate impact can be reduced through possible measures for the various stakeholders in the construction and demolition sector. The selected measures are a compilation of recommendations identified in various studies and reports and are not comprehensive. They have been verified through consultation with a reference group from the construction and demolition sector.

All of the measures are based on the principle that reducing production and use of fossil raw materials will result in climate impact reductions. The exact climate impact of the various measures depends on many factors, such as the amount of material used, the type of raw material, the manufacturing process and transports. There is currently insufficient data to quantify the impact of individual measures. For this reason, the report suggests that stakeholders in the construction and demolition sector consider the measures to be a source of inspiration and use their own life cycle analyses to identify the measures they want to implement in their organisations.

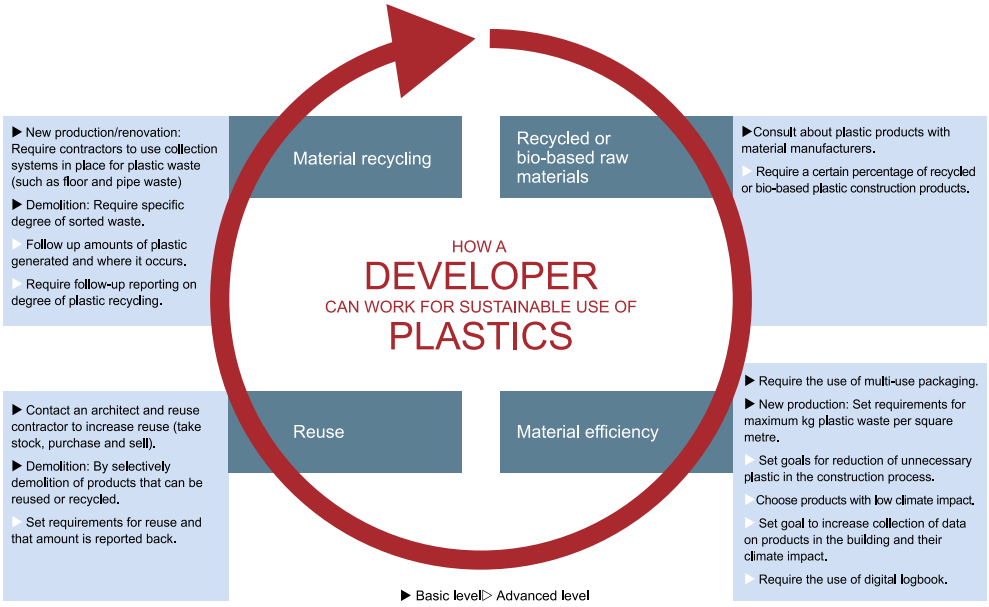
The measures are presented at two different levels for the various stakeholders:

- *Basic level*: This means that logistics solutions, information and tools already exist that will make it possible to implement the measures immediately.
- *Advanced level*: This means that a specific measure is linked to an area that is less developed or under development, and its implementation will contribute to its development.

4.1 The Developer

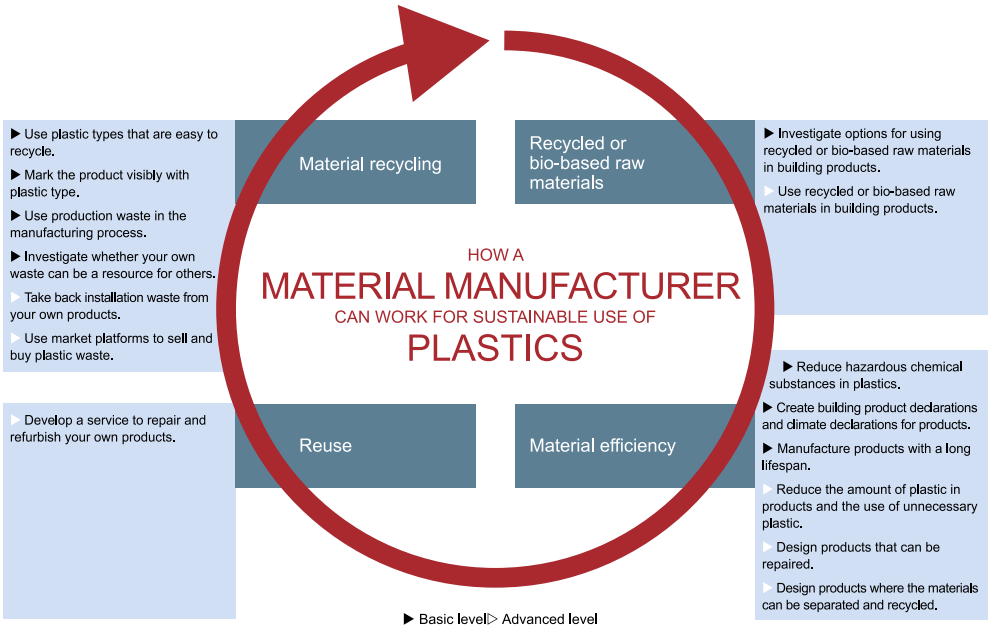
The developer has an important role in achieving the sustainable use of plastic in the construction and demolition sector. Many of the demands made by the developer early in the construction process affect both product selection at a later stage and the key figures to be followed up during the construction project. To this end, it is proposed that this stakeholder group focus on the following measures:

[83] (SOU 2018:51)



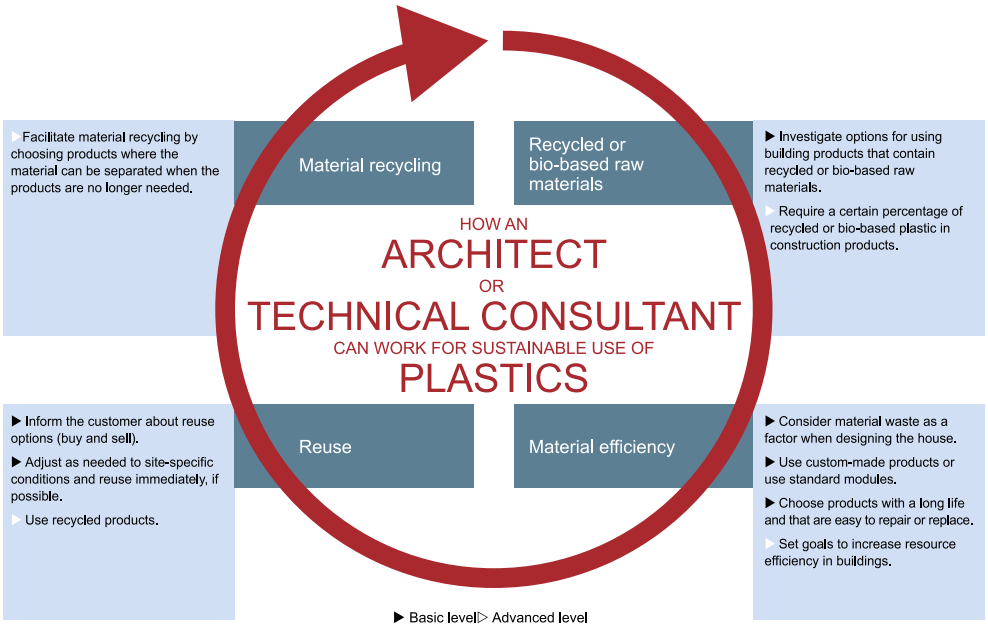
4.2 Materials manufacturers

As noted earlier in this report, the raw materials for a plastic product and its manufacture have a major impact on climate change. It is important that the material manufacturer focuses on measures at these stages of the product life cycle. To this end, it is proposed that this stakeholder group focus on the following measures:



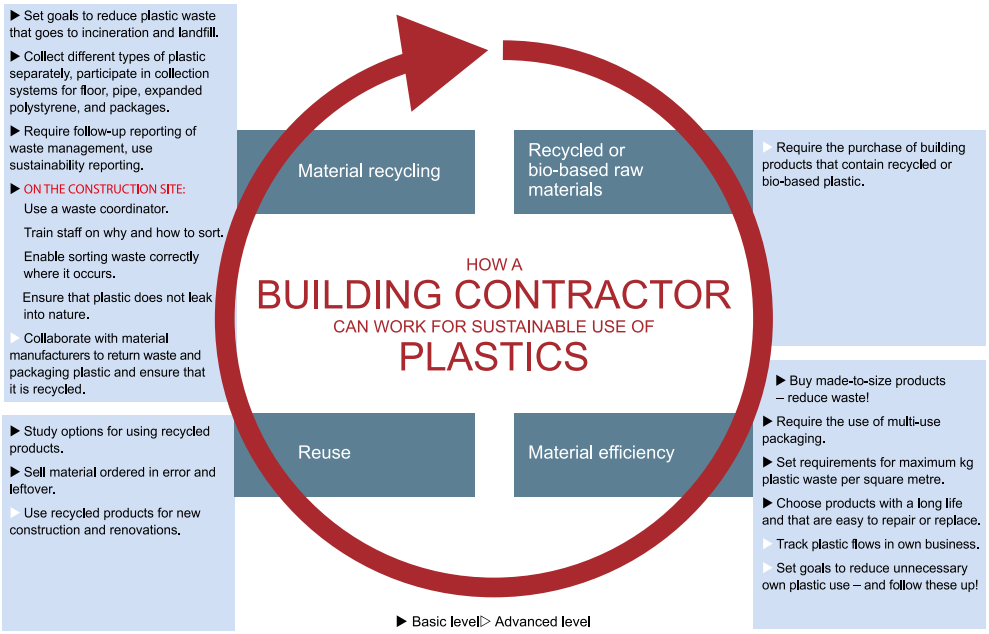
4.3 Architects and technical consultants

Architects and technical consultants will use their knowledge of different materials and technology solutions to design a building that meets the requirements of the developer. To this end, it is proposed that this stakeholder group focus on the following measures:



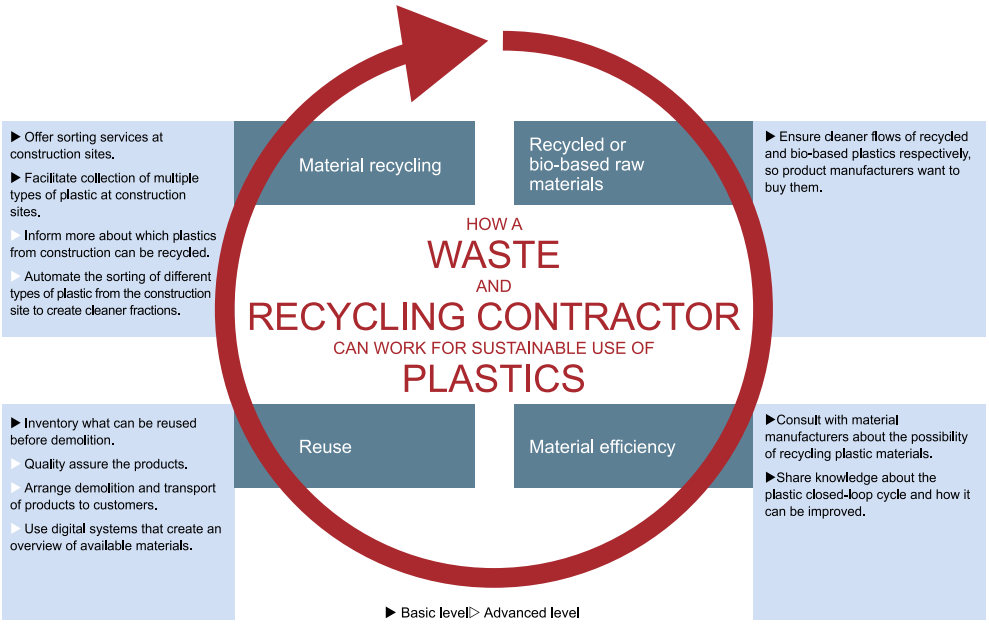
4.4 Building contractors

The building contractor is often responsible for purchasing construction materials and thus has a major impact on the final climate impact of the building. The building contractor is also responsible for ensuring that there is no pollution of the surrounding environment. To this end, it is proposed that this stakeholder group focus on the following measures:



4.5 Waste and reuse contractors

The roles of waste and demolition contractors are changing. Many acknowledge their social responsibility for completing the material cycle, but the whole value chain must work together to achieve this goal. Some waste and demolition contractors already work on reuse, as indicated by this stakeholder group's name: waste and reuse contractors. Priority measures for this stakeholder group are as follows:



5. Identified obstacles, needs and knowledge gaps

As shown in this report, there are several measures that the stakeholders in the construction and demolition sector can take to reduce the climate impact of plastic in the sector. However, there are also areas that the industry needs to develop jointly to meet future demands for sustainable plastic use.

Several obstacles and knowledge gaps have been identified from the review of the state of knowledge and during oral review with representatives from the various stakeholder groups when the proposed measures in Chapter 4 were discussed. Some of the most important measures apply to all stakeholder groups and are based on interaction throughout the whole value chain:

Combining the right data: The main knowledge gap is that there is no data showing the climate impact of plastic in the construction and demolition sector. Information is available on the general climate impact of the construction and demolition sector and on the climate impact of plastic, but information about the combination is needed. Producing this data is essential for our prioritisation of future measures.

Overview leads to development: If sustainable use of plastic is to come about, the plastics cycle needs to function properly. We need an overview, partly of what plastic flows in the construction and demolition sector look like and partly of the opportunities for material recycling and reuse that are available for different types of plastic – from technical, commercial and sustainability perspectives. This overview should highlight several prioritised plastic flows and work to ensure that they function so that all the stakeholders in the construction and demolition sector can work together to create a circular flow of plastic.

Another obstacle is the fact that it can be difficult to choose which plastic material should be used in different designs. Products are selected on the basis of a variety of aspects, including:

- the necessary function the material
- existing standards
- their climate impact
- how easy or difficult they are to recycle
- demand for them in the recycling market

In addition, the construction and demolition sector should continue exploring the option of using bio-based raw material, because this is currently only a minuscule part of the plastic used.

Support for product selection: There is currently no knowledge of the climate impact of these different aspects, but there is industry interest in such an overview. Environmental product declarations (EPD) for plastic construction products are important sources of information that can facilitate the selection of individual products. But

more guidance in the form of easily accessible information and knowledge-increasing initiatives is needed in this area. It should be easy to do the right thing and it should be easy to understand what measures can be implemented. One way would be to create a guide to which materials and products should be chosen from different perspectives, another would be to produce key figures that make the selection easier.

Digital information flows: A fundamental requirement for creating a sustainable circular plastic flow is that quality assured, accessible, up-to-date digital information about the content of products is available and that it is possible to link the information to the building and location of the installed products. Information on recycled raw material in the product, about its constituent chemical substances and how to handle the material in the waste chain can be found in the product's construction product declaration and saved in the building logbook. At present, a lot of information is processed manually and in an analogue way, which is both resource-intensive and precarious from a quality assurance point of view. This makes continued digitisation in the construction and demolition sector important from a circular perspective.

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Appendix 1: Purpose, target group, limitations and method

Purpose and target group

The purpose of this study was to compile, analyse and present the state of the field related to:

- Opportunities to promote a more sustainable use of plastics in the construction and demolition sector to contribute to:
  - Reduced climate impact and
  - Reduced seepage of plastic (debris, microplastic, etc.) into nature
- What different stakeholders in the construction chain can do to leverage these opportunities

The target group for the report is environmental and sustainability managers in the construction and demolition sector, who can use it to set goals for their sustainability work and to show what can be done to achieve their objectives. Another important target group could be organisations that develop and manage certification systems in the construction field. Other stakeholders in the construction chain are secondary target groups.

The aim of the report was to compile available information in a way that is easily accessible to the target group.

Limitations

This study was carried out from 16 October to 31 December 2019 and was based exclusively on desk surveys.

There is currently insufficient knowledge and data about the use of plastic in the construction and demolition sector and its climate impact. Because of this, it was not possible to prioritise the various measures based on quantitative data showing climate impact.

There will be a need for more development projects and case studies to produce the data and information about plastic use in the construction and demolition sector. The construction and demolition sector also needs to report more information about materials used in buildings, including where they are located and what they contain.

Methodology

This review of the state of knowledge built on earlier reports published by the Swedish Environmental Protection Agency about plastic flows and measures to increase the reuse and recycling of construction and demolition waste.

Thereafter, a survey of available knowledge, information and data contained in reports, articles and publications on the web was produced. Over 50 relevant sources were found associated with one or more of the following topics:

- Use of plastic
- Recycling of plastic
- Construction and demolition waste and recycling
- Plastic in construction and demolition waste
- Recycling in the construction and demolition sector
- The climate impact of the construction and demolition sector
- The climate impact of plastic
- Material efficiency in the construction and demolition sector

Relevant measures for sustainable plastic use in the construction and demolition sector were identified and used as a basis for the figures in Chapter 4. The selected measures have been verified through a discussion with a reference group from the construction and demolition sector.

Other relevant information is presented in the other chapters and sources are referred to in footnotes.

REPORT 7077 | MAY 2020 ISBN 978-91-620-7077-9 ISSN 0282-7298

Opportunities for reducing climate impact through the circular use of plastic in the construction and demolition sector

State of knowledge in the field

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