Nordic Council of Ministers

Improving quality of construction & demolition waste – Requirements for pre-demolition audit

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Margareta Wahlström, Malin zu Castell-Rüdenhausen, Petr Hradil, Katrine Hauge Smith, Anke Oberender, Maria Ahlm, Johan Götbring and Jette Bjerre Hansen

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The project has been coordinated by VTT from Finland. The project group consisted of the following persons:

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December 2018
Project group

Preface

Construction and demolition (C&D) waste is one of the priority areas in Europe according to the Action Plan for Circular Economy.[1] C&D waste is the largest contributor to waste streams generated in Europe, and according to Eurostat about 8 million tonnes of mineral C&D waste was generated in the Nordic countries in 2014. The waste is typically used as unbound materials in road construction, used for backfilling or landscaping, disposed of in landfills or incinerated. The recycling and reuse potential of C&D waste is still underexploited. The major challenge is the poor quality of the waste, typically due to the low degree of identification and removal of hazardous substances or undesirable fractions at source and poor sorting of waste fractions, which results in heterogeneity and potential content of hazardous substances.

An audit (named pre-demolition audit) prior to the demolition or renovation of buildings is the crucial starting point in ensuring proper C&D waste management. As such, an audit is a tool that can be used to both identify hazardous substances and assess the materials to be removed from the building or infrastructure, and consequently their potential value, prior to the demolition or renovation activity can be established. It is also an important tool when planning and implementing safe and sound deconstruction. Such audits are essential, since they enable all stakeholders involved to get information on the composition of materials and waste and make it easier to find markets and recovery options for different types of materials and waste.

The EU Waste Framework Directive (Directive 2008/98/EC) requires the Member States of the European Union to take the necessary measures to achieve a minimum of 70% (by weight) reuse, recycling and other material recovery (including backfilling) of non-hazardous C&D waste by 2020. The EU regulation brings pressure to bear on more sustainable use of materials in construction and on closing the material loops. The Commission is now considering new material-specific reuse and recycling targets, e.g.

[1] Communication from the Commission to the European Parliament, The Council, The European Economic, and Social Committee and the Committee of the regions. Close the loop – An EU action plan for the Circular Economy, Brussels, 2 December 2015COM(2015) 614 final.

for wood, plastics, and gypsum, etc. in C&D waste by 2024. In addition, the EU regulation on waste encourages Member States to take actions to promote selective demolition and sorting.

Since there are same goals for resource efficiency and environmental protection in the Nordic countries, the common Nordic approach to the pre-demolition auditing will be beneficial by providing a common mindset, knowledge base and methodologies, taking into account the differences between the countries. If possible, a common format of C&D waste identification and documentation would simplify the cross-border trade of valuable materials and components between the Nordic countries.

This report compares the current situation for C&D waste management and focuses on pre-demolition audits in Denmark, Finland and Sweden, and to a limited extent Norway. The authors present recommendations on key elements to be included in audits for improving the quality of the C&D waste. Hopefully the results of this work can be utilized as background information in the further development of national guidance documents on pre-demolition audits.

The project was funded by the Nordic Waste Group (NWG) under the Nordic Council of Ministers.

Helena Dahlbo
Chairman of the Nordic Waste Group

Terms and definitions

BIM	Building information modelling
BREEAM	Building Research Establishment Environmental Assessment Method
CLP	Classification, Labelling and Packaging Regulation. Regulation (EC) No 1272/2008 of the European Parliament and of the council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006
DEHP	Di(2- ethylhexyl) phthalate
DG GROW	European Commission. Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs
DGNB	Deutsche Gesellschaft für nachhaltiges Bauen e.V. – German Sustainable Building Council
EAD	European Assessment Document
EoW	End of waste
ETA	European Technical Approval Guidelines
HBCDD	Hexabromocyclododecane
LEED	Leadership in Energy and Environmental Design
LoW	Commission Decision 2014/955/EU: Commission Decision of 18 December 2014 amending Decision 2000/532/EC on the list of waste pursuant to Directive 2008/98/EC of the European Parliament and of the Council (European List of Waste)
PCB	Polychlorinated biphenyls
PFOS	Perfluorooctanesulfonic acid
POP	Persistent organic substances
VOC	Volatile organic compound
WFD	Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Waste Framework Directive)
ÖNORM	Österreichisches Normungsinstitut (Austrian Standards Institute)

Summary

Construction and demolition (C&D) waste arises from the construction, renovation and demolition of buildings and infrastructure, which accounts for around a third of the waste streams generated in the Nordic countries. C&D waste consists of various materials, including concrete, bricks, gypsum, wood, glass, metals, plastic, solvents, hazardous substances (asbestos, PCBs, etc.) and excavated soils. The waste is typically used as unbound materials in road construction, for backfilling or landscaping, or is disposed of in landfills or incinerated. The recycling and reuse potential of C&D waste is still underexploited. The major challenge is the poor quality of the waste, typically due to the low degree of identification and removal of hazardous substances or undesirable fractions at source and poor sorting of waste fractions, which results in heterogeneity and potential content of hazardous substances.

It is likely that the Commission will recommend Member States to make the waste audit mandatory in order to increase the quality of recycling. A pre-demolition waste audit is the crucial starting point in ensuring proper C&D waste management – it is a tool to identify and assess the materials to be removed from the building or infrastructure and their potential value prior to the demolition or renovation activity. It is also an essential tool when planning and implementing safe deconstruction. Such audits are essential since they enable all stakeholders involved to get information of the composition of waste and make it easier to find markets and recovery options for different waste types.

The basis for the project was the Waste Audit Guideline published by the European Commission in 2018.[2] The Guideline provides information about the best practices for the assessment of C&D waste streams prior to demolition, deconstruction or renovation of building or infrastructure, called "waste audit". The auditing process aims to deliver such documents that the owner can submit a building permit application and open a call for demolition tenders. Furthermore, the outcome of the auditing should also provide a reliable basis for the order of a contractor concerning demolition waste.

[2] European Commission. (2018). Guidelines for the waste audits before demolition and renovation works of buildings https://ec.europa.eu/docsroom/documents/31521

The Waste Audit Guideline sets out the steps to be included in an audit and defines the stakeholders to be involved in the process along the value chain.

The detailed and practical implementation of most elements of the pre-demolition audit is decided at national level. A number of elements (e.g. thresholds for mandatory audits, templates for reporting, methodologies for sampling, etc.) are already implemented in the Nordic countries. Furthermore, there are several activities and Nordic guidelines available or planned which support the implementation of waste auditing at national level.

The aim of this report was following:

- To make an overview of the implementation of waste auditing in Denmark, Finland, Sweden and to a limited extent in Norway;
- To identify tools and good practices that can further be included in the implementation of pre-demolition waste audits in the Nordic countries;
- To give recommendations on elements to be included in waste auditing for improving the quality of construction and demolition waste.

In the report, the legislative background in Denmark, Finland and Sweden and to a limited extent in Norway is briefly presented. The content of existing guidelines is reviewed. In addition, the current practice in waste management of C&D waste in three of the Nordic countries is briefly described, including examples of best practice. A short review on the practice on C&D waste management in other countries is also included.

There are mandatory requirements for waste audits in Denmark, Finland and Sweden and also in Norway. The guidance documents contain same elements but partly with different focus. In Denmark, the main focus of the survey on hazardous substances is on the health aspects in renovation and demolition. The Finnish guideline describes in detail the materials and products containing hazardous substances for identification as well as covers the practical aspects in sampling. Additionally, work safety aspects especially in the handling of asbestos wastes are included. The Swedish guidance has broader scope on the waste management of the demolition process by covering the recycling potential of the demolition wastes. Finland and Sweden also have systems for certification of auditors conducting an inventory of hazardous substances. Not much guidance on the assessment of waste amounts arising from demolition has been published.

The recovery rate of the mineral and metal fraction of the C&D waste is rather high in all three Nordic countries. However, part of the waste is still backfilled. For waste other than the mineral and metal fraction, there are still needs for improving the recycling and reuse. The main barrier observed related to the difficulties in establishing markets for the recyclables, due to the price, quality and quantities of the secondary raw materials. High-quality recycling and reuse require greater effort compared to energy recovery and low-grade material recycling.

A short survey on practice in other countries revealed supporting information that could be helpful in the further development of Nordic guidelines for implementation of a pre-demolition audit. For example, the following interesting practices were identified: the complementary knowledge on hazardous substances in Norway, the traceability system developed for tracking C&D waste along the process chain in Belgium in Flanders, the Austrian standard which includes a list of construction materials that need to be removed from the building prior to demolition, a certification system for the demolition process developed in the Netherlands, and in Spain in the Basque region, the obligation to compare the estimated waste amounts to the actual waste amounts generated in the demolition.

The project group recommended the following:

- Development of a harmonized protocol for auditing of hazardous substances. Special focus could be on how to identify hazardous materials for the assessment of both recyclability of the construction products and for identifying the need for decontamination. Also, practical guidance would be helpful, e.g. on minimum hazardous substances to be identified, recommendations for sampling and analysing, minimum requirement for documentation, and development of a check list. The project group also noted that there is a need for separate documents for different target groups (owners, auditors, contractor, end-users). It is important that guidelines are easily readable for the target group;
- Development of a certification system for auditors in the Nordic counties because many demolition companies operate today in several Nordic countries. There is also a common need for education in all countries, where sharing of competence (common education materials, teachers) could be valuable. Furthermore, actions are needed which aim to raise awareness for all stakeholders through brochures, presentations at construction conferences, and collation of Nordic examples of good practice which support better waste management;

- Development of a supply chain tracking system: documentation, labelling, building passport, potentially the development of new technological tools for tracing. Inclusion of a traceability system could also be an important part of potential future end-of-waste status of waste directed at high-grade recycling;
- Development of new tools for material inventory. For example, the use of the Building Information Modelling (BIM) provides opportunities for data storing. Also, tools to estimate future waste amounts in different scenarios before demolition could be useful.

1. Introduction and background

The scope of this report includes waste from demolition, deconstruction and renovation works. It excludes construction waste, building equipment, excavations and dredging soils.

The report has the following target groups of stakeholders:

- Industry practitioners; construction sector (including renovation companies and demolition contractors), waste treatment, transport and logistics as well as recycling companies;
- Public authorities at local, regional, national and EU levels; and
- Certification bodies for building and infrastructure.

This report is aligned with European strategies for the construction sector and C&D waste management. It follows the objectives of the Waste Framework Directive 2008/98/EC [3], Construction 2020 strategy[4], the Communication on Resource Efficiency Opportunities in the Building Sector[5] and the Circular Economy Package presented by the European Commission in 2015.[6]

In the scope of this report, the audit prior to deconstruction or renovation is called pre-demolition audit, which covers the process initiated and organized by the building or infrastructure owner. The audit means verification of the current state of the building or infrastructure and gathering all the necessary information for the future demolition,

[3] Directive 2008/98/EC on waste (Waste Framework Directive) (updated in 2018) available online from http://ec.europa.eu/environment/waste/framework/

[4] COM (2012) 433: Communication from the Commission to the European Parliament and the Council: Strategy for the sustainable competitiveness of the construction sector and its enterprises, Brussels, accessed online at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2012:0433:FIN

[5] http://ec.europa.eu/environment/eussd/pdf/SustainableBuildingsCommunication.pdf

[6] COM (2015) 614: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Closing the loop - An EU action plan for the Circular Economy, Brussels, accessed online at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52015DC0614

deconstruction or renovation works. According to the EU C&D Waste Management Protocol[7], the pre-demolition audit is a preparatory activity with the purpose of collecting information about the qualities and quantities of the materials that will be released during the demolition, deconstruction or renovation works and giving site-specific recommendations regarding the hazardous waste to be removed and handled safely. In addition to the inventory of hazardous and non-hazardous wastes, reusable materials and components, the audit may include recommendations for specific management options for these materials and components, their value and environmental footprint.
This report gives recommendations and best practices for the implementation of the EU Waste Audit Guideline[8] in the Nordic countries. It is focused especially on contractors, consultants/auditors and facility owners. The aim is to provide a harmonized approach for performing the pre-demolition audits in the Nordic countries which takes the existing legislation and current Nordic practice/knowledge base into account.

The main aim of this report is to facilitate the introduction of pre-demolition audits in the Nordic countries.

This is done by:

1. Mapping of the legal requirements for the pre-demolition audits in Denmark, Finland and Sweden.
2. Identifying key elements in the pre-demolition audits in a Nordic perspective.
3. Creating a knowledge base for status of implementation of key elements of the pre-demolition audits in practice, including examples of best practice – How far are we already and what remains to be implemented?
4. Identifying instruments and prerequisites that can further improve implementation of the pre-demolition audits in practice.
5. Exchanging knowledge across countries and identifying education needs in the value chain.
6. Presenting recommendations for implementation of key elements in the national guidelines.

[7] European Commission (2016) "EU Construction and Demolition Waste Protocol", available online from https://ec.europa.eu/growth/content/eu-construction-and-demolition-waste-protocol-0_en
[8] European Commission (2018) "Guidelines for the waste audit before demolition and renovation works of buildings", available online from https://ec.europa.eu/growth/content/eu-construction-and-demolition-waste-protocol-0_en

1.1 The EU Waste Audit Guideline

The EU Waste Audit Guideline was published by the European Commission (DG GROW) in 2018.[8] The Guideline provides information about the best practices for the assessment of C&D waste streams prior to demolition, deconstruction or renovation of building or infrastructure, called "waste audit". The aim of the Guideline is to facilitate and maximize the recovery of materials and components for beneficial reuse and recycling without compromising the safety measures and practices outlined in the EU Construction & Demolition Waste Management Protocol.[9] This C&D Waste Management Protocol states that:

- Any demolition, renovation or construction project needs to be well planned and managed in order to reduce environmental and health impacts while providing important cost benefits;
- Waste audit (part of pre-demolition audit as defined in the C&D waste Management Protocol) is to be carried out before any renovation or demolition project, for any materials to be reused or recycled, as well as for hazardous waste;
- Public authorities should decide upon the threshold for pre-demolition audits;
- Pre-demolition audits take full account of local markets for C&D waste, reused and recycled materials;
- A good pre-demolition audit must be carried out by a qualified expert (the auditor).

Additionally, a Construction Waste Measurement Protocol was published by Encord in 2013[10] that provides guidance on the measuring and reporting of waste that arises from construction activities.

The EU guidance documents (Figure 1) give the basis for the implementation of the pre-demolition audit. The detailed and practical implementation of most elements of the pre-demolition audit is decided on national level.

[9] European Commission (2016) "EU Construction and Demolition Waste Protocol", available online from https://ec.europa.eu/growth/content/eu-construction-and-demolition-waste-protocol-0_en

[10] Waste Measurement Protocol (2013) available online from http://www.encord.org/wp-content/uploads/2013/06/2013-05-ENCORD-Waste-Measurement-Protocol-Issue-V1-Low-Res.pdf

Figure 1: Guidelines and protocols published by the European Commission: EU guideline for Waste audit (2017)[11], EU Construction & Demolition Waste Management Protocol[12] and Construction Waste Measurement Protocol was published by Encord in 2013[13]

An effective process for carrying out a waste audit should follow the following steps (see Figure 2):

- *Desk study*: Collection of all the relevant information from the documentation of the building or other work (age and use of the building, drawings, materials used, hazardous materials etc.), planning of inspections and measurements;
- *Site visit:* Visual inspections, comparisons with collected documents, assessment of materials, sampling to determine presence and levels of hazardous substances, preliminary planning of deconstruction techniques and waste handling on site as well as communication between actors engaged by the owner of the process. The site visit can be organized by the owner or any actor on his/her behalf;

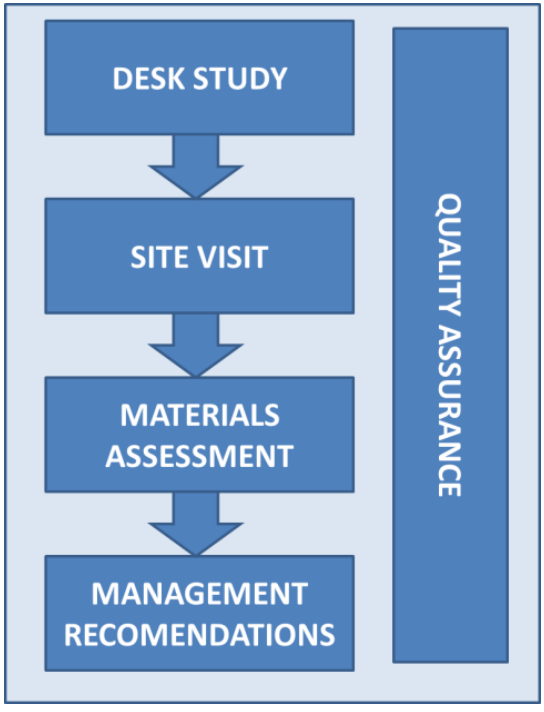
[11] European Commission (2018). Guidelines for the waste audits before demolition and renovation works of buildings https://ec.europa.eu/docsroom/documents/31521

[12] European Commission (2016). "EU Construction and Demolition Waste Protocol", available online from https://ec.europa.eu/growth/content/eu-construction-and-demolition-waste-protocol-0_en

[13] ENCORD (2013). Construction Waste Measurement Protocol A guide to measuring and reporting waste from construction ctivities. http://www.encord.org/wp-content/uploads/2013/06/2013-05-ENCORD-Waste-Measurement-Protocol-Issue-V1-Low-Res.pdf

- *Materials assessment:* The materials assessment is a summary of the amount of waste (in mass or volume) in the various European waste classes;
- *Site recommendations:* Suggestion for opportunities to increase recyclability (also reusability) of materials and construction products to minimize the disposal or incineration of the waste.

Figure 2: The audit process steps



Source: DG GROW study, 2017.[14]

[14] Arevalillo, A., Hradil, P., Wahlström, M. (2017). EC "Technical and Economic Study with regard to the Development of Specific Tools and/or Guidelines for Assessment of Construction and Demolition Waste Streams prior to Demolition or Renovation of Buildings and Infrastructures". Final report of EU Specific Contract 30-CE-0751644/00-00 – SI2.720069 (2017). https://ec.europa.eu/docsroom/documents/24562/attachments/1/translations/en/renditions/pdf

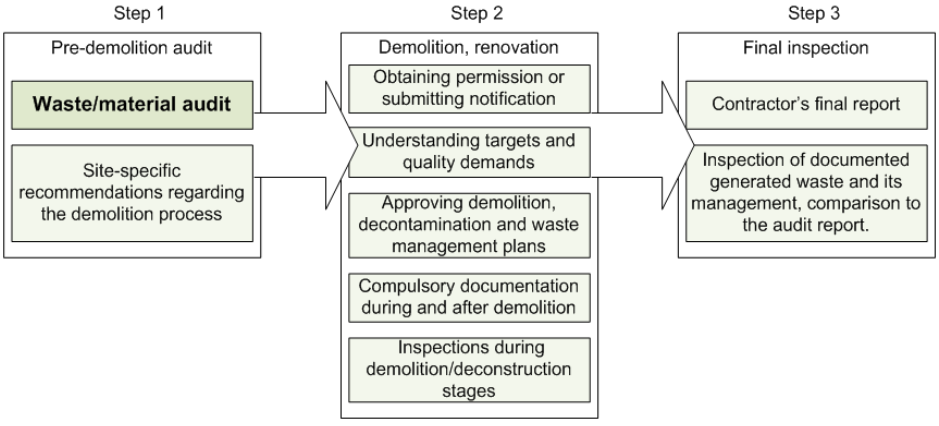
1.2 Context of the pre-demolition audit

If the materials or components in the terminology of the Waste Framework Directive are discarded, they become wastes. The goal of the pre-demolition audit is to produce the necessary information needed to reduce the amount of discarded materials and components and to keep their quality and purity as high as possible during the demolition process for the further recycling.

The pre-demolition audit belongs to the first part of a three-step material tracing process (see Figure 3):

- *Step 1 – Auditing phase:* An inventory of materials suitable for recovery and of hazardous and non-hazardous materials is made before the demolition process in order to prepare a good quality demolition plan which allows building materials suitable for reuse or recycling to be recovered in time and hazardous substances and materials to be removed before demolition. It also serves as documentation in order to obtain a demolition permit;
- *Step 2 – Monitoring phase during demolition and renovation:* Materials and components are removed from the building or infrastructure and their amount is typically measured for the future on-site or off-site management. The results of the on-site measurement are often used as declaration for the waste shipping companies that deliver the material for recycling or disposal;
- *Step 3 – Final inspection:* At the end of the demolition process, the building or environmental authorities often inspect the site and check the documented amounts of generated waste.

Figure 3: Waste audit as part of the demolition process



The implementation should be decided on national level. The most basic elements to be defined at national or regional level for the implementation of the waste audit are the following:

- Thresholds (minimize size, conditions, materials, etc.) for executing the mandatory audit or its parts (if any);
- Templates or electronic forms for waste audit reporting;
- Methodologies for sampling and materials identification and hazardous materials detection;
- Required skills and certifications for the auditors;
- Best practices in waste identification and reporting;
- Regulations for waste sorting, landfill and waste treatment;
- Incentives to support waste treatment, separation and reuse.

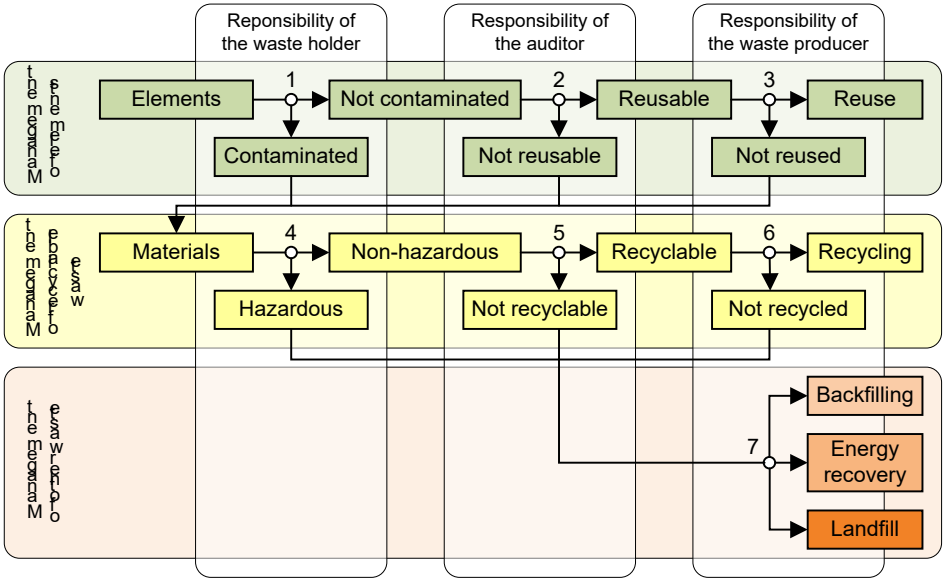
Several actors are involved in the process:

- *The building owner* is in principle the owner (holder) of the waste and reusable materials. The ownership can be contracted to the demolition contractor. The *public and private procurement office* can act as building owner in some cases. It operates in a similar way to the owners and developers in a demolition, deconstruction or renovation project but it is usually engaged in stakeholder communication procedures before any actual project. The building owner can be represented by the *technical and environmental consultants* (designer, architect, structural engineer and environmental engineer) who are in charge of producing expert plans and technical documentation for the owner which form the basis for the demolition permit application (including the pre-demolition audit) and for the call for tenders. The documentation is also the basis for the contractor to prepare a contract and plan safe and efficient procedures for the demolition, deconstruction or renovation work;
- *The contractor* (demolition contractor) provides various services depending on the technical competences, networks and equipment; for instance, small-scale demolition, deconstruction or renovation activities, heavy machinery, transport services, decontamination and recycling facilities. The contractor usually prepares the tender based on the preliminary plans for the building permit application. In the beginning of the project, a contractor is in charge of preparing the detailed work plan and presenting it to the owner and to the building permit authorities on request. The contractor is in charge of site planning for the waste management (separation and storing classified waste in accord with the regulation);
- *The building authority* is typically the municipal office for building or environmental projects' supervision that is in charge of granting demolition permits, conducting inspections of the building site and collecting the information reported by the building owner or contractor;
- *The waste authority* is typically in charge of ensuring correct waste handling and inspection at the demolition site. The waste authority is in contact with the contractor and consultant;
- *The waste manager* provides waste collection services or retail of waste and reports directly to the authorities or keeps the register documents available for further inspection. Sometimes contractors take on this role. More often they hire relevant waste management companies to handle this task.

Three basic roles can be identified in the auditing process and further management of the generated information (see Figure 4):

- *The waste holder (waste owner = building owner)* is the natural or legal person who is in possession of the waste [WFD] at the time of waste declaration. In principle, this means the owner (developer) of the audited property, but the ownership can be transferred to the contractor. The waste holder is responsible for the accuracy of the data concerning the quality and quantity of the material streams and hazardous substances (EU Waste audit guideline). The waste holder shall have the knowledge about hazardousness and contamination of the building materials and components (decisions 1 and 4 in Figure 4). This information can be obtained from the auditor.
- *The auditor (pre-demolition auditor – e.g. environmental consultant) means* the expert or the team of experts performing the audit. The auditor can be represented by the owner (developer) of the property or technical consultant acting on behalf of the owner (DG GROW). Apart from the identification of waste streams, the auditor is responsible for the expert assessment of reusability of deconstructed building components and the recyclability of separated materials. The auditor shall have the experience and skills to decide about the reusability of components (decision 1 in and recyclability of materials (decision 5) and to recommend the most feasible material management options for the contractor/waste producer (decisions 3, 6 and 7).
- *The waste producer* means anyone whose activities produce waste according to the Waste Framework Directive. The waste producer is the waste holder or the contractor who executes the demolition, deconstruction or renovation work on behalf of the waste holder.

Figure 4: Decisions about waste management (from DG GROW Waste audit)



2. Review of current waste audit systems in Denmark, Finland and Sweden

2.1 General overview of legal requirements for pre-demolition audits in the Nordic countries

In this section the legal requirements for pre-demolition waste audits in Denmark, Finland and Sweden are reviewed.

For Denmark, Finland and Sweden, general information about the national legislation and management of C&D waste is available from the EU study[15] published in 2017. Here information on waste amounts, legal requirements (concerning waste prevention, sorting, hazardous waste management, and recycling/reuse targets) and policies, good practice, guidelines for promoting waste recycling/reuse and drivers and barriers are reported in the country factsheets. Also, in the final report[16] to DG GROW study on the waste auditing guideline, country-specific information linked to waste auditing has been compiled.

Table 1 summarizes the existing regulations for C&D waste management and auditing in the three Nordic countries. The table summarizes whether or not the four countries have specialized regulation for C&D waste management. Moreover, the table shows whether or not pre-demolition audits are required by legislation and/or supported by guidelines. Although there are legal requirements for pre-demolition audits in Denmark, Finland, Norway and Sweden, there are some differences related to the scope of the audits and the threshold for waste auditing (see Table 2)

[15] Bio by Deloitte. (2017). Resource efficient use of mixed wastes improving management of construction and demolition waste. https://publications.europa.eu/en/publication-detail/-/publication/78e42e6c-d8a6-11e7-a506-01aa75ed71a1/language-en

[16] Arevalillo, A., Hradil, P., Wahlström, M. (2017). EC "Technical and Economic Study with regard to the Development of Specific Tools and/or Guidelines for Assessment of Construction and Demolition Waste Streams prior to Demolition or Renovation of Buildings and Infrastructures". Final report of EU Specific Contract 30-CE-0751644/00-00 – SI2.720069. https://ec.europa.eu/docsroom/documents/24562/attachments/1/translations/en/renditions/pdf

Table 1: Legislation and guidance for C&D waste management with requirements for audits

Country	Specialized regulation on C&D waste Management	AUDITS		Legislation, and other documents with requirements to Audits
		Regulation	Guideline	
Denmark	Yes[17]	Yes[18]	Yes[19]	Specialized regulation only in terms of NMK 96 – "Nedrivningsbranchens Miljøkontrolordning" – Agreement on selective demolition 1996[20] (in principle only for state owned buildings). Otherwise, no regulations dedicated to C&D waste management only. Statutory order on waste No. 1309/2012[21] (containing requirements for pre-demolition audits with focus on PCB for buildings constructed or renovated during the period 1950–1977) Statuary order on residues No. 1672/2016 (containing limit values for content of PCB in materials for recycling and reuse) Environmental Protection Act, No. 966/2017[22]
Finland	Yes	Yes[23]	Yes	Regulations discuss CDW, but there is no specific document dedicated to CDW Management – Government Decree on Waste (179/2012)[24] Act on Certain Requirements Concerning Asbestos Disposal Work (648/2015)[25] Government Decision[26] on Construction Waste Guidelines and templates are published by professional associations and municipalities
Sweden	No	Yes[27]	Yes[28]	Regulations include CDW, but there is no specific document dedicated to CDW Management Building Code (SFS 2010:900)[29] Swedish Ordinance on PCB (SFS 2007:19)[30]

[17] Danish Protection Agency is working on guidelines for C&D waste management, which gather all relevant legislation on C&D waste.

[18] Statutory order on waste address the issue of inventories of hazardous substances, but only PCB is specifically mentioned in the statutory order on waste. Inventories of resources are not mentioned, but there is a requirement of reporting expected amount of waste to the municipality.

[19] Guidelines for resource inventories have been published, but they are not mandatory.

[20] Brancheaftale mellem Miljø- og energiministeren og Entreprenørforeningens Nedbrydningssektion, tiltrådt af Boligministeriet 1996, Bekendtgørelse om selektiv nedrivning af statsbygninger 1997. https://www.retsinformation.dk/Forms/R0710.aspx?id=84458

[21] Affaldsbekendtgørelse. https://www.retsinformation.dk/Forms/R0710.aspx?id=144826

[22] Miljøbeskyttelsesloven. https://www.retsinformation.dk/forms/R0710.aspx?id=192058

[23] Waste Act (646/2011). http://www.finlex.fi/en/laki/kaannokset/2011/en20110646.pdf

[24] Government Decree on Waste (179/2012). http://www.finlex.fi/en/laki/kaannokset/2012/en20120179

[25] Act No. 648/2015 on certain requirements concerning asbestos removal work (in Finnish). http://www.finlex.fi/fi/laki/alkup/2015/20150684

[26] Finnish Government Decision No. 295/1997 on construction and demolition waste (in Finnish). http://www.finlex.fi/fi/laki/alkup/1997/19970295

[27] Ds 2000:61, The Environmental Code. http://www.government.se/contentassets/be5e4d4ebdb4499f8d6365720ae68724/the-swedish-environmental-code-ds-200061

[28] Vägledning för bygg- och rivningsavfall. http://www.naturvardsverket.se/Stod-i-miljoarbetet/Vagledningar/Avfall/Bygg--och-rivningsavfall/

[29] Plan- och bygglag (2010:900). https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/plan--och-bygglag-2010900_sfs-2010-900

[30] Förordning (2007:19) om PCB. http://www.notisum.se/rnp/sls/lag/20070019.htm

Table 2: List of thresholds and requirements for material inventory in waste auditing

Country	Threshold for audits	Requirement for waste plan	Comment
Denmark	A "PCB screening" has to be carried out for buildings constructed or renovated. If the screening shows that PCB may be present, an audit of the building has to be carried out. Sources for PCB contamination and concentrations have to be determined. Moreover, other type of hazardous waste have to be identified, since they should always be removed from waste. Expert assessment on which substances to be included in the sampling/audit.	Parts of it are covered by an obligatory waste declaration, which has to be filled in if the demolition/renovation projects cover more than 10 m² or generate more than 1 ton of waste. It does not however include a waste handling plan as such.	There is no national guidance regarding which substances to include in the pre-demolition audit. The environmental consultants/ contractors in dialog with municipalities decide which other hazardous substances beside PCB are included as the statutory order on waste is not specific about this.
Finland	(Proposal) Independent audit on hazardous wastes shall be carried out by a specialized auditing company in all buildings that fulfil at least one of the following criteria: Building was built before 1995 Floor area of the building is larger than 100 m².	Currently: Waste types to be reported depends on the municipality.	Exceptions are listed. Municipalities can have their own templates and requirements e.g. for waste types to be reported.
Sweden	Always required	Concerns all buildings	As regulated in plan--och-bygglag-2010900_sfs-2010-90, chap 10 §6–8 and Boverkets allmänna råd om rivningsavfall (2013:15) it is mandatory to make a pre-demolition audit with a waste management plan including information about HW and other waste, handling of waste, materials that can be reused or recycled. Resource and waste guidelines from Sveriges byggindustrier is the construction industries guidelines that is agreed on by all parties in the industry (Voluntary).

2.2 Guidance documents and hazardous substances of concern

In this section the published guidance documents in Denmark, Finland and Sweden for inventory of hazardous substances in constructions is reviewed.

2.2.1 Denmark

In Denmark, there is no national guideline on how to carry out waste audits and what to include in terms of hazardous substances as yet. However, municipalities, knowledge organizations and networks provide best practice and guidance on this issue.

It is the responsibility of the environmental consultant carrying out the audits to ensure representative sampling and to decide on what hazardous substances to include in the pre-demolition audit. This is based on expert knowledge and experience regarding what type of hazardous substances can be expected in buildings/construction of a certain age, use, with certain types of materials, etc. This leads to uncertainty among stakeholders and results in different ways of implementation in the different municipalities in Denmark.

However, due to the large focus on PCB in buildings, a number of publications on PCB have been published over the past years – SBI instruction nr. 241 Investigation[31] and assessment of PCB in Buildings and nr. 242 Renovation of buildings with PCB[32]. SBi instruction 242 describes how a PCB renovation process generally proceeds and explains possible remediation methods and practical aspects of renovation, including waste management and environmental and health protection measures. The instruction relates to SBI instruction 241, Investigation and assessment of PCBs in buildings, describing how to determine whether a building has an unsatisfactory indoor climate due to PCB contamination. Both instructions are aimed at professional building owners, contractors, and consultants.

[31] SBi-anvisning 241. (2013). Undersøgelse og vurdering af PCB i bygninger (Study and assessment of PCB in buildings – guideline). Statens Byggeforskningsinstitut.

[32] SBi-anvisning 242. (2013). Renovering af bygninger med PCB (Renovation of buildings polluted by PCB). Statens Byggeforskningsinstitut.

Furthermore, the Danish Construction Federation have published guidelines for demolition and renovation of buildings containing of asbestos[33], lead[34] and PCB[35]. The guidelines focus on the safe removal of hazardous substances with respect to the safety of workers. Also, guidance is available in the following reports: SBI anvisning nr. 241, Investigation and assessment of PCB in Buildings and nr. 242 Renovation of buildings with PCB.

DAKOFA is a competence centre on waste and resources. DAKOFA host a stakeholder network on C&D waste. The network raises challenging topics related to resource recovery and the safe identification and handling of waste. The network produces best practises on C&D waste based on the discussions in the network (see https://dakofa.dk/element/bygge-og-anlaegsaffald/).

VHGB provides information and knowledge of C&D waste to the sector. VHGB is an independent knowledge centre. Guidelines for proper handling of C&D waste are made for 4 target groups: building owners, constructors, consultants and municipalities. On the web page, typical hazardous substances found in C&D waste are listed, typical C&D waste fractions and management options are described, central pieces of legislation and a list of relevant reports can be found. Furthermore, fact sheets, quick guides and check lists provide a quick overview for stakeholders on specific relevant subjects. Best practice and cases are described. Also, a digital version of the Materialeatlas is available (see www.vhgb.dk).

As part of a project carried out under the network "InnoBYG – Innovationsnetværk for bæredygtigt byggeri", DTI has compiled the Materialeatlas[36] listing construction products potentially containing hazardous materials. The Danish Materialeatlas is a description of typical construction products used during different building periods and aims to give an overview of which hazardous substances are typically to be expected in the different building parts, and thus gives an overall assessment of whether the building part is potentially suitable for recycling or reuse or not. The target group of the

[33] Dansk Asbestforening. (2010). Vejledning og beskrivelse for udførelse af asbetsanering. https://www.nedbrydningssektionen.dk/media/27405/asbest_vejledning.pdf
[34] Dansk Asbetsforening. (2016). Vejledning og beskrivelse for udførelse af blysanering. https://www.nedbrydningssektionen.dk/media/27406/bly-vejledning.pdf
[35] Dansk Asbetsforening. (2010). Vejledning og beskrivelse for udførelse af PCB sanering. https://www.nedbrydningssektionen.dk/media/27407/pcb-vejledning_red.pdf
[36] Videncenter for Håndtering og Genanvendelse af Byggeaffald (VHGB). Materialeatlas http://vhgb.dk/genanvendelse/materialeatlas/

Materialeatlas is architects or other professionals, who are not experts on hazardous substances, but who need an overview of which hazardous substances can be expected. The Materialeatlas is based on a project carried out for the Danish EPA.[37]

Figure 5: Examples of Danish guidance documents for identification and management of hazardous substances

2.2.2 *Finland*

In Finland, the renewed law on regulating asbestos work [684/2015] requires the investigation of asbestos content prior to demolition in buildings built before 1995. Guidelines for an inventory of hazardous substances in construction or best practices for the removal of asbestos are published either by professional or industrial associations (e.g. The Finnish Association of Civil Engineers, or INFRA – Infra Contractors Association in Finland) or by The Building Information Foundation RTS sr – RATU which is owned by several associations. These guidelines are voluntary but often regarded as "official recommendations" also by the permit administrators.

INFRA is currently updating their guidelines for the demolition work including information on legislation, duties of stakeholders, safety issues and check-lists for documentation and waste management. The techniques and methods of the demolition works are described in detail in the various factsheets – called "cards" published by RATU. Examples of published factsheets for asbestos inventory and removal are RT 08-10521 and KH 90-00181, LVI 00-10218, RATU 82-0347, 2009 and for

[37] Miljøprojekt nr. 1656, (2015). "Metoder til fjernelse af miljøproblematiske stoffer – udrening af teknologier til identification og fjernelse af miljøproblematiske stoffer og materialer fra bygninger til nedrivning eller renovering", https://www2.mst.dk/Udgiv/publikationer/2015/03/978-87-93283-86-2.pdf

inventory of hazardous materials RT 18-11245.[38] The RT 18-11245 is planned to be updated in the near future. The supervision and monitoring by the authorities varies among municipalities. Large municipalities (e.g. Helsinki) have inspectors who follow up the surveys on hazardous substances especially in public buildings to be demolished, and the inspectors are also involved in the planning of samples for analytical tests.

The guideline RT 18-11245 for the inventory of hazardous substances in construction lists materials and products in old construction products containing hazardous substances. The scope of the guidance is both on materials to be removed prior to demolition and on identification of substances emitting hazardous substances in indoor air. Special focus is put on materials and products containing asbestos. Furthermore, the guidance includes sampling instructions for several products/materials (especially for taking samples from surfaces). The guideline RT 18-11244[39] linked to RT 18-11245 contains templates for an ordering inventory of hazardous substances in construction.

The Finnish Ministry of the Environment has published in 2017 a web-page[40] with information on the management of waste from renovation. Several categories of construction materials with product names and photos are included. The web-page also provides information about the possibilities for recycling and reuse and the potential content of hazardous substances. The main target group for the database is private persons and small companies conducting renovation (see Figure 6 and 7).

[38] RT 18-11245 Haitta-ainetutkimus. Rakennustuotteet ja rakenteet. (2016). Rakennustietosäätiö. RT 18-11244 Haitta-ainetutkimus. Tilaajan ohje. 2016. Rakennustietosäätiö.

[39] RT 18-11244 Haitta-ainetutkimus. Tilaajan ohje. (2016). Rakennustietosäätiö.

[40] Finnish EPA. (2017). Vanhojen rakennusmateriaalien tietopankki. http://www.ymparisto.fi/fi-FI/Rakentaminen/Korjaustieto/Rakennusmateriaalien_tietopankki

Figure 6: Finnish guidance RT 18-11245 for inventory of hazardous substances in construction

RT®

RT 18-11245
KH 90-00617
LVI 01-10585
Infra 061-710163

OHJEET
marraskuu 2016
1 (29)
korvaa RT 20-11160
KH 90-00553
LVI 01-10553
Infra 061-710135

HAITTA-AINETUTKIMUS
Rakennustuotteet ja rakenteet

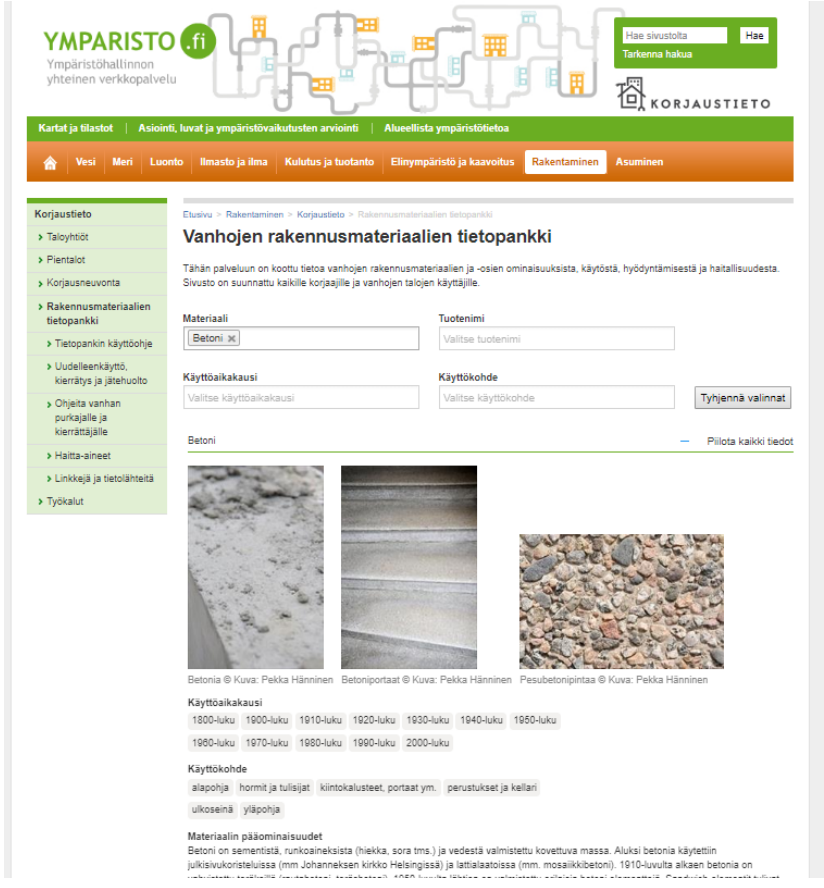
Tässä ohjeessa käsitellään voimassaolevan lainsäädännön mukaan vaarallisiksi määriteltyjä haitta-aineita sisältävien rakennusosien, rakenteiden sekä johtojen ja laitteiden materiaalien tutkimista. Liittelssä esitetään tutkimusta ja analysointia koskevat käsitteet, rakennusaineiden ja -tarvikkeiden markkinoillaoloaikoja ja rakennusjätteiden jäteluokitus ja purkutapa. Tässä ohjeessa ei käsitellä kosteus- ja homevaurioita eikä niiden tutkimista.

Ohjeessa *RT 18-11244, KH 90-00616, LVI 01-10586, Infra 061-710162 Haitta-ainetutkimus. Tilaajan ohje* esitetään ohjeita haitta-ainetutkimuksesta kiinteistönomistajan ja tilaajan kannalta. Sen liittelssä esitetään tarjouspyyntömalleja.

Tämä ohje on uusittu *valtioneuvoston asetuksen asbestityön turvallisuudesta 785/2015* perusteella.

SISÄLLYSLUETTELO

Figure 7: Material database published by the Finnish Ministry of the Environment. Material search based on the following key words: material type, products names, period of use and application



2.2.3 Sweden

In Sweden, guidance is given by the Swedish National Board of Housing, Building and Planning, and according to the Building Code [SFS 2010:900], an inventory of hazardous waste is required prior to the demolition of buildings. The management of hazardous and non-hazardous waste should be stated in the inspection plan submitted to the local authorities. Furthermore, the Swedish Ordinance on PCB [SFS 2007:19] requires identification of PCB-containing products in buildings and facilities.

The Swedish Construction Federation (SCF) has published guidelines entitled "Resource and waste guidelines during construction and demolition (2015)"[41] (see Figure 8) which is continuously updated (and also available in English[42]). It includes information on the identification of hazardous material (e.g. asbestos, PCB) prior to demolition and in some cases exceeds the mandatory legal requirements. The appendices to the Resource and Waste Guidelines give information on hazardous wastes potentially appearing in constructions (Appendix 1), a list of typically generated waste fractions during demolition – basic level (Appendix 2), waste fractions – overall list (Appendix 4) and several templates useful for waste management.

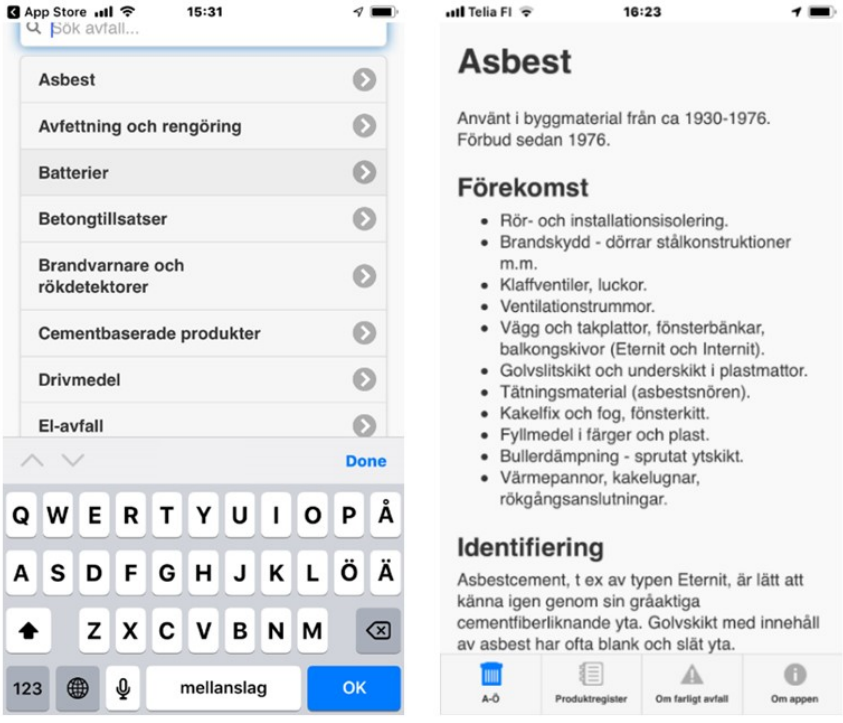
In addition, a Hazardous Waste app was launched in 2013 by the SFC which can be downloaded free (Figure 9). The app helps to identify hazardous waste and gives guidance about waste management.

Figure 8: "Resource and waste guidelines during construction and demolition"

[41] Sveriges byggindustrier. (2015). Riktlinjer för Resurs- och avfallshantering vid byggande och rivning. https://www.sverigesbyggindustrier.se/nyheter/uppdaterade-riktlinjer-for-resurs--och-a__5101

[42] Swedish Construction Federation (SCF). (2015). Resource and waste guidelines during construction and demolition. https://publikationer.sverigesbyggindustrier.se/en/resource-and-waste-guidelines-during-con__1094

Figure 9: Hazardous Waste App launched by the Swedish Construction Federation (SCF)



2.3 Comparison of inventory guidelines for hazardous substances

As described before, both regulation and guideline documents are available in the Nordic countries. In order to highlight and compare the key elements in conducting pre-demolition audits, the key elements in Nordic guidance documents for identification or inventory or mapping of hazardous substances are compared in Table 3. A comparison of hazardous substances of concern in the guidelines is further discussed in Chapter 3.1.

The guidance documents contain the same elements but partly with different focus. In Denmark, the main focus in the survey on hazardous substance is on health aspects in renovation and demolition. However, since 2013 focus has also been on the identification and handling of PCB. The Finnish guideline RT 18-11145 describes in detail such materials and products containing hazardous substances for identification and also covers the practical aspects in sampling. Also work safety aspects especially in the handling of asbestos wastes are included. The Swedish guidance has a broader scope in giving guidance on the waste management of the demolition process as well as covering the recycling potential of the demolition wastes.

Guidance documents identified in the Nordic countries are complementary with different target groups – a summary is given in Table 3.

- The target group in Danish guidelines is broad, ranging from building owners and architects to waste authorities and waste management companies.
- The target group in the Finnish guidelines is primarily the auditor conducting inventories. Description of typical construction products used during different building periods (35 products listed with photos). Principles in sampling are briefly described.
- The Swedish guidance document describes the different aspects of waste management. One key target group is the building owner and persons responsible for the waste management.

Table 3: Elements in Nordic guidance documents for identification or inventory or mapping of hazardous substances. See references in the core text

	Denmark	Finland	Sweden
Reference	SBI-instructions 241 and 242 PCB-vejledning Bly-vejledning Asbest-vejledning Dansk Asbestforening (Dansk Byggeri) Materialeatlas DAKOFA – Viden om – den gode kortlægningsrapport and several other useful best-practice sheets VHGB – Den gode kortlægningsrapport Elements can be found in different guidance documents	RT 18-11244, RT 18-11245 (in Finnish)	A handbook for how to identify and manage hazardous waste was developed by SITA, White Arkitekter and BI Parts of the handbook were used to develop a smart phone app called "Farligt avfall" (Hazardous Waste) which is available free and is easy to use. Both the app and the handbook are under the administration of Sveriges Byggindustrier (Swedish Construction Federation)) Resource and waste guidelines during construction and demolition (Swedish Construction Federation)
Scope	Decontamination and demolition of buildings with lead, PCB and asbestos (as well as other substances) Reporting of pre-demolition audit	Inventory of hazardous substances in constructions (the RT-card 11245 also includes material emissions to indoor air (VOC, Radon, mould).	Identification and management of hazardous waste in construction, management of waste
Desk study	Elements and phases described in DAKOFA, VHGB	Elements and phases in the inventory described	
Worker safety	Guidelines for the decontamination of lead, PCB and asbestos are available from the Danish Construction Association Also addressed in the SBI instructions	Risks listed. References to other documents	Described
Information on materials potentially containing hazardous substances	Detailed descriptions are available for lead, asbestos and PCB Furthermore, descriptions available via Materialeatlas/miljøprojekt nr. 1656, 2015	Description of typical construction products used during different building periods (35 products listed with photos)	Search list – Materials and products from demolition/exchange (Appendix 5 to Resource and Waste Guidelines during construction and demolition)
Guidance for sampling	Some general recommendations are available in the Guidelines for the decontamination of lead and PCB from the Danish Construction Association, in the SBI instructions and Miljøprojekt nr. 1656, 2015. Recommendations focus primarily on sampling techniques and sampling equipment. However, they typically do not cover suitable number of samples per e.g. building/floor/section. See also guide from VHGB and DAKOFA on sampling. Sampling by drilling, cutting, surface scratch, core sampling	Principles in sampling briefly described. Guidance on how to take samples from surfaces (concrete, paints, tubes with isolation, isolation or acoustic boards, floors (PVC; plastic, rubber…), sealants, walls. Sampling by drilling also included.	Two approaches for sampling mentioned (surface sampling and sampling by drilling). No specific guidance

	Denmark	Finland	Sweden
Hazardous substances of concern	Focus on lead, asbestos and PCB Furthermore, hazardous substances are chosen based on expert knowledge about building – age, use, materials.	See Table 7 (Chapter 3)	See Table 7 (Chapter 3)
Recommendations for analytical methods		Visual checking based on experience, only to limit extent testing, to limit extent recommendations for analytical methods	Not included
Documentation of the inventory	DAKOFA, VHGB – recommendations on what elements to include	Content of report described (elements to be included)	
Templates	No templates available. Decided by the consultant carrying out the audit.	Templates for ordering	Template for contracts with auditor for hazardous waste survey Example for start-up meeting report, demolition contractor/waste contractor (Appendix 12 to Resource and Waste Guidelines during construction and demolition)
Guidance for management plan	Out of scope for the documents	Out of scope for the document	Form for waste management plan (Appendix 9 to Resource and Waste Guidelines during construction and demolition)
Others		Guidance on selection of waste codes according to the European list of waste (LoW)	Guidance for selection of LoW codes (Appendix 1)
Additional information	Recent studies related to the topic: A literature review of hazardous substances in crushed concrete has been published by the Danish EPA[43]. As follow-up, an experimental study with a total of 41 samples of crushed concrete (31), crushed concrete and tiles (7), and crushed tiles (3) were collected in 2016/2017 and analyzed in 2017. Most of the samples were collected from private and municipal treatment plants for C&D waste.[44]	Links made to asbestos inventory and removal; RT 08-10521 and KH 90-00181, LVI 00-10218, RATU 82-0347, 2009	

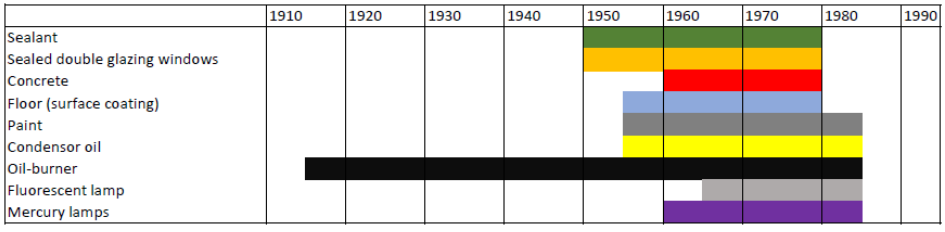
[43] Hjelmar, O. & Hougaard, T. (2015). Forurenende stoffer i beton og tegl, Miljøprojekt nr. 1806. https://www2.mst.dk/Udgiv/publikationer/2015/12/978-87-93352-99-5.pdf

[44] Hjelmar, O. *et al.* (2018.) Forekomsts og udvaskning af problematiske stoffer i knust beton og tegl. Miljøprojekt nr. 1991. https://www2.mst.dk/Udgiv/publikationer/2018/03/978-87-93614-87-1.pdf

2.4 Examples of use of specific hazardous substances in historical construction products

Knowledge of construction products that potentially contain hazardous substances is crucial in identifying materials to be separated prior to or during demolition so these materials can be directed to specific treatment with the aim of safe handling and in order to ensure resources of high quality. In addition, good background information on the use of construction products and materials in construction is important. Several guidance documents with information on period for use of certain materials have been published in the Nordic countries. Examples of the use of PCB in historical construction products are given in and Table 4.

Figure 10: Year for production of construction production containing PCB



Source: RT 18-11245, Rakennustietosäätiö RTS 2016. With permission from Rakennustietosäätiö (2018).

Table 4: Examples of occurrence of PCB mentioned in general guidance documents to be considered in different construction products

	Denmark	Finland	Sweden
Reference	Materialeatlas[45]	RT 18-11245, Komulainen *et al*[46]	
Floor	PCB, metals, asbestos	phthalates, asbestos (in glues for PVC floor), PCB (banned 1979) (softeners)	PCB[47], Asbestos
Painted surface (roof, façade, window, floor, walls)	Metals (Zn, Hg, Cu, Ni, Pb, As, Cd, Cr) and PCB	PCB (especially during 1940–1979 in special applications, up to 10% in paint. Used in glues for PVC mats. Additionally, metals (Zn, Hg, Sb, Cu, Ni, Pb, As, Cd, Co, Cr, V)	PCB[47], Asbestos
Lighting fixtures (capacitors)	PCB (during years (1950–1986)		
Sealant	PCB (during years 1950–1977) Chlorinated paraffins	PCB (during years 1957–1979)	
Windows	double-glazing; PCB (during years 1950-1977)	PCB (used during 1965–1979)	Pb, PCB (1956–77)
Condensators		PCB used	

Note: NB This is not a comprehensive list; for a few applications also other hazardous substances are mentioned.

Due to the recent high concern of POPs (persistent organic pollutants) in waste materials, several inventories of the presence of POPs in various construction materials have been conducted. In Table 5, a summary of some results in recently published reports has been compiled. The data in the table indicate that for certain construction products there is a need for further studies also on other POP substances than PCB. Factsheets on POPs have been published in all Nordic countries but these could benefit from a review and alignment, since different POPs in different material fractions are addressed in the countries. In this context it should be noted that for some POPs (e.g. HBCDD), the limits for the classification of waste as a POP waste is lower than the limits for hazardous waste classification. Wastes classified as POP waste must be destroyed.

[45] Videncenter for Håndtering og Genanvendelse af Byggeaffald (VHGB). Materialeatlas. http://vhgb.dk/genanvendelse/materialeatlas/

[46] Komulainen, J, Säntti, J., Huttunen, J. (2011) Haitalliset aineet rakennuksissa ja niiden hallinta. Rakennustieto. https://www.rakennustieto.fi/Downloads/RK/RK110305.pdf

[47] Naturvårdsverket. PCB, avlägsna fog- och golvmassor. http://www.naturvardsverket.se/Stod-i-miljoarbetet/Vagledningar/Kemikalier-och-miljogifter/PCB/PCB-sanera-byggnader/PCB-avlagsna-fog--och-golvmassor/

Table 5: Examples of recent Nordic inventories on POP substances in C&D waste

Chemical	Range in products[48, 49, 50]	Examples of measured concentrations in surveys carried out in the Nordic countries	Limit for hazardous waste
HBCDD (flame retardant)	2% insulation materials	levels up to 15000 ppm measured[51]	30,000 mg/kg (= 3%)*
	1% tubes		
Short chained chlorinated paraffins (SCCP)	5% paint		2,500 mg/kg
	2% floors/mat	up to 5900 mg/kg (6 samples exceeding hazard limits of 74 studied samples)[52]	
	15% glues, sealants		
	21% insulation materials		
Bisphenol A	8% floors, mat		3,000 mg/kg
	35% glues, sealants	no sample exceeding hazard limits (20 samples)[53]	
PFOS	PVC floors, lightweight concrete		3,000 mg/kg

Note: * Limit for POP waste is 1,000 mg/kg.

The tables and studies show that there is a great deal of knowledge regarding which substances to expect in "older" construction products and materials. However, as we become aware of new problematic substances, the focus in audits will shift.

[48] SYKE, Finland: Chemicals management in the circular economy (the report includes information on POP substances in construction products).
[49] Danish EPA. (2014). Survey of shortchain and mediumchain chlorinated paraffins.
[50] Nordic Council of Ministers. 2017. How to tackle hazardous substances in recycling of plastics. TemaNord 2017:505. https://norden.diva-portal.org/smash/get/diva2:1070548/FULLTEXT01.pdf
[51] Inka Honkala. (2018). HBCD IN INSULATION MATERIALS. XRF in Preliminary Detection. Tampereen Ammattikorkeakoulu. https://www.theseus.fi/bitstream/handle/10024/149579/Honkala_Inka.pdf?sequence=1&isAllowed=y
[52] Norwegian Forum "Forum for miljøkartlegging og -sanering". (2017). Klorparafiner I vinyl gulvbelegg (Presence of SCCP in floors): data from 34 products with illustrative photos. https://docs.wixstatic.com/ugd/01b968_f89fe81bb1f140dbae591e46offa96a4.pdf
[53] NorConsult. (2014). Kartleggning av nyere frakjonera av farlig avfall i bygg. https://docplayer.me/8713649-Kartlegging-av-nyere-fraksjoner-av-farlig-avfall-i-bygg.html

This requires expertise and continuous upgrade of knowledge for auditors to keep up to date with respect to hazardous substances in construction materials and products.

2.5 Education and certifications and skills

There are education requirements in Finland and Sweden for the auditors. In Denmark, no specific education requirements have been given, but education and courses on the topic are arranged. An overview of the different education systems are compiled in Table 6.

Table 6: Overview education systems in Denmark, Finland and Sweden

	Education, pre-demolition audits	Accreditation or Certification, pre-demolition audits	Remarks
Denmark	No full education of pre-demolition auditors, but courses exist on regulation and hazardous substances, C&D waste management and sampling (to some extent). Education of demolition companies is provided by DAKOFA, VHGB and some industry organizations. New courses are under development.	No certification schemes exist. However, this has been discussed and proposed[54]. There are requirements that demolition of buildings with asbestos should be done by a professional with a certificate of asbestos.	In Denmark it has been proposed to have an educated coordinator of waste audits involving both hazardous substances and resource inventories.[54] Selective demolition is one of the initiatives in the Government Strategy on circular economy published in September 2018. In the strategy, standardized demolition plans and education are specifically mentioned.
Finland	Commercial AHA course (3 days) available for survey on hazardous substances in constructions prior to demolition. No commercial courses for resource assessment. Voluntary system. Additionally, several courses under planning (e.g. in universities), currently generally seminars or workshops conducted with presentation about hazardous materials and recycling potentials	Certified auditors for asbestos	Proposed to include competence requirements, but not specified how to prove competence
Sweden	The pre-demolition audit consultant should fulfil one of the following requirements have training in environmental inventory and environmental legislation, have experience of pre-demolition audit and at least five years' relevant work experience, e.g. in the construction sector have experience of pre-demolition audit of at least ten objects, together with experience from consultant as above. References should be stated.	Consultants for environmental inventory for property are certified following testing according to the requirements in the Swedish Property Federation's CMF Requirement specification13. This covers other areas in addition to pre-demolition audit. SWEDAC provides accreditation for bodies certifying environmental consultants for property.	Separate education by STF/BFAB called Miljöinventering av byggnader (Environmental Inventory of buildings).

[54]Miljøprojekt nr. 1962. (2017). Projekt om selektiv nedrivning. https://mst.dk/service/publikationer/publikationsarkiv/2017/okt/selektiv-nedrivning/

2.5.1 *Danish education of stakeholders at demolition companies*

The education is established by the Danish Construction Association. The education takes 1½ year, 22 weeks of theoretical training and the rest of time is practical training. The education covers building constructions, safety, material theory, environmental conditions, machine operations and tooling. During the education participants receive certificates for, e.g. asbestos and PCB.

Another shorter education has been established by the association, Danish Machine stations and Entrepreneurs, DM&E. This education takes 8 weeks where the participant also receives certification for asbestos and PCB. DAKOFA and VHGB offer 1–2 day courses on C&D waste legislation and management, which covers activities from before demolition (including pre-demolition audits for hazardous waste) to recycling options. DAKOFA offers a 2-day course in classification of hazardous waste.

Required skills:

- The auditor shall have sufficient knowledge and experience to identify all hazardous materials and to fulfil all the legal requirements for the waste audit report and waste declaration;
- It is recommended that the auditor is independent in all demolition, deconstruction or renovation projects so the audit results are not biased by the specific interests of the owner or contractor;
- The auditor should have adequate educational background and specific training, and knowledge of current and historical construction, construction systems, standardization, materials and hazardous substances.

2.5.2 *Finnish certificate for asbestos and hazardous substances experts*

In Finland, Eurofins Expert Services Oy grants a certificate for asbestos and hazardous substance experts. The certification requires basic education, work experience and participation in training courses. The basic education is a three-year course in building or house engineering, which can also be substituted by five years of professional working experience with asbestos and hazardous substance mapping in buildings. In addition to this, the requirements for work experience includes at least two years of experience from inspection and/or repairing of old buildings and knowledge of

construction materials used in old buildings in Finland, as well as knowledge of the characteristics of asbestos and hazardous substances.[55]

The training courses for the certificate includes a written exam and a demonstration, which must be passed to receive the certificate. The certificate training is conducted by Rateko, which is an academy approved by Eurofins Expert Services.

The certificate is valid as long as required reporting and further training are being reported to Eurofins annually. To keep the certificate valid, the accredited person must keep a log of references, which is to be sent to the assignor annually and accompanied by one full report. Furthermore, the accredited person must also participate in one relevant course every third year and report this to the assignor.

2.5.3 Sweden

In "Resource and waste guidelines during construction and demolition" it is specified that the auditor must have sufficient knowledge as described below. The knowledge must be stated by reference.[56]

> "The auditor shall have sufficient knowledge and experience to identify all hazardous materials and to fulfil all the legal requirements for the waste audit report and waste declaration.
>
> It is recommended that the auditor is independent in all demolition, deconstruction or renovation projects so the audit results are not biased by the specific interests of the owner or contractor.
>
> The auditor should have adequate educational background and specific training, and knowledge of current and historical construction, construction systems, standardization, materials and hazardous substances."

[55] Eurofins/Expert Service. Finland. https://www.vttexpertservices.fi/Pages/Osaamisvaatimukset--Asbesti--ja-haitta-aineasiantuntija-(AHA-asiantuntija).aspx

[56] Resurs- och avfallshantering vid byggande och rivning. https://publikationer.sverigesbyggindustrier.se/en/resource-and-waste-guidelines-during-con__1094

3. Review of management of hazardous substances in waste

3.1 Hazardous waste classification

Legislation in all the Nordic countries sets the obligation for the building owner to identify and to remove hazardous materials from the building prior to demolition. The aim of the inventory of the hazardous or undesired materials is as follows:

- To identify the location of hazardous substances/materials and to estimate the waste/material amount containing hazardous substances and/or contamination;
- To identify wastes to be classified as hazardous to ensure appropriate waste management;
- To take measures to ensure safe demolition management (minimizing the exposures during the demolition process);
- To prevent materials containing hazardous materials or contamination from being recycled; and
- To create trust in the recovered waste as a safe material (especially for end-user).

This requires specialized knowledge and skills regarding hazardous substances in buildings and building materials and regarding sampling of those materials. This also requires a uniform approach to auditing and classification of C&D waste.

The hazardous waste classification is primarily based on the European List of Waste[57] in which the listed waste types are classified as hazardous or non-hazardous. In some cases, a particular type of waste on the list can be either hazardous or non-hazardous

[57] Commission Decision 2014/955/EU. Commission Decision of 18 December 2014 amending Decision 2000/532/EC on the list of waste pursuant to Directive 2008/98/EC of the European Parliament and of the Council (European List of Waste).

depending on the specific properties of the waste, and in these cases the waste status has to be assessed based on its hazardous properties.[58, 59] EU guidance for assessment of hazardous waste[60] was published in 2018 by the Commission, and furthermore, in Denmark[61] and Finland[62] national guidance documents have been developed. However, these guidance documents provide general information on waste classification, and do not specifically focus on the classification of waste from construction and demolition.

The hazardous waste concentration limits are the same throughout Europe, but the implementation may differ. Moreover, the scope and extent of an audit can influence the proportion of waste that is classified as hazardous. For example, classification of C&D waste requires a decision on the material fractions in question, substances in question and sampling strategy (surface samples, e.g. in the paint layer or core samples, e.g. average concentration of hazardous substances in the waste material). Furthermore, the choice of substances for the assessment, e.g. only lead as opposed to including lead, arsenic, cadmium, etc. may determine or have an influence the result of the waste classification. There are several open questions in the assessment of hazardous waste properties in practice.

Special attention is required to the EU POPs regulation (No 850/2004) on persistent organic pollutants, which requires that wastes containing substances listed in the annex to the regulation and exceeding certain concentration limits need to be destroyed and not circulated in new products. Examples of the POP substance are PCB, certain flame retardants (e.g. HBCDD), SCCP, Bisphenol A and PFOS which might occur in some construction products or materials. The list of POPs is continuously updated and new substances are added to the list. One candidate substance under review is pentachlorophenol (e.g. typically used as a wood preservative in Finland and Sweden).

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[58] Commission Regulation No 1357/2014. Commission Regulation (EU) No 1357/2014 of 18 December 2014 replacing Annex III to Directive 2008/98/EC of the European Parliament and of the Council on waste and repealing certain Directives Text with EEA relevance. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014R1357, supplemented.

[59] Commission Regulation 2017/997. Council Regulation (EU) 2017/997 of 8 June 2017 amending Annex III to Directive 2008/98/EC of the European Parliament and of the Council as regards the hazardous property HP 14 'Ecotoxic'. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R0997&from=EN

[60] Commission notice on technical guidance on the classification of waste (2018/C 124/01). http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2018.124.01.0001.01.ENG&toc=OJ:C:2018:124:TOC

[61] Danish EPA. (2018). Vejledning i klassificering af farligt affald. http://mst.dk/media/93596/vejledning-i-klassificering-af-farligt-affald_april-2017.pdf

[62] Häkkinen E. (2016). Jätteen luokittelu vaaralliseksi jätteeksi. Ympäristöhallinnon ohjeita 1/2016. Ympäristöministeriö, Helsinki 2016. (updated version to be published 2018).

Table 7 below summarizes the different types of hazardous substances that can be found in construction products and materials. This list is based on the experience with waste audits and does not focus on "new" construction products, i.e. products currently brought on to the market. The table highlights the hazardous concentration limits for the substances mentioned and indicates whether there is a legal requirement and/or guideline in Denmark, Finland, and Sweden, respectively, to include the substances in the waste audits to be carried out.

Generally, the same substances are of concern. Especially asbestos has been in focus in Denmark, Finland and Sweden, and PCB in Denmark (and also in Norway). The Danish Materialeatlas additionally mentions POP substances (brominated flame retardants, chlorinated paraffins (SCCP) and Bisphenol A) which are, for example, missing in the current Finnish guidance RT 18 11245 and only to limited extent discussed in the Swedish guideline.

Examples of construction products containing hazardous substances are presented in Chapter 3.1.2 Additional information from Norway is compiled in Chapter 5.1.

Table 7: Hazardous substances in historical construction products and materials included in some Nordic guidance documents. Note! for some substances the limit for POP waste is lower than the limit for hazardous waste.

Potential hazardous substances in constructions	Hazardous waste limit	Denmark	Finland	Sweden
Reference		Statutory order on waste/ guidelines[63]	RT 18 1145	SCF (2016)
PCB (7 congeners)	Total 50 mg/kg [a)]	Yes	Yes	Yes
Asbestos	Total ban	Yes	Yes	Yes
CFC	0.1%			Yes
Arsenic	As compound 1,000 mg/kg [b)]	Yes	Yes	Yes
Lead	2,500 mg/kg [c)]	Yes	Yes	Yes
Cadmium	As compound 1,000 mg/kg [b)]	Yes	Yes	Yes
Chromium VI	As compound 1,000 mg/kg [b)]			
Chromium tot.	As compound 2,500 mg/kg [d)]	Yes	Yes	Yes
Chlorinated paraffins (SCCP)	2,500 mg/kg	Yes		Yes
Copper	As compound 2,500 mg/kg [d)]	Yes	Yes	Yes
Mercury	2,500 mg/kg [a)]	Yes	Yes	Yes
Nickel	As compound 1,000 mg/kg [b)]	Yes	Yes	Yes
PAH/creosote	1,000 mg/kg	Yes	Yes	Yes
Naphthalene	2,500 mg/kg		Yes	
Zinc	As compound 2,500 mg/kg [d)]	Yes	Yes	Yes
Hydrocarbon C_{10}-C_{40}	Limit depends on composition: 1,000, 10,000 or 25,000 mg/kg[64]	Yes	Yes	Yes
Flame retardant used in insulation materials (e.g. HBCDD, TBBPA, PBDE, PBB)	30,000 mg/kg (HBCDD) [e)]			Yes
Chlorophenols	2,500 mg/kg (pentachlorophenol)		Yes	Yes
PCDD/PCDF Dioxine (soil)	15 µg/kg (WHO-TEQ/kg)		Yes	
Phthalates	3000 mg/kg (DEHP)		Yes	

Note: NB! For hazardous waste classification, it is important to check national guidance documents for the detailed rules especially for metals.

a) Sum of PCB: calculated from 7 congeners multiplied by a factor for the estimation of the total content of PCB.
b) Worst case: here considered compounds with acute toxicity properties (HP 6)/carcinogenic properties (HP 7) (according to the CLP regulation) are considered.
c) Generic limit for metallic form. NB! Exceptions for certain compounds specified in CLP Regulation, Annex VI.
d) Here considered compounds with ecotoxicity properties (HP14). NB! The summation rules needs to be considered in assessment.
e) Limit for POP waste: 1,000 mg/kg.

[63] Only PCB is specifically in legislation, but guidance documents from DAKOFA and VHGB provide best practices on other substances.
[64] See further: Hyks, J. & Hjelmar, O. (2015). Klassificering af shredderaffald ud fra indhold af kulbrinter. Miljøprojekt nr. 1662, 2015. https://www2.mst.dk/Udgiv/publikationer/2015/03/978-87-93283-95-4.pdf

3.2 Assessment of waste management

The sampling and analysis of construction materials and products as part of the audit for identification and potential removal of materials containing hazardous substances provide information on the content of hazardous substances and potentially also of other properties of the material to be collected as waste. Based on the knowledge of the waste characteristics, appropriate waste management can be recommended.

Table B.1 in Appendix B gives information on the limits for hazardous substances used in Denmark, Finland and Sweden for hazardous waste classification. The table also contains information on limits used to distinguish between contaminated and non-contaminated waste. Furthermore, limit values for the use of concrete waste in earth construction in the four Nordic countries are compiled in Table B.2 in Appendix B. In Denmark and Norway, special focus is on PCB and in Norway also on Cr(VI) whereas in Finland and Sweden asbestos is of concern.

In the Nordic countries, concrete and other crushed mineral wastes are typically used in earth construction, e.g. in road structures. It is interesting to note that there are differences in the approach for to assessing the suitability of non-hazardous concrete for recovery. In Denmark and Norway, the main focus is on verifying the non-contamination of the concrete in the construction prior to demolition, whereas especially in Finland the main focus is on the quality control of the crushed concrete for recovery. In this context, it is also worth mentioning that a Norwegian guideline for sampling and testing for assessment of concrete quality has also been developed and is currently under review (see Chapter 5.1).

In Denmark, C&D waste consisting of crushed concrete and/or tiles (as well as mixtures of these fractions) can be used, without a specific permit,[65] for construction purposes as a replacement for virgin raw materials, provided the C&D waste has been sorted, has undergone treatment and is unpolluted (no national criteria, except for certain limits on the content of PCB in the C&D waste).

[65] Under the Environmental Protection Act and in accordance with Statutory Order No. 1672 of 15 December 2016 on recovery of residual waste, soil and sorted construction and demolition waste.

Finnish legislation[66] permits the use of reclaimed concrete in roadway and field structures and in floor structures of industrial and storage buildings. Waste that fulfils specific requirements (e.g. origin, leaching limit values, content for specific organic substances given in the legislation) does not require an environmental permit, and only a notification need be given to a regional environment centre. The decree does not apply to operations in areas of important aquifers. Furthermore, a new decree is under preparation aimed at improved recovery of soils from construction.

The Swedish EPA has published a handbook[67] on the recovery of waste in civil engineering. The handbook provides guidance on when the recycling activity requires notification or licensing and a procedure is put forward for assessment of environmental and health risks. Criteria for when recycling can be performed without prior contact with the authorities are given for the content and leaching of both hazardous and non-hazardous substances. These criteria only apply to granular waste and not to products used in monolithic constructions such as asphalt courses. It should be noted though, that these guidance values do not have legislative force.

Table 8: Use of concrete waste in earth construction: Quality requirements on content and leachability for recovery of concrete from constructions not requiring an environmental permit, only a notification

	Denmark	Finland	Norway	Sweden
Prior to demolition				
Limit values for non-pollution	*Common practice:* comparison to criteria listed in Appendix B[1)]	No	Proposed limit values for non-polluted concrete (limits also for paint surface)	No
After demolition				
Limit values for total content	No	Yes, but only for some organics	No	Yes, for metals and PAH
Limit values for released amounts	No	Yes, application specific limit values given for different (several types of applications covered)	No	Yes, use of waste in civil engineering

Note: A limit value for slightly contaminated PCB waste is available in the statutory order on recovery of residual waste, soil and sorted C&D waste. This limit value is 2.0 mg/kg PCB-total.

[66] Government Decree 843/2017 concerning the recovery of certain wastes in earth construction; English translation of Decree: https://www.finlex.fi/en/laki/kaannokset/2017/en20170843

[67] SEPA. (2010). Återvinning av avfall i anläggningsarbeten (Guidelines for recycling of waste in civil engineering), Handbok 2010:1. Swedish Environmental Protection Agency, Stockholm (inSwedish).

4. Review of waste management in Denmark, Finland and Sweden

4.1 Current practice in management of waste and materials/products

In all 3 countries, there are legal requirements on sorting into different waste fractions. In Denmark the requirements are stated in the statutory order on waste, in Finland in the Government Decree on Waste (179/2012) and in Sweden they are stated in the waste ordinance (Avfallsförordning (2011:927). Furthermore, in all 3 countries, there are obligations on source separation, which means that the waste should be separated at the construction and demolition site, although in all 3 countries there is a possibility to allow mixed construction waste to be sorted at a sorting facility (see Table 9).

Table 9: Requirements for source separation, inventories and traceability in the Nordic countries

	Obligations on source separation	Obligations on inventories of resources	Obligations on control actions on amount of waste throughout the value chain	Systems for traceability for recovered materials
Denmark	Obligation by statutory order on waste to separate waste into different fractions, but companies can choose to sort at a regulated sorting facility.	No, but companies have to make an inventory of expected waste generated before demolition according to the statutory order on waste	No.	No, but Danish EPA are working on a digitalization of the inventory of expected waste generated.
Finland	Yes. Obligation by Government Decree on Waste (179/2012, Section 15) to separate waste into different fractions, but companies can choose to sort at a regulated sorting facility.	New environmental recommendations and guidance coming up.	New environmental recommendations and guidance coming up.	New environmental recommendations and guidance coming up.
Sweden	Yes. Obligation by the guidelines for C&D waste to separate waste into different fractions, but companies can choose to sort out fraction "mixed waste – for post-sorting".	Yes. Obligation by the guideline for C&D waste that pre-demolition audits should include a complete inventory of all products and materials that can be or become reused, recycled, or energy recovered. This also includes hazardous waste.	Yes. Obligation by the guidelines to present a waste report after the project is finished. The waste report should include waste fractions, volumes, treatment and final destination of the waste.	No, but new initiatives are coming up in research projects.[68]

[68] Centrum för cirkulärt byggande. A research project about reuse of interior building products. www.ccbuild.se

Table 10: Best practises for material-specific separation of C&D waste in the Nordic countries

	Denmark	Finland	Sweden
Brick/Tiles	X	X	X
Concrete	X	X	X
Glass	X	X	
Gypsum	X	X	X
Insulation	X (rock wool)		X
Mixtures of stone materials, concrete and brick	X		
Mixture of concrete and asphalt	X		
Paper	X	X	X
Cardboard	X		
Plastics	X	X	X
PVC	X	X	
Scrap metal	X	X	X
Stone materials (e.g. granite)	X		
Tiles and ceramics	X		X
Wood	X	X	X

4.2 Status on reuse, recycling and material recovery of C&D waste

Waste streams must be separated in order to obtain a higher percentage of reuse and recycling compared to recovery (material or energy recovery) or landfilling. In this section, state-of-the-art of the most important waste streams is compared in Denmark, Finland and Sweden.

It is acknowledged in all three countries that the earlier the potentials for reuse and recycling are identified the better the chances that it will happen with high quality. The mapping of resources prior to demolition, deconstruction or renovation is thus essential and should therefore be a part of the pre-demolition audit.

Table 11: Best practise: Include energy recovering

	Denmark	Finland	Sweden
Concrete	Reuse – RD Recycling – C Recovery – C	Recovery – C	Recycling – RD Recovery – C
Bricks	Reuse – C Recovery – C	Recovery – C	Recovery – C
Gypsum	Recycling – C Recovery – (C)	Recycling – C	Recycling – C
Scrap metal	Recycling – C	Recycling – C	Reuse – C Recycling – C
Insulation	Recycling – C	Recycling – C	Reuse – C Recycling – C
PVC	Recycling – C		Recycling – C
Other plastics	Recycling – C Recovery, energy	Recovery, energy	Recycling – C Recovery, energy
Glass	Recycling – C	Recycling – C	Reuse – C Recycling – C
Wood	Recycling – C Recovery, energy	Recycling – RD/C Recovery, energy	Reuse – C Recycling – C Recovery, energy
Roofing Bitumen	Recycling – C (tar paper)	Recycling – C	Recycling – C

Note: Definition of terms:
Reuse – according to waste frame directive.
Recycling – according to waste frame directive.
Recovery – according to waste frame directive.
RD – research development (one or more research project exists).
C – commercial (one or more companies have a business).

4.2.1 *Concrete*

In Denmark, Finland and Sweden concrete is the major waste stream in C&D waste and the majority of concrete waste is used for recovery as crushed concrete, where it is used in roads and other construction work as a substitute for primary raw materials.

In Denmark research projects on the reuse and recycling of concrete are ongoing with funding from the Danish "Environmental Technology Development and Demonstration Program". The project "Circular House" demonstrates how concrete can be reused by the use of design for disassembly, while another project carried out by a waste treatment facility and a concrete producer focuses on the recycling of used concrete as aggregates in new concrete. Recycling of concrete is an emerging area, but knowledge is still lacking on the technical and environmental performance. Referring to European standard

DS/EN 206 DK NA Concrete – specification, performance, production and conformity, 20–30% of aggregates for concrete can be substituted by recycled crushed concrete. Former demonstration projects and recent demonstration projects in Denmark have proven 100% recycled aggregates can be used in new concrete. This has resulted in the first commercial activities for the recycling of concrete.

In Sweden a few research projects have been carried out on the possibility to reuse crushed concrete as ballast when making new concrete.[69]

In Finland a revised Government Decree[70] to promote the use of reclaimed concrete from selective demolition in earth constructions through simplification of the environmental permit system was published in 2017. In the decree the conditions for use (type of applications) are prescribed as well as requirements for the quality control system (including limit values for the release and content of harmful substances). A Finnish standard SFS 5884[71] has been developed for CE-marking of high-quality use of reclaimed concrete as aggregate in road construction. The Finnish Ministry of the Environment is currently reviewing the possibility for end-of-waste status for high-quality reclaimed concrete waste fulfilling strict environmental requirements (content, release).

4.2.2 Bricks and tiles

In Denmark, Finland and Sweden most bricks and tiles are crushed for recovery and used as road materials. In Finland a mixture of crushed bricks and concrete is used in roads and other construction projects as a substitute for primary raw materials. The Finnish Government Decree mentioned above for reclaimed concrete sets a limit for maximum content of 30% bricks in concrete waste.

The reuse of bricks still occurs on a small commercial scale in Denmark, although it has been proven feasible for reuse. It is, however, challenging to obtain undamaged bricks from demolition works mainly due to the lack of requirement for selective demolition and

[69] Johansson, P. *et al.* (2017). Kvalitet hos byggnadsmaterial i cirkulära flöden. RISE report 2017:55.

[70] Government Decree 843/2017 concerning the recovery of certain wastes in earth construction; English translation of Decree: https://www.finlex.fi/en/laki/kaannokset/2017/en20170843

[71] SFS 5884. "Factory Production Control of crushed concrete for earth construction" issued by the Finnish Standardization Organization 2018.

thus economy. In Denmark, bricks for facades and roof tiles are widely used building materials and they often provide a great architectonic value.
There are several examples of the reuse of old bricks in new buildings, and the company "Gamle Mursten" is an example of such a company that uses a patented method to clean bricks so they can be reused. A recent project has dealt with the issue of documentation of bricks and has made the basis documentation for CE marking of bricks through an ETA and EAD.[72]

From approximately 1955, cement mortar has replaced lime mortar in Danish building, making it harder to separate the bricks from the mortar. Research projects are looking into this.

In Finland and Sweden the reuse of bricks is unusual.

4.2.3 Gypsum

In Denmark gypsum is recycled into new gypsum (plasterboard production) or used in the production of cement. In some cases it is used as a fertiliser in soil, but this requires a special permit from the Danish authorities. A Danish company, "Gypsum recycling", has a patented treatment facility, which makes it possible to separate and recycle gypsum as powder.

In Finland gypsum is also recycled in plasterboard production, although there have been some problems with the profitability of this business, since storage in Nordic conditions (high risks for wetting) seem to reduce the material quality. The market interest has been limited partly due to the small quantities available.

In Sweden small amounts of gypsum are recycled[73] as raw material for new gypsum, used in the production of cement or as an additive for incineration, but the majority of gypsum waste is landfilled.[74]

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[72] Danish EPA.(2018). Genbrug af mursten. Miljøprojekt nr. 2002 April 2018. https://www2.mst.dk/Udgiv/publikationer/2018/04/978-87-93710-01-6.pdf

[73] Gips recycling. Sverige. web page: http://www.gipsrecycling.se/

[74] Sundqvist, J-O. *et al.* (2013). Återvinning av plastavfall från byggsektorn – möjligheter och hinder. Report B2127 IVL Swedish Environmental Research Institute.

4.2.4 Scrap metal

In Denmark, Finland and Sweden scrap metal is recycled to a large extent.

In Denmark, discussion of how to deal with painted metal and in particular how to classify painted metal is ongoing as the paint may contain hazardous substances above hazardous concentration limits. The ecotoxicity (HP 14) concentration limits have made this discussion even more relevant.

In Finland, an EU research project PROGRESS[75] led by VTT Finland investigating the possibilities for reuse of metallic building components is currently ongoing.

In Sweden, building products made of metal are also being reused to a small extent such as stainless sinks, kitchen fittings, stairs and gratings, etc.[76]

4.2.5 Insulation

In Denmark and Sweden, producers of stone wool recycle old stone wool insulation together with ceramic plates and sanitation and produce new stone wool materials.

Other isolation materials such as glass wool is produced from recycled glass such as car glass and glass packaging such as bottles, etc. In Sweden, the recycling of glass wool insulation as raw material for new insulation is difficult to manage due to safety and economy, since the insulation has to be melted to glass culets before being reintroduced to the production process. In Denmark, glass wool is not recycled in the production of new glass wool due to the sensitivity of the furnaces. The reuse of insulation slabs cut into small flakes and then used as blowing wool is done by a handful of companies[77] in Sweden. Mineral wool, which is not reused or recycled, is landfilled.

In Finland, mineral wool is typically landfilled at landfills for non-hazardous substances. Possible alternative solutions for the recycling of mineral wool waste include, for example, the utilization of material in concrete, cement-based composites, composite ceramics, wood-plastic composites or growth substrates. The main challenges of mineral wool recycling are ensuring the purity and steady availability of recycled mineral wool and managing the transportation costs effectively. A research

[75] PROGRESS - Provisions for greater reuse of steel structures. https://www.vtt.fi/sites/progress/about-the-project

[76] Kompanjonen. www.kompanjonen.se

[77] https://www.isolerproffs.se/, http://www.sbiab.com/vara-tjanster/atervinning-av-isolering/

project[78] for demonstrating the use of mineral wool in wood composite is ongoing (EU HISER). More comprehensive research[79] has been carried out at Lappeenranta Technical University (LUT).

4.2.6 PVC

In Denmark, there is a collection scheme for hard PVC that can be recycled. The scheme, called WUPPI, is run by the Danish producers of hard PVC. PVC which cannot be recycled, e.g. soft PVC, is landfilled. The statutory order on waste states that PVC is not suitable for incineration.

In Finland, PVC recycling is complicated due to the different additives, and PVC waste is currently incinerated.

In Sweden, production waste from the installation of PVC floors is collected and recycled as raw material for new floors. This is done by the flooring industry through a company called GBR floor recycling.[80] Takduksproducenternas Förening[81] (the Swedish roofing membrane association) has a collecting system that accepts both installation waste and end-of-life PVC roofing membranes for recycling.

4.2.7 Other plastics

In Denmark, there is an upcomming focus on plastic in C&D waste. Plastics in the building sector may come from the packaging of new building materials. There is no specific scheme in Denmark for this type of waste, and most of this type of waste goes to incineration. However plastic recycling companies do exist, but there are difficulties with mixed polymer materials.

In Finland, plastics from C&D waste are mainly recovered as energy. PE has the potential for recycling as the material and mixed plastics could be recycled as composite products (plastic-wood, plastic-mineral).

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[78] EU HISER: http://www.hiserproject.eu/index.php/our-goals/new-building-products-through-the-partial-replacement-of-virgin-raw-materials

[79] LUT University. Recycled materials improve the properties of wood plastic composites. http://www.lut.fi/web/en/news/-/asset_publisher/lGh4SAywhcPu/content/recycled-materials-improve-the-properties-of-wood-plastic-composites

[80] Golvbranschen. Golvåtervinning för installationsspill. https://www.golvbranschen.se/miljo-hallbarhet/golvatervinning/

[81] Takdukproducenternas Förening. Återvinning. http://www.takdukproducenterna.se/miljo.htm

In Sweden since 1996, a company called NPG[82] has a system for collecting plastic pipes from new installations or old pipes from demolition or renovation in Sweden. The recycling system includes pipes and fittings of PVC, PE and PP. The collected material is sorted, washed and recycled. However, the majority of plastic waste from the building sector is used as a fuel mix in incineration or landfill. Only a small amount is recycled as raw material for new plastic due to difficulties with mixed polymer materials and the consumption of energy needed to melt the plastics.

4.2.8 Glass

In Denmark, most glass is recycled. Windows are often broken down to glass and frame, where the glass is recycled.

In Finland, glass is recycled as foam glass as insulating lightweight aggregate material in road construction by one Finnish company, Uusioaines.[83]

In Sweden, glass from windows is often broken down to glass and frame, where the glass is recycled by Scandinavian Glass Recycling[84] or Swede Glass United,[85] two companies that make glass culets from the recycled glass.

4.2.9 Wood

In Denmark, Sweden and Finland the majority of wood waste is incinerated with energy generation.

In Sweden and Denmark there is a distinction between impregnated wood, painted wood and non-painted wood. Non-painted wood can be used in the production of chipboards, whereas painted wood and impregnated wood goes to incineration or landfill. Currently in Sweden, the volumes of wood needed for chipboard production are fulfilled by the waste streams from the forest industry, and wooden waste from the building industry is rarely recycled.[86] In Denmark non-painted wood waste from both

[82] NPG. Rörårtervinning. http://npgnordic.com/sverige/roratervinning/
[83] Uusioaines Oy. https://www.uusioaines.com/en/
[84] Scandinavian Glass Recycling AB (SGR). www.sgr.se
[85] Swede Glass United. www.swedeglassunited.com
[86] Johansson, P. et al. (2017). Kvalitet hos byggnadsmaterial i cirkulära flöden. RISE report 2017:55.

the building industry and other sectors is used in the production of chipboard and companies exist in Denmark and Germany for this purpose.

In Finland high amounts of wood waste are produced, but recycling wood waste sets high requirements on quality. The potential of construction and demolition wood material for the use of wood and plastic composites as panels is under research. There is also a recently commercialized product that uses wood chips inside a concrete block to produce garden stones.

In Denmark, there is also a potential for the reuse of old timber from roof constructions and some case studies have dealt with this issue. In Sweden, the use of construction wood such as ladders for scaffolding has become more and more common since the contractors are focusing on the sustainable use of resources.

4.2.10 Roofing bitumen

In Finland and Denmark, roofing bitumen is recycled in asphalt production by one company in Finland. The main problems concern the relatively small waste amounts collected for recycling. In Denmark, asbestos has previously been used in tar paper but the quality requires checking.

4.2.11 Packaging

According to the WFD, packaging made of wood, glass, paper and cardboard must be separately collected for recycling. In Finland (PYR/RINKI), Denmark and Sweden (FTI) there is a producer responsibility scheme for packaging with a nationwide collection and recycling system. Packaging waste from C&D sources is also included in the producer responsibility.

4.3 Examples for best practice

4.3.1 Resource inventories

Resource inventories are a key element in pre-demolition audits and are a developing area due to the increasing focus on the circular economy. This chapter describes elements of best practice in Denmark, Sweden and Finland.

Inventories of resources before demolition together with control actions and systems for traceability are upcoming issues in the field of C&D waste. In Sweden, an inventory of resources and obligation on control actions already exist and are required by the guidelines (reference to be added). In Denmark, the statutory order on waste sets the obligation to make an inventory of expected waste generated before demolition, and recently the Danish EPA published guidelines[87] on how to make a resource inventory before demolition. In Finland, new recommendations and guidelines for improving the quality of waste generated in demolition work (including definition of responsibility of actors) are under preparation and will be published in 2019. In none of the countries does a system for traceability exist, but several new initiatives cover this issue.

The Danish guidelines for resource inventory are based on experiences from several cases, which have shown that dialogue with the stakeholders in the value chain is important, and that the inclusion of results from the inventory in the tender is crucial to obtain a higher percentage of reuse or recycling when carrying out the demolition or renovation work. Among a number of other aspects, the guidelines describe how to estimate resources and waste:

- For a first indication of the amount, an estimate can be used: 1 m^2 of a one-story building will generate 1–2 tons of construction waste depending on whether it is a light or heavy construction;

[87] Miljøprojekt nr. 2006, 2018. Ressourcekortlægning af bygninger. https://www2.mst.dk/Udgiv/publikationer/2018/04/978-87-93710-05-4.pdf

- For a more detailed calculation, a floor plan (tonnes per square meter) of building with measures can be used. Measures can be confirmed by an inspection of the building.

For the waste declaration, estimated waste amounts should be made in tonnes based on the material densities. However, there is no common understanding of which material densities should be used in Denmark. If some materials are planned to be reused, the dimensions, type and colour of the material should be used.

In the future, tools will be available (e.g. the use of building information modelling (BIM) will contain the information). To date, no Swedish or Finnish guidelines for resource inventories on waste amount arising from demolition have been published.

Denmark

In Denmark, resource inventories are not mandatory, but in recent years more and more examples of resource inventories have appeared and many stakeholders see a benefit from them. The Danish EPA therefore initiated a project with the aim of producing a guideline for a resource inventory.[88] Furthermore, a resource inventory is part of the recommendations for selective demolition[89] which were published in 2017 in Denmark.

A resource inventory basically consists of 4 steps:

- clear definition of the purpose of the project;
- desktop study;
- examination of building; and
- data processing.

[88] Miljøprojekt nr. 2006, 2018. Ressourcekortlægning af bygninger. https://www2.mst.dk/Udgiv/publikationer/2018/04/978-87-93710-05-4.pdf

[89] Miljøprojekt nr. 1962, 2017. Projekt om selektiv nedrivning. https://mst.dk/service/publikationer/publikationsarkiv/2017/okt/selektiv-nedrivning/

It is important to use the results of the resource inventory in the tender for the demolition. This will encourage a discussion of how the waste and resources should be handled afterwards and will demonstrate for the building owner what possibilities there are for reuse and recycling.

A resource inventory will contain information of all the materials in the building in the different parts of the buildings (unless the scope of the inventory is limited to parts of the building, e.g. in renovation works). The resource inventory contains a calculation of the amounts of the materials or the dimensions of the materials. The resource inventory may have a special focus on reused materials or parts of the building that are worth preserving. The resource inventory will also consist of a description of demolition possibilities, application along with waste hierarchy and a list of which companies/projects can receive the resources. A strong focus in the resource inventory is that recycling opportunities must be exploited. Special concern is put on opportunities for match-making between the availability of demolition waste with actual needs for recycled materials, i.e. how to match the demolition project with construction project in need of the materials.

Useful tools in resource inventories:

- Drawings and data of the building
- Equipment to measure distances/heights in the building
- Systems for moisture measurement
- Tools for destructive intervention
- Camera to document building with images
- Tablet with a scheme to record information.

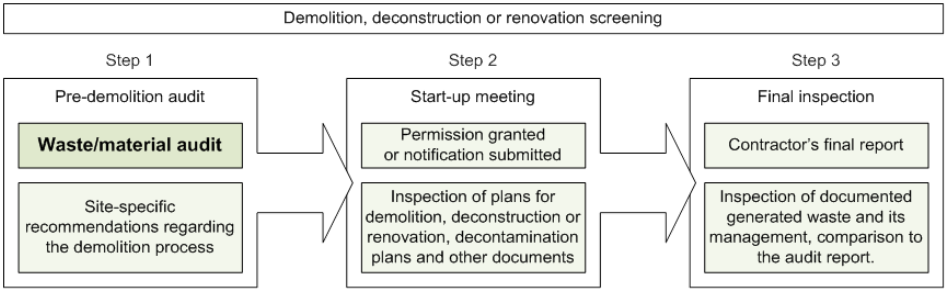
Finland

A revision to the guidance document for the demolition process is currently under preparation. The demolition guidance document will also include recommendations for waste auditing by extending the Framework guidance document published by the European Commission in 2017 to Finnish conditions. The guidance is financed by the Finnish association INFRA, the Finnish Ministry of the Environment and the Finnish Ministry of Economic Affairs and Employment. The project covers quality aspects to be considered during the whole demolition process chain. The aim is to improve the

quality of the recovered materials to enable recycling. As part of the project, the current practices in some demolition projects were followed up in order to identify good practice and areas for improvements.

The Finnish Ministry of the Environment is currently developing a guideline for Green Public Procurement (GPP) for the demolition of public buildings to be published in 2019. Green Public Procurement is a voluntary instrument to be used by the municipalities. The aim is to improve the recycling of C&D waste arising from the demolition of public buildings. Potential criteria to be taken into public procurement processes are proposed. One of the suggested criteria relates to the scope and content of the pre-demolition audits, e.g. including plans for reuse or recycling of C&D waste. In addition, criteria related to the competence of the auditor are proposed.

Figure 11: Legal framework in demolition work



4.3.2 *Reuse of interior building products prior to demolition – example from Sweden*

A Swedish study on reusability potential of specific construction products as a resource potential gives a new perspective on reconstruction. In August 2018, the report "Potential and solutions for reuse of interior building products in Sweden"[90] was published. This report shows that office furniture and interior building products (such as doors, glass panels and chairs), are not reused as much as they could be in Sweden today.

Table 12 shows the estimated reuse potential for Swedish interior building products at a national level, per square meter of office space, and for an example office of 2,000 square

[90] Andersson, J. *et al.* (2018). Potential och lösningar för återbruk på svenska kontor. IVL Svenska Miljöinstitutet report C339

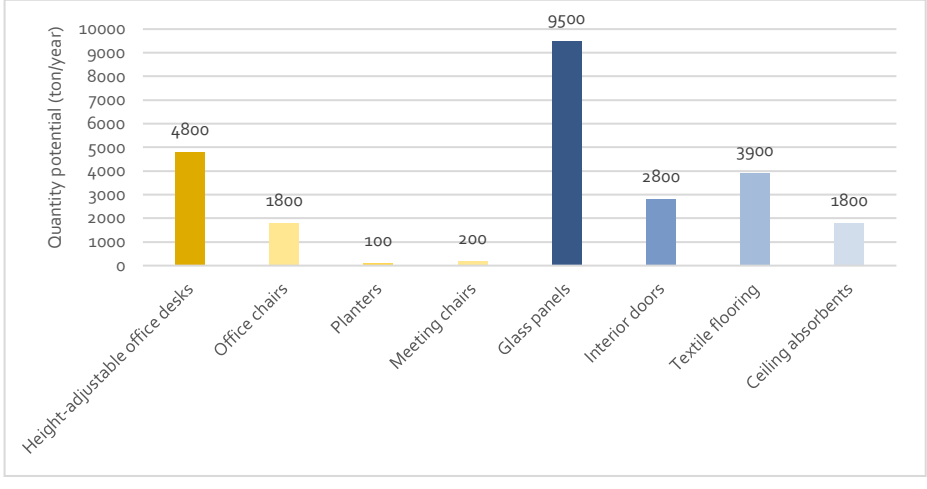
meters. It is worth noting that the figures presented in the table represent the potential for the specific products examined in the mentioned study, and that this potential is in reality often distributed among several actors, such as tenants and property owners.

Table 12: Estimated reuse potential for Swedish interior building products at a national level, per square meter of office space, and for an example office of 2,000 square meters

Quantities		Climate savings	Financial savings
Per year (national level)	25,000 tonnes waste	43,000 tonnes carbon dioxide	SEK 1.3 billion (around EUR 125 million)
Per square meter	20 kg waste	30 kg carbon dioxide	SEK 1,000 (around EUR 90)
Per example office (2,000 m²)	40 tonnes waste	60 tonnes carbon dioxide	SEK 2 million (around EUR 190,000)

As can be seen from below, the largest quantity potential can be found in the reuse of glass panels, height-adjustable office desks and textile flooring. In total, approximately 70% of the quantity potential is allocated to the reuse of interior construction products (blue in figure), while about 30 percent of the quantity potential can be found in the reuse of office furniture (yellow in figure).

Figure 12: The amount of potential for recycling Swedish office products divided into different products and distributed on office furnishings (yellow shades) and interior construction products (blue shades)



One common perception is that the climate impact of transportation and reconditioning of reused products risk removing the climate savings from reuse. However, this study shows that the climate savings of reuse are high despite extensive transportation and reconditioning of the products in relation to the reuse process. According to the study, reconditioning of the products has a greater impact on the climate savings of reuse than transportation, which play a marginal role in the overall climate impact over the products' life cycles. On the other hand, it is clear that also reuse processes which involve extensive reconditioning measures lead to climate savings. This is due to the large portion of the products' materials that are nonetheless reused, leading to a reduction of extraction and production of new materials, and often extensive climate impacts.

To test the reuse idea in practice, IVL has refurbished their own offices in Gothenburg and Stockholm (Figure 13) with the solutions. The calculations have been verified.

Figure 13: Photo from IVL´s office in Gothenburg where reused doors, glass panels , absorbers and furniture have been used

5. Practice outside Denmark, Finland and Sweden

A mapping of practice outside the project group was conducted in order to identify activities that could be used to support the project recommendations (e.g. experience or systems implemented in other countries). Only a few countries have introduced a mandatory pre-demolition audit in legislation, but several countries have voluntary based systems focusing on some parts of the auditing, typically on the identification of hazardous waste. In this section, practices in the following countries or regions are reviewed:

- Norway recommended already in 2007 the screening of hazardous substances in buildings prior to demolition. Several guidance documents and reports on hazardous substances have been published;
- Austria has legislated on mandatory pre-demolition audits for demolition works over a specific size;
- In Belgium, a pre-demolition audit is not mandatory. However, in Belgium/ Flanders a traceability system has been created by a non-profit C&D waste management organization in order to support the traceability of selectively collected stony construction waste materials to assure the quality of the recycled demolition waste. This traceability system goes one step further than the pre-demolition audit;

- The Dutch Municipalities require a pre-demolition audit for every demolition in which more than 10 m^3 of waste is generated. Additionally, a certification scheme for the demolition process also covering the pre-demolition audit is used voluntarily in the Netherlands. A certified demolition contractor operates according to the demolition process described in the BRL SVMS-007[91] (the certified demolition process not further described in the text below);
- The Basque region in Spain requires that the estimated waste amounts in the inventory are compared to actual wastes generated.

5.1 Norway

In Norway, legislation[92] requires a pre-demolition audit. The threshold for conducting a pre-demolition audit is as follows:

- Floor area of the building is larger than 100 m^2
- More than 10 t of waste is generated.

The legislation sets a requirement on waste sorting of 60 weight% of waste generated and handled at the treatment plant or sent directly to recycling with a waste treatment permit. Furthermore, the estimated waste should also be compared with the actual generated waste amount.

In Norway there has been concern about hazardous substances in buildings already in the late 2000s. The Norwegian EPA has published a factsheet M14 "Disponering av betong og teglavfall"[93] describing under which conditions the recycling of concrete is not in conflict with the pollution ban of the environment. When the conditions are fulfilled, no environmental permit is needed. Only a notification has been proposed for

[91] Stichting Veilig en Milieukundig Slopen. Steps of the certified demolition process. https://www.veiligslopen.nl/en/certified-demolition-process/

[92] Regulation concerning technical requirements on construction (Forskrift om tekniske krav til byggverk, Byggteknisk forskrift): https://lovdata.no/dokument/SF/forskrift/2017-06-19-840/KAPITTEL_9#KAPITTEL_9 see §§ 9-5 9-9.

[93] Miljødirektoratet. Disponering av betong- og teglavfall. FAKTAARK M - 14|2013. http://www.miljodirektoratet.no/Documents/publikasjoner/M14/M14.pdf

limit values for the recovery of concrete from construction without an environmental permit. In addition to the limit values for hazardous substances in concrete, also separate limit values for the paint surface layer are included. Special concern is placed on PCB and CrVI and lately also on persistent organic pollutants.

Several factsheets (2–4 pages) on hazardous substances in construction products (e.g. isolation materials, concrete, wood, windows, paints) and also on waste management have been published by the Norwegian authorities. The Norwegian EPA has also initiated several studies on potential waste streams arising from demolition, hazardous substances in concrete, waste classification and surveys of hazardous substances in construction. Examples of some recent reports are collated in Table 13. References to a few Norwegian reports on the presence of different persistent organic pollutants (HBCDD, SCCP) in construction products are included in 2.5.

The Norwegian Forum "Forum for miljøkartlegging og -sanering"[94] has developed a guidance for assessment of the quality of concrete for recyclability and waste management (Table 13). The guidance document covers sampling methodology, analysis, documentation, limit values and the decision tree for the assessment. Several illustrative photos of different construction products are collated.

Furthermore, the Norwegian Forum has elaborated recommendations for good practice in the offering of a survey of hazardous substances in constructions to be demolished. The recommendations include a list of potential criteria for selection of auditor (e.g. own work experience, participation in courses, company references, knowledge of legal requirements, and taxation information of the company).

In Norway, also the standard NS 3420-CD entitled "Miljøsanering, demontering og riving" on the management (documentation) of the removal of hazardous substances from buildings during dismantling and demolition has been developed. The standard also contains guidance on a selection of codes according to the European list of waste.

The Norwegian forum for civil engineers (RIF) regularly arranges courses on inventory of hazardous substances in constructions. The course (5 days) include an exam.

[94] Forum for miljøkartlegging og - sanering. Dokumenter. https://www.miljokartlegging.com/dokumenter-1

Elements in the courses are:

- key hazardous substances of concern in material/waste inventory prior to demolition
- legislation
- tools for detection
- assessment of results, documentation
- practical work
- exam.

Østfold Research, in cooperation with Sintef Byggforsk, has prepared a material flow analysis of concrete waste from construction (see reference in Table 13). In this study the current quantities of concrete waste from new constructions, renovation and demolition, as well as future concrete waste amounts were estimated. The study also covered current handling of gypsum waste and windows (windows contaminated with PCB, SCCP, phthalates, isocyanates and newer additives as well non-contaminated windows). In Norway, concrete waste is mainly used in earth construction (55–74% of the generated waste). No concrete waste is directed to recycling in new concrete due to the strict quality requirements for use in concrete. It is estimated that 80% of the gypsum waste can be recycled new gypsum products in 2020. The glass from windows containing hazardous substances is sent for recycling, but in the statistics reported as hazardous waste and not included as recycled waste.

Table 13: Estimated reuse potential for Swedish interior building products at a national level, per square meter of office space, and for an example office of 2,000 square meters

Reference (report title)	Focus	Specification, Link
Engelsen, C. *et al.*, (2017), Betongavfall Bindemidler, tilsetninger og maling benyttet til betong og vurdering av utlekkingspotensiale	Additives in concrete, leaching potential	Financed by the Norwegian EPA
Farligt avfall, COWI, (2015)	A chapter with a list of hazardous waste in buildings; examples of potential presence of hazardous substances in constructions	Financed by the Norwegian EPA http://www.norsas.no/Farlig-avfall/Farlig-avfallsveileder
Wærner, E.R., Mejlgaard Ulla, K.M. & Skogvold, S., (2017). Betongveilederen Prøvetakingsstrategi, regelverk, tolking av analyseresultater, miljøkartlegging, og søknad om nyttiggjøring av betongavfall Versjon 1.0 Rapport 00-2017	Guidance for assessment of clean concrete for recycling: detailed guidance for sampling of concrete constructions prior to demolition (e.g. sampling methodology) and also assessment of results (several illustrative photos)	Study initiated by the Norwegian "Forum for miljøkartlegging og -sanering" https://www.miljokartlegging.com/dokumenter-1
Rønning, A., Engelsen, C.J. & Andreas Brekke, (2016) Materialstrømsanalyse – byggavfall Betong, gips og vindusglass.	Management of concrete, gypsum and windows from demolition Estimation of current and future amounts of concrete waste, gypsum waste and windows in Norway. Report of current and potential recycling rate of the waste streams	Financed by the Norwegian network "Nettverk for gjennomføring av Nasjonal handlingsplan for bygg- og anleggsavfall" https://www.ostfoldforskning.no/no/aktuelt/materialstroemsanalyse-byggavfall-betong-gips-og-vindusglass/
Hvordan planlegge for mindre avfall (financed by Norwegian Green Building Council (NGBC)	Guidance for implementing BREEAM: BREEAM concepts for increased recycling and reuse in construction/demolition	http://ngbc.no/wp-content/uploads/2017/06/NGBC_veileder_Hvordan-planlegge-for-mindre-avfall.pdf

5.2 Austria

The recycling regulation concerning the recycling of waste for demolition of buildings includes also requirements for a pre-demolition audit. The regulation makes references to the Austrian standard ÖNORM B 3151 "Dismantling of buildings as a standard method of demolition", issued on 1 December 2014, which describes the elements in the pre-demolition audit and also requirements for controls after demolition.

For every demolition project with an estimated waste production of more than 750 tonnes a pre-demolition audit is obligatory, either:

- according to the standard *ÖNORM B3151* by an *internal (or external) expert* ("orienting pre-demolition audit"); or
- for demolition projects with *more than 3,500 m³* building volume according to *ISO 16000-32* by an *external expert* only ("extensive pre-demolition audit").

The pre-demolition audit is documented by a standardized form (ÖNORM B3151) or an expert report (ISO 16000-32).

For materials from *line structures* (streets, railroads, canals, etc.) the pre-demolition audit can be replaced by sampling and chemical analysis.

Based on the result of the pre-demolition audit, a "Concept for deconstruction" has to be developed. This concept should determine how all examined materials/construction parts containing dangerous substances or impurities have to be removed and by whom. The plan is described either by an internal or external expert (the limits as for the pre-demolition audit (750 tonnes, 3,500m³) apply here) and has to include:

- estimated masses out of main components (asphalt, concrete, excavation material, wood, metals, others);
- name(s) of the demolition company(-ies) which will execute the removal of relevant materials or construction parts;
- methods for deconstruction/special provision (e.g. removal of asbestos) – if necessary.

The concept for deconstruction is to be documented by a standardized form (ÖNORM B3151), for larger objects a more detailed report is generally generated.

After complete removal of all relevant materials or construction parts containing hazardous substances or impurities – according to the concept for deconstruction – the building is ready for mechanical demolition. The confirmation has to be conducted by an internal or external expert (the limits as for the pre-demolition audit (750 tonnes, 3,500 m³) apply here) based on an on-site inspection. The confirmation has to be documented and represents (together with the documentation for the audit) a "quality certificate" for the generated demolition waste.

Table 14: List of C&D materials that need to be removed from the building before demolition – example of Austrian standard ÖNORM B3151 in Annex D

C&D materials that need to be removed from the building before demolition
Loose artificial mineral fibre (if hazardous)
Components or parts containing mineral oil (e.g. oil tank)
Smoke detectors with radioactive components
Industrial smoke stacks (e.g. fireclay boxes, bricks or lining)
Insulating material of components containing chlorofluorocarbon ((H)CFC) (e.g. sandwich elements)
Slags (e.g. slags in inserted ceilings)
Oil-contaminated or otherwise contaminated soils
Fire debris or otherwise contaminated debris
Isolations containing polychlorinated biphenyl (PCB)
Electrical components or equipment with pollutants (e.g. vapor discharge lamps containing mercury, fluorescent tubes, energy-efficient lamps, capacitors containing PCB, other electrical equipment containing PCB, cables containing insulation liquids)
Cooling liquid and insulations from cooling devices or air-conditioning units containing chlorofluorocarbon ((H)CFC)
Materials containing polycyclic aromatic hydrocarbon (PAH) (e.g. tar bitumen, tar board, cork block, slags)
Components containing or impregnated with salt, oil, tar, phenol (e.g. impregnated wood, cardboard, railway sleepers, masts)
Material containing asbestos (e.g. asbestos cement, sprayed asbestos, night storage heaters, asbestos flooring)
Other hazardous materials

Table 15: C&D materials representing or containing impurities

C&D materials representing or containing impurities
Stationary machinery (e.g. building services, electrical devices)
Floor constructions and double-floor constructions
Non-mineral flooring and wallcovering (except wallpaper)
Suspended ceilings
Non-plastered synthetic installations (e.g. cables, cable channels, sanitations)
Facade constructions (e.g. curtain-wall facing, glass front, thermal insulation composite systems)
Sealings (e.g. roofing cardboard, plastic sheeting)
Building materials containing gypsum (e.g. gypsum plaster board, gypsum floorboard, screed containing gypsum) except wall plaster, ceiling plaster, bonded screed
Partition walls from cork, porous concrete, cement-bounded wood-wool slab, wood, plastics
Glass, glass walls, glass bricks
Loose mineral rock wool, glass wool or other insulating material except impact sound insulation
Doors and windows (except those for dust protection during demolition)
Plants and soil (e.g. from vegetated roofs)

5.3 Belgium/Flanders

Pre-demolition audits are not mandatory in Flanders, but a pre-demolition inventory of the types/quantities of materials present in buildings is mandatory for non-residential building with an enclosed volume over 1,000 m^3. Hazardous waste and other waste materials are to be identified.

For ensuring good quality of stony waste for recycling a Tracimat system on traceability and management has been developed by the Flemish Construction Confederation (VCB), a non-profit C&D waste management organization. The tracing process starts with the identification of all the materials present in the building (with a specific focus on hazardous waste) and the preparation of a demolition waste inventory and waste management plan, prepared by an expert according to a specific procedure. Tracimat will check the quality of the waste inventory and waste management plan and issue a declaration on its conformity. The waste inventory and waste management plan and its attestation of conformity are added to the tender specifications for the selective demolition works.

When the demolition works start, the contractor notifies Tracimat at least 24 hours in advance of the start of the works and the planning for the removal of hazardous waste. The notification specifies the planning for the removal of hazardous waste. This allows the CDW management organization to organize random inspections on site. After the hazardous waste is removed, the expert performs an inspection visit on site (to confirm removal of the hazardous waste). The report from the inspection needs to be approved by Tracimat for the demolition contractor to be able to apply for an approval for the remaining material to be accepted as low environmental risk material.

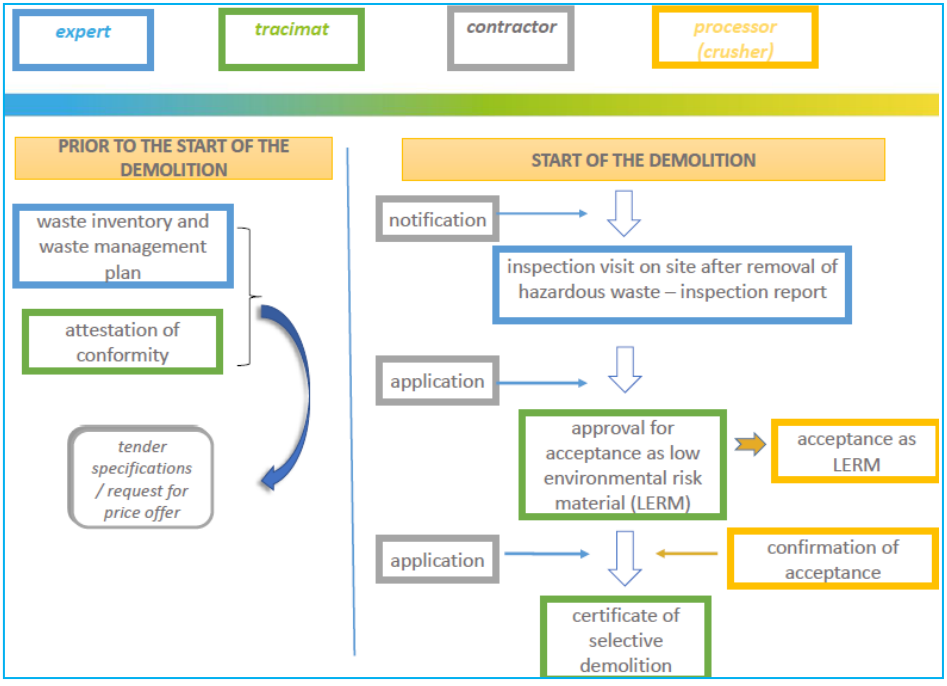
During the transport of the waste to the crusher, a transport document containing the approval acceptance as low environmental risk material needs to be present. The crusher confirms the amount of accepted stony demolition waste to the CDW management organization and specifies the type(s) and amount(s) of stony waste accepted as low and/or high environmental risk materials and/or refused.

Once the demolition works are finished, Tracimat checks that both the hazardous waste and the non-hazardous waste have been selectively and properly disposed of. If so, Tracimat will issue a certificate of selective demolition.

Table 16: TRACIMAT system developed for traceability and monitoring of stony fractions for recycling

Scope	The Tracimat focus on the stony fraction from C&D waste and covers the following steps: Waste inventory and waste management plan; to have a clear idea of the waste materials and how to treat them. Dismantling of the building: removal of hazardous materials, fixed apparatus and machinery, as well as demountable components. Structural demolition: demolition of the remaining construction. Transport to and acceptance by crusher.
Purpose	The purpose of Tracimat is to provide a quality assurance by certifying the selective demolition process and the produced waste streams. Non-contaminated waste streams with a low environmental risk clearly have a greater upcycling potential. The certificate will enhance trust in the quality of the material and in the recycled product, resulting in an improved and more widespread marketing of recycled products. The following of the Tracimat traceability system is not mandatory in Flemish regulation, but is driven from an economical incentive. The Flemish environmental regulation requires crushers to distinguish between materials with a low environmental risk and materials with a high environmental risk at the time of acceptance, with the priority of enabling cheaper processing. If the C&D waste is accompanied by the selective demolition certificate, the processor can accept and process the demolition waste as low environmental risk material. Tracimat will initially focus on the stony fraction, where possible, the organization's field of activity will be expanded in the future to include other types of C&D waste materials.
Elements included	identification of hazardous substances/hazardous waste monitor the streams supervise the flows certification system (demolition certificate shows the processor whether the C&D material can be accepted as "low environmental risk material" which means that the purchaser (recycling plant) can be quite sure that the C&D material meets the quality standards for processing at the recycling plant.
Competence of auditor	The expert has to have the necessary knowledge of current and past building materials and building techniques. Knowledge of the environmental policy and regulation (applicable in the region and/or country), specific regulation on demolition and demolition waste treatment, as well as insight in asbestos and other types of hazardous waste, and the applications these materials have been used in, is equally important. The expert also needs to know how (selective) demolition is performed: what is feasible, which fractions are collected separately given the market, etc.
Stakeholders involved	Actors in the tracing procedure for selective demolition are the expert, the C&D waste management organization (i.e. Tracimat), the demolition contractor and the processor of the waste (i.e. the crusher).
Tracimat system developers	The development of Tracimat has been carried out by the Flemish Construction Confederation, VITO, the Belgian Building Research Institute (BBRI), the Public Flemish Waste Agency (OVAM), the Belgian Demolition Association (CASO), the Belgian Federation of Producers of Recycled Granulates (FPRG) and the Association representing the Belgian Engineers (ORI).

Figure 14: Tracimat system – flowchart



Note: LERM = low environmental risk material

5.4 Basque country/Spain

The Basque country in Spain has strict regulations for compulsory pre-demolition audits (all construction, demolition and renovation works) and compulsory waste sorting.[95] Nonetheless, these practices are hardly implemented, possibly due to lacking control and surveillance. Furthermore, lacking infrastructure hampers actual

[95] Arevalillo, A., Hradil, P., Wahlström, M. (2017). EC "Technical and Economic Study with regard to the Development of Specific Tools and/or Guidelines for Assessment of Construction and Demolition Waste Streams prior to Demolition or Renovation of Buildings and Infrastructures". Final report of EU Specific Contract 30-CE-0751644/00-00 – SI2.720069. https://ec.europa.eu/docsroom/documents/24562/attachments/1/translations/en/renditions/pdf

management of (these compulsory to-be-sorted) streams. There is also an important lack of control of unauthorized landfills.

In the Basque country, the amount of wastes arising from demolition works is estimated use of computer application. The waste amounts are estimated by applying waste factors that depend on the type of activity (construction, demolition, refurbishment, urbanization), type of building (residential, industrial), size, etc. Demolition contractors from the Basque country interviewed in the EU HISER project[96] claimed that it is not a precise assessment (as it tends to overestimate quantities and gives rough information of the waste types) and should be used only as a reference (and not to bail the licensing of works by municipalities).

In order to improve the ratio of audits performed and the correct management of CDW, the Basque country (in Spain) requests the owner to deposit the amount of money needed to perform waste management according to the budget. This deposit is paid back when the monitoring against real data has been performed and necessary justifications provided. Public contractors or owners contracting certified companies do not need to deposit this fee. The inventory audit developed within the project (called "study of CDW management") is further developed in the so called "plan of CDW management" by the contractor that will execute the works once commissioned. The (first) waste audit is part of the technical project and can only be performed by an authorized professional (typically an architect). The second waste audit in Spain is part of the contract between the property and the demolition company. In case there are differences in the estimated and actual amounts an explanation needs to be provided to the authorities.

[96] EU H2020 HISER project: Holistic Innovative Solutions for an Efficient Recycling and Recovery of Valuable Raw Materials from Complex Construction and Demolition Waste (2015–19). www.hiserproject.eu

6. Elements for further improvement of pre-demolition audit

6.1 Analysis of implementation

6.1.1 Denmark

Legislation in Denmark does not require a full pre-demolition audit, only the inventory of PCB is mandatory. The requirement is limited to the time period 1950–1977. However, there are requirements on the removal of hazardous waste from construction waste, which in practice means that contaminants other than PCB have to be included in the inventories in order to fulfil this obligation. A principle in the legislation is also that the contaminant must be removed at the source, which in practice means that contaminants must be removed from the building prior to demolition. This also means that, e.g., paint is often removed from the building before demolition.

Legislation also requires that the expected waste amounts are declared to the municipality two weeks before the demolition takes place. In Denmark there has been guidance on how to handle asbestos, lead and PCB in constructions with special focus on health safety. Guidelines have been published about construction products containing hazardous substances, but there is a need for practical guidance on how to identify hazardous substances (including sampling guidance) as the general practice is very different for different stakeholders.

There is no education or common requirements on skills of pre-demolition auditors. The recycling rate for C&D waste is high (over 85%) in Denmark, but this number covers mainly recovery as concrete waste is used in road constructions. For all recyclable wastes, the traceability of materials will be important in the future for ensuring high quality for reuse and recycling.

6.1.2 Finland

In Finland, there is a mandatory auditing of asbestos and the municipalities require an estimate of the C&D waste prior to demolition. The development of pre-demolition audit guidance has been mentioned as a priority area in the National Waste Management Plan[97]. The pre-demolition audit concept will be introduced as part of the guidance for the quality management in the demolition process. There will therefore probably be an increased need for qualified auditors in the future.

A revised guidance document (RT card 18-11245) for identification of construction products containing hazardous substances was published in 2016, and there are plans to update the document. The main focus has been on asbestos. Further information is needed on the recycling potential of construction waste, especially on quality requirements for different applications. In addition, guidance on the identification of flame retardants and to some degree also selected persistent organic pollutants needs to be reviewed.

The recovery rate has in recent years increased (near or around the target of 70%), but there is still the need for improvements. For example, part of the concrete waste is still backfilled and the recycling rate of other C&D waste is low. The main problem is the lack of demand for recyclable construction products and materials.

6.1.3 Sweden

In Sweden, the pre-demolition audit is mandatory for hazardous waste and there are basic guidelines available for the identification and management of materials containing hazardous substances. As a result of both EU targets and the push from the industry, in the future the audit will also include an inventory of reusable construction products (when the revised version of the guideline is published). Furthermore, the Swedish waste management plan and the programme aim for waste prevention and for more resource-efficient and non-toxic waste management in accordance with the waste hierarchy. "Together we win having a non-toxic and resource-efficient society."

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[97] Laaksonen, J., Salmenperä, H., Stén, S., Dahlbo, H., Merilehto, K. & Sahimaa, O. 2018. Kierrätyksestä kiertotalouteen. Valtakunnallinen jätesuunnitelma vuoteen 2023, Suomen ympäristö 01/2018. http://julkaisut.valtioneuvosto.fi/handle/10024/160441

6.2 Future aspects to be considered in the implementation of pre-demolition audits

So far, the main focus in the pre-demolition audits has been on the identification of hazardous substances prior to demolition. The mapping of the wastes is not always done very accurately, if even done at all. In cases where quantification of waste streams to be generated from the demolition is included in the audit, the main interest has often been in estimating the mineral fraction for recovery or recycling. Only to a limited extent has attention been paid to other waste streams, which is partly due to lacking demands for the recyclable materials.

The Nordic ambitions for resource efficiency put pressure on the more sustainable use of materials in construction and on closing the material loops. The Commission is now considering new reuse and recycling targets for material-specific fractions, e.g. wood, plastics, gypsum, etc. in C&D waste.[98] Merely continuing with current practices, future demands and closing the material loops are not achievable. Also, the non-toxicity of materials loops is recognized in the Nordic countries.

One key question in implementing the pre-demolition audit is to link the information contained in the pre-demolition audit to the demolition activity. Discussion is needed on the question: How should the audit be further developed to provide input to the demolition activity in order to later secure high-grade recycling or reuse? All stakeholders in the value chain also need to be involved, especially the end-users of the recovered materials or products.

6.3 Barriers and drivers for recycling and reuse

Recycling and reuse of building materials exist in Finland, Sweden and Denmark, but especially reuse often only on a small scale. Barriers to recycling and reuse exist on a wide scale, and effective markets are difficult to establish. This is related to the price, quality and quantities of the secondary raw materials. Precautions in demolition process can be taken to ensure high quality for recycling if a market for

[98] The revised Waste Framework Directive forces states that: "The Commission shall consider the setting of preparing for reuse and recycling targets for construction and demolition waste and its material-specific fractions by 31 December 2024"

some materials have been identified based on information gathered in the predemolition audit.

High-quality recycling or reuse requires greater effort compared to material and energy recovery (use as road materials and incineration). On the other hand, demands on sustainability in the construction area are growing, and the circular economy has been a high focus area in these countries in recent years. Creating a strong brand/image of sustainability and new business opportunities are drivers for companies.

Some common barriers and drivers for the studied countries are described below.

6.3.1 Quantities and logistics

Barrier: Small volumes of waste/resources with a sufficient quality to be recycled or reused. Waste/resources are not available at the desired time and place and there is a lack of match-making between supply and demand in order to make an efficient market.

The pre-demolition audit supports the possibilities to obtain larger volumes of quality materials and a marked/user for the secondary materials may be found in time prior to demolition.

6.3.2 Quality

Barrier: Strict requirements on new materials/products in construction have to be met by reused and recycled materials as well, if they are to be used for the same purpose. However, the lack of documentation of technical and environmental quality results in no or little knowledge on the content of hazardous substances and the performance of products. The degradation of products when they are in use may in some cases (e.g. wood) hinder reuse or recycling. There is uncertainty regarding who is responsible for warranty, and no common quality system exists in order to measure sufficient quality of recycling and reuse.

The pre-demolition audit is a prerequisite for high quality materials suitable for reuse and recycling. Hazardous substances are identified and if necessary removed prior to demolition. Also reusable and recyclable materials are identified prior to demolition and actions can be planned for securing high quality materials during the demolition.

Other important drivers: Standards for the quality of recycled materials is a driver. In Finland, there is new legislation on the use of waste material in earth constructions

including limit values and quality systems for use and a standard for CE-marking of reclaimed concrete.

6.3.3 Availability of primary raw materials

Barrier: Good availability of virgin sand and stone aggregates as well as virgin wood limit the demand for recycled materials.

The pre-demolition audit enables the building owner for seeking the most cost efficient waste management solutions (including costs for upgrading), through also avoiding landfilling of mineral waste or incineration of mixed wastes.

Other important driver: Lack of some primary raw materials – especially locally available resources – is an efficient driver, also because transportation costs of construction materials are high. In Denmark a recent report[99] has shown that the supply of primary raw materials from the current production sites is limited from 14 years in some regions to 43 years in other regions. Also increasing landfill costs, increasing fee on non-recycled waste, increasing fee on raw material and taxation are instruments, which can be used to boost the demand for recycled materials.

6.3.4 Economy

Barrier: It is difficult to get a profitable business case for recycling and reuse, e.g. due to demolition, storage, reprocessing and transport. Ideally, the business case needs to be beneficial for the owner of the building to be demolished and for the developer of the new building potentially receiving reused and recycled materials. Generally, low confidence in recovered building materials and components performance and reliability are observed in their end-users, designers and insurance companies. This creates a considerable gap between the acceptable costs of virgin and recovered products.

Information gather in the pre-demolition audit supports the planning of the cost efficient waste management. The economic savings can be achieved through income from recyclables and reduced costs for waste to be landfilled or incinerated.

[99] Danske regioner. (2017). Råstoffer. Er der behov for en national strategi.

Other important driver: The cost of production of building materials from non-renewable resources is going to increase in the following decades for many reasons, for instance, because of the scarcity of virgin materials and implementation of new carbon-neutral processes. At the same time, it is assumed that the taxes and fees for landfilling and lower-grade recovery are going to be used to promote more efficient recycling and reuse. Technology development within demolition is important to improve business cases. Other factors such as environmental performances and aesthetic/historical values are important to measure, and lifecycle assessments are crucial. Certification of sustainable buildings is also a driver as it gives the building owner a possibility of branding and informing the end-users about the environmental benefits caused by responsible material sourcing. Internationally recognized certification of new projects, such as BREEAM, LEED or DGNB which are used in the studied countries, provides also higher confidence in the proper and high-quality design. Certified buildings may also receive incentives from building or environmental authorities.

6.3.5 Knowledge Gap

Barrier: Lack of knowledge among stakeholders in the value chain as legislation and technical and environmental issues are complicated.

The auditor for the pre-demolition audit shall have sufficient knowledge and experience to identify materials containing hazardous substances to fulfil all legal requirements for waste audit report and waste declaration. Furthermore, the auditor shall have the experience and skills to decide about reusability of components, recycling potential of C&D waste and the legislative requirements related to waste management. A certification scheme for the auditors involved in the inventory of hazard substances has been developed in Finland and Sweden.

Other important driver: Networking and collaboration on all levels is important across the value chain. In Denmark a knowledge centre has been set up in order to provide all stakeholders with sufficient knowledge of building and construction waste.

6.4 Recommendations

6.4.1 Development of harmonized protocol for auditing of hazardous substances

Ideally a harmonized approach to performing pre-demolition audits in both the Nordic countries and in EU would support the inventory work and to facilitate that sufficient volumes are created and thus supports the security of supply to the marked. A harmonized approach could address a list of key hazardous substances to be identified depending on material fractions in questions, potential tools for identification (e.g. photos, methods), good practice and also health safety aspects for the auditors performing auditing (later also demolition workers). Audits should cover all basic building materials and preferably give recommendations for the waste management. Country-specific hazardous substances or other country-specific features should be listed separately. In addition, documentation is important for the later removal of construction materials containing hazardous substances. A detailed inventory creates the liability for the construction waste to be recycled or reused. A minimum requirement for documentation could be elaborated on a Nordic level.

As part of the harmonized approach, the development of a Nordic guidance document for the inventory including important elements would be helpful. All the Nordic countries have guidance documents or handbooks for the inventory, but protocols for practical work could be further developed. The harmonized protocol could include documents with the following elements:

- key hazardous substances of concern;
- key elements in the desk study prior to field visit;
- good practice in field visit;
- wearable analyzers (applicability of equipment);
- check list of materials potentially containing hazardous substances (including photos and guidance on how to identify the materials);
- development of a sampling plan (sampling technique, number of samples, analysis methods, etc.;

- elements to be included in documentation;
- templates for reporting of waste;
- action limits for materials to be removed when possible; and
- action limits for recyclables when possible.

6.4.2 Education and certification

Auditors performing pre-demolition audits especially need to have sufficient experience in auditing. Furthermore, knowledge about waste legislation, hazardous substances and the construction sector are required for the auditor. As described in Chapter 2, courses dedicated to auditors of hazardous substances in construction products are arranged especially for auditors in all the Nordic countries.

Ideally auditors educated in one country should be able to prove competence in other countries (many building and demolition companies are working in several Nordic countries). The creation of a common base of course content is recommended. Furthermore, some common teaching materials could be developed and shared. In addition, the spreading of good practice is valuable and also benefits the competence in specific topics, e.g. if supported through common teachers.

6.4.3 Quality aspects

The big barrier to recycling is the quality of the construction products and wastes potentially suitable for reuse or recycling. A tracing system would create confidence in the quality of the recovered material. The Belgian Tracimat concept for mineral waste could be further expanded to include other products. In addition, the building product passport concept developed in the EU BAMB project "Buildings as material banks"[100] could be a good basis for the development.

A Nordic concept for traceability could be developed taking into account the products and materials used in the Nordic countries as well as the features of the end-users. The traceability system could be built on pre-demolition audits to ensure that all

[100] EU Horizon 2020 project Buildings as material Banks. https://www.bamb2020.eu/

information is kept through the value chain. Ideally, new buildings should have a building passport with information used for the pre-demolition audit.

6.4.4 Scope of pre-demolition audit

The pre-demolition audit could be broadened with more focus on the building as a resource. The audit is proposed to cover also construction products suitable for reuse. The building owners are especially the target group for information on the potential reusable construction products and recyclable materials and the value of the waste. Avoiding landfilling of waste could also give a cost saving in waste management.

The development of tools is necessary for estimation of waste arising from demolition, also including information on the quality and value of the streams. Special attention is needed on construction products that are reusable. There is also a need to develop methods and tools for assessment of the quality (ageing, purity) of the materials or products in the construction prior to demolition. Ideally, the Nordic countries could develop a harmonized protocol for auditing of materials for recycling/reuse.

6.4.5 Good practice and sharing of information

Documentation and spreading of information on good practice for reuse and high-grade recycling of construction products and materials would be useful for all stakeholders involved in the value chain. Focus could be on the Nordic solutions that are replicable. The survey of current practice clearly indicates a need for new solutions, especially for materials that are lost due to landfilling and incineration.

The aim of the task could be to identify good practice for different types of construction products and materials and to collect information on the conditions for the solutions. The overall aim is to contribute to the better use of construction resources, especially in the Nordic countries.

6.5 Further research

In the future, the building information modelling (BIM) can be a tool used for material inventories. BIM carries information of the construction products during the whole lifecycle up to the deconstruction stage and increases the traceability of the materials. There is potential to improve existing knowledge of the quality of recyclable materials/reusable products and to simplify the whole process in the future. This sets the need to also develop data storage in the BIM system to enabling data searching later in an easy and useful way.

Calculation of carbon footprints for demolition work has not been widely done. In the future, for example, the municipalities may require information on the carbon footprint of big demolition projects.

New tools for material inventory are under development, e.g. handheld spectroscopy and hyperspectral imaging devices for material identifications. Also, modern scanning and remotely controlled technologies can be applied for the identification of recoverable materials and components in buildings to be demolished.

Sammanfattning

Bygg- och rivningsavfall från byggnader och infrastruktur utgör omkring en tredjedel av allt avfall som genereras i de nordiska länderna. Avfallet består av olika materialslag såsom betongkross, tegelstenar, gips, trä, glas, metaller, plast, lösningsmedel, farligt avfall (asbest, PCB etc.) och uppgrävda jordmassor. Byggavfallet används vanligen som obundna material i vägbygge, som fyllnadsmaterial och i landskapsbygge eller deponeras eller förbränns. Materialåtervinning och återanvändning förekommer i begränsad omfattning. De största utmaningarna är materialets låga kvalitet, vilket ofta beror på bristen på identifiering och avlägsnande av farliga ämnen, eller närvaro av oönskade ämnen vilket beror på dålig sortering men även på möjlig kontaminering av farliga ämnen.

Det är sannolikt att Kommissionen kommer att ge rekommendationer till medlemsländerna att genomföra en obligatorisk materialinventering före rivning för att förbättra kvaliteten för återvunnet bygg- och rivningsavfall. En materialinventering är en förutsättning för att byggavfall ska hanteras på ett säkert sätt. Avsikten är dels att identifiera material som skall separeras före rivning av byggnad eller infrastruktur och dels att kartlägga återvinnings- eller återanvändningspotentialen hos olika material. Materialinventeringen är också viktig vid planering och genomförande av en säker demontering. Genom materialinventeringen erhålls uppgifter om avfallens materialinnehåll, vilket gör det möjligt att hitta marknader och alternativ för återvinning av olika avfallsslag.

Grunden för projektet var riktlinjerna för materialinventering som offentliggjordes av Europeiska kommissionen 2018.[101]. Riktlinjen ger information om bästa metoder för bedömning av byggavfallsströmmar före rivning, demontering eller renovering av byggnader och infrastruktur, kallad ”materialinventering”. Inventeringsprocessen strävar till att leverera sådana handlingar som ägaren kan lämna

[101] European Commission. (2018). Guidelines for the waste audits before demolition and renovation works of buildings https://ec.europa.eu/docsroom/documents/31521

in ansökan om bygg- eller rivningslov och öppna en anbudsinfodran. Dessutom bör resultatet av inventeringen också ge en tillförlitlig grund angående rivningsavfallet, för entreprenörerna att lägga in bud. Riktlinjerna för materialinventeringen anger de steg som ska ingå i en inventering och definierar de intressenter längs värdekedjan som ska vara involverade i processen.

Det detaljerade och praktiska genomförandet av de flesta delarna av materialinventeringen beslutas på nationell nivå. Ett antal element (t.ex. gränser för obligatoriska inventeringar, mallar för rapportering, metoder för provtagning, etc.) är redan implementerade i Norden. Vidare finns det flera tillgängliga eller planerade aktiviteter och nordiska riktlinjer som stödjer genomförandet av materialinventering på nationell nivå.

Syftet med denna rapport är:

- Att göra en översikt över genomförandet av materialinventering i Danmark, Finland, Sverige och i begränsad utsträckning i Norge.
- Att identifiera verktyg och god praxis som ytterligare kan inkluderas i genomförandet av materialinventeringar i Norden.
- Att ge rekommendationer om element som ska ingå i materialin-ventering för att förbättra kvaliteten på bygg- och rivningsavfall.
- Att ge rekommendationer om element som ska ingå I materialinventering för att förbättra kvaliteten på bygg- och rivningsavfall.

I rapporten presenteras kortfattat lagstiftningsbakgrunden i Danmark, Finland och Sverige och i begränsad utsträckning i Norge. Även ländernas riktlinjer kartläggs. Dessutom beskrivs kortfattat den aktuella praxisen för hanteringen av byggavfall i tre av de nordiska länderna, samt goda exempel presenteras. En kort granskning av hanteringen av byggavfall i andra länder ingår också.

Det finns obligatoriska krav för materialinventeringar i Danmark, Finland och Sverige samt i Norge. Riktlinjerna innehåller samma element, men delvis med olika fokus. I Danmark ligger fokus på farliga ämnen och hälsoaspekter vid renovering och rivning. De finska riktlinjerna beskriver i detalj de material och produkter som innehåller farliga ämnen och bör identifieras, samt handledning för provtagning. Dessutom ingår arbetssäkerhetsaspekter, särskilt vid hantering av asbestavfall. Den svenska

vägledningen har ett bredare synsätt på materialinventeringen i rivning-sprocessen och täcker främst återvinningspotentialen i rivningsavfallet. Finland och Sverige har också system för certifiering av inventerare för materialinventeringen av farliga ämnen. Det har inte publicerats mycket vägledning om bedömningen av avfallsmängderna som uppstår vid rivning.

Återvinninsgraden för mineral- och metallfraktionen av byggavfallet är ganska hög i alla tre nordiska länderna. En del av avfallet används dock fortfarande som fyllnadsmaterial. För de andra fraktionerna (än mineralfraktionen och metallavfallet) finns det fortfarande ett behov av att förbättra återvinningen och återanvändningen. Det främsta identifierade hindret hänför sig till svårigheterna med att skapa marknader för återvunna material på grund av pris, kvalitet och kvan-titeter av de återvunna materialen. Högkvalitativ återvinning och återanvändning kräver större insats jämfört med energiåtervinning och materialåtervinning av låg kvalitet.

En kort undersökning om praxis i andra länder tog fram information som kan vara till hjälp vid vidareutvecklingen av nordiska riktlinjer för genomförandet av en materialinventering. Till exempel identifierades följande intressanta praxis i andra länder: kunskap om farliga ämnen i Norge, spårning av byggavfall längsmed processkedjan i Flandern, Belgien, en österrikisk standard med en lista över byggmaterial som måste avlägsnas från byggnaden före rivning, ett certifieringssystem för rivningsprocessen i Nederländerna, och i den baskiska regionen i Spanien är det obligatoriskt att jämföra det uppskattade avfallet med de faktiska genererade avfallsmängderna. demolitio.

Projektgruppen rekommenderar följande:

- Utveckling av ett harmoniserat protokoll för inventering av farliga ämnen. Särskilt fokus kunde vara på identifieringen av farliga material för bedömning av både återvinningsmöjligheter för byggprodukterna och för att identifiera behovet av dekontaminering. Även praktisk vägledning skulle vara till nytta, t.ex. för gränsvärden för farliga ämnen som bör identifieras, rekommendationer för provtagning och analys, minimikrav för dokumentation, och utveckling av en check-lista. Projektgruppen noterade också att det finns behov av separata dokument för olika målgrupper (ägare, inventerare, entreprenörer, slutanvändare). Det är viktigt att riktlinjerna är lättlästa för målgruppen.

- Utveckling av ett spårningssystem för processkedjan: dokumentation, märkning, byggpass, och eventuell utveckling av nya tekniska verktyg för spårning. Införing av ett spårningssystem skulle också kunna vara en viktig del av en möjlig framtida end-of-waste status för avfall som genomgår högkvalitativ återvinning.
- Utveckling av nya verktyg för materialinventering. Till exempel ger användningen av BIM möjligheter till datalagring. Verktyg för att uppskatta framtida avfallsmängder i olika scenarier före rivning kan också vara nyttiga.

APPENDIX A: Glossary

Accreditation	Means that the certification body meets the requirements of a national or an international standard as assessed by an accrediting agency.
Auditor	Means the expert or the team of experts (auditors team) performing the waste audit. It can be represented by the building owner or consultant (e.g. an architect or structure engineer) acting on behalf of the owner.
Backfilling	Is any recovery operation where suitable waste is used for reclamation purposes in excavated areas or for engineering purposes in landscaping or construction instead of other non-waste materials which would otherwise have been used for that purpose.
Building authority	Means the national or regional administration responsible for granting the demolition or renovation permits and supervision of the demolition or renovation process.
CE Marking	Indicates that manufacturers take responsibility for the conformity of their products with the declared performance.
Certificate	Demonstrates to the buyer of product, process or service that the supplier complies with certain standards. It is provided by independent third party making it more convincing than if the supplier itself provided the assurance.
Certification	Is a procedure by which a third party gives written assurance that a product, process or service is in conformity with certain standards. Certification can be seen as a form of communication along the supply chain.
Closed-loop recycling	Is a process in which products are recycled into materials aimed to manufacturing products with the same function. An example of closed-loop recycling is recycling steel into steel by re-melting.
Component (or module)	Is part of a building, which may itself be an assembly of several smaller components.
Collection of waste	Means the gathering of waste, including the preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility.
Construction and Demolition waste (C&D waste)	Is any waste (embodied waste or packaging) generated in the activities of companies belonging to the construction sector and included in category 17 of the European List of Wastes. C&D waste originates at sites where construction, renovation or demolition takes place.
Deconstruction	Means removal of building elements from a demolition site in order to maximize their recovery and reuse.
Decontamination	Is reduction or removal of chemical agents and hazardous materials.
Downcycling	Is the recycling process when the product created from recycled material is of lower commercial value, quality or functionality than the original product. One example is the crushing of concrete for use as road fill or aggregate.
Hazardous substance	Is a substance defined as hazardous according to regulation (EC) No 1272/2008.
Hazardous waste	Is a waste that due to its (intrinsic) chemical -or other- properties poses a risk to the environment and/or human health. Waste listed as hazardous in the European List of Waste are marked with and asterisk in the List of Waste.
Inventory	Means the list of waste types and quantities.
Landfill	Means a waste disposal site for the deposit of the waste onto or into land (for instance underground).
Open loop recycling	Is a process where the material gained from recycling is used in a different product system than the original product. It comprises both upcycling and downcycling.

Pre-demolition audit (or waste audit)	Means assessment of construction and demolition waste streams prior to demolition or renovation of buildings and infrastructures. It assesses both qualitatively and quantitatively the waste that will be produced from a building to be demolished or refurbished. In addition to the inventory, the waste audit may include recommendations for specific management options for these waste materials, depending on different issues (such as legislation, economics or availability of treatment infrastructure). It is important that the term "waste audit" be considered in the broad sense of the word, and include at least every initiative that results in a documented work. For the purpose of this document, a waste audit should be considered as a qualitative and quantitative assessment of waste that will be produced from the construction, demolition/deconstruction or refurbishment activities including residual waste that is not part of the building. An important part of the waste audit is also the identification and removal of materials/components containing hazardous substances.
Property owner	Means the owner of the building or infrastructure, the developer or the party stated by the national legislation as the original waste holder.
Recovery of waste	Means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. (Annex II of the Waste Framework Directive sets out a non-exhaustive list of recovery operations.)
Recycling of waste	Is defined as any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.
Reuse of waste	Means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived.
Selective demolition	Means removal of materials from a demolition site in a pre-defined sequence in order to maximize recovery and recycling performance.
Upcycling	Means recycling when resulting product or material is of a higher commercial value, quality or functionality than the original item.
Waste	Means any substance or object that the holder discards or is required to be discarded with the following exceptions: (a) uncontaminated soil and other naturally occurring material excavated in the course of construction activities where it is guaranteed that the material will be used for the purposes of construction in its natural state on the site from which it was excavated and (b) waste waters (such as trade effluent disposed of via tankers, foul sewers, surface water drains, water courses, etc.). Object is here the complete element or its part removed from the building or infrastructure during the demolition, deconstruction or renovation process, substance means the waste material that can be classified according to the European List of Waste.
Waste holder	Means the waste producer or the natural or legal person who is in possession of the waste. The waste holder is the owner of the building or infrastructure, if not specified otherwise in the national legislation or the demolition/renovation contract. It is the duty of the waste holder to gain knowledge about the objects and substances intended for to discard and about their hazardous nature and contamination.
Waste management	Is the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker.
Waste management plan	Sets out the approach to demolition, the treatment and logistics of the materials identified in the pre-demolition audit.
Waste prevention	Means measures taken before a component has become waste, that reduce the quantity of waste, including through the reuse of the component or the extension of the service life of the component.
Waste producer	Means anyone whose activities produce waste1. The waste producer is the person or legal entity that executes the demolition/renovation work.
Waste treatment	Means recovery or disposal operations, including preparation prior to recovery or disposal.

APPENDIX B: Hazardous substances in construction products included in some national guidance documents

Limit and action values for hazardous substances in waste

Table B.1: Limit values and action values for hazardous substances

	Hazardous substances	Limit value (action value)	Remarks
Denmark			
Legislative requirement	PCB-total	In the statutory order of residues, a limit value of 2.0 mg/kg TS PCB-total is specified. CDW with a content of PCB below 2.0 mg/kg TS can be used as a substitute for raw materials in construction projects under certain conditions Limit of hazardous waste, PCB is 50 mg/kg PCB-total	Measured at source before demolition – peak concentration PCB-total = 5*(PCB28+PCB52+PCB101+ PCB118+PCB138+PCB153+PCB180) Waste containing PCB has always to be removed from C&D waste
Common practice	PCB-total	In order to decide if the CDW is non-contaminated with PCB a guidance value of 0.1 mg/kg PCB-total is used	
Legislative requirement	Asbestos		Waste containing asbestos always has to be removed for CDW
Common practice	Asbestos	If asbestos is detected in the waste, the waste is considered as contaminated with asbestos.	
Common practice	Arsenic	Limit value (non-contaminated) < 20 mg/kg Limit Value (Hazardous) >1,000 mg/kg	The non-contaminated values are based on soil quality criteria and the hazardous waste values are based on EU regulation. It is the municipalities, who decide the limit value and there are variations between municipalities.

	Hazardous substances	Limit value (action value)	Remarks
	Lead	Limit value (non-contaminated) < 40 mg/kg Limit Value (Hazardous) >2,500 mg/kg	See comment for Common practice/Arsenic
	Cadmium	Limit value (non-contaminated) < 0.5 mg/kg Limit Value (Hazardous) >1,000 mg/kg	See comment for Common practice/Arsenic
	Chromium (VI)	Limit value (non-contaminated) < 20 mg/kg Limit Value (Hazardous) >1,000 mg/kg	See comment for Common practice/Arsenic
	Chlorinated paraffins (short-chained)	Limit value (non-contaminated) - Limit Value (Hazardous) >10,000 mg/kg (1%)	See comment for Common practice/Arsenic
	Copper	Limit value (non-contaminated) < 500 mg/kg Limit Value (Hazardous) >2,500 mg/kg (=0.25%)	See comment for Common practice/Arsenic
	Mercury	Limit value (non-contaminated) < 1 mg/kg Limit Value (Hazardous) >1,000 mg/kg	See comment for Common practice/Arsenic
	Nickel	Limit value (non-contaminated) < 30 mg/kg Limit Value (Hazardous) >1,000 mg/kg	See comment for Common practice/Arsenic
	PAH (sum)	Limit value (non-contaminated) < 4 mg/kg Limit Value (Hazardous) >1,000 mg/kg	See comment for Common practice/Arsenic
	Zinc	Limit value (non-contaminated) < 500 mg/kg Limit Value (Hazardous) >2,500 mg/kg (50,000 mg/kg)	See comment for Common practice/Arsenic
Finland Legislative requirement	asbestos	Ban (not specified)	To be identified/ measured prior to demolition. Asbestos content must be analyzed in practice in all buildings built in Finland before 1995
	As, Cr, Cu in wood preservative (Impregnant of wood)		Use of arsenic containing preservative restricted (application, only professional use)
	Chlorophenol in wood preservative	Ban	Use of chlorophenols ended in 2000

	Hazardous substances	Limit value (action value)	Remarks
	Creosote impregnated wood	May be used for professional purposes only, if the content of benzo(a)pyrene is under 0.005 w-% and the extractible phenols are under 3 w-%.	Use permitted in certain applications
Common practice[102, 103]	Asbestos		
	PAH & Creosote		Bitumous materials hard to identify.
	PCB	50 mg/kg (the sum of 7 congeners PCB 28, 52, 101, 118, 153, 138 and 180 is multiplied by a factor 5 to get an estimate of the total content of PCB)	use of PCB banned in the beginning of 1990s. Testing procedures defined in RT cards
	Metals (Pb, Cd, Zn…)	Limits for hazardous waste classification used, Note! absolute limit for lead2,500 mg/kg)	
(based on case judgement)	Flame retardant used in insulation materials (e.g. HBCDD, TBBPA, PBDE, PBB)	Limits for hazardous waste classification used	Screening can be based on XRF (correlation with Bromine)
(based on case judgement)	Chlorophenols	Limits for hazardous waste classification and limits for POP waste (if stricter) used	
(based on case judgement)	phthalates	limits for hazardous waste classification used	a survey currently done in Finland about the relevance of the hazardous substance for demolition waste
(based on case judgement)	SCCP	limits for hazardous waste classification used	a survey currently done in Finland about the relevance of the hazardous substance for demolition waste
(based on case judgement)	BisPhenol A	limits for hazardous waste classification used	a survey currently done in Finland about the relevance of the hazardous substance for demolition waste
Sweden			
	Asbestos	Used in building materials between 1900–1976. Ban in 1976 and 1982.	To be identified/ measured prior to demolition. Asbestos content must be analysed in practice in all buildings built before 1982. To be identified/ measured prior to demolition. asbestos content must be analysed in practice in all buildings built before 1982.

[102] Finnish Waste Audit Guidance Draft (prepared for the Finnish Ministry of the Environment the Finnish Ministry for Economic Affairs and Employment) – NB List of compulsory substances still under discussion.

[103] RT 18-11244 Haitta-ainetutkimus. 2016. – Survey of harmful substances in construction. (Draft for review in 2018). The Finnish Building Information Foundation RTS sr – NB here only reported about substances relevant for management of waste from demolition and renovation.

	Hazardous substances	Limit value (action value)	Remarks
	CFC HCFC	> 0.1% hazardous waste CFC as refrigerant banned in 1995 and HCFC in 1998	Regulation (EC) No 1272/ 2008. Swedish ordinance SFS 2007:846. To be identified/ measured prior to demolition.[104]
	PCB	Used in the period 1950–1973 Building materials. Ban Ban in 1972. Electric equipment /components ban 1978. Total ban 1995 Oils> 2ppm are hazardous Sealants > 50ppm are hazardous PCBs can remain in joint and flooring materials from 1956–1973. Regarding condensers with PCBs, equipment installed until 1980 should be checked. The manufacture of insulated window panes stopped in Sweden in 1973, but insulated window panes were imported until 1980.	To be identified/ measured prior to demolition.[18] The Swedish ordinance 2007:19 on PCBs etc. sets requirements for the inventory of joint compounds and flooring materials with PCBs and reporting of the results. If such products are present with more than 0.05% PCBs, the property owner must have them removed no later than 30 June 2014 or 30 June 2016 depending on the type of building, whether the product is internal or external and the year the PCB-containing material was integrated into the building Sampling and decontamination of joint compounds containing PCBs is described in more detail at www.sanerapcb.nu
	As, Br, Co, Cr, Sn and Creosote	In impregnated wood, should be treated as hazardous waste. Since 2004 restrictions on use of arsenic for wood impregnation.	EU Directive 2004/107/EG – Swedish law since 2007
	Mercury	Banned in electronics and measuring instruments since 1993. Waste with over 0.1 weight% Hg should be stored in deep rock repository at the latest one year after the waste is generated (since 2015).	A tool to find appliances that could contain mercury can be found in report 5279 from NV (Swedish Environmental Protection Agency).
	PAH/Asphalt	In building material hazardous waste 1,000mg/kg. Until 1973, tar was used for road surfacing. Road tar produced from coal tar contains PAHs. If it is suspected that a material contains PAHs, it must be analyzed with regard to the occurrence of PAHs in order to be classified. It can be difficult to take samples of painted tar products for analysis.	The cities of Stockholm and Gothenburg have joint guidelines for handling asphalt containing PAHs Table 5. Guidance on classification of asphalt together with guidelines for recycling of asphalt in road constructions [18]

[104] Riktlinjer avfallshantering Sveriges Byggindustrier.
https://publikationer.sverigesbyggindustrier.se/Userfiles/Info/860/160313_Guidelines_.pdf

	Hazardous substances	Limit value (action value)	Remarks
	Lead	Limit value (non-contaminated) < 40 mg/kg Limit Value (Hazardous) >2,500 mg/kg	Commonly occurring lead compounds in paints are lead phosphite and lead phosphate, both of which have a limit value of 0.5% by weight for classification as hazardous waste.[18] Lead additives in plastic flooring can be found until the mid-1970s. If the paint contains more than 1% lead, the Swedish Work Environment Authority's regulations for working with lead should be followed during the work. AFS1992:17, AFS2005:21
	Cadmium	The limit value for a material containing cadmium to be classified as hazardous waste varies from 0.01 to 25% by weight, depending on the form in which the cadmium is present in the waste.[18]	Cadmium was used a great deal in the 1960s and 1970s, primarily as a stabiliser or colour pigment in plastic materials. Cadmium was also used for surface treatment of building fittings and sheet metal, and as an alloying element. The use of cadmium as an additive to plastic and for surface treatment was prohibited in Sweden in 1982.
	Electric waste	Mercury, lead, cadmium, PCBs, oils, batteries, asbestos, brominated flame retardants, etc.	According to Section 8 of the Swedish Waste Ordinance, electrical and electronic products are: 1. products which in their design and for correct function are dependent upon electrical current or electromagnetic fields 2. equipment for the generation, transmission and measurement of electrical currents or electromagnetic fields, or 3. material included in or which has been included in such products or equipment as are referred to in 1 and 2.
	Chlorophenol in wood preservative	Chlorophenol was in use until 1978[105]	Report 5911 from NV (Swedish Environmental Protection Agency).

[105] Naturvårdsverket. 2009. Betydelse av pentaklorfenolbehandlat trä för spridning av dioxiner i miljön. Rapport 5911, Januari 2009. https://www.naturvardsverket.se/Documents/publikationer/978-91-620-5911-8.pdf

	Hazardous substances	Limit value (action value)	Remarks
	Chlorinated paraffins	There are a variety of chlorinated paraffins and not all are classified as toxic. Limit values for HW: SCCP/MCCP 0.25% SCCP 1%	Chlorinated paraffins function as softeners and flame retardants and are found in materials including joint compounds, pipe insulation, paint and plastics. They are still employed today, although use has reduced. Certain of these are extremely toxic to aquatic organisms, primarily vertebrates.[106]
	PVC	Non-HW unless containing lead or cadmium.	PVC waste is not by definition classified as hazardous waste. But really old PVC matting and pipes, for example, can contain lead or cadmium which can lead to another classification. See the sections describing these substances.[107]

Criteria for assessment of environmental suitability for concrete waste in earth construction

Environmental suitability of concrete waste for use in earth construction may be assessed from construction prior to demolition through drill cores (especially in Denmark, Norway) and/or from testing samples taken from the reclaimed concrete processed. In Finland and Sweden, limit values for the content of certain substances and leachability for metals and salts for assessment of the recyclability/recovery of concrete waste in earth construction have been developed.

Examples of limit values used for assessment of quality of the materials suitable for use in earth constructions have been compiled in Table B2. The Table also includes limit values published in Norway. Finland and Sweden have also limit values for leachable amounts (not reported here)

[106] Miljökonsultgruppen i Stockholm. http://www.sanerapcb.nu/web/page.aspx?refid=58&hlt=klorparaffiner

[107] Sternbeck, J. *et al.* (2006). Särskilt farliga ämnen, avfall och materialåtervinning. https://www.naturvardsverket.se/upload/miljoarbete-i-samhallet/miljoarbete-i-sverige/regeringsuppdrag/2016/giftfria-resurser/farliga-amnen-avfall-studie-20160204.pdf

Table B.2: Limits of hazardous substances for assessment of concrete for recycling or for use of reclaimed concrete waste for earth construction (e.g. roads). NB The table only contains limits for total content even if limits for leaching of hazardous substances have been published in Finland and Sweden

	Denmark*	Finland**	Norway***	Sweden****
Sampling approach	Sampling prior to demolition	Sampling from processed reclaimed concrete	Sampling prior to demolition	Sampling from processed reclaimed concrete
PCB	In the statutory order of residues, a limit value of 2 mg/kg PCB-total is specified. CDW with a content of PCB below 2 mg/kg can be used as a substitute for raw materials in construction projects under certain conditions In order to decide if the CDW is non-contaminated with PCB a guidance value of 0.1 mg/kg PCB-total is used	1 mg/kg (NB only arithmetic sum of 7 congeners)	0.01 mg/kg	
Asbestos				
CFC				
Arsenic	20 mg/kg[108]		8 mg/kg	10 mg/kg
Lead	40 mg/kg		60 (inorganic lead)	20 mg/kg
Cadmium	0.5 mg/kg		1.5 mg/kg	0.2 mg/kg
Chromium VI	20 mg/kg		2 mg/kg	
Chromium tot.			50 mg/kg	40 mg/kg
Copper	500 mg/kg		100 mg/kg	40 mg/kg
Mercury	1 mg/kg		1 mg/kg	0.1 mg/kg
Nickel	30 mg/kg		60 mg/kg	35 mg/kg

[108] The non-contaminated values for metals are based on soil quality criteria.

	Denmark*	Finland**	Norway***	Sweden****
PAH	4 mg/kg	30 mg/kg	2 mg/kg	0.5–2 mg/kg
Naphthalene		5 mg/kg		
Benzo(a)pyrene			0.1 mg/kg	
Zinc	500 mg/kg		200 mg/kg	120 mg/kg
Benzene		0.02–0.2 mg/kg (depending on use)		
Toluene-Ethylbenzene-Xylene		25 mg/kg		
Hydrocarbon C_{10}-C_{40}		500 mg/kg		
Aliphatic C_5-C_6			7 mg/kg	
Aliphatic C_6-C_8			7 mg/kg	
Aliphatic C_8-C_{10}			10 mg/kg	
Aliphatic C_{10}-C_{12}			50 mg/kg	
Aliphatic C_{12}-C_{35}			100 mg/kg	

Notes: * Limit for non-contaminated

** Content limit for recycling of processed reclaimed concrete waste through a notification system, note leaching additionally to be studied

*** Proposed limit values, NB for the paint layer different limit values apply, recycling of concrete and bricks[109]

**** Content limit for recycling of reclaimed concrete through a notification system, note leaching additionally to be studied[110]

[109] Miljødirektoratet, Norway. FAKTAARK M-14|2013. http://www.miljodirektoratet.no/Documents/publikasjoner/M14/M14.pdf

[110] Target for Construction and Demolition Waste. Nordic Working Papers. Published by the Nordic Council of Ministers, NA 2014:916. ISSN 2311–0562. http://dx.doi.org/10.6027/NA2014-916

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Improving quality of construction & demolition waste – Requirements for pre-demolition audit

A pre-demolition audit is a tool that can be used to both identify hazardous substances and assess the materials to be removed from the building or infrastructure, and consequently their potential value, prior to the demolition or renovation activity can be established. Audits are essential since they enable all stakeholders involved to get information on the composition of waste and make it easier to find markets for different waste types. It is likely that the European Commission will recommend all Member States to make this pre-demolition audit mandatory to increase high quality recycling of construction and demolition waste. The report presents the current pre-demolition audit systems and existing guidelines in Denmark, Finland and Sweden. The report gives recommendations on key elements to be included in audits for improving the quality of the construction and demolition waste.

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