



Martin Hoefft

Dr. rer. nat. Annett Pollex

## Project Report

Report on market research, national incidents, problems and lacks within national guidelines

Version Final

Date 28.06.2013

Deliverable Number 2.2 (Part A and C)

Project manager Waltraud Emhofer

waltraud.emhofer@bioenergy2020.eu

Scientific partner DTI, DBFZ, BE2020, SLU, SP

Commercial partner AEBIOM – European Biomass Association, Danish Straw Association, DEPV – German Pellets Association, PF – Swedish Pellets Association, PPA – ProPellets Austria, Firefly AB (SE), Laxå Pellets AB (SE), Pusch AG (DE), Dansk Træemballage AS (DK), Verdo Energy AS (DK)

Project duration 1 January 2012 – 31 December 2014

Supported by Research for the benefit of specific groups/ Research for SME associations/groupings within the Seventh Framework Programme of the European Union (FP7-SME-2011 287026-Safepellets)

# Table of Content

1. Introduction	5
<b>PART A: Market Survey for Pellet Production, Logistic and Storage</b>	<b>7</b>
2. Material and Methods	8
3. Pellet Production	9
3.1 Definition Pellets	9
3.2 Raw Material Feedstock	9
3.3 General Description of the Pelletizing Proess	11
3.3.1 Raw Material Supply and Pre-processing	12
3.3.2 Pelletizing	12
3.4 Storage	14
3.4.1 Large Scale Storage for Industrial Use	14
3.4.2 Small Scale Storage	16
3.5 Logistics and Transport	19
3.5.1 Shipping	20
3.5.2 Transport via Train	21
3.5.3 Transport via Truck	22
4. Pellet Market	25
4.1 Market worldwide	25
4.2 Market in the EU	28
4.3 Consumers of Pellets	30
4.3.1 Large Scale Users	30
4.3.2 Medium Scale Users	31
4.3.3 Small Scale Users	32
4.4 Country Reports	32
4.4.1 Current Market Austria	32
4.4.2 Current Market Denmark	35
4.4.3 Current Market Germany	37
4.4.4 Current Market Sweden	40
5. International Trade	44
<b>Part B: Problems and Incidents during Pellet Transportation and Storage</b>	<b>47</b>
6. Evaluation of Risks	48
6.1 Storage Risks	48
6.2 Risks of Wetness and Transshipment	49



<b>Part C: Guidelines and Standards</b>	<b>51</b>
<b>7. Standards, Guidelines and Certification Schemes</b>	<b>52</b>
7.1 Existing Standards and Guidelines	54
7.2 Fuel standard EN 14961	54
7.2.1 EN 14961-1:2010: Solid Biofuel Specifications and Classes – General Requirements	55
7.2.2 EN 14961-2:2011: Solid Biofuels Specification and Classes –Wood Pellets for Non-industrial Use	55
7.2.3 EN 14961-2:2011: Solid Biofuels Specification and Classes - Non-woody Pellets for Non-industrial Use	56
7.2.4 Evaluation of EN 14961 with Respect to Security Relevant Aspects	56
7.3 Quality Assurance Standard EN 15234	56
7.3.1 EN 15234-1:2011 Fuel Quality Assurance, Part 1 – General requirement	57
7.3.2 EN 15234-2:2012 Fuel Quality Assurance – Part 2: Wood Pellets for Non-industrial Use	58
7.3.3 Evaluation of EN 15234 with Respect to Security Relevant Aspects	58
7.4 Certification Systems	59
7.4.1 European Pellet Council - Handbook for the Certification of Wood Pellets for Heating Purposes (ENplus)	60
7.4.2 Other European Certification Systems	61
7.5 Further Guidelines	64
7.5.1 Nordic Innovation Centre – Guidelines for Storing and Handling of Solid Biofuels	64
7.5.2 DEPV - Recommendations for Storage of Wood Pellets	64
7.5.3 VDI -Emission Control - Storage of Wood Pellets at the End-user - Requirements for the storage room concerning safety aspects	65
7.5.4 International Maritime Organization (IMO) - International Maritime Solid Bulk Cargoes (IMSBC) Code	66
7.5.5 Material Safety Data Sheet (MSDS) from Wood Pellet Association of Canada (WPAC)	66
<b>8. Problem Areas Not Solved Within Existing Standards and Guidelines</b>	<b>68</b>
<b>9. Indexes</b>	<b>70</b>
9.1 Index of Tables	70
9.2 Index of Figures	70
<b>10. Bibliography</b>	<b>73</b>
<b>Annex</b>	<b>75</b>
10.1 List of Austrian Pellet Producer	75
10.2 List of Danish Pellet Producer	75

10.3 List of German Pellet Producer	76
10.4 Map of German Pellet Producer	78
10.5 List of Swedish Pellet Producer	79
10.6 Map of Swedish Pellet Producer	82
10.7 Industrial Wood Pellets Specifications from WPBI	83
10.8 MSDS for Bulk Pellets	84
10.9 Questionnaire for Sector Data	98



## 1. Introduction

Biomass pellets are used for residential heating and for industrial scale combined heat and power production. The market for pellets is still relatively young but rapidly growing in terms of usage and capacity building. European quality standards (CEN) exist for woody and non-woody pellets for non-industrial use. However for industrial use no such quality standards have been introduced so far. The demand for biomass pellets is increasing across Europe in particular for co-firing in coal fired power plants. To fulfill the demand, increasing amounts are imported from overseas.

Transportation and storage of wood pellets resulted in several deadly accidents in connection with off-gassing and self-heating. After the first incidents, several national research projects concerning aspects of off-gassing and self-heating have been initialised.

The Austrian project “A-safepellets” focuses on carbonmonoxid (CO) off-gassing. The Danish LUBA-project concentrates on large scale storage of biopellets and the associated risks. The main intention of LUBA is to identify appropriate measuring methods for risk monitoring and to minimize any potential risks by means of technological solutions as well as suggestion of guidelines for correct handling and storage of unknown biopellets. The final report is to be published in the beginning of 2013. The University of Göttingen performed a research project together with the German pellet association (DEPV) investigating the influence of various process parameters in the production of wood pellets from spruce, pine and poplar. In particular, the emission of volatile organic compounds (VOCs) and formaldehyde as well as, carbon dioxide and carbon monoxide has been focused. Results of the latter project lead to the development of the VDI 3464 guideline “Emission control – Storage of wood pellets at the end user – Requirements for the storage room concerning safety aspects” which will be published shortly.

The SafePellets project aims to answer the question, where and under which conditions off-gassing and self-heating from biomass pellets occurs and what measures can be undertaken to reduce these risks. This project should result in a draft for an international standard on safety measures and inspection methods along the whole pellets supply chain (e.g. by developing Material Safety Data Sheets for wood pellets). The safety issue is decisive for the further extension of pellets markets and is thereby of high relevance for all enterprises in the pellet utilization chain.

Within the Safepellets project the different approaches and results on safety in pellet supply chains are linked with each other and integrated to a supranational scope. This is of great importance because pellet markets are no longer isolated and grow increasingly to international resource flows.

In the first part of this report (Part A) available production, handling and storage technologies will be described. Furthermore, an overview about the current and forecasted production, logistic and storage capacities is given. Consecutively, reported incidents occurring in connection with off-gassing and self-heating will be discussed and described in Part B. In the last part of this report (Part C) the current status for standards and guidelines as well as lacks within the existing guidelines will be discussed.



## PART A: Market Survey for Pellet Production, Logistic and Storage

Within this part the actual situation for pellet production, logistic and storage will be described for Europe and the partner countries Austria, Denmark Sweden and Germany. This is important to highlight the relevance of the safety topic.

## 2. Material and Methods

The market survey is based on the publications of IEA, FAO and EUBIA which cover the market situation until 2010. Additional information was gathered from the national associations and partners using a questionnaire which was developed within the SafePellets project (Annex 10.9). Some further aspects could be gathered from the incidents questionnaire which was used for Part B of this report (Annex 10.9). In Chapter 3 of Part A technical aspects of pellet production, logistic and storage will be covered. The current pellet market and common trade routes will be described in Chapter 4 and 5 of Part A.



## 3. Pellet Production

At first, a definition of pellets will be given and the most common raw materials will be described. In the following, a general description of the technologies used for wood pellets production, storage and transportation will be provided.

### 3.1 Definition Pellets

For several years, pelletizing of biomass has been used for animal food and fodder production using straw, hay and other materials. In the early 1980s, Swedish companies started to use saw dust for wood pellet production. Initially, the wood pellets were used as fuel in large power plants.

The upcoming ISO Standard 16599 “Solid biofuels – Terminology, definitions and descriptions” defines pellets as a “solid biofuel made by mechanically compressing biomass to mold the solid biofuel into a specific size and shape such as cubes or pressed logs”. Originally, fuel pellets were prepared exclusively from the residues of the forestry and wood working industry. Recently, also other raw materials like agricultural residues, such as straw, are increasingly used. Since 2010, the CEN multipart standard EN 14961 “Solid biofuels – Fuel specifications and classes” are successively implemented and provide the quality requirements for pellets and firewood for non-industrial use. For pellets the following three parts are relevant:

14961-1:2010 - Fuel specifications and classes – General requirements

14961-2:2011 - Fuel specifications and classes – Wood pellets for non-industrial use

14961-6:2012 - Fuel specifications and classes – Non-woody pellets for non-industrial use

Typical diameters of wood pellets are in a range from 6-12 mm with a length of 10-30 mm. During pelletizing, the bulk density increases from about 200 kg/m<sup>3</sup> to 650-700 kg/m<sup>3</sup> for wood pellets. The moisture content is typically below 12%. Wood pellets are not moisture resistant. If the pellets get wet, the structure disintegrates. Thus, adapted loading, transportation and storage is required protecting the pellets from rain and humidity. With the standards, requirements both on physical-mechanic, e.g. geometry, bulk density, durability and on chemical characteristics, e.g. moisture content, content of critical elements and ash content are defined.

### 3.2 Raw Material Feedstock

In general, any biomass is suitable as raw material for pelletizing. Currently woody biomass is the predominant raw material for fuel pellet production.

The main constituents of wood are the elements carbon (C), hydrogen (H) and oxygen (O). Other important elements are nitrogen (N), sulfur (S), magnesium (Mg), chlorine (Cl) and potassium (K) which are present in varying amounts. The density of logged wood is between 400-750 kg/m<sup>3</sup>. In contrast, bulk density of sawdust is approximately 200 kg/m<sup>3</sup>. The ash content is around 1% or less but is strongly dependent on bark and needle portion as well as the level of secondary contamination like adhering soil. An important quality parameter for the energy related use is the water content in the timber. In winter, the water content in freshly felled wood is about 45-55%, while in summer it can rise up to 65%. Hardwood has a lower water content than softwood. In most tree species, the calorific value of absolute dry wood amounts to about 18.5 MJ/kg. However, pellets made of hardwood usually have lower qualities, especially with regard to durability. Furthermore, pelletizing of hardwood is more difficult and requires the adaptation of the pelletizing process. Thus, softwood is most commonly used with spruce, fir and pine being the most common woody raw materials. The molecular composition and the ash content of selected woody biomasses are summarized in Table 1.

Table 1: Composition of woody biomasses in Mass-% on dry basis (Kaltschmitt 2009)

Fuel	Cellulose	Hemicellulose	Lignin	Resins/Fats	Ash
Fir	42.3	22.5	28.6	2.3	1.2
Pine	41.9	21.5	29.5	3.2	1.3
Spruce	41.0	24.3	30.0	n.d.	n.d.
Ash tree	40.2	25.0	26.0	2.2	1.3
Beech	45.4	22.2	22.7	0.7	1.6
Birch	40.9	27.1	27.3	2.2	1.8
Poplar	48.4	18.2	21.6	2.4	1.3
Willow	42.9	21.9	24.7	2.0	1.2

n.d. ... not determined

The rising demand for wood, both for the energy related use and as building material, results in increasing competition and price peaks. Consequently, alternative woody raw materials like low quality wood, short rotation coppice (e.g. poplar, willow, black locust) as well as non-woody raw materials like agricultural residues (e.g. straw) and energy plants (e.g. miscanthus, reed canary grass) are experiencing growing interest.

If wood pellets are produced from short rotation coppice, the high proportion of bark (up to 25% by mass) has to be considered since bark contains higher amounts of ash which could result in operational problems in small household heating systems.

The properties of agricultural residues and herbaceous crops are significantly different from those of the woody biomass. In particular, the ash content is usually higher, while the ash melting temperatures are generally lower. Additionally, higher concentrations of nitrogen, sulfur, potassium and chlorine are often found, leading to the formation of harmful emissions (nitrogen oxides, sulfur dioxide, hydrogen chloride, particulate matter). Moreover, these substances are involved in corrosion process on metallic surfaces. Thus, the market integration of alternative



and mixed biomass pellets is still very low. Table 2 summarizes characteristics of selected non-woody biomass raw materials (MixBioPells 2012).

Table 2: Characteristics of selected non-woody biomasses (MixBioPells 2012)

Kind of biomass	NCV (MJ/kg db)	Ash content (Mass-% db)	Water content (Mass-%)	AST (°C)	(Mass-% db)		
					N	S	Cl
Miscanthus	17.5 - 17.9	1.6 - 3.0	7.5 - 14.0	820 - 1172	0.20 - 0.43	0.02 - 0.09	0.02 - 0.13
Reed canary grass	17.5 - 19.0	4.5 - 6.0	10.0 - 15.0	1150 - 1650	0.30 - 0.60	0.07 - 0.08	0.03 - 0.04
Hemp	19.1 - 19.6	1.6 - 2.3	56.6	1200 - 1250	0.30 - 1.40	0.06 - 0.10	0.02 - 0.30
Straw	17.0 - 19.0	4.4 - 7.0	9.0 - 15.0	800 - 900	0.30 - 0.80	0.06 - 0.12	0.03 - 0.05
Vine pruning	17.5 - 18.2	2.2 - 3.5	15.0	795 - 1200	0.50 - 0.75	0.02	0.05 - 0.07
Corn cobs	16.5	1.0 - 3.0	6.0 - 7.0	1100	0.70 - 0.90	0.03	0.02
Corn stalks	16.6 - 17.5	11.0 - 17.0	15.0 - 18.0	1250	1.20 - 1.70	0.08 - 0.10	n.d.
Cereal spilling	16.5	9.8 - 10.0	10.0 - 12.0	1055	0.20	0.20	0.16 - 0.3
Hay	18.3	5.5	15.0	820 - 1150	0.04	0.04	0.09
Rape straw	18.5	3.4	15.0 - 25.0	n.d.	0.50	0.20	n.d.
Rape press cake	20.8	6.5	9.0	860 - 1115	0.36	0.36	0.01

NCV... net calorific value, AST... ash softening temperature, n.d. ... not determined, db ... dry basis

### 3.3 General Description of the Pelletizing Process

The main process steps along of the pelletizing process are depicted in Figure 1.

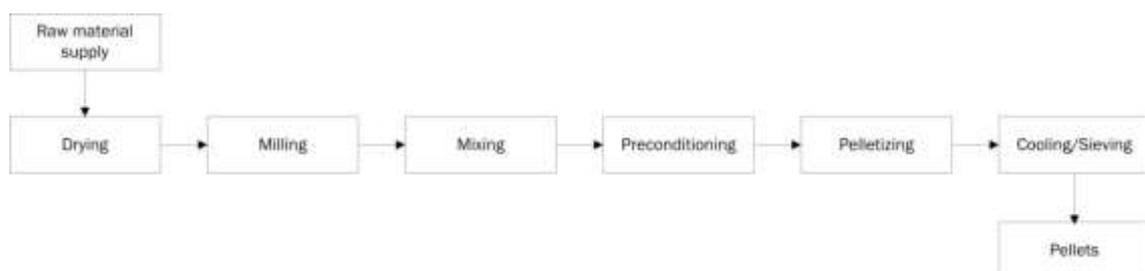


Figure 1: Process steps for pellet production

In the following, the individual steps are described in more detail.

### 3.3.1 Raw Material Supply and Pre-processing

At the moment, the predominant raw material for the production of pellets is sawdust produced as a byproduct from wood processing, e.g. from saw mills. Typically, sawdust from coniferous trees makes up 70% to 95% of the raw material (EUBIA 2012).

Based on the rising demand and the resulting scarcity of this preferred raw material, whole trees are increasingly chipped and milled to ensure sufficient raw material supply. Usually, sawdust for pellet production is stored outside on paved ground. Often, saw dust originating from different tree species are stored separately and mixed prior to pelletizing. Subsequently, the mixed raw material is dried in low-temperature belt dryer or in a drum-dryer to reduce the water content to about 10% to 15%. A low water content is crucial to ensure high pellet quality and sufficient durability and to avoid biodegradation. In some cases an intermediate storage is used for the dry and pre-conditioned raw material. Other producers use the sawdust directly from the dryer taking advantage from the pre-warming of the raw material during drying.

During the preconditioning step, the moisture content may be adapted if necessary. Furthermore, binders or inorganic additives can be mixed with the raw material. Conditioning can improve the press performance up to 75% and can significantly reduce the energy consumption during pelletizing.

### 3.3.2 Pelletizing

For fuel pellet production flat die and ring die presses are most commonly used. The flat die type has a circular perforated disk on which two or more rollers rotate and force the material through the holes (Figure 2). In flat die presses either the die or the rollers rotate. The material is fed to the die from the top. Flat die presses have the advantage of easy cleaning and additional shear forces acting on the raw material. Flat die presses are more commonly used for animal feed and fodder production.

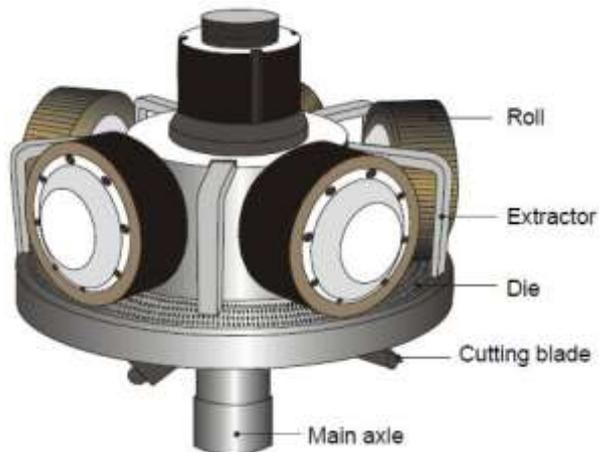


Figure 2: Flat die press (VTT 2002)

For wood pelletizing ring die presses are most commonly used (Witt 2012). Ring die presses feature a rotating perforated ring on which rollers press the raw material through the holes of the die (Figure 3).

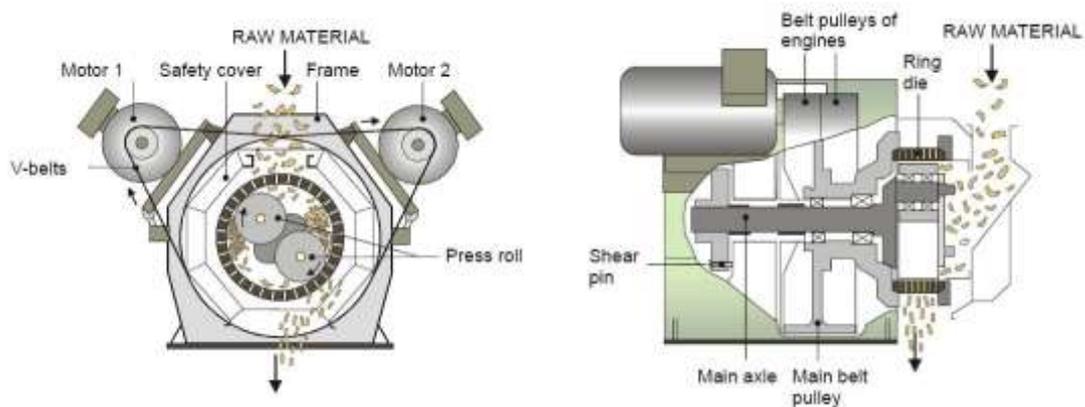


Figure 3: Ring die press (Source: [www.salmatec.de](http://www.salmatec.de))

Typical pellet plant capacities range from 1.5 to 7 tons per hour. The most common output range for pellet presses is 3 to 5 tons per hour. According to manufacturers, pellet dies have an average service life of 1.000-1.500 hours, corresponding to approximately 10.000 tons (EUBIA 2012).

The still warm and elastic pellets are transported to a cooling device. There, the pellets are cooled to around room temperature. The cooling increases the durability of the pellet thus limiting the formation of fines during the following transportation and handling and reducing dust explosion risks. After cooling, the pellets are sieved in order to remove fines formed during the production process. The pellets are either sacked in 15-25 kg bags or stored in bulk or in big bags.

After production, the pellets are fed to the supply chain. As shown in Figure 4 pellets can be supplied directly to the customer. Alternatively, they can be transported to an intermediary storage or wholesaler. For the different delivery options appropriate technologies are available. In the following chapters technical aspects of transportation and storage will be described.

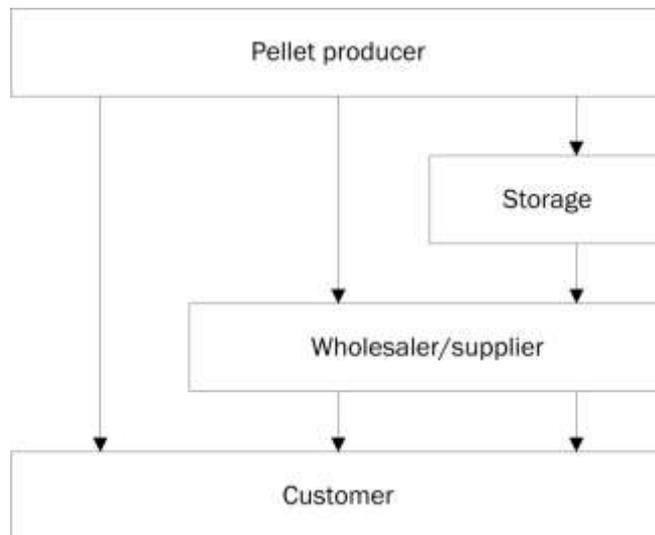


Figure 4: Supply chain of pellets

### 3.4 Storage

Large amounts of pellets are stored either in silos (metal or concrete) or in flat storages. Extensive research has been conducted on the storage of grains in different types of vessels in different climates. However, only limited research has been conducted on wood pellet storage. What has been done so far was performed in closed or sealed containers because of costs and other limiting factors (Curci 2011).

During pellet storage a quality decrease may occur. Possible reasons for decreasing quality are biodegradation or rewetting. Consequently, reduced pellet quality could result in higher amounts of fines which could lead to problems with transportation (bridging) and to an increased dust explosion risk. Furthermore, the storage of pellets can pose the risk of self-heating and off-gassing. Problems and incidents during pellet transports and storage will be discussed in Part B.

#### 3.4.1 Large Scale Storage for Industrial Use

A typical construction for flat storages is the A-frame storage which can take up to several 10.000 m<sup>3</sup> of material (Figure 5). The name refers to the shape of cross-section and roof construction. Usually, it is utilized as an intermediate storage at a power plant site or at harbor terminals. The normal way to load pellets into such storages are belt conveyers. In most cases,



the conveyer belt is mobile so it may drop material lengthwise or in heaps in certain parts of the storage. For discharge, screw conveyers load the pellets on the belt conveyors.



Figure 5: Typical A-frame storage at a harbor ([www.shippingmovements.co.za](http://www.shippingmovements.co.za))

Silos made of metal or concrete are the most common storage systems for pellets (Figure 6). Very large silos with sizes of several thousand cubic meters are also quite common for intermediate storage in harbors or at power plants. Large pellet producer prefer a “just-in time” storage principle. For that reason, their storages are typically limited to several hundred cubic meters. Wholesale contribute further storage capacity, their possibilities are limited since pellet storage is relatively expensive (Oberberger 2010). The effective volume of intermediate storage depends on the fuel delivery logistics.



Figure 6: Pellet silo of 2200 tons capacity ([www.ostschweizerpellets.ch](http://www.ostschweizerpellets.ch))

There are different types of discharge equipment in a silo. However, discharge from the bottom using gravity forces is the most common solution. In silos with a wider diameter combination of screw feeder and a bottom flow device is often needed (Nordic Innovation Center 2008).

Storage at power plants should be designed to enable the continuous material flow. Therefore, these storages are usually equipped with a transport system (Figure 7 and Figure 8). Often, devices for the removal of impurities (magnets, screens) are installed.

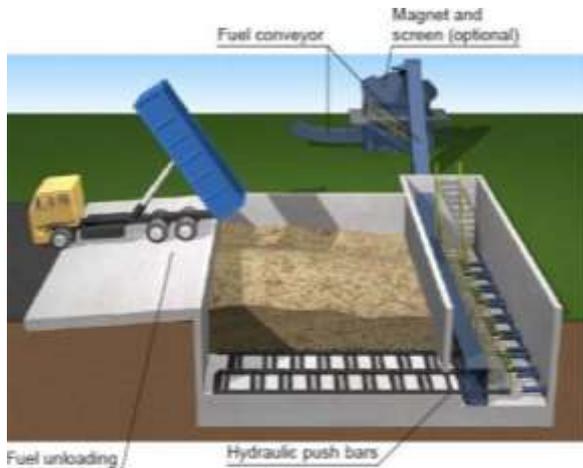


Figure 7: Example of a small volume push bar storage (Nordic Innovation Center 2008)

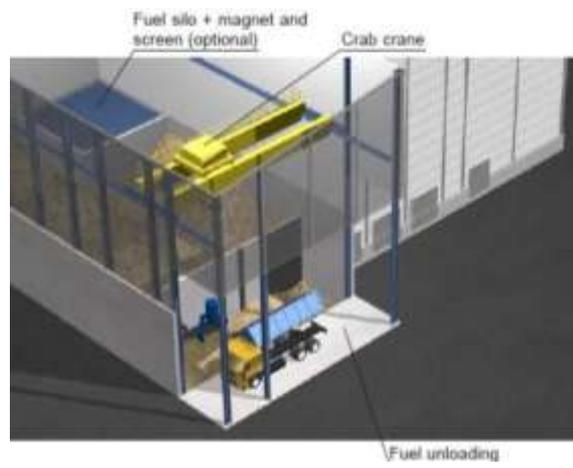


Figure 8: Example of large volume crab crane storage for wood fuel capacity of 20 MW (Nordic Innovation Center 2008)

### 3.4.2 Small Scale Storage

The type and capacity of pellet storages in domestic households with a maximal size of 10 tons depends on several aspects (e.g. accessibility for filling, spatial situation within the house or around the house, costs for the storage). Consequently, different storage solutions will be realized. Both, commercially available storage systems and customized, self-built storages are possible. Requirements for wood pellet quality and safety of storage have clearly increased over the last few years and are better addressed by purpose-built storage systems than by home-built solutions. The size of the storage space depends on the heat demand of the building. It should be ensured that the required amount of fuel for one year may be stored with a reserve. Storagerooms for pellets for small scale users often have inclined walls to facilitate the discharge but which reduces the potential storage volume. This must be considered when planning the storage size. As a rough estimate about 0.5 m<sup>3</sup> of storage volume including free space are required per 1 kW heating load (DEPV 2011).

Storage can be installed either within the building or as external storage. Often, external storages are built underground (Figure 10 and Figure 11). Outside storage is preferred for heavily insulated and intensively used buildings because the interior is too valuable for fuel storage. The discharge can be realized either from the bottom or from the top of the storage. For both options appropriate discharge technologies are available.



Figure 9: Below-ground silo made of synthetic materials, discharged from the bottom of the storage (DEPV 2011)



Figure 10: Below-ground silo made of concrete, discharged from the top of the storage

When a storage system is mounted outside the house, the following DEPV recommendations (Table 3) should be considered to secure the storage, respectively the stored pellets, against weather influences (DEPV 2011), especially when mounted above ground.

Table 3: Requirements for outdoor storage of pellets

Storage type	Static demand		Protection against UV radiation	Protection against precipitation
	Floor	Wind load		
Fabric silo	yes	yes	yes	yes
Above ground metal silo	yes	yes	no	no
Above ground fiberglass silo	yes	yes	no	no
Above ground plastic silo	yes	yes	depends	no
Above ground concrete silo	yes	yes	no	no

Commercial indoor storage systems are made of flexible polyester fabric, plastic or metal sheeting. All systems have to be protected against electrostatic charging.

Purpose-built systems are available in shapes and sizes that match the storage room (round, square, rectangular and in different heights). Pellets discharge is realized either by gravity forms connected with a screw conveyor or with pneumatic suction devices.



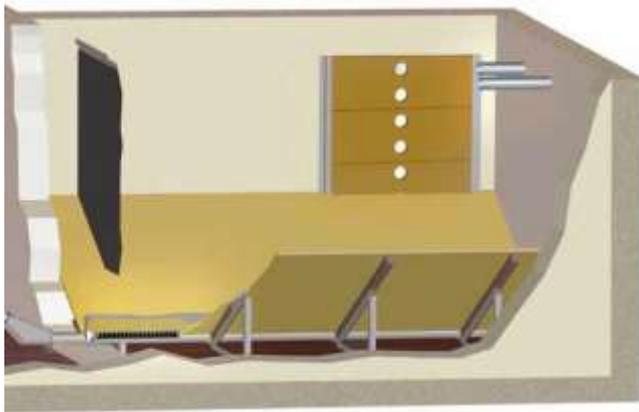
Silo with a wooden frame

Conical silo

Trough silo

Figure 11: Different indoor pellet storage systems (DEPV 2011)

Furthermore, individual homemade pellet storage solutions are possible (Figure 12). To ensure safe storage without operational problems in such storage systems, careful planning and skilled building is required. Usually, pellets are stored in a basement room, often in exchange of a former oil vessel. It must be ensured that the room is appropriate for the use and that no regulation prohibits the use of the room for storage purposes. Interconnection between the storage and rest of the building should be avoided to limit dust infiltration to adjoining rooms during filling. The static load on the floor and the adjoining walls (as long as the construction is leaning against the walls) needs to be considered. The brickwork has to be isolated against moisture uptake from the ground. The storage room must be constructed in such a way that it can withstand the weight load of the pellets plus the momentary load presented by pressure changes which is up to ca. 0.2 bar during filling. The inclination of the storage bottom has to be high enough to ensure proper pellet discharge. Horizontal surfaces have to be minimized to prevent the build of dust layers. To avoid pellet disintegration during filling, sharp corners in the filling lines should be avoided as well as the blowing of pellets against hard walls during filling. The filling and discharge facilities should be professionally earthed to prevent the build-up of an electrostatic charge. The filling neck and the exhaust should preferably be placed at the short side of the silo. To ensure ventilation of the storage room, the filling neck should be equipped with a ventilation cap. Ideally, it should be possible to completely close the connection between storage room and boiler during filling. The size of the storage room depends on the heat load of the building but should not exceed twice the annual fuel consumption.



Pellet silo with inclined bottom and screw conveyer



Pellet silo with inclined bottom and suction extraction

Figure 12: Examples of self-build pellet silos (DEPV 2011)

### 3.5 Logistics and Transport

Depending on the pellet demand and the distances between production site and end-use different vehicles can be used for transportation. Rewetting has to be prevented for any type of transport. Pellets have to be handled with more care than other bulk goods since they have only limited durability and any loading and unloading contributes to decrease in pellet quality. Dirt and impurities caused by previous cargoes must be avoided. Cargo ships and large ocean vessels have the highest transportation capacities. In contrast, trucks are used for rather small amounts of pellets. Trains can be used for intermediary loads. Accordingly, the different transportation systems are used for different user groups. Table 4 highlights the interdependencies between pellet production capacities, pellet demand and the mainly use transportation option.

Table 4: Overview of user groups and transport

	Large Scale User	Medium Scale User	Small Scale User	
	(bulk)	(bulk)	(bulk)	(small bags)
Suppliers	International pellet production plants	European pellet production plants	domestic production plants	domestic production plants
Typical way of transport	(Inter-)continental shipping in Panamax or Handymax vessel Frights: 10.000-100.000 t	European sea shipping or truck transport (up to 40 t)	truck transport (delivery of 1-6 t per household per year)	Both truck transport and private cars to households
Quality criteria	General criteria, company specific		detailed, strict criteria; country or European specific standards like EN 14961-2 as well as ENplus	

### 3.5.1 Shipping

The international shipping trade is an important part of the global economy. Large ocean vessels are also an efficient means for goods transportation (Figure 13). Shipping transport is used when long distances have to be passed. Common pellet transportation routes connect Europe and Canada or the US. Pellet transports across the Baltic Sea are also realized by ship. Because of the longer transportation distance and higher delivery costs it is more profitable to transport large volumes. Therefore, imported pellets are mainly used by large scale users of heat and power plants. The problem of higher amounts of fines within the delivery plays a less important role for these user groups since they are usually equipped with proper dust handling equipment and since the pellets are crushed and grinded before combustion anyway.

The main logistic problem is the storage at the beginning and at the end of the transportation route. A typical amount of transportation is 7000 to 30.000 tons (Sälkimäki 2010). Other sources mention bulk amounts of up to 40.000 tons (Magelli 2009) and 47.000 tons in ships (Holz-Zentralblatt, 2012, p. 981) for transports between Canada and Europe. In order to limit demurrage costs, these ships must be loaded and unloaded as quickly as possible. This requires high capacity material handling facilities to be constructed at the loading and unloading ports (Figure 14). Care must be taken in the design of these systems to minimize pellet degradation. Existing coal unloading facilities can be used; however the equipment needs to be modified in order to handle pellets with the required care. Large, covered storage spaces are needed at the harbor facilities. In these facilities, but also during shipping, the risk of self-heating and off-gassing must assumed as high and has to be handled accordingly.



Figure 13: Ship for ocean transport (Melin 2012)

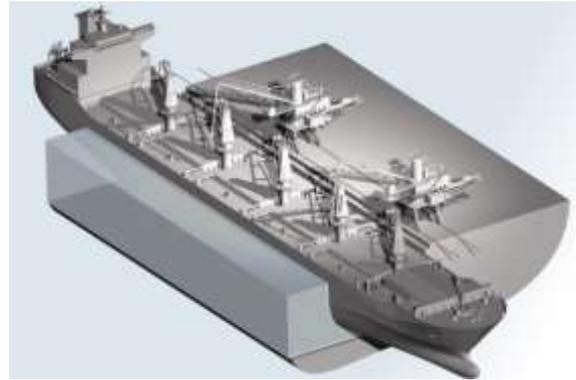


Figure 14: Pneumatic ship pellets unloading system (www.bulkinside.com)

### 3.5.2 Transport via Train

For long overland distances, train transport is usually more economic than truck transport. In general, the railway goods transport increased during the last year, but not at all in the same pace as road transport. Train transport should be preferred for the medium distances between big plants like for example pellet production sites and big utilities power plants (EUBIA 2009). A single wagon can take an amount of 90-100 tons of pellets (Figure 15 and Figure 16).



Figure 15: Wagon for bulk pellets (Melin 2012)



Figure 16: Train transport for pellets (Melin 2012)

Especially in Canada, the majority of pellets exported to Europe come from the interior of the country which requires trains to deliver them to the harbors on the coast where pellets are shipped (Urbanowski et al. 2005). Another example is the world's largest pellet manufacturing plant located in Cottondale (Florida, USA). There, trains are used for transportation of pellets directly from the plant to the ports (100 km in the South) where they are delivered by walking floor wagons and stored in large hall of 35.000 tons capacity (EUBIA 2009). Figure 17 illustrates the main routes for pellet transport via train in North America. According to our questionnaire the delivery to the end-consumer via train does not play a role in Europe.



Figure 17: Rail- and shipping routes in North America (Source: North American Railroad)

### 3.5.3 Transport via Truck

In Europe, the transport by truck is one of the most developed ways to transport goods. The maximum profitable driving distance for truck-transportation of “forest fuels” is approx. 60-100 km, depending on the material, bulk density, moisture content and transportation system. In case of pellets the road transport over long distances of about 200–300 km is not economic. This is also reflected by the current structure of pellet production in Europe (see Chapter 4). Pellet manufacturers and suppliers try to establish local markets and co-operate with the local wood and timber industries. Thus, truck transport takes place predominantly for the delivery of pellets to the end user in households (EUBIA 2009). The questionnaire underlined the high importance of truck-transportation, especially in the developed pellet markets. Due to their flowability, pellets are a fuel which can be transported just like liquid fuels such as oil. Pellets can be supplied by silo trucks and pumped pneumatically into the pellet storage of the customer by means of a fuel hose (Figure 19). In order to ensure a dust free delivery and avoid any overpressure in the storage room, air suction and filtering are imperative for exit air.



Figure 18: Truck for loose pellet delivery

When pellets are sacked in bags, it is possible to use cargo trucks which are normally used for all kind of delivery. Sacked pellets are typically sold by wholesalers. They are particularly suitable for customers with a relatively low heat demand e.g. pellet stoves which are used only as auxiliary heating or if there is a short heating period (Italy, Spain).

15-25 kg sacks are most common. They are sold and delivered on pallets of 800 kg (Figure 19) or as single bags. Consumers buy the pellets in household goods stores, filling stations or agricultural supply stores. The advantage of sacked pellets is that the pellets are protected against wetness and that amount of fines in the fuel is very low provided that the sacks are handled properly. However, pellet prices in this package form are much higher than purchase of bulk pellets.



Figure 19: Delivery of bagged pellets ([www.sabi.se](http://www.sabi.se))

Big bags with 1 to 1.5 m<sup>3</sup> content are offered by most manufacturers (Figure 20). Big bags have to be moved by stacker track, tractor front-loader or crane, which is inconvenient, especially for transport to the end consumer. This transport form is used mostly for transport of pellets to retailers. Conventional trucks can transport large bags in the same way as small bags. Mostly, a deposit is paid because bags are reusable.



Figure 20: Pellets in big bags ([www.holzenergie.de](http://www.holzenergie.de))



## 4. Pellet Market

The survey of the market is based on the data from the pellet associations and on the results of current research projects and IEA tasks. The major markets in Europe were identified by evaluating the questionnaires provided to the national associations.

### 4.1 Market worldwide

The global wood energy market continues to grow, motivated and driven by public policies that have set ambitious targets for renewable energy. The EU 2020 targets for renewable energy and the goals for reducing of greenhouse gas (GHG) emissions are among the predominant drivers of growth in European wood energy consumption (UNECE/FAO Wood energy markets 2012) since wood pellets are both a renewable energy source and can contribute to an energy supply with significantly lower GHG emissions. Consequently, the world production of wood pellets has experienced a large growth in the last five years and was about 14.3 million tons in 2010 while the consumption was about 13.5 million tons (IEA Task 40, 2011).

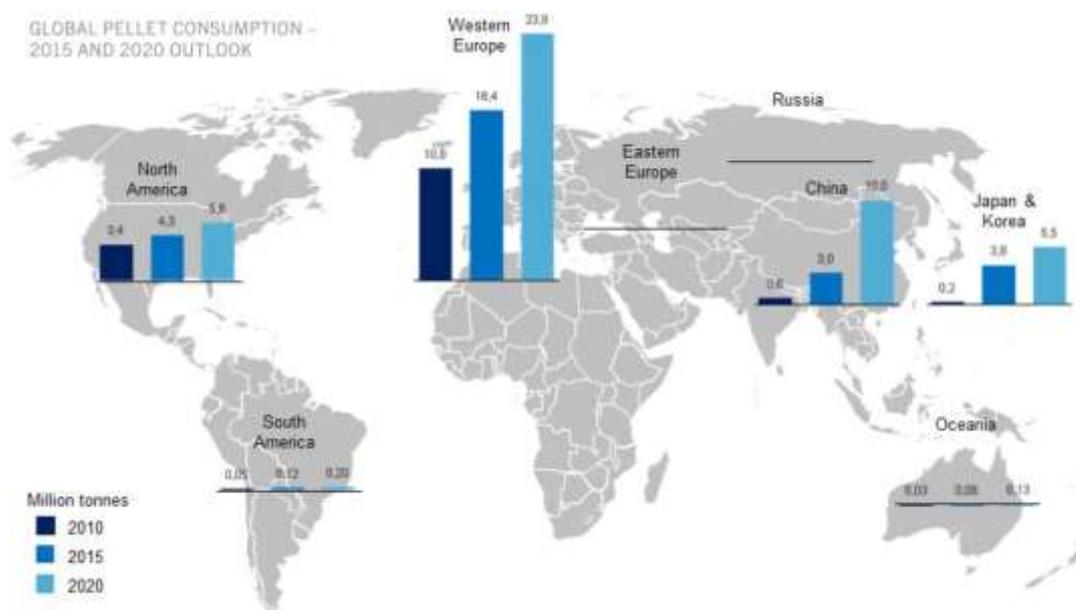


Figure 21: Global pellet consumption and outlook (Pöyry, 2012)

Figure 21 and Figure 22 illustrate the increasing importance of pellets worldwide. Both, consumption and production will increase in all parts of the world. Particularly in Europe, a significant increase in pellet consumption is predicted (Figure 22). Thus, it is expected that the European wood pellet demand cannot be covered by the own production. This results in increasing imports of pellets from other parts of the world.

GLOBAL PELLET PRODUCTION – 2015 AND 2020 OUTLOOK

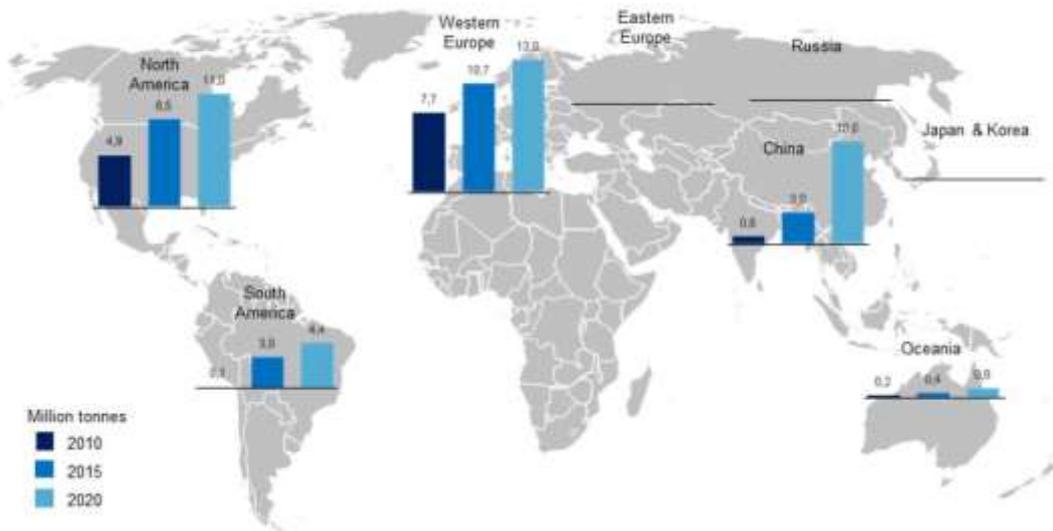


Figure 22: Global pellet production and outlook (Pöyry, 2012)

Production capacities of pellets plants are increasing worldwide. Between the years 2009 and 2010 the global installed production capacity increased by 22% reaching over 28 million tons (Figure 234). Even though more recent worldwide statistics are not available, it can be assumed that the production capacity has reached 33 million tons in 2012 including also other biomasses besides wood. According to the survey performed in the course of the “PelCert project” less than half of the capacity is actually used (PelCert project 2012)

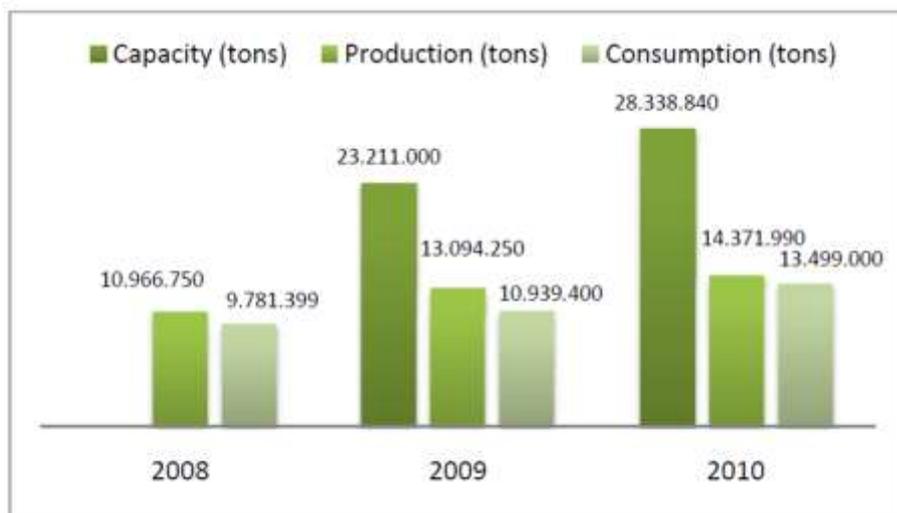


Figure 23: Global wood pellet production and consumption (IEA Task 40, 2012)

The highest increase in capacity building was observed in the U.S., Canada and the Russian Federation. At the same time, these countries are the largest exporters of wood pellets. In Europe the following wood pellet production capacities have been determined (Figure 24).

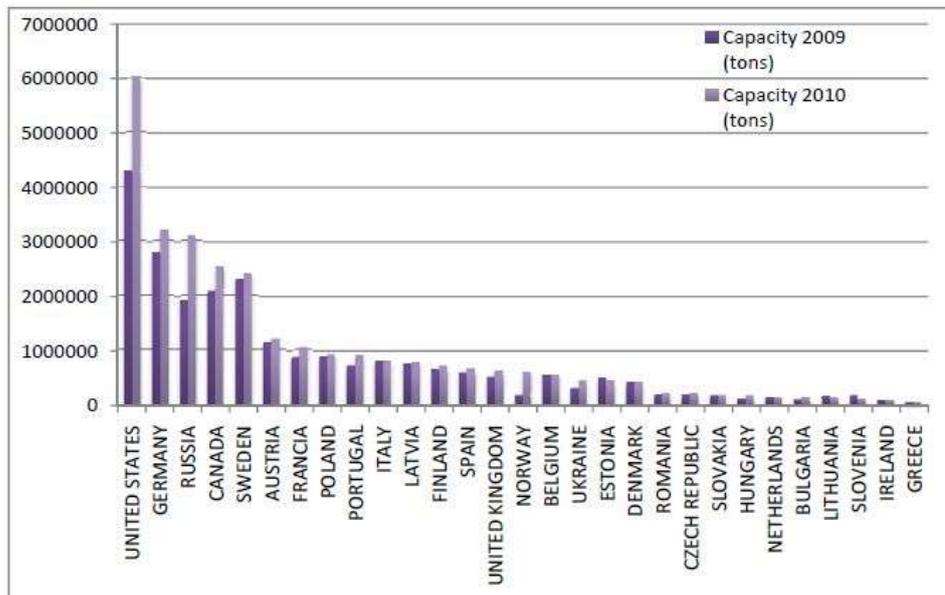


Figure 24: Wood pellet production capacity by country worldwide (IEA Task 40, 2012)

The rising demand and the expected further increase in pellet demand have stimulated investments in new large-scale production plants and to enlarge existing ones in the range of several hundred thousand tons. This development takes place in EU as well as in the U.S., Russian Federation and other countries. Currently, in most countries the production exceeds the own consumption (Figure 25). Exemptions are Sweden, Italy and the United Kingdom as well as the Netherlands, Belgium and Denmark. The growth in wood pellet utilization has been mainly driven by a demand for industrial pellets for co-firing and combined heat- and power production as well as the increasing interest in high quality wood pellets for residential heating.

The large scale utilization of industrial pellets for co-firing in coal power plants and for combined heat and power generation particularly in Northern European countries is a rather recent phenomenon. Belgium, the Netherlands, Denmark and lately the UK are the main users of this technology. Mainly, it is driven by the availability of feed incentives for green electricity and the possibilities to save CO<sub>2</sub> certificates. To further spur this development, it is crucial to maintain a supportive political framework. In Sweden with its established market for district heating and a traditional large wood pellets production, the consumption has increased too and is well above the production.

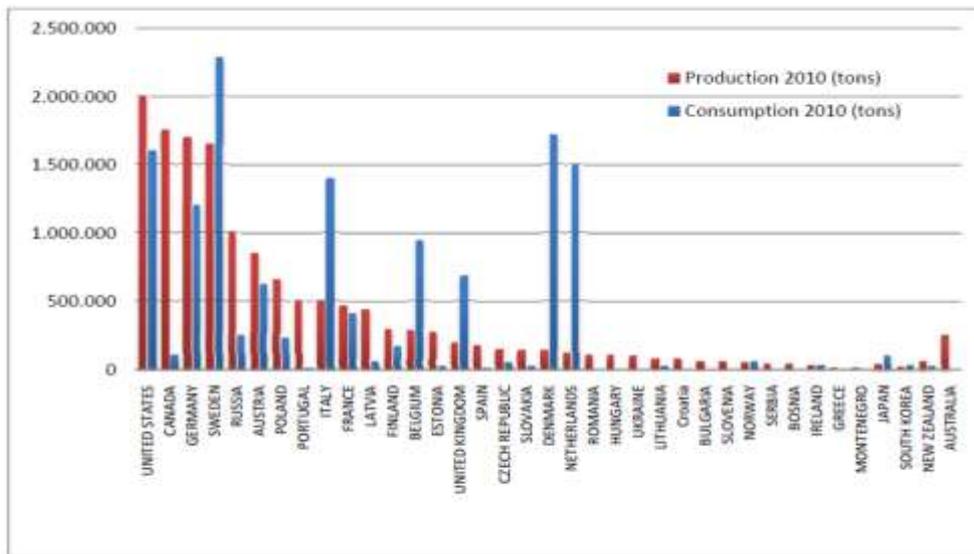


Figure 25: Production and consumption of wood pellets worldwide (Source: IEA 2012)

In the segment of residential heating the main drivers for market expansion are often indirect support measures for the installation of pellet stoves and boilers as well as the low and stable prices of wood pellets compared to fossil fuels such as heating oil and natural gas. Especially in rural areas that are not connected to the gas grids it is a cost efficient alternative. In this market segment Italy, Austria, Germany and Denmark are among the main consumers.

#### 4.2 Market in the EU

The European Union is still the main market for wood pellets and will remain as such for the next several years. Between 2008 and 2010 the production of wood pellets in EU increased by 20.5% and reached 9.2 million tons in 2010 covering 61% of the global production. In the same period, EU wood pellet consumption increased by 43.5% to reach over 11.4 million tons in 2010, covering for 85% of the global wood pellet consumption (Figure 26).

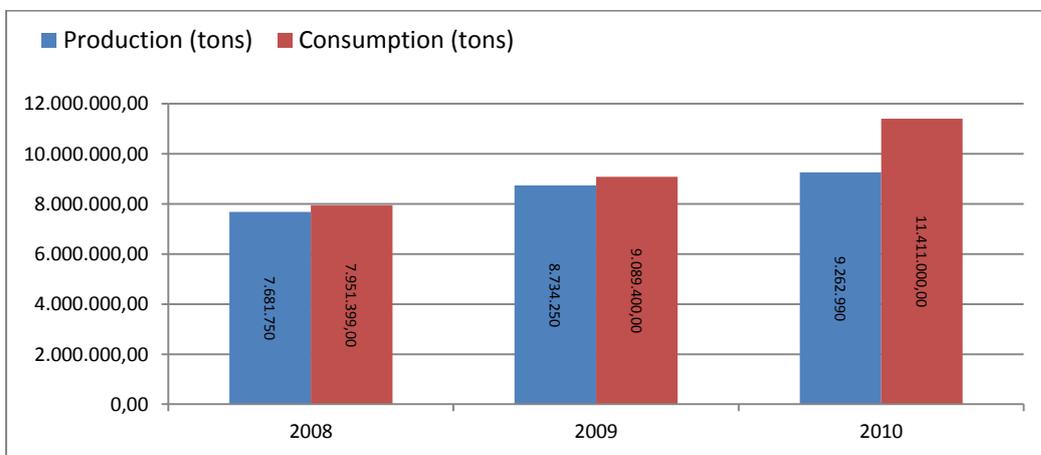


Figure 26: Production and consumption of wood pellets in the EU (source: IEA 2012)



In 2010, the European pellet production covered 81% of the demand. However, the gap between production and consumption has been growing from only 262.250 tons in 2008 to 2.148.000 tons in 2010, which is more than an 8-fold increase (IEA Task 40, 2012).

The market development was stimulated by incentives for biomass and renewable heat. Within the EU the countries with the highest imports for industrial wood pellets are Belgium, the Netherlands, United Kingdom, Sweden and Denmark. The largest producers are Germany, Lithuania, Estonia, Latvia, Portugal, Finland and Sweden. For the future, a constantly growing market is expected.

Table 5: Overview of European pellet demand in tons

	<b>2011</b>	<b>2015</b>	<b>2020</b>
Austria	710.000	1.490.000	3.500.000
Belgium	100.000	150.000	200.000
Denmark	700.000	1.000.000	1.250.000
France	560.000	1.400.000	2.500.000
Finland	70.000	150.000	450.000
Germany	1.400.000	1.900.000	3.500.000
Ireland	40.000	60.000	70.000
Italy	1.900.000	3.100.000	4.250.000
Spain	150.000	450.000	1.150.000
Sweden	1.000.000	1.200.000	1.400.000
Switzerland	160.000	250.000	400.000
UK	50.000	500.000	1.250.000
other	1.100.000	1.600.000	2.200.000
total	7.940.000	13.250.000	22.120.000

In Table 5 the estimated demand development of the largest European pellet consumer is summarized. For 2020, the European Pellet Council (EPC) predicted a 3-fold higher cumulated pellet demand compared to 2011. The increase affects all countries but especially for Austria, France, Germany, Italy, UK and Spain a multi-fold increase is expected.

## 4.3 Consumers of Pellets

With respect to the capacity and the according pellet demand, three different market segments can be divided: large scale users (e.g. co-firing, centralized combined heat and power production (CHP)), medium scale users (e.g. district heating, regional CHPs) and small scale users (e.g. residential heating). With the decreasing pellet demand from large scale users to small scale users, the predominant supply and storage varies. Large scale users obtain pellets from international traders and are equipped with large on site storages. In contrast, small scale users obtain the pellets from domestic traders and usually store the pellet amount required for the average annual use.

Due to the different developments and frameworks in each country on the field of heat supply, the borders of these size classes can differ. In our survey, the requested associations responded differently in terms of the size classification. Furthermore, the demand directly influences the quality requirements of the pellets and leads to a different buying behavior.

### 4.3.1 Large Scale Users

Large scale users are industrial users and power plants. Typical examples are centralized combined heat and power plants (CHP). However, depending on the framework and the statistic method used in each country, even industries with rather small capacities may be classified as industrial user (see Figure 27). For large scale utilization, the firing is usually combined with other solid fuels such as coal, wood chips or peat and thus wood pellets are used as co-firing material. Different kind of pellets can be used. Also, pellets assortments with higher ash content, e.g. bark pellets can be employed. Annual consumption of few thousand up to several hundred thousand tons of bulk pellets are common. The pellets are transported loose and directly by train, ship or regular truck to the storage facility of the end-user. The number of large scale users is not known in Sweden but the amount of used pellets in this market is estimated with approx. 800.000 tons. Only few industries are using pellets at regular basis. However, the demand for pellet can increase rapidly in the large scale sector during cold periods. In Germany and Austria the number of industrial users is rather high. This result is based on the fact that also small and medium enterprises (e.g. regional saw mills) using pellets to fulfill their heat demand would be identified as “industrial” users.

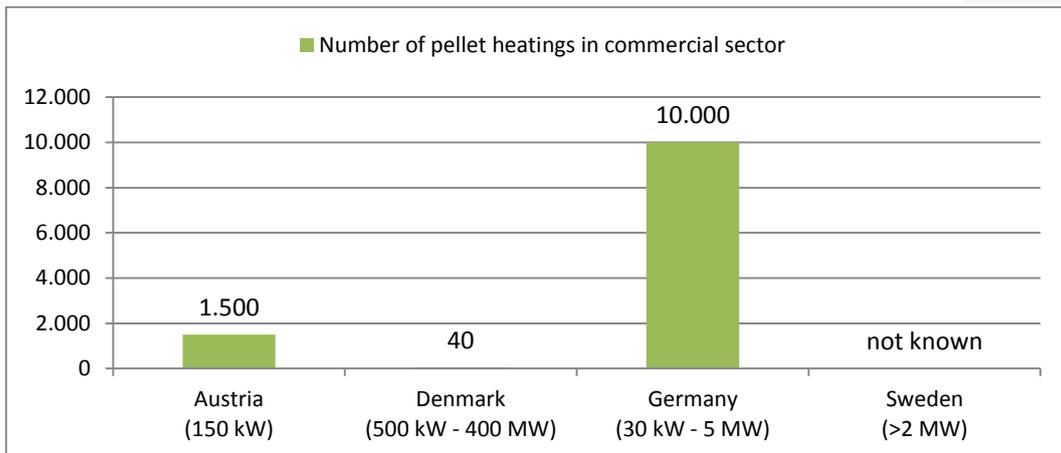


Figure 27: Number of pellet heating systems in commercial sector

#### 4.3.2 Medium Scale Users

Public and commercial buildings as well as industrial premises and apartment buildings are typical medium scale users. Examples are schools, greenhouses, health centers, commercial centers and malls, administrative buildings and multifamily houses. The boiler size is usually between 25 kW and 2 MW (Figure 28). Mainly first class pellets are used but the combustion facilities can also handle lower quality pellets with ash content up to 2%. Annual consumption usually varies between 100-500 tons. Pellets are mainly delivered in bulk, but also big bags of 500 up to 1000 kg are possible. In Sweden, there are no actual and relevant statistics available for medium scale boilers. Thus, the number of pellet heating systems in this sector is unknown. However, it is estimated that approx. 500.000 tons of pellets are used in the Swedish medium scale sector.

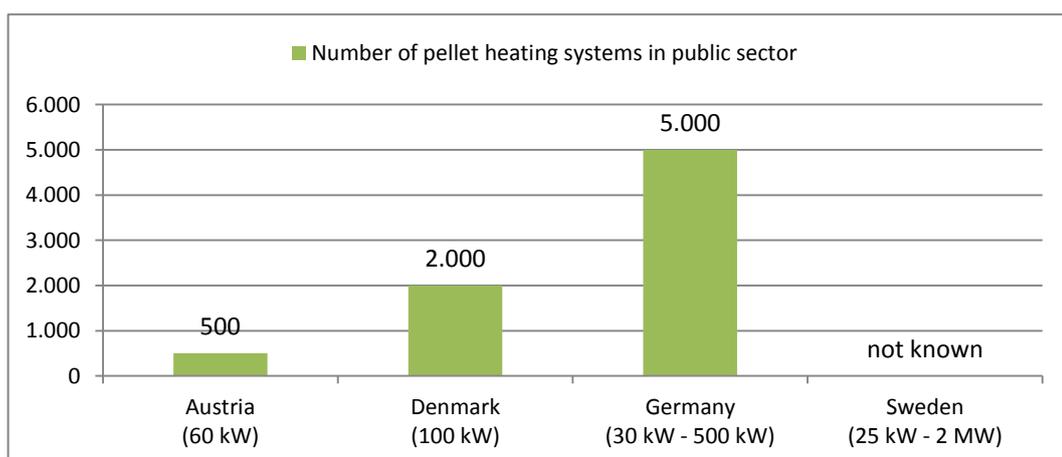


Figure 28: Number of pellet heating systems in public sector

### 4.3.3 Small Scale Users

Typical small scale users are private households. Such residential buildings use pellets as the primary or secondary heating source in pellet boilers or pellet stoves. The usual boiler size in this sector is approx. 25 kW, whereby this is seen differently from country to country as illustrated in Figure 29. The equipment is not able to handle pellets with high ash content. Therefore, only high quality wood pellets should be used, such as ENplus or DINplus certified pellets. This material guarantees low ash content of below 1% and ensures minimized operational problems. Pellets are usually delivered as bulk pellets or in bags of 15-25 kg.

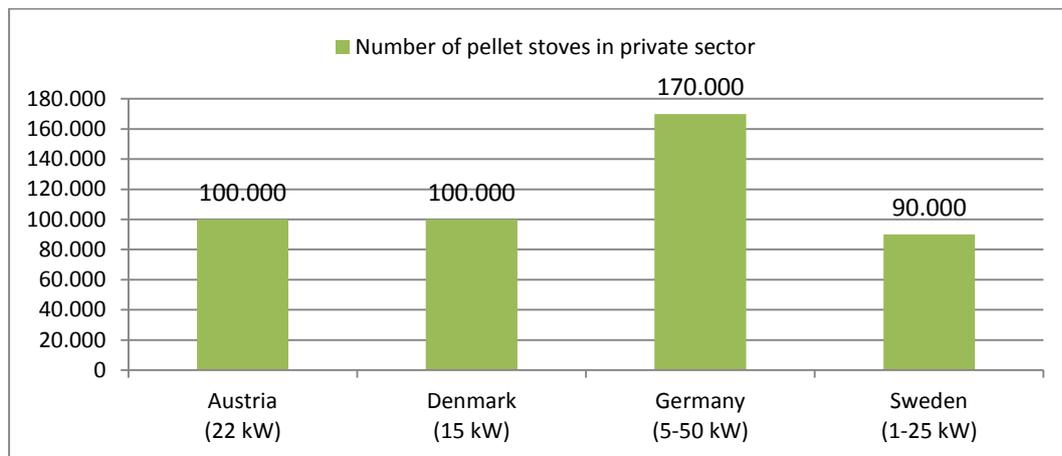


Figure 29: Number of pellet boilers and stoves in the private sector

## 4.4 Country Reports

The country reports are based on the questionnaire that was sent to the pellet associations of Germany, Austria, Denmark and Sweden. The intention was to have a more detailed overview on main actors of the European pellet sector and how pellet markets and actors differ between countries. Additional information was extracted from IEA Task 40 report and the country reports of the PelCert project. For each of the above countries, the national regulatory framework will be described first. In the following, the actual production and consumption will be illustrated. Finally, the quality of the predominantly used pellets as well as the mainly used raw material feedstock will be described.

### 4.4.1 Current Market Austria

#### National regulatory framework

In Austria, wood pellets as heating fuel have been introduced to the market in the middle of the 1990s. Since then, the use of wood pellet for residential heating has grown rapidly with a short interruption in 2007 resulting from too small pellet production capacities and consequently rising prices. The strong increase in the use of wood pellets within few years can be explained by a



long tradition to use wood for heating. Consequently, wood pellets are considered as a related fuel with the additional advantage of being more comfortable and convenient. Furthermore, there are several promotion programs and incentives available in Austria. The cumulate capacity of the 100.000 pellet stoves in private households corresponds to about 1600 MW. This amount is not reached by the public sector (110 MW) or the industrial sector (230 MW) (IEA Task 40, 2012).

### Production and capacity

The Austrian pellet industry has 23 pellet producers at 31 different production sites. A list of Austrian pellet producers can be found in the Annex 10.1. The data illustrated below (Figure 30 and Figure 31) is based on the information provided by 18 pellet producers. Large pellet producers with an output over 100.000 tons such as “Binderholz” and “Pfeifferholz” are counted as one facility even though, they have different production sites.

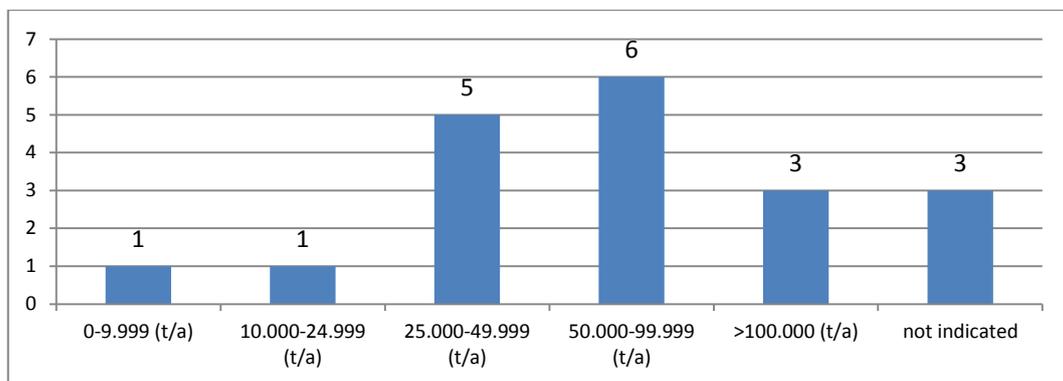


Figure 30: Pellet producer according to size class

According to Figure 32, more than half of the actual pellet production is realized by companies with capacities of more than 100.000 tons/year. These companies are Binderholz (with production at five sites) Pfeifferholz (two sites in Austria) and RZ Pellets. These companies accumulate unused production capacities of approx. 200.000 tons/year.

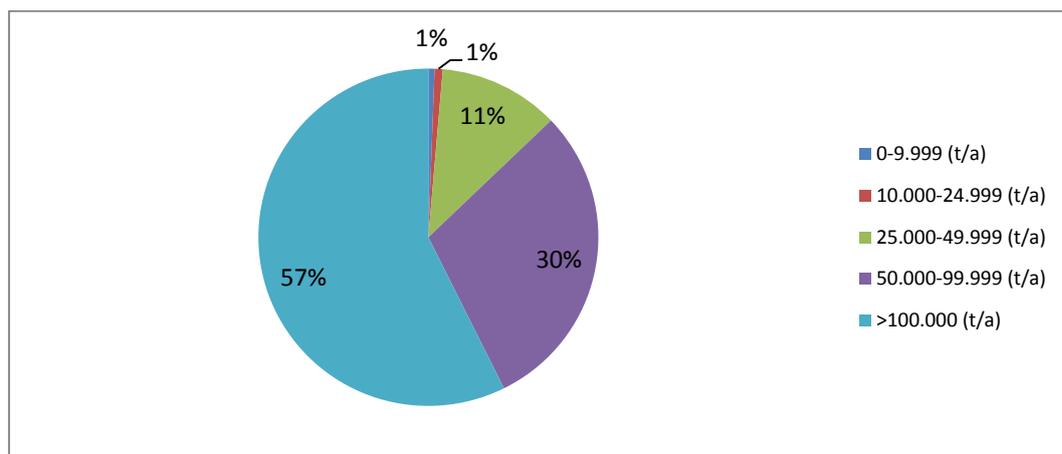


Figure 31: Austrian pellet production according to size class

A strong increase both in pellet utilization and capacity building is expected for the next years. In the period 2011-2020, the actual production and the production capacity is expected to nearly double (Figure 32). In 2012 only 150 people are working in the pellet producing industry which creates a total turnover of approx. 170 million Euros.

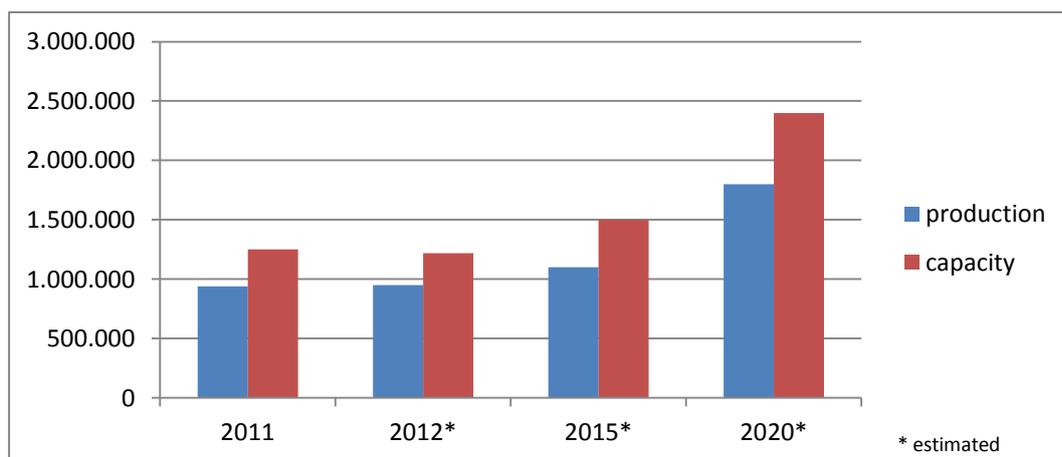


Figure 32: Estimated production and capacity in Austrian pellet industry

### Quality and Feedstock

Most producer are certified according to the current standards – 88% to ENplus, 60% to the German DINplus and 95% to the Austrian standard ÖNorm which expired in the end of 2012.

Based on approx. 100.000 pellet stoves for residential heating there is a high demand for sacked premium pellets. About 43% (440.000 tons) are traded this way. Furthermore, a large share of sacked pellets is exported to Italy. The remaining part of the production is delivered in bulk. Mostly special equipped silo-trucks (86%) or normal trucks (10%) are used. Transport by train (2%) or ship (2%) plays only a marginal role. Industrial-pellets are not produced.



The raw material mix is closely related to the wood working industry. 90% of the feedstock for pelletizing is provided as residues of saw mills, which are processing mainly spruce (85%), larch (10%) and smaller amounts of pine (5%). The rest is produced from stem wood without bark (9%) and forest residues (1%). Alternative raw materials play a negligible role in Austria. Accordingly, 99% of the feedstock is stem wood mainly harvested in Austria. Only 25% of the stems come from outside Austria but all from EU countries. Figure 33 shows the location of major pellet facilities and the major trading routes.

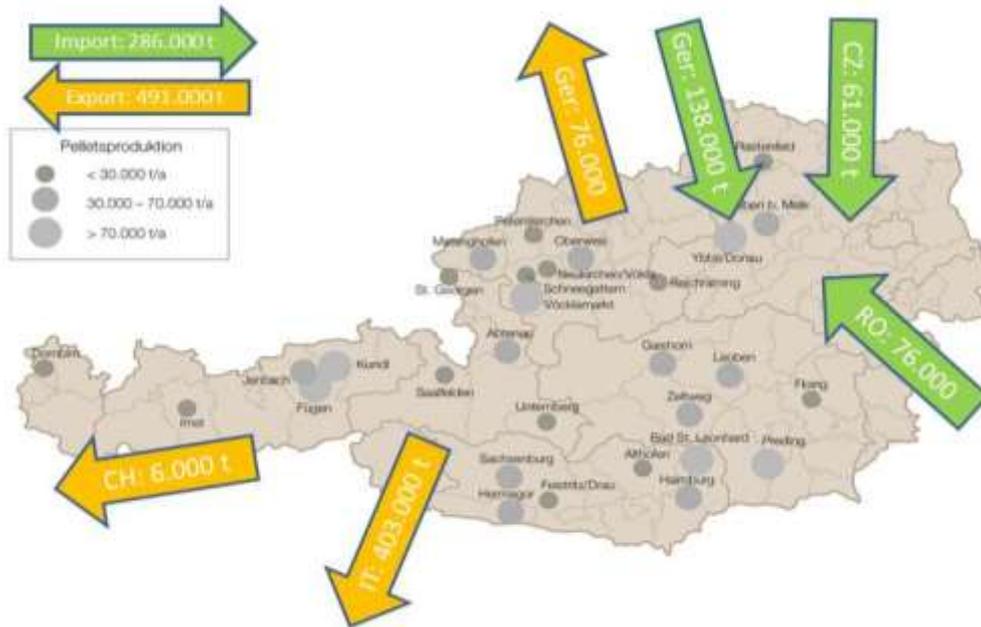


Figure 33: Pellet production and trade in Austria 2010 (Propellets Austria)

#### 4.4.2 Current Market Denmark

##### National regulatory framework

Denmark started using wood pellets in the late 80's mainly in the district heating sector. The aim was to replace coal. The increase in pellet consumption in the last decades is based on an increased consumption in power plants, public buildings and for residential heating. Since 1998, a steady increase in the use of pellets has been observed. Denmark is one of the great importers of wood pellets for co-firing. In 2003, a combined heat and power (CHP) plant co-fired with pellets (Avedøre II) started operation and increased the Danish pellet consumption significantly (Figure 34). Tax exemptions on pellets are a major driver. The main barriers are that the supply chain for pellets needs large investments, overseas shipment, roofed storage facilities and modifications for in-house transportation systems, milling equipment and combustion facilities (IEA Task 40, 2012).

As illustrated by Figure 34, pellets are used both in large, medium and small scale. The average capacity of private pellet stoves is estimated with 15 kW. Accordingly, the 100.000 (estimated) privately installed pellet stoves cumulate 1500 MW. The public sector uses 2000 heating

systems of about 100 kW with a cumulated capacity of 200 MW. In the industry sector, there are 40 heating facilities on pellet basis with a total capacity of 600 MW.

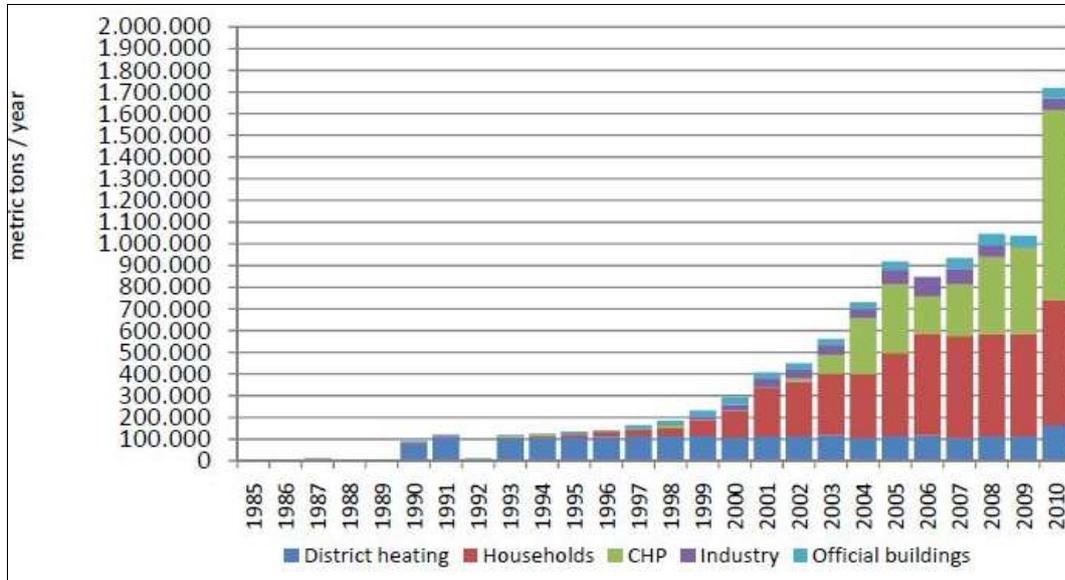


Figure 34: Wood pellet consumption in Denmark (IEA Task 40, 2012)

### Production and Capacities

The Danish pellet industry has eight producers of pellets and equal amounts of producing facilities. There are several trader and distributor of pellets, six of them who deal in amounts greater than 50,000 tons a year. In addition, there are two shipping companies and one machine producer. The total turnover in this sector can be estimated to around 150 million Euros per year. As shown in Figure 35, the own pellet production capacity is fully used.

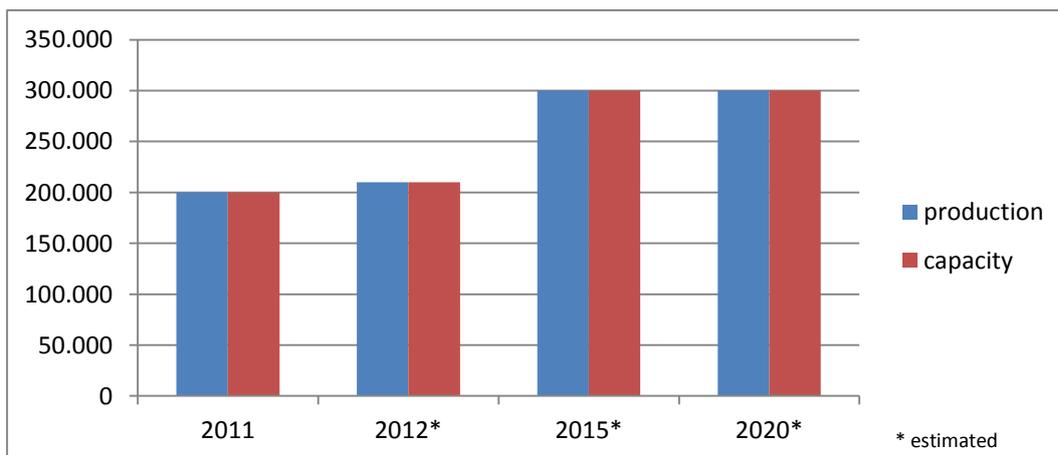


Figure 35: Current and estimated production and capacity of Danish pellet industry



## Quality and Feedstock

Half of the Danish production is certified material for premium pellets, 25% according to the ENplus standard another 25% according to the German standard DINplus which corresponds respectively to 50.000 tons each. Half of the produced pellets are delivered to end users or district heating facilities either with trucks, which includes also dumper truck, container or walking floor setup. The other half is transported with ships directly to power plants. The delivery in special silo-trucks or by train plays a negligible role.

Since 2003, the amount of wood pellets imported has increased from 385.000 tons to 1.581.000 tons in 2010. The overall pellet production capacity is 200.000 tons, which covers less than 13% of the Danish pellet demand in 2010. Therefore, import plays the predominant role in the country's pellet supply. Because there are only few wood resources in Denmark a wider feedstock basis is used in the Danish pellet production. Especially straw is used in large amounts (with 47%). 95% of the used feedstock for pellet production comes from Denmark and only 5% are imported from neighboring countries.

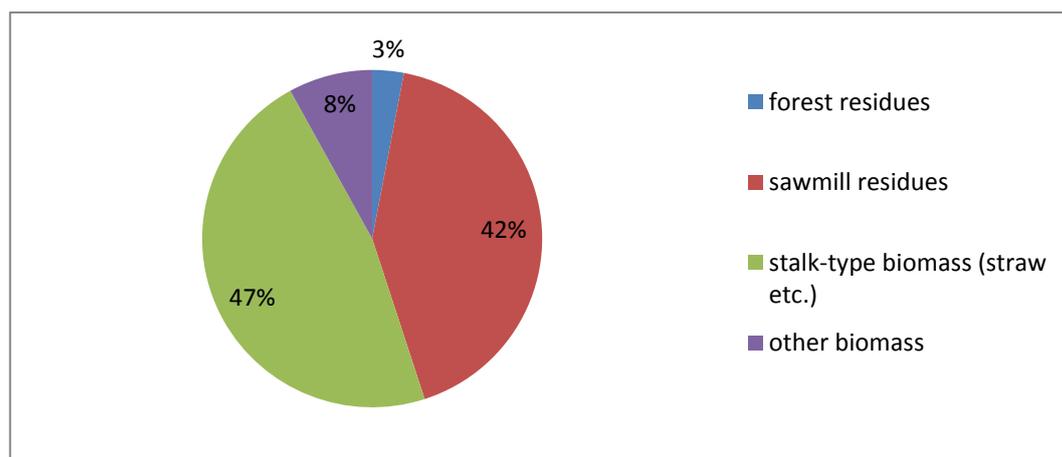


Figure 36: Feedstock mix in the Danish pellet industry

### 4.4.3 Current Market Germany

#### National regulatory framework

In the last couple of years, the German pellet market has been one of the markets with the fastest development. A further increase is expected for the future. In particular, the market for pellet boilers and stoves for small- and medium-scale applications has experienced a rapid increase. Factors as the legal framework promoting the use of pellets in the residential sector and the increasing oil and gas prices gave incentives for house owners to install wood pellet heating systems. Main drivers are the market incentive programme (MAP) and the Renewable Energies Heat Act (EEWärmeG). Thus, since 2000 one of the largest wood pellet markets worldwide could establish (IEA 2012).

### Production and Capacity

Germany has approximately 38 pellet producing companies at 54 different locations. A list of German pellet producer, provided by “Deutsches Pelletinstitut”, can be found in Annex 10.3. The majority of the produced pellets comes from a rather small number of larger pellet producers (Figure 37). The smaller pellet producers with capacities of less than 50.000 tons per year contribute only 20% of the production but provide about half of the production sites (27). This illustrates the highly regional approach of pellet production in Germany.

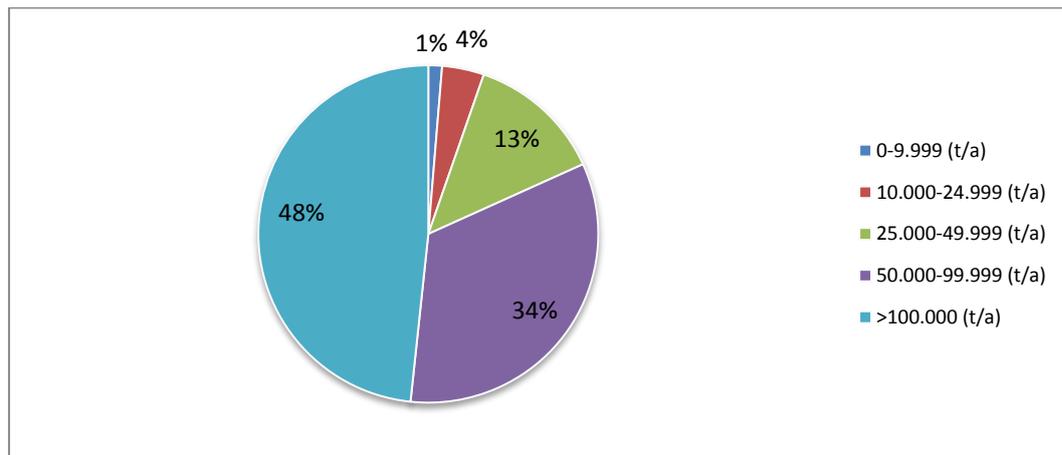


Figure 37: Proportion of size class by capacity

Five manufacturers have plants that produce more than 100.000 tons a year. This accounts to approx. 55% of the real annual production in 2011 .The producer “GermanPellets” on his own has five of these large scale producing facilities (Figure 38) and produces approx. 800.000 tons of pellets.

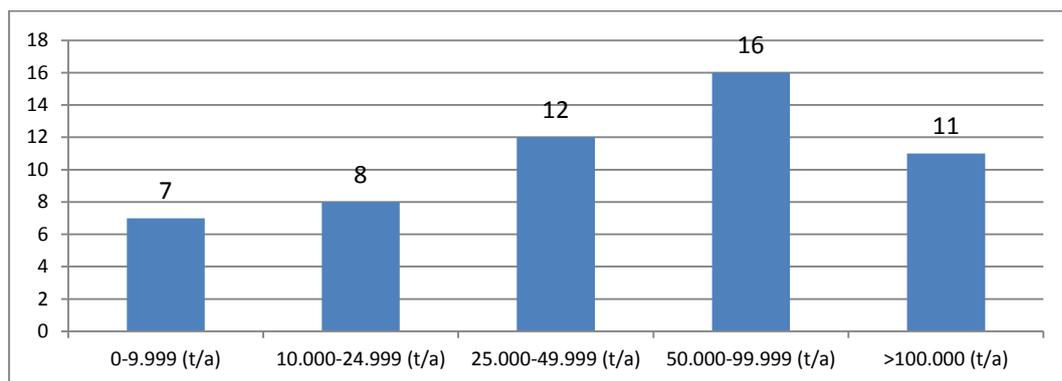


Figure 38: Amount of pellet-facilities per size class

In Germany, the production capacities are not fully used. Only two third of the capacity is actually used for pellet production (Figure 39). Nevertheless, a further massive expansion of production and capacity is expected till 2020 with an assumed capacity of up to six million tons per year in 2020 which would be more than twice as much as the current state.

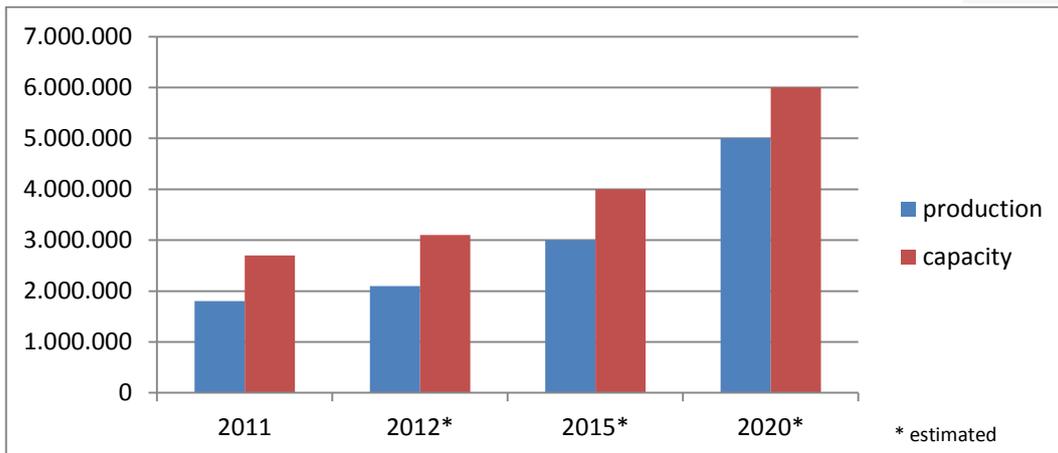


Figure 39: Estimated production and capacity of German pellet industry

### Quality and raw material

Most of the producers are certified. 95% of the German pellet producers are certified according to the former national standard DINplus and 80% use the European standard certification ENplus. Having certification for both systems is possible and usual since ENplus can be considered as an upgrade of the already achieved DINplus certification. More than two-thirds of the German production is delivered as bulk pellets whereby the industrial pellets play a minor part with only 8%. 92% of the pellets were produced as premium pellets and 20% of these premium pellets are delivered in bags (Figure 40).

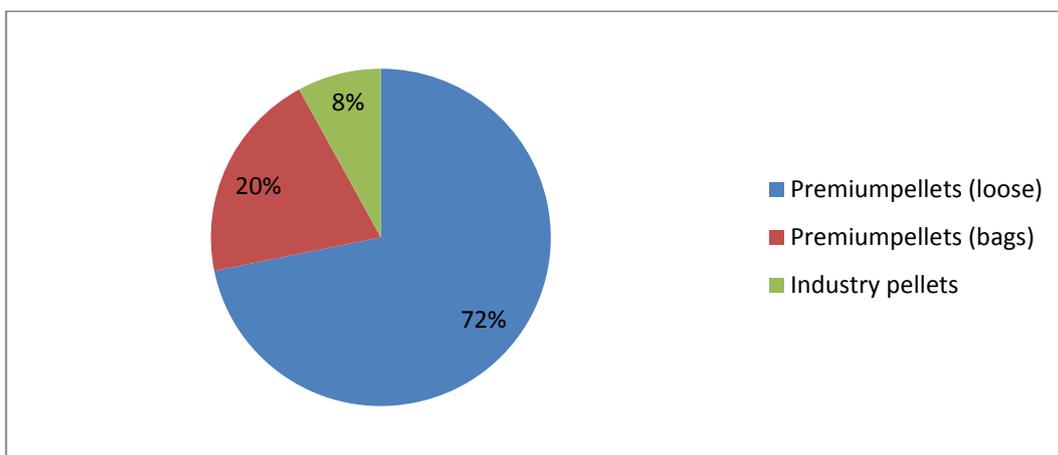


Figure 40: Produced pellet quality in Germany

Predominant raw feedstock material is saw mill residues with 92%. The remaining 8% are provided by stem wood without bark. The used tree species are almost exclusively coniferous wood from spruce (90%) and pine (10%). Other assortments were not mentioned in the questionnaire. The raw material feedstock originates in 90% from Germany and only 10% were imported from other European countries.

#### 4.4.4 Current Market Sweden

##### National regulatory framework

In Sweden district heating is applied in most cities and towns. Since the 1980's, wood pellets have been used as fuel when many district heating plants and CHP plants were changed from oil to wood firing often in combination with coal. Today, around 200 of these plants use biomass, many of them using wood pellets as fuel. In 1991, a general CO<sub>2</sub> tax on fossil fuels was introduced for thermal energy, electricity generation and industry plants. Today the legal framework combines a green certificate system for electricity combined with renewable obligations and exemptions from CO<sub>2</sub> taxes. For private households, the low biomass price is an important incentive especially in comparison with high oil prices, increasing electricity costs, and heavy taxation on fossil fuels. These are the main drivers for small-scale users to invest in pellet boilers. Consequently, the wood pellets consumption in private households is now 20 times higher than 13 years ago (IEA Task 40, 2012).

##### Production and capacity

In Sweden, around 55 pellet producers produce wood pellets at 72 different production sites. A list of Swedish pellet producer given by the Swedish pellet association Svebio can be found in Annex 10.5. Ten of the Swedish pellet producers own a production capacity of more than 100.000 tons per year. Figure 41 shows the allocation of pellet plants to the different size classes. Accordingly, about 80% of the Swedish pellet production is provided by the 20 largest pellet producers (Figure 42). The estimated total turnover in the pellet producing branch is about 180 million Euros per year.

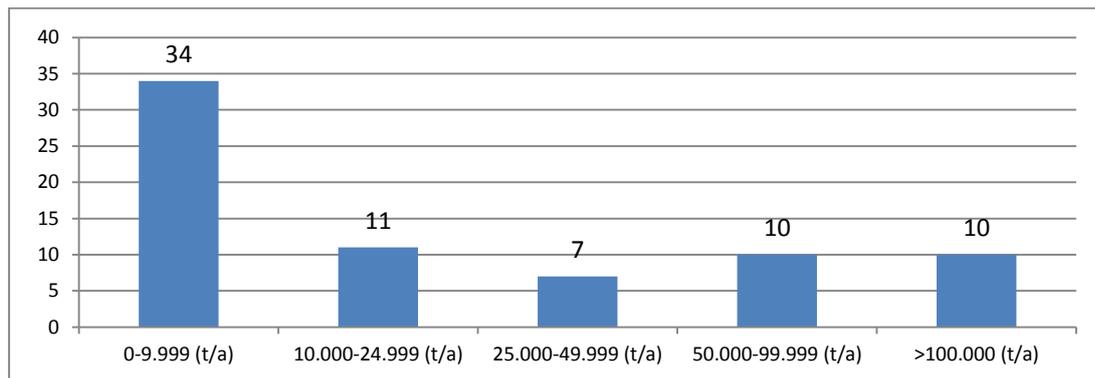


Figure 41: Quantity of pellet production per size-class

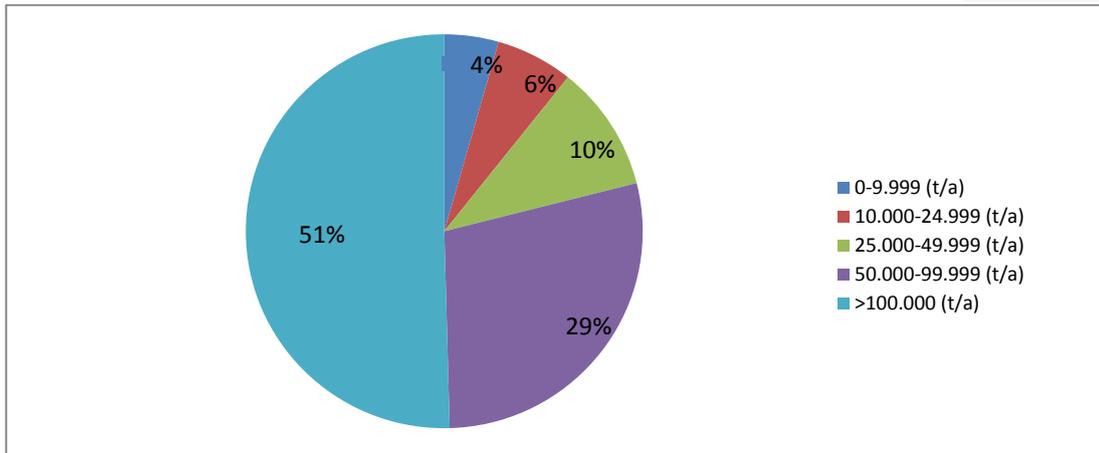


Figure 42: Proportion of size-class by capacity

According to the data provided by the national Swedish pellet association PF (Pelletsförbundet), a non-profit member organization accounting for approx. 85% of the Swedish pellet production, the Swedish pellet market has experienced a remarkable development in the last couple of years. In 1997 the annual consumption of wood pellets was 494.000 tons and only 39.000 tons or 8% were used in private households while the remaining 455.000 tons were used for district heating and electricity production. These figures changed dramatically over the following 13 years. The total consumption in 2010 was 2.280.000 tons and the use in private households was 785.000 tons or 34% of the total use. Since 2010, the pellet production and consumption in Sweden is decreasing (Table 6). A possible explanation could be the relatively mild temperatures in winter 2011 and 2012.

Table 6: Pellet-use in Sweden (source: PIR) in tonnes

Year	Production	Export	Import	Total consumption	Pellet-use in households
2009	1.575.823	88.212	430.389	1.918.000	695.000
2010	1.649.567	64.610	695.043	2.280.000	785.000
2011	1.475.961	126.806	665.415	1.882.500	549.500
2012	1.337.620	128.506	490.686	1.699.800	524.000

Depending on the sources the actual production amounts to 1.35 million tons of pellets (Figure 1Figure 43). Only about 60% of the Swedish production capacity is used. Sweden has already comparatively high pellet consumption and thus, the estimated increase of the pellet market for the next years is less pronounced compared to other countries.

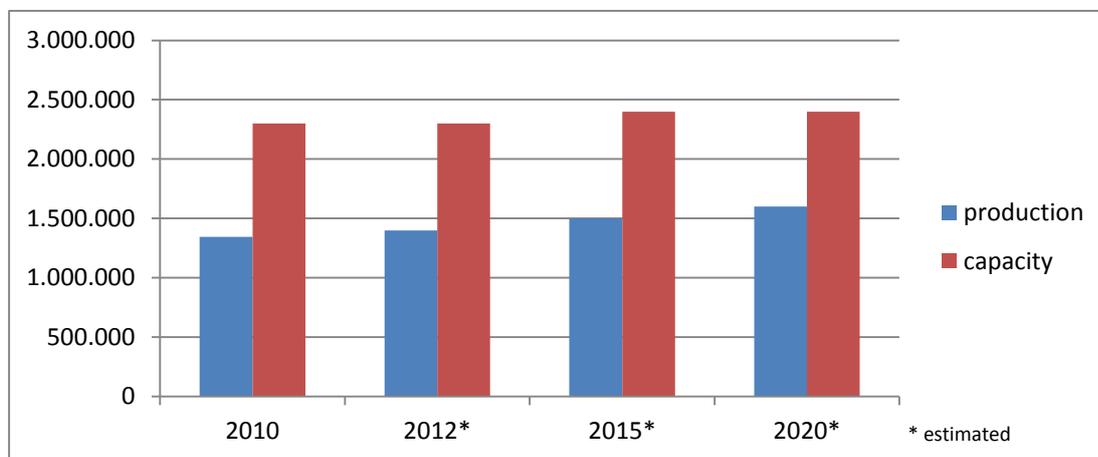


Figure 43: Production and capacity of Swedish pellet industry

### Quality and raw material

Pellets produced in Sweden can be used both for industrial and residential purposes. More than half of the production (Figure 44) is used as industry pellets (60%) the rest is declared as premium pellets for residential heating. A high amount is delivered in bags (30%). Swedish pellet producers don't use a certification system comparable to the EN standard and no Swedish producer is certified according to ENplus or DINplus. A quality label, established by the Swedish pellet producers association will probably be introduced in 2013. The label focuses on quality parameters only.

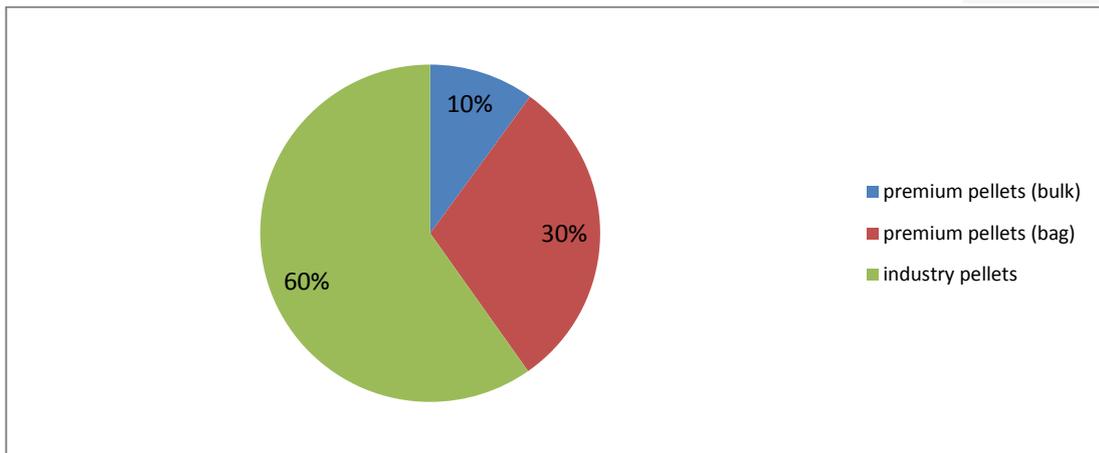


Figure 44: Pellet quality in Sweden

The main raw material used for pellet production in Sweden is saw mill residues (saw dust). In addition, some manufacturers use smaller fraction of “energy wood” (e.g. broad leaf trees) but also in some cases dry material such as cutter shavings. The raw material is mainly stored outdoors in piles. Only cutter shavings would be stored indoors. In Sweden, most commonly used tree species for wood pellet production are spruce and pine. The mixture of these wood assortments varies and depends on the manufacturer and their location ranging from 100% spruce to 100% pine. Other raw materials are rarely used.

## 5. International Trade

Pellet supply for small and medium scale is realized predominantly by domestic traders and retailers. However, for industrial scale use pellets are traded globally. Currently, important trade flows to fulfill the European demand come from Northern America and Russia (Figure 45).

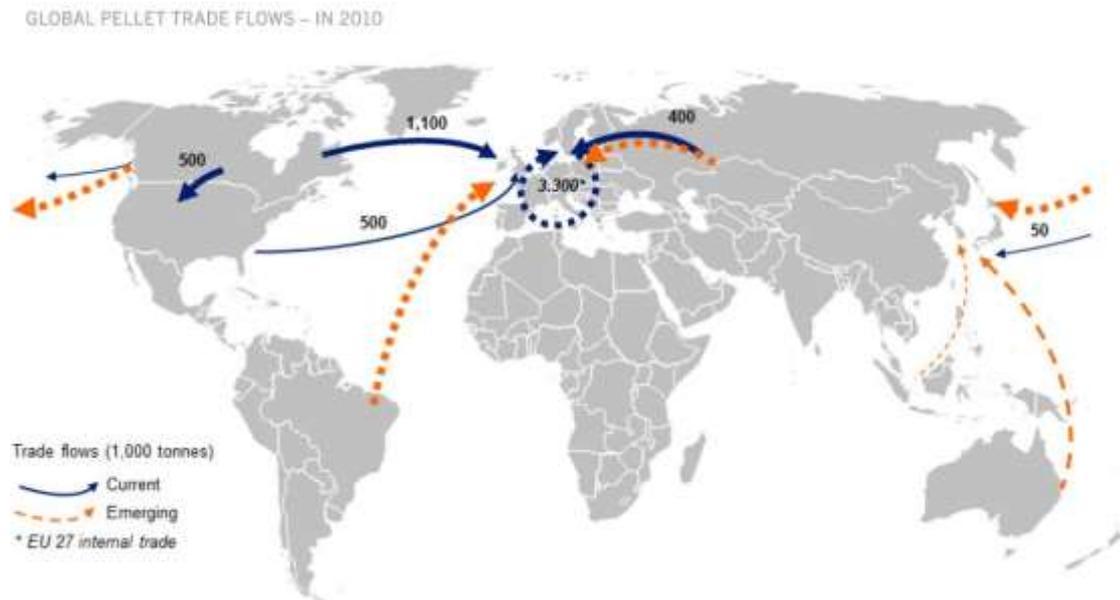


Figure 45: International trade flows (Pöyry, 2012)

In 2011, more than two thirds of the pellet imports to Europe were realized from Canada and the USA (Table 7). In the next years, it is expected that larger amounts of pellets will be imported from South America. Furthermore, Australia, South East Asia and South Africa are expected to enter the pellet market contributing significant amounts of industrial pellet to fulfill the demand e.g. in Japan (PelCert project, 2012). Within Europe, the largest importers are the Netherlands, Belgium, Denmark, Sweden, Italy and the United Kingdom. According to the evaluation of the PelCert project, Ukraine realized a tremendous increase in pellets export rising the traded amounts from 30.000 tons in 2009 to 149.000 tons in 2011. In the same period, pellet imports both from Canada and the USA roughly doubled (**Fehler! Verweisquelle konnte nicht gefunden werden.**).



Table 7: Origin of Pellet Imports to EU 27 (Pellcert 2012)

Exporting country	2009	2010	2011	main target country
Argentina	10.000	9.000	6.000	IT
Australia	9.000	66.000	14.000	NL
Bosnia	54.000	44.000	47.000	IT SI
Belarus	75.000	90.000	100.000	LT, DK
Canada	520.000	983.000	1.160.000	UK, NL, BE
Chile	0	1.000	3.000	IT
Croatia	73.000	95.000	115.000	IT
New Zealand	0	21.000	30.000	IT, UK
Norway	10.000	4.000	13.000	SE
Russia	379.000	396.000	475.000	DK, SE
South Africa	42.000	25.000	43.000	NL, UK
Switzerland	6.000	15.000	3.000	IT
Ukraine	30.000	57.000	149.000	PL
USA	535.000	763.000	1.001.000	NL, UK, BE
total Import to EU 27	1.743.000	2.569.000	3.159.000	

Since 2009 pellets have their own standard CN code and official Eurostat statistics for pellet trading are available. According to Eurostat, Europe (EU27) imported approx. 2.6 million tons of pellets from non-EU countries in 2010. In the same year, more than 3.3 million tons were traded among EU member states (Table 8).

Table 8: Inter-European pellet export

Exporting country	2009	2010	2011	Main Target
Austria	159.000	285.000	274.000	IT, DE
Belgium	119.000	50.000	51.000	FR, NL
Bulgaria	11.000	8.000	6.000	IT
Czech R	72.000	102.000	83.000	AT, IT, NL
Denmark	20.000	124.000	184.000	DE, SE, NL
Estonia	316.000	383.000	562.000	DK, SE
Finland	154.000	187.000	116.000	DK, SE
France	59.000	62.000	87.000	IT, BE, DE
Germany	370.000	543.000	680.000	DK, AT, IT
Hungary	33.000	13.000	20.000	IT
Italy	2.000	4.000	10.000	
Latvia	231.000	420.000	670.000	DK
Lithuania	93.000	126.000	203.000	DK, IT
Luxembourg	7.000	15.000	37.000	
Netherlands	74.000	103.000	136.000	DK, BE
Poland	98.000	142.000	135.000	DK
Portugal	138.000	199.000	508.000	DK, UK, NL
Romania	62.000	142.000	176.000	AT, IT
Slovakia	46.000	64.000	44.000	IT, HU
Slovenia	75.000	81.000	106.000	IT
Spain	59.000	138.000	121.000	PT, FR
Sweden	104.000	69.000	154.000	DK
UK	6.000	61.000	57.000	DK
EU27	2.308.000	3.321.000	4.420.000	source: eurostat



## Part B: Problems and Incidents during Pellet Transportation and Storage

As described in Part A, production, utilization and trading of pellets is increasing in Europe and worldwide. In this context, it is crucial that safe handling and storage can be ensured along the whole pellet supply chain. As a natural product, wood pellets pose some inherent risk that have to be taken into account. Within Part B of this document, possible problems during pellet transportation and storage will only be described in short. A detailed report on incidents that occurred in the context of pellet production, transportation and storage including the analysis of backgrounds and reasons for the incidents will be provided as a separate document (Deliverable 2.2, Part B).

## 6. Evaluation of Risks

In the following, the inherent risks that are caused by the handling of wood pellets are described. Along the pellet supply chain, pellets are handled by different actors. Thus, it is crucial to ensure proper training and information for all involved actors (see also Figure 4).

### 6.1 Storage Risks

Most research was done for small scale users. Generally, domestic pellet storages should have similar risks as producers and wholesalers. However, large pellet bearings are usually equipped with temperature and CO detectors to locate self-heating processes and fire as quickly as possible. Furthermore, employers are usually well trained and aware of possible risks. In contrast, knowledge about possible risks and appropriate handling of these risks is less common among small scale users. In the past, at isolated cases this led to fatal accidents as a result of air poisoning when entering pellet storages. Recent results indicate that proper ventilation can minimize the risks from harmful gas emissions. Fresh pellets (within the first three months after pelletizing from fresh wood) seem to bear under certain circumstances a higher risk for off-gassing and self-heating.

The risk of a hazardous gas concentration is greater when the storage space is full of pellets because the remaining air volume can accumulate faster with the off-gassing products if the air exchange rate is too low. With the help of special filler neck with integrated ventilation function it should be possible to realize a natural air exchange on the basis of different temperature and pressure conditions between the storage room and the ambient air. Additional warnings on the access door should inform others about the risks. **Fehler! Verweisquelle konnte nicht gefunden werden.** shows an example of such warning sign invented by DEPV.

In tendency, the risk of fire in large warehouses is greater. The larger the storage capacity is, the higher the risk of spontaneous ignition of the fuel because the ratio of surface area to volume decreases (heat dissipation for storage space/wall to self-heating of the pellets). In case of an incipient smoldering the temperature rises quickly and may cause inflammation of the pellets. The auto-ignition temperature is dependent on the quality of the pellets and is influenced by the similar factors as the off-gassing. Spontaneous combustion reactions are therefore more frequently immediately after the pellet production than in long stored pellets (Witt, 2012). It is highly recommended to install CO-sensing systems.



Figure 46: Warning advice for pellet stores (DEPV, 2011)

Some guidelines for a safe use of pellet stores are already in use (Part C). For all fuels, safety rules governing handling, heating with that fuel and storage apply. In general they provide information on:

- Safety
- Fuels specifications
- Fire protection
- Static requirements
- Equipment in pellet storage

## 6.2 Risks of Wetness and Transshipment

Transshipment means the moving, loading, unloading of the pellets that may cause disintegration. Wood pellets can break up every time they are handled; they can break up at every transfer point and even from rubbing together when being transported. When they break up, fines are produced causing problematic transportation and storage properties and increase the dust explosion risk. Thus, conveying shall be conducted with a minimum of wear and damage to the solid biofuel. Minimal length of belt conveyor line should be applied and many crossings and high drops should be avoided. Though fines are also an issue that is relevant for pellet safety, this topic is not discussed in more detail since it affects more the dust explosion risk that is beyond the scope of the SafePellets project.

One of the risks during long storage, mainly on shipping transports, is the off-gassing and self-heating phenomenon (Curci, 2011). Precautions also should be taken against mixing pellets

with other previous stored rests of wood fuel (i.e. chips). If chips are mixed with pellets severe problems may be experienced during pneumatic filling, conveying and combustion.



## Part C: Guidelines and Standards

This part provides an overview about existing standards for pellets and guidelines for the handling, transportation, storage and utilization of pellets. Main focus is set on the storage of pellets though handling and storage are often correlated and have to be considered accordingly. At first, the importance of standards and the way they are developed will be highlighted. In the following, existing national and European standards for biofuels and quality assurance systems will be compared. Furthermore, technical guidelines for production, transport and storage of wood pellets on European and national level will be described. The standards and guidelines will then be evaluated according to their practical relevance with regard to security relevant aspects and lacks not solved within existing standards and guidelines.

## 7. Standards, Guidelines and Certification Schemes

Currently, the development of quality standards for wood pellets is set on five different levels in Europe. The top level consists of the European Commission and European Committee for Standardization. The second level includes EU member state governments, while the third level consists of the European Biomass Association and European Pellet Council, which represent the European biomass sector. The fourth level is the Wood Pellet Buyers Initiative, which represents end users of biomass, and finally on the fifth level are standards developed by individual private companies.

Standards exist on national (e.g. DIN), European (EN) and on international level (ISO). They are prepared at request of the industry or executive bodies like the European Commission (Figure 47). Standards define requirements of a product (standard specification) or of a procedure (standard method). Standards can help to overcome market barriers and facilitate trading. For this it is important that all market participants refer to the same standards. Thus, in many fields international standardization is aspired. Ideally, standards are developed as consensus of all interested parties such as manufacturers, consumers, and regulatory bodies of a particular material, product, process or service. Standardization increases product safety and quality and may contribute to lower transactions costs and prices.

The standards for solid biofuels have been developed by the Committee for European Standardization (CEN). This organization works in a decentralized way. It's 32 members – the National Standardization Bodies of the 27 EU and 3 EFTA countries and of Croatia and Turkey – operate the technical groups that draft the standards. The CEN-CENELEC Management Centre (CCMC) in Brussels manages and coordinates this system. More than 60.000 technical experts from industry, associations, public administrations, academia, and societal organizations are involved in the CEN network representing over 590 million people. The European Commission and the EFTA (European Free Trade Association) Secretariat act as CEN's Counselors in terms of regulatory or public interest. Standards are prepared at the request of the industry or the European Commission.

Within CEN different technical committees (TC) are entrusted to deal with certain topics, e.g.:

- CEN/TC 383 sustainability standards for solid biofuels or
- CEN/TC 335 standard specification of solid biofuels.

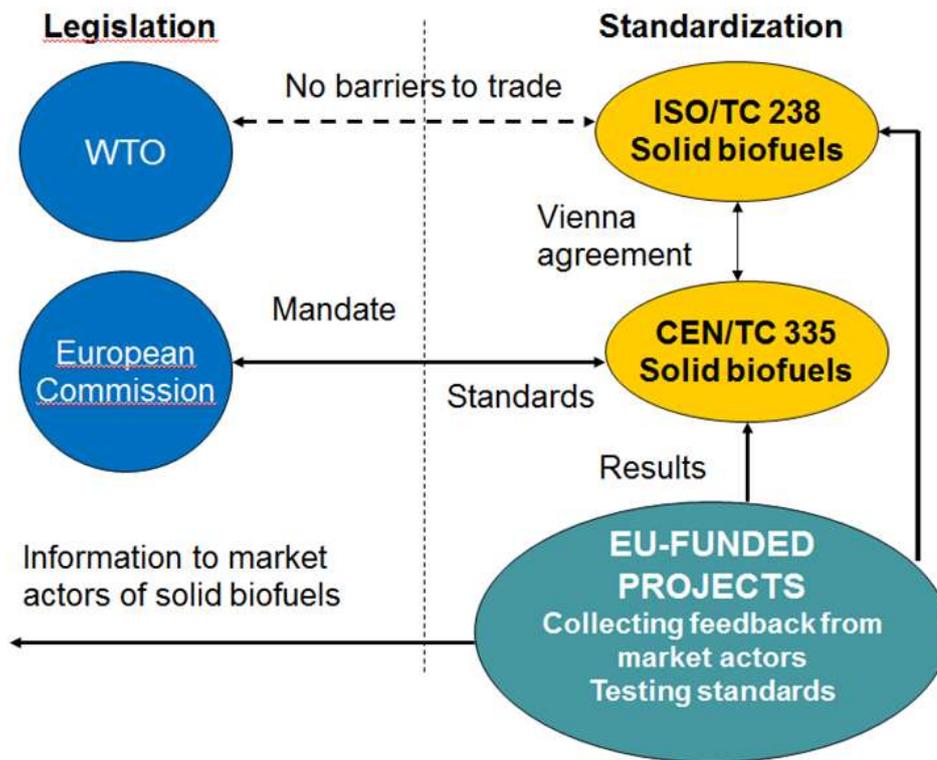


Figure 47: Linkage between legislation and standardization

Usually, standards developed by standards organizations are voluntary but can become mandatory if adopted by a government, business contract etc. In Germany for example, a simplified legal approval of wood pellet boilers <1 MW is possible provided that the used pellets fulfill the requirements of DINplus certification that comply with the requirements of the standard EN 14961-2 (A1). Similarly, boiler manufacturers can refer to standards as precondition for warranty. Utilization of biofuels not according to the standards would lead to exclusion of warranty.

Based on the completed work of CEN/TC 335 “solid biofuels” that has finished its work with the publication of the last standard EN 14961-6 in April 2012, ISO/TC 238 is now developing international standards for solid biofuels. The European standards focus on non-industrial uses whereas the international standards will also include industrial use of the solid biofuels. In addition, the international standards will include aquatic biomass as a raw material and classification of thermally treated biomass (e.g. torrefied biomass).

ISO/TC 238 is currently preparing almost 60 standards for solid biofuels. ISO/TC 238 and CEN/TC 335 have decided to apply Vienna agreement, which means that European standards will be superseded by new ISO standards. Other nations will make their national decisions. (Solidstandards 2011)

## 7.1 Existing Standards and Guidelines

For solid biofuels there are standards both for the fuel (EN 14961) and for quality assurance during production, transport, storage and supply (EN 15234). In the following, the two multipart standards will be discussed separately. Figure 48: Interacting of CEN standards for wood pellets. Terminology, testing and fuel specifications contribute to the quality assurance standards.

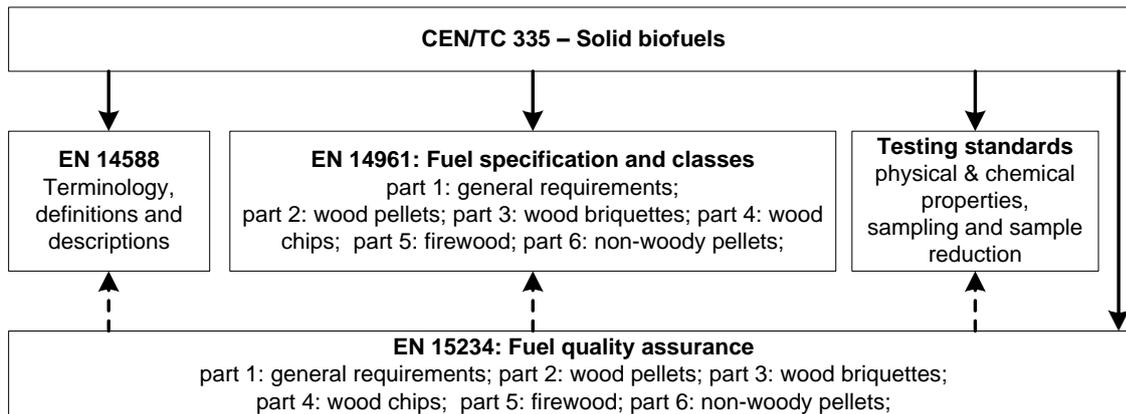


Figure 48: Interacting of CEN standards for wood pellets

## 7.2 Fuel standard EN 14961

The standard EN 14961 is a multipart standard consisting of six parts. The first part (General requirements) provides the framework for a common and clear classification method for solid biofuels. The other five parts are product standards for commonly traded forms of biofuels such as woody and non-woody pellets, wood briquettes, wood chips and firewood. In the context of the Safepellets project only standards dealing with pellets are relevant. Thus, only these standards will be discussed in more detail.

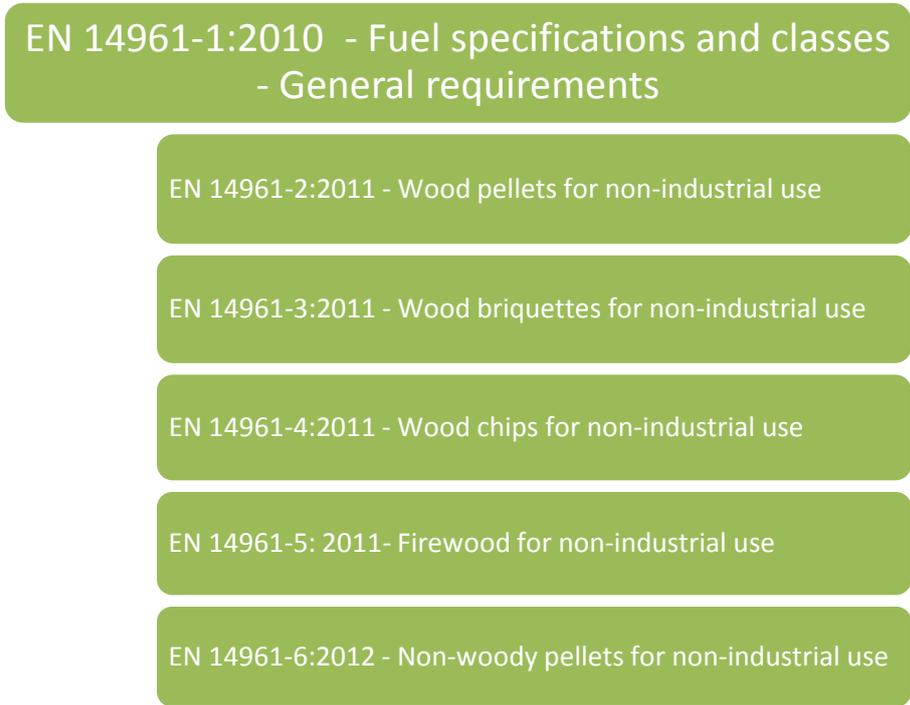


Figure 49: European standards for solid biofuels

#### 7.2.1 EN 14961-1:2010: Solid Biofuel Specifications and Classes – General Requirements

This standard determines the fuel quality classes and specifications for solid biofuels for general use. The classification of the solid biofuels is based on origin and source. The hierarchical classification system includes four subgroups: woody biomass, herbaceous biomass, fruit biomass and biomass blends and mixtures. Definitions both for raw materials and for major traded forms are provided. Furthermore, all characteristics of the fuel that are used for its classification (e.g. dimension, moisture content, ash content, durability, bulk density) are defined in EN 14961-1.

#### 7.2.2 EN 14961-2:2011: Solid Biofuels Specification and Classes –Wood Pellets for Non-industrial Use

This product standard specifies the quality of wood pellets for non-industrial use. Non-industrial use means that wood pellets are targeted to households, and small public or industrial buildings. Classification includes three classes: A1, A2 and B. Most of the properties are normative only ash melting behavior is informative. Property class A1 for wood pellets represents virgin woods and chemically untreated wood residues low in ash and nitrogen content. Fuels with slightly higher ash content and nitrogen content fall within class A2. In class A1 and A2 only chemically untreated wood is allowed. In class B, chemically treated industrial wood by-products and residues and used wood are also allowed. However, there are very strict threshold values for heavy metals for all three classes.

### 7.2.3 EN 14961-2:2011: Solid Biofuels Specification and Classes - Non-woody Pellets for Non-industrial Use

This European standard determines the fuel quality classes and specifications of non-woody pellets for non-industrial use. This European standard covers only non-woody pellets produced from the raw materials (see EN 14961-1:2010, Table 1) herbaceous biomass, fruit biomass and biomass blends and mixtures. Herbaceous biomass includes grains or seeds crops from food processing industry and their by-products such as cereal straw. Blends and mixtures can contain all raw materials defined in 14961-1. Blends are intentionally mixed biofuels, whereas mixtures are unintentionally mixed biofuels. The origin of the blends and mixtures should be described using EN 14961-1:2010, Table 1. If solid biofuel blend or mixture contains chemically treated material, it should be stated.

### 7.2.4 Evaluation of EN 14961 with Respect to Safety Relevant Aspects

The EN 14961 part two and part six are product standards that define threshold for the chemical and physical characteristics of woody and non-woody pellets. The aim is to ensure a constant quality. However, some aspects are also relevant for safety during transportation and storage. Limitation of fines is one critical aspect. The standard limits the content of fines to below 1%. To ensure low fines the durability has to be high and the product has to be sieved prior to delivery. With high durability and low fines convenient mechanical handling with limited disintegration of the pellets is ensured. Thus high levels of dust are avoided reducing dust explosion risks but also deduce self-heating associated with high amounts of fines.

A second security relevant aspect is the moisture content. A low moisture content is not only important to ensure a high heating value but also limits biodegradation which could lead to emission of carbon-monoxide and carbon-dioxide as well as increasing temperatures. Table 9 shows the stipulated safety relevant tests.

Table 9: Stipulated test according to EN 14961-2

Parameter	Point of Test	Frequency
Bulk density (BD)	after production, before storage	at least once per shift
Moisture (M)	after production, before storage	at least once per shift
Mechanical durability (DU)	after production, before storage	at least once per shift
Length (L)	after production, before storage	at least once per shift
Fines (F)	at the last possible point before delivery	at least once per shift

## 7.3 Quality Assurance Standard EN 15234

The standard EN 15234 is also a multipart standard. This standard defines the basis of a quality assurance system for the whole solid biofuel supply chain. It includes general definitions of specifications necessary for agreements between actors along the supply chain, needs for



documentation and traceability as well as critical control points. Part two gives an overview on critical quality issues specifically for the wood pellets supply chain.

### 7.3.1 EN 15234-1:2011 Fuel Quality Assurance, Part 1 – General requirement

The main aim of this standard is to ensure the quality of solid biofuels throughout whole the supply chain, from raw material supply to the delivery to the end-consumer. The typically process steps of the biofuel supply chain are shown in Figure 50.

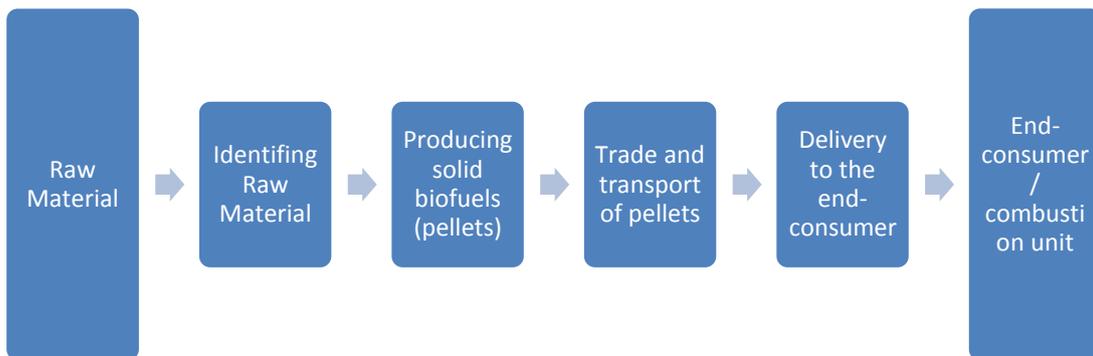


Figure 50: Controlled supply chain according to EN 15234-2

This standard describes measures to provide adequate confidence that quality requirements specified in EN 14961 are fulfilled. It covers the fuel quality assurance of the supply chain and the information to be used in the quality control of the product, which ensures traceability and gives confidence by demonstrating that all processes along the supply chain up to the point of the delivery to the end-user are under control. The methodology described in this standard facilitates the design of a fuel quality control and assurance system. There are six consecutive steps (Figure 51) that have to be followed by every stakeholder in the supply chain.

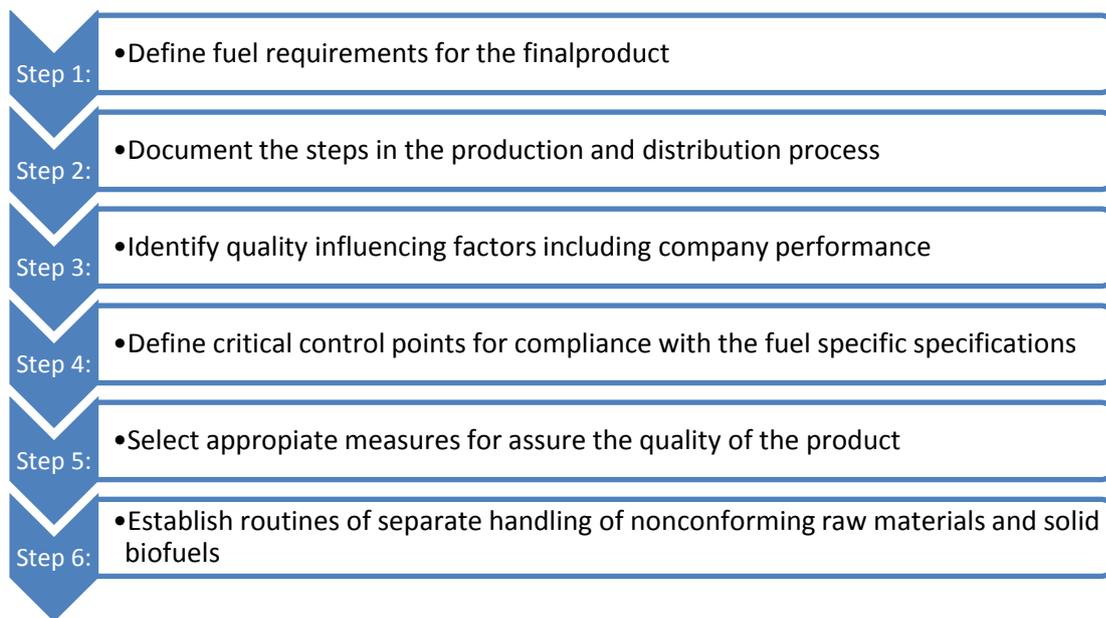


Figure 51: Assurance system along the supply chain according to EN 15234

Fuel quality assurance needs to be applied to the entire supply chain. As the supply chains for solid biofuels in the most cases need to be kept very simple, the same documents are often used for documentation of quality assurance and quality control measures. This standard gives also templates for product declarations.

### 7.3.2 EN 15234-2:2012 Fuel Quality Assurance – Part 2: Wood Pellets for Non-industrial Use

This standard defines the procedures to fulfill the quality requirements (quality control) and describes measures to ensure adequate confidence that the wood pellet specification described in EN 14961-2 are fulfilled (quality assurance). This standard covers the quality assurance for production and along the delivery chain, from purchasing of raw materials to point of delivery to the end-user and quality assurance for wood pellets according to EN 14961-2. Examples of the process description with the corresponding quality influencing factors and critical control points are given in standards and also templates for a product declaration is included.

### 7.3.3 Evaluation of EN 15234 with Respect to Safety Relevant Aspects

The EN 15234 standard provides an overview of quality and safety relevant aspects. In 15234-2 crucial factors that have to be considered for transport, storage and delivery of wood pellets. The aspects that are relevant for safety are the following:

- Inspection of incoming raw material and other goods by visual inspections of the delivered raw material
- protection of wood pellets from all kind of moisture e.g. snow, rain, damp or from condensation
- storage conditions with respect to air-exchange, water uptake and storage duration



- storage buildings should be suitable for pellets with regards to size, protection against impurities from ground and should be cleanable
- during loading pellet temperature has to be below 40°C, measured by qualified personal
- all measures to assure the quality shall be documented
- a system for complaint management is installed that allows to trace safety problems back to raw material and production conditions

The standard requires constant monitoring of several aspects at critical control points. All these data have to be documented and have to be kept for a certain period of time. Therefore, it gives all involved partner an overview about the quality aspects but also it is helpful in terms of safety. Rewetting can be prevented when the critical points are observed reducing biodegradation and off-gassing risks. The risks associated with off-gassing can be minimized when the air exchange rate is high enough and when pellet stores have a suitable size for the stored pellets. The critical control points are usually between several production steps but also inside the storage (e.g. measurement of temperature, CO, CO<sub>2</sub>), after sieving (e.g. amount of fines) and at the delivery point of the end user or retailer. It is possible to set more critical control points. However, this has to be mentioned in the documentation. The complaint management makes it affordable to have a complete traceability along the supply chain. All operators in the supply chain are responsible for the traceability of the origin and source of the material delivered by them. The first operator is responsible for the documents being prepared the first time. The documents shall be available and provided on justified request throughout the entire supply chain according to EN 15234-1. This quality assurance combined with certification system (see next chapter) provides a high level of quality and health safety for the users. However, both product standard and quality standard EN 15234 are developed and applicable only for non-industrial use mostly on small scale.

## 7.4 Certification Systems

The key objective of a certification system for pellets is to secure the supply of pellets that comply with the requirements of the according standards. The EU pellet standard EN 14961-2 was an important step to create a harmonized set of wood pellet qualities. A European quality certification scheme is crucial to simplify work of the pellets producers and increase confidence by pellets equipment manufacturers and consumers. There are several voluntary certification scheme available in Europe (e.g. DINplus). Among them ENplus is the most advanced since it covers not only pellet quality but also various other steps along the supply chain. Furthermore, it includes a quality control and management part (including obligations for documentation) and allows for a traceability of problem to the corresponding raw materials and production conditions. A scheme that would be accepted both by the small scale heat market and the medium/large scale industrial users will improve flexibility and fluidity of the market, thereby improving delivery reliability and reducing detrimental price peaks.

#### 7.4.1 European Pellet Council - Handbook for the Certification of Wood Pellets for Heating Purposes (ENplus)

For wood pellets the ENplus certification scheme was developed by the German Pellets Association (DEPV). The ownership of the ENplus trade mark stays with the European Biomass Association AEBIOM, which hosts the European Pellet Council. The right to award the license to use the ENplus brand to qualifying companies is passed on from AEBIOM to national pellet associations that apply. In Germany, it is the German Pellet Institute, for Austria Propellets Austria is responsible. In Austria and Germany about 90% of the produced pellets are ENplus. In contrast, there is only one Danish pellet producer certified according to ENplus and none in Sweden so far.

Businesses whose products and practices consistently prove conformity with the relevant standards are allowed to use labels certifying the compliance with the standard (Figure 52). These labels guaranty the required quality, safety and performance along the whole supply chain. Thus, the certification system combines aspects of EN 14961-2 and EN 15234-2 as well as ISO 9001.



Figure 52: ENplus certificate logo for A1 class

With the classes ENplus-A1 and ENplus-A2, as well as the class EN-B, three wood pellet qualities are defined that ensure pellet qualities according to the European standard EN 14961-2, "Solid biofuels – Fuel Specifications and Classes –Part 2: Wood pellets for non-industrial use". Furthermore, it guarantees that production, handling and storage of the pellets are performed in accordance with the requirements of EN 15234-2. The certification system contains the following essential points:

- Requirements for wood pellet production and quality assurance
- Requirements for the product (EN 14961-2)
- Requirements for labeling, logistics and intermediate storage
- Requirements for the delivery to end customers



Internal quality management and control ensures that the set product requirements are maintained. Requirements for technical facilities, operation procedures and documentation are defined, which make the operation processes transparent and should lead to a rapid identification and solving of problems. Companies displaying the ENplus quality label are regularly inspected by independent experts and have to comply with extensive quality guidelines.

#### 7.4.2 Other European Certification Systems

Before the ENplus certification system was developed and implemented other voluntary systems existed on national base. Some of these systems are still in force but will run out or will be transformed into European system. Most of the national certification systems are decreasing in relevance and acceptance on the market since the European certification system was implemented in 2011.

In Germany the “DINplus” system, certified by DINCertco, is still in use. It is based on former German and Austrian standards but is now based on the existing European standards EN 14961-2. 80% of the German pellet production is certified to DINplus and the system is also used in neighboring countries, e.g. Austria and France. This system certifies pellet producers for the production of wood pellets according to the A1 class of EN 14961-2. However, DINplus covers neither a quality assurance nor the transportation aspect. Regular inspections are not mandatory.

The Austrian certification system “ÖNorm-M 7135 tested” was introduced by the Austrian Standardization Organization. To ensure the quality of wood pellets according to ÖNORM M 7135 between the producer and the customer, in ÖNORM M 7136 requirements for transportation and storage are determined. Due to this, quality of wood pellets during transport and storage can be ensured. When operating in accordance with this certification system, pellets manufacturers, transport companies, operators of intermediate warehouses and distributors avoid errors. In addition to the above standards, ÖNORM M 7137 provides essential requirements for the specification and design of pellets storages. Storages built according to ÖNORM 7137 ensure the operational safety, fire safety, the structural requirements and the maintenance of pellet quality. Anyhow, the certification system had run out at the end of 2012 but certified producers and traders can use this certificate till it expires.

The pellet quality certification labeled Pellet Gold is a voluntary certification system introduced by Italian pellet association AIEL (L'Associazione Italiana Energie Agroforestali) and started in 2006 to monitor the pellet quality in Italy. Before the introduction of Pellet Gold it was not mandatory for pellet producers, traders and importers to provide clear information concerning product characteristics, quality certification and the full address of the manufacturer, trader and importer. Surveys covering the Italian production clearly showed that the quality of pellets produced by Italian companies has improved significantly since the introduction of Pellet Gold. Since 2011 the “Pellet Gold” system was adapted to be in line with the EN 14961-2 standard.

Pellet Gold aims at insuring that pellet production meets the standards outlined in the certification requirements. It is the only European certification system that also contains formaldehyde (HCHO) testing, essential in order to detect the presence of materials (glues and paints) dangerous to the health of consumers, as well as the presence of radioactivity.

NF Biocombustibles is a certification scheme of AFAQ - AFNOR, a French certification organization in different kind of markets. AFAQ mandated the FCBA (France Cellulose Bois Ameublement) for the management of this certification. This system includes a real delivery certification scheme for the retailers. The “NF BIOCMBUSTIBLES SOLIDES” brand also includes charcoal and wood-logs. Certification of pellets according to NF guarantees compliance with the relevant requirement as e.g. dimensions, moisture, the level of fines and mechanical durability. Besides that the distributor of bulk pellets must also be certified NF to ensure the quality of the product in the silo. The following aspects have to be controlled:

- level of fines at each stage of conditioning or storage
- meet a minimum length of pipe in the delivery
- vacuuming fine unloading
- monitor and adjust the blowing pressure
- staff training
- separate storage of granules according to NF from non-certified pellets
- indicate the quantity delivered

Table 10 provides an overview of national product standards and certification systems for the countries/regions Germany, Austria, Switzerland, Italy, France, Sweden and Scandinavia in comparison to the European standard (Döring 2010, Witt 2012, translated and adapted by author). It shows the variation in the countries regarding relevant parameters e.g. ash content, ash melting behavior or size. While the quality requirements are harmonized by the European standard EN 14961-2 there are still differences in the voluntary certification systems. The differences hamper the free trade of pellets within the EU because quality is hardly comparable when different quality requirements and certification systems are applied.



## 7.5 Further Guidelines

In addition to the standards, there are other guidelines and regulations. Typically, they are created by professional organizations and associations of the affected industries. These guidelines often occur when official standards and regulations do not yet exist or existing standards do not fulfill a necessary quality for the end-use. This is the case for the storage of pellets mainly for the industrial use and the storage of large quantities.

### 7.5.1 Nordic Innovation Centre – Guidelines for Storing and Handling of Solid Biofuels

This best practice guideline gives recommendations for utilizing available knowledge, experience, methods and technology in storage and handling to secure the quality of the solid biofuel and to minimize health and safety risks. It is intended for persons and organizations that manufacture, plan, sell, install or use machinery, equipment, tools and entire plants related to the production, purchase, sale and utilization of these fuels on a commercial and industrial level. The guideline is not addressed to single households and individual small producers. It was published in October 2008. This guideline covers several woody biomass fuels and not exclusively wood pellets.

With regard to health risks related to off-gassing, this guideline recommends to measure the gas composition before entering storages. Exposure levels and personal exposure can be minimized by structural and technical measures, work arrangement and by use of proper personal protection. A list of the national limit values for gas emissions in Denmark, Sweden and Finland is given in the annex. To prevent self-heating and fire it should be avoided mixing different types of fuels, mixing fuel batches with different moisture contents, high amount of fines and in general large storage volumes, especially when the risk for spontaneous ignition is unknown. Besides this, the guideline gives information about the risks of fire and explosion, molds and other micro-organisms and organic dusts and how to prevent these risks.

### 7.5.2 DEPV - Recommendations for Storage of Wood Pellets

The original guideline was developed in German by the German Wood Fuel and Pellet Association (DEPV) and translated into English. The guideline is aimed at private households constructing pellet storage facilities not larger than 10 tons of storage. The document is designed very user friendly addressing particularly little experienced users. The guideline includes the following sections:

- Safety in regards of off-gassing and fire
- Certified fuel
- Storage of wood pellets – This includes the location of the storage room, accessibility of the pellet storage silo and the filling operation.
- Purpose-built storage facilities – detailed information is provided on the requirements of purpose-built storage systems.



- Construction examples of purpose-built silo systems – This chapter covers above ground mountings, silos for below-ground storage and examples of storage systems.
- Homemade storage systems – Detailed information is included that allows comparison with alternative homemade storage methods.
- Construction examples of pellet silos – Four different construction examples are described.
- Monitoring systems for silos – Two different methods are briefly explained.
- Fire protection measures at the silo – This is mostly explained through the use of diagrams that explain what actions need to be carried out.

Clear information on the dangers from off-gassing has to be exhibited at the entrance of the pellet storage. It should make aware of the risks of emissions from biomass. Therefore, it is crucial to ensure well ventilation for at least 30 minutes before entry. Additionally the use of special ventilation cap systems for pellet storages provides a reliable solution to prevent high amounts of dangerous gases because the ventilation caps can ensure a regular air-exchange.

### 7.5.3 German Engineering Association (VDI) -Emission Control - Storage of Wood Pellets at the End-user - Requirements for the storage room concerning safety aspects

Within this guideline, requirements for specification and design of pellet storage up to a capacity of about 100 tons are given. These requirements serve to prevent and mitigate potential issues or risks in pellet storage. They are based on the exclusive use of pellets according to EN 14961-2. The directive is aimed at all people that build operate or monitor a pellet store. It was published in September 2012 as a draft version. The final version should follow shortly.

Regarding safety relevant aspects, the guideline gives advices about safe delivery of bulk pellets to the end consumer by specialized pellets-transporter, the filling and equipment in storages and feeding to the heating system. Different aspects with regards to the storage size are mentioned on the warning signs which are highly recommended. In general, the entrance for unauthorized personal is prohibited. Special attention was given on the ventilation of storages and the supervising of CO emissions. In particular these are:

- Protection against electrostatic charging during filling
- Follow ATEX regulations for lightning within the storage
- Ensure proper ventilation prior to entering the storage (recommended ventilation cap)
- Switch off combustion device prior to filling to prevent back burning
- Strict recommendations for protective actions prior to entering of storage (ensure proper ventilation by opening the storage of at least 15 minutes before entering and leave doors open during presence)
- For large storages (>40 tons) CO level should be monitored

Besides, the guideline provides recommendations for explosion protection and sound insulation.

#### 7.5.4 International Maritime Organization (IMO) - International Maritime Solid Bulk Cargoes (IMSBC) Code

The International Maritime Organization's (IMO) main task has been to develop and maintain a comprehensive regulatory framework for shipping and its responsibility today includes safety, environmental concerns, legal matters, technical co-operation, maritime security and the efficiency of shipping. As a result of changes in world trade, new solid bulk cargoes with their own particular hazards are often introduced and presented for shipment (IMSBC). These international maritime solid bulk cargoes shall be labeled with an IMSBC code. The IMSBC Code replaced the Code of Safe Practice for Solid Bulk Cargoes (BC Code), which was first adopted as a recommendatory code in 1965 and has been updated at regular intervals since then. One of these codes relates directly to wood pellets. The format of the IMSBC Code is similar to that of the existing BC Code. Just like the BC Code, the IMSBC Code categorizes cargoes into three groups: A, B, and C. The more detailed requirement as to each cargo type is stated in individual schedules. The development and inclusion of wood pellets in the coding system was requested by Canada as a result of accidents in ocean vessels carrying wood pellet. The present code includes description of material characteristics that could result in hazardous conditions during transport, such as oxygen depletion and off-gassing. The code stipulates operational requirements such as entry permit, gas monitoring and fire extinguishing practices. Compliance with the amendments is mandatory since 1. January 2013.

#### 7.5.5 Material Safety Data Sheet (MSDS) from Wood Pellet Association of Canada (WPAC)

In Canada, every material that is controlled by WHMIS (Workplace Hazardous Materials Information System) must have an accompanying MSDS that is specific to each individual product or material (both the product name and supplier on the MSDS must match the material in use). The Wood Pellet Association of Canada (WPAC) developed two Material Safety Data Sheets (MSDSs) for bulk and bagged pellets that provide advice related to the off-gassing issue, including formulas for predicting the amount of off-gassing and oxygen depletion. One of the key recommendations is that all persons working in areas where large amounts of pellets are handled and stored should at all times be equipped with a well-maintained combined oxygen/carbon-monoxide meter. Using only one or the other could easily generate a false sense of safety. The MSDS, separated in 11 sections according to the Canadian regulation Bill C-45, gives detailed information about gas emissions and corresponding health relevant limit values and first aid measures. Furthermore, it provides recommendations how to handle fire and explosion measures during storage in open and enclosed space and how safe handling can be assured. For safe handling and storing the MSDS highly recommends the following precautionary measures to avoid hazardous conditions (Figure 53).



State of Wood Pellets	Precautionary measures
General	Always store Wood Pellets in space with a minimum of 1 air exchange per 24 hours at + 20°C and a minimum of 2 air exchanges per 24 hours at + 30°C and above.
	Protect the Wood Pellets from moisture penetration to avoid swelling, increased off-gassing, self-heating and increased microbial activity.
	Always protect Wood Pellets from direct penetration by heat sources, sparks, halogen lamps and exposed electrical circuitry which could set off a fire or explosion.
	Always segregate the Wood Pellets from oxidizing agents or in-compatible materials.
	Do not expose Wood Pellets to rain.
	Do not smoke in the vicinity of Wood Pellets or wood dust.
During handling	Install heat and gas detectors with alarm.
	Avoid breakage caused by dropping the Wood Pellets.

Figure 53: Precautionary measures for wood pellets (source: MSDS of WPAC)

## 8. Problem Areas Not Solved Within Existing Standards and Guidelines

It appears so far that only for high-quality pellets adequate solutions have been found. The existing standards and quality securing certification systems provide in a comprehensible manner handling advices for small scale user of pellets. But it must come more in focus that pellets are a fuel and therefore have to be handled similarly like oil or gas. Especially inexperienced users have to be informed about potential health risks from gas emissions.

A gap in the existing rules is the lack of a minimum storage period at the pellet producer side. As described before, freshly produced pellets seem to bear a higher emission potential than pellets stored for a certain period. Also the temperature to which fresh pellets should be cooled before being stored is not a fixed value. Only the ENplus certification system has the requirement that pellets before delivery to the end-consumer shall not exceed 40°C. Comparable regulations do not exist for the pellet fabrication sites.

For the pellet used in large, industrial scale, safety problems are not entirely sufficient solved. Here are the highest risks in regards to off-gassing and self-heating during transport and storage. Especially for this user group, solutions have to be found because the strong increase in terms of use and production might result in potential dangers that have to be considered. The quality requirements are different compared to those for premium pellets. The combustion technology and the logistic facilities as presented in this report largely determine the quality requirements. Therefore, not all industrial actors have the same technical specifications.

For future use of wood pellets the implementation of MSDS is a useful step. In addition, large scale users are interested to build up a reliable system in the form of standards and certifications. The Wood Pellets Buyer Initiative (WPBI), a coalition of industry scale users, are developing relevant agreements and want to introduce them to the international standardization process at ISO level. A suggestion from Sweden was introduced on the ISO meeting in March this year and it was agreed to start working on several documents related to safety issues of pelletized biofuels. Furthermore, incorporation of SafePellets results to the development of ISO standards is foreseen within the project duration and will be realized by SP. However, at the moment there is neither a standard, nor label of quality for wood pellets for the industrial scale use. The WPBI gathering the main utilities using wood pellets in Europe in large scale aims at defining such reference for technical specifications. An overview of these requirements can be seen on the table of the WPBI in the Annex 10.7. Their approach is complemented by consultation of the audit companies and wood pellet producer. The main interest is in knowing the technical parameters they have to comply with to avoid any risk of contractual problems and ensure their access to bulk market (PellCert 2012 b).

According to the "First international workshop on pellet safety" taking place in Fügen (Austria) from 4<sup>th</sup> – 6<sup>th</sup> March 2013 the increase of pellet safety has to be realized by a multistep



approach. As one of the main problems, the limited knowledge base for the underlying reasons of some safety risks was identified. Thus, at the current state it is difficult to find precautional actions. Rather, the handling of known risks has to be addressed. Among the main issues are the storage risks. It was intensively discussed if the safe storage has to be limited to a certain size. As well, the proper monitoring to identify problems before they get serious and the according correct reaction to a detected problem was of great relevance. An intense dialogue was initiated that should help to develop guidelines based on the extensive pool of experience that is already available among the actors along the supply chain. However, the progress to merge these experiences to accomplish a higher safety level has just started.

Topics that will be included are:

- ensuring safety during production
  - in particular dust explosion
  - prevent problems in the following storage and transportation step by sufficient quality control based on already available knowledge (reaction of fines, proper durability, sufficient cooling)
- ensuring safety during storage
  - in particular how to store, what to measure and how to react
- ensuring safety during transport and supply
  - monitoring, gentle handling
- ensuring safety at end-consumer (small scale)
  - dedicate storages according to already existing guidelines
  - home-made storage solutions
  - proper information and training of pellet supplier to ensure higher safety standards

## 9. Indexes

### 9.1 Index of Tables

Table 1: Composition of woody biomasses in Mass-% on dry basis (Kaltschmitt 2009) .....	10
Table 2: Characteristics of selected non-woody biomasses (MixBioPells 2012) .....	11
Table 3: Requirements for outdoor storage of pellets .....	17
Table 4: Overview of user groups and transport .....	20
Table 5: Overview of European pellet demand in tons .....	29
Table 6: Pellet-use in Sweden (source: PIR) in tones.....	42
Table 7: Origin of Pellet Imports to EU 27 (Pellcert 2012) .....	45
Table 8: Inter-European pellet export.....	46
Table 9: Stipulated test according to EN 14961-2.....	56
Table 10: Characteristics of European pellet standards .....	63

### 9.2 Index of Figures

Figure 1: Process steps for pellet production .....	11
Figure 2: Flat die press (VTT 2002) .....	13
Figure 3: Ring die press (Source: www.salmatec.de) .....	13
Figure 4: Supply chain of pellets .....	14
Figure 5: Typical A-frame storage at a harbor (www.shippingmovements.co.za) .....	15
Figure 6: Pellet silo of 2200 tons capacity (www.ostschweizerpellets.ch) .....	15
Figure 7: Example of a small volume push bar storage (Nordic Innovation Center 2008) .....	16
Figure 8: Example of large volume crab crane storage for wood fuel capacity of 20 MW (Nordic Innovation Center 2008) .....	16
Figure 9: Below-ground silo made of synthetic materials, discharged from the bottom of the storage (DEPV 2011) .....	17
Figure 10: Below-ground silo made of concrete, discharged from the top of the storage .....	17
Figure 11: Different indoor pellet storage systems (DEPV 2011) .....	18
Figure 12: Examples of self-build pellet silos (DEPV 2011).....	19
Figure 13: Ship for ocean transport (Melin 2012).....	21
Figure 14: Pneumatic ship pellets unloading system (www.bulkinside.com).....	21
Figure 15: Wagon for bulk pellets (Melin 2012).....	21
Figure 16: Train transport for pellets (Melin 2012) .....	21
Figure 17: Rail- and shipping routes in North America (Source: North American Railroad) .....	22



Figure 18: Truck for loose pellet delivery .....	23
Figure 19: Delivery of bagged pellets (www.sabi.se).....	23
Figure 20: Pellets in big bags (www.holzenergie.de).....	24
Figure 21: Global pellet consumption and outlook (Pöyry, 2012) .....	25
Figure 22: Global pellet production and outlook (Pöyry, 2012).....	26
Figure 23: Global wood pellet production and consumption (IEA Task 40, 2012).....	26
Figure 24: Wood pellet production capacity by country worldwide (IEA Task 40, 2012).....	27
Figure 25: Production and consumption of wood pellets worldwide (Source: IEA 2012) .....	28
Figure 26: Production and consumption of wood pellets in the EU (source: IEA 2012) .....	28
Figure 27: Number of pellet heating systems in commercial sector .....	31
Figure 28: Number of pellet heating systems in public sector .....	31
Figure 29: Number of pellet boilers and stoves in the private sector .....	32
Figure 30: Pellet producer according to size class .....	33
Figure 31: Austrian pellet production according to size class .....	34
Figure 32: Estimated production and capacity in Austrian pellet industry .....	34
Figure 33: Pellet production and trade in Austria 2010 (Propellets Austria) .....	35
Figure 34: Wood pellet consumption in Denmark (IEA Task 40, 2012).....	36
Figure 35: Current and estimated production and capacity of Danish pellet industry .....	36
Figure 36: Feedstock mix in the Danish pellet industry .....	37
Figure 37: Proportion of size class by capacity.....	38
Figure 38: Amount of pellet-facilities per size class .....	38
Figure 39: Estimated production and capacity of German pellet industry .....	39
Figure 40: Produced pellet quality in Germany.....	39
Figure 41: Quantity of pellet production per size-class .....	40
Figure 42: Proportion of size-class by capacity .....	41
Figure 43: Production and capacity of Swedish pellet industry .....	42
Figure 44: Pellet quality in Sweden.....	43
Figure 45: International trade flows (Pöyry, 2012) .....	44
Figure 46: Warning advice for pellet stores (DEPV, 2011) .....	49
Figure 48: Linkage between legislation and standardization .....	53
Figure 49: Interacting of CEN standards for wood pellets .....	54
Figure 50: European standards for solid biofuels .....	55
Figure 51: Controlled supply chain according to EN 15234-2 .....	57
Figure 52: Assurance system along the supply chain according to EN 15234.....	58
Figure 53: ENplus certificate logo for A1 class .....	60

Figure 54: Precautionary measures for wood pellets (source: MSDS of WPAC) ..... 67



## 10. Bibliography

### AEBIOM 2011

European Biomass Association - AEBIOM; *2011 ANNUAL STATISTICAL REPORT ON THE CONTRIBUTION OF BIOMASS TO THE ENERGY SYSTEM IN THE EU 27*, Brussels 2011

### Curci, 2011

Curci, M.; *BULK PELLET BEHAVIOUR*, Canadian Biomass Magazine, Simcoe, March 2011  
[<http://www.canadianbiomassmagazine.ca/content/view/2399/63/>]

### DEPV 2011

Deutscher Energieholz- und Pellet-Verband e.V. (DEPV), *EMPFEHLUNGEN ZUR LAGERUNG VON HOLZPELLETS*, Trans. Kofman, P.D. 2012. Recommendations for storage of wood pellets, Irish edition COFORD, Dublin ISBN: 978-1-902696-71-3, 2011

### Döring 2010

Döring, S.; *PELLETS ALS ENERGIETRÄGER – TECHNOLOGIE UND ANWENDUNG*, Springer Verlag, Heidelberg 2010, ISBN 978-3-642-01624-0

### EUBIA 2009

Sénéchel S.; et.al., *LOGISTIC MANAGEMENT OF WOOD PELLETS: DATA COLLECTION ON TRANSPORTATION, STORAGE AND DELIVERY MANAGEMENT*, EUBIA – European Biomass Industry Association, Brussels, pellets@tlas project report, October 2009  
[[www.pelletsatlas.info](http://www.pelletsatlas.info)]

### EUBIA 2012

European Biomass Industry Association - EUBIA, [<http://www.eubia.org/154.0.html>]  
(sited 10.01.2013)]

### Holz-Zentralblatt 2012

Anonymous; *HAFEN AMSTERDAM WILL PELLET-UMSCHLAG VERVIELFACHEN*, Article, Issue 39 p. 981, DRW-Verlag Weinbrenner, Leinfelden-Echterdingen 2012,

### IEA Task 40, 2011

Cocchi, M., et. al.; *GLOBAL WOOD PELLET INDUSTRY – MARKET AND TRADE STUDY*, Report IEA Bioenergy Task 40: Sustainable International Bioenergy trade, 2011  
[<http://www.bioenergytrade.org/reports/country-reports-2010/index.html>]

### Kaltschmitt 2009

Kaltschmitt M, Hartmann H.; *ENERGY FROM BIOMASS—PRINCIPLES, TECHNIQUES AND METHODS*, Springer Verlag Berlin, 2009

### Melin 2012

Melin S.; *DESIGN OF LOGISTICS FOR REGULAR AND TORREFIED PELLETS (TRANSPORTATION AND STORAGE)*, UBC Presentation from 20th March 2012  
[<http://www.bcbioenergy.com/wp-content/uploads/2012/03/Staffan-Melin-2012-03-20-UBC-Korea-Presentation.pdf> (seated 16.01.2013)]

### MixBioPells 2012

Pollex, A. et.al.; *HANDBUCH FÜR INITIATOREN*, Project-report April 2012, , IEE-project  
[[www.mixbiopells.eu](http://www.mixbiopells.eu)]

### Nordic Innovation Center 2008

NT METHOD – *GUIDELINES FOR STORING AND HANDLING OF SOLID BIOFUELS*, Nordic Innovation Centre, Oslo, 2008, Nt envir 010

Obernberger 2010

OBERNBERGER; I., ET.AL; *THE PELLET HANDBOOK – THE PRODUCTION AND THERMAL UTILISATION OF BIOMASS PELLETS*, EARTHSCAN LONDON 2010

PellCert project 2012

Audigane, N.; et.al., *European Pellet Report*, PellCert project report, April 2012, Supported by Intelligent Energy Europe , Project number IEE/10/463/S12.592427

PellCert project 2012 b

Verhoest, C., et.al.; *Industrial Wood Pellets Report*, PellCert project report, March 2012, Supported by Intelligent Energy Europe , Project number IEE/10/463/S12.592427

PIR 2012

Pelletsindustrins Riksförbund; *Leveransstatistik Sverige*,  
[<http://www.pelletsforbundet.se/web/Leveransstatistik.aspx> (sited 06.02.2013)]

Pöyry 2012

Lechner, H.; et.al.; *Pellets – Becoming a global commodity?*  
*Pöyry view point: Global market, players and trade to 2020 study*, Pöyry London, 2012

Sälkimäki 2010

Sälkimäki, M.; et. al.; *Present and future in pellet markets, raw materials and supply logistics in Sweden and Finland*, Renewable and Sustainable Energy Reviews 14, 2010 3068-3075

Solar Promotion 2012

Anonymous, *Marktübersicht Pelletsproduktion in Deutschland*, Article, pellets – Markt und Trends, Issue 06-12, page 28, Solar Promotion GmbH, Pforzheim 2012

Solidstandards 2011

Alakangas, E., et.al.; *Enhancing the implementation of quality and sustainability standards and certification schemes for solid biofuels*, Solidstandards project report, December 2011, Supported by Intelligent Energy Europe (EIE/11/218)  
[[www.solidstandards.eu](http://www.solidstandards.eu)]

UNECE/FAO Wood energy markets 2012

Aguilar, F., et. al.; *Wood energy market 2011-2012, UNECE/FAO Forest Products Market Review 2011-2012*, United Nations Publications, New York and Geneva, 2012

Urbanowski 2005

Urbanowski E. et. al.; Strategic analysis of pellet fuel opportunity in Northwest British Columbia, Project work, Simon Fraser University 2005  
[<http://summit.sfu.ca/item/10128> (seated 18.12.2012)]

VTT 2002

ALAKANGAS, E. ; PAJU, P.; *Wood pellets in Finland- technology, economy and market*  
OPET Report 5. Jyväskylä. VTT Processes, 2002. 64 p.+ app. 21p.

Witt, 2012

Witt, J.; *Holzpelletbereitstellung für Kleinfeuerungsanlagen – Analyse und Bewertung von Einflussmöglichkeiten auf die Brennstofffestigkeit*, DBFZ Report Nr. 14, Leipzig 2012, ISSN: 2190-7943



## Annex

### 10.1 List of Austrian Pellet Producer

<b>Company</b>	<b>Locations</b>	<b>Capacity 2012 [tons/year]</b>	<b>Production 2012 [tons/year]</b>	<b>Main Raw material</b>
Binderholz GmbH	Fügen, Jenbach, St. Georgen, Unterbernbach, Kösching (Ger)	300.000	250.000	
Cycleenergy Gaishorn GmbH	Gainshorn am See	25.000	25.000	
Firestixx Abtenau (GermanPellets)	Abtenau	50.000	n.i.	
Glechner GmbH (GermanPellets)	Mattighofen	70.000	60.000	
H & H Pellets GmbH	Stainach	n.i.	n.i.	
HASSLACHER Holding GmbH	Hermagor	55.000	55.000	
Holzindustrie Schweighofer	production in Romania	90.000	88.500	
Johann Pabst Holzindustrie GmbH	Zeltweg	60.000*	52.000*	
Ländle Pellets	Dornbirn	7500*	n.i.	
MAK-Holz	Haimburg	25.000*	24.000*	
Mayr Melnhof Pellets Leoben GmbH	Leoben	45.000	42.000	
Ökostixx GmbH	Reichramig	10000*	n.i.	
Pelletswerk Waldviertel GmbH	Rastenfelde	25.000	20.000	
Peter Seppel GmbH	Sachsenburg	60000*	60000*	
Pfeifer Holz GmbH & CO KG	Imst, Kundl	240.000	120.000	
RZ Pellets GmbH	Ybbs / Donau	200.000	170.000	
Schößwendter Holz GmbH	Saalfeld	28.000*	24.000*	
Sum		1.100.000	830.500	

n.s. ... not indicated

### 10.2 List of Danish Pellet Producer

<b>Company name</b>	<b>Location</b>	<b>Capacity 2012 [tons/year]</b>	<b>Production 2012 [tons/year]</b>	<b>Mainly used raw material</b>
Dansk Træemballage (DTE)	Ribe	75.000	60.000	Spruce residues from sawmill
Vattenfall	Køge	100.000	100.000	Straw
Steen's biobrændsler	Kjellerup	25.000	15.000	Mixed dry sawdust
Vapo	Vildbjerg	100.000	10.000	Mixed dry sawdust
Agroform	Agerskov	10.000	5.000	Mixed dry sawdust

## 10.3 List of German Pellet Producer

Company	Location	Production Capacity 2012 [tons/year]	Production 2012 [tons/year]	Raw material SMR = Sawmill residues SW = Stemwood RFW=Residual forest wood
ABW GmbH	Apolda	4.000	3.800	SMR
Allspan Spanverarbeitungs GmbH	Karlsruhe	Zentrale	-	
Allspan Standort Karlsruhe ante-Holz	Karlsruhe	8.000	3.000	SMR
ante-Holz	Bromskirchen- Somplar	52.000	n.i.	SMR
ante-Holz	Rottleberode	80.000	n.i.	SMR
Baust Holzbetrieb-GmbH	Eslohe-Bremke	20.000	15.000	SMR
Bayerwald Pellet GmbH	Regen	30.000	30.000	SMR
Binderholz Deutschland GmbH	Kösching	140.000	120.000	SMR
Bioenergie Sonnen Pellet GmbH	Buchenbach	50.000	n.i.	SMR
BioPell GmbH	Empfingen	90.000	65.000	SMR
EC Bioenergie GmbH	Heidelberg	Zentrale	n.i.	
EC Bioenergie Standort Hardegsen	Hardegsen	60.000	n.i.	SMR
EC Bioenergie Standort Kehl	Kehl	50.000	n.i.	SMR
EC Bioenergie Standort Mittenaar	Mittenaar	115.000	n.i.	SMR
Energiepellets Hosenfeld GmbH	Hosenfeld	42.000	35.000	SMR
German Pellets GmbH	Wismar	Zentrale	787.500	
German Pellets Wismar	Wismar	256.000		
German Pellets Herbrechtingen	Herbrechtingen	256.000		
German Pellets Ettenheim	Ettenheim	128.000		
German Pellets Torgau	Torgau	150.000		
German Pellets Oranienbaum	Oranienbaum	75.000		
German Pellets Heidegrund	Heidegrund	60.000		
German Pellets Löbau	Löbau	60.000		
German Pellets Erndtebrück	Erndtebrück	120.000		
German Pellets Pfarrkirchen	Pfarrkirchen	20.000		
Hanse Pellet GmbH & Co KG	Buchholz	45.000	30.000	SMR



Table (continued)

Company	Location	Production Capacity 2012 [tons/year]	Production 2012 [tons/year]	Raw material SMR = Sawmill residues SW = Stemwood RFW=Residual forest wood
Holzwerk Grasellenbach Monnheimer GmbH & Co. KG	Gras Ellenbach	9.000	1.000	SMR
Holzwerke Weinzierl GmbH	Vilshofen	115.000	90.000	SMR
Juwi Bio Service und Betriebs GmbH/ Rio Holzenergie GmbH & Co KG	Morbach	16.000	n.i.	SMR
Juwi Rio Holzenergie Standort Bad Arolsen	Bad Arolsen	15.000	n.i.	SMR
Juwi/Rio Holzenergie Standort Dotternhausen	Dotternhausen	15.000	n.i.	SMR
Juwi/ Rio Holzenergie Standort Langelsheim	Langelsheim	60.000	n.i.	SMR
Megapellet Energy GmbH	Hürtgenwald	40.000	n.i.	SMR (0,45), SW(0,25), RFW (0,3)
Moselpellets Standort Trier	Trier	0	0	SMR
Moselpellets Standort Rötweiler	Rötweiler	10.500	6.500	SMR
Pfeifer Timber GmbH	Unterbernbach	150.000	110.000	SMR
I. van Roje und Holzhandlung GmbH & Co. KG	Oberhonnefeld	48.000	42.000	SMR
Timbory ( Haas Holzprodukte GmbH)	Falkenberg	10.000	6.000	SMR
Sägewerk Schwaiger GmbH & Co. KG	Hengersberg	140.000	120.000	SMR
Schellinger KG	Krauchenwies	50.000	n.i.	SMR (0,8), SH (0,2)
Westerwälder Holzpellets GmbH	Langenbach	42.000	35.000	SMR (0,5), SW (0,15)
Westpellets GmbH	Titz	20.000	11.000	SMR
further 16 companys with 18 production sites		868.000	637.000	
Sum		3.519.500	2.527.900	

Source: Solar Promotion GmbH 2012

n.i. = not indicated (For companies who have not indicated the production a capacity utilization of 70% was assumed)

## 10.4 Map of German Pellet Producer





## 10.5 List of Swedish Pellet Producer

Company	Location	Capacity	Production	Capacity	Production
		2011 [tons/year]	2011 [tons/year]	2012 [tons/year]	2012 [tons/year]
SEA BioNorr	Härnösand	160.000	150.000	160.000	142.000
Stora Enso Kopparfors Sågverk	Norrundet	160.000	111.000		
Neova	Vaggeryd	110.000	108.000	110.000	100.000
Laxå Pellets	Laxå	118.000	95.200	125.000	100.000
Lantmännen Agroenergi	Norberg	100.000	92.400	110.000	102.000
Lantmännen Agroenergi	MalmbäEk	100.000	92.300	100.000	95.000
Lantmännen Agroenergi	UlriEehamn	100.000	91.700	100.000	92.000
Skellefteå Kraft	Hedensbyn	130.000	87.000	130.000	80.000
Bioenergi i Luleå	Luleå	105.000	82.500	105.000	95.000
Stora Enso Gruvöns Sågverk	Gruvön	100.000	82.000	100.000	88.000
Rindi Biobränsle	Älvdalen	70.000	60.000	70.000	70.000
BooForssjö Energi	Forssjö	54.000	55.000	54.000	54.000
Neova	Främlingshem	67.000	52.200	67.000	60.000
Neova	Forsnäs	90.000	51.100	90.000	48.000
Rindi Biobränsle	Vansbro	66.000	50.000	66.000	61.000
Derome Bioenergi	Kinnared	70.000	44.000	70.000	55.000
PemEo Träpellets	Säfte	40.000	35.000	40.000	35.000
Skellefteå Kraft	Storuman	105.000	35.000	105.000	45.000
Vida Energi	Hok	50.000	32.000	50.000	40.000
Neova	Ljusne	40.000	29.400	40.000	37.000
Fågelfors Hyvleri	Fågelfors	25.000	21.500	30.000	28.000
SEA BioNorr	Stugun	19.000	18.000	19.000	18.000
MoEkfjärds Biobränsle	MoEkfjärd	30.000	16.000	30.000	18.000
Södra Skogsenergi	Långasjö	35.000	15.000	35.000	25.000
Stenvalls Trä	Sikfors	30.000	15.000	30.000	20.000
StoEkhorvan Trä & Pellets	Hultsfred	20.000	12.000	20.000	16.000
HMAB	Sveg	65.000	12.000	65.000	12.000
Pajala Bioenergi	Pajala	18.000	10.000	18.000	12.000
Klintpellets f.d. MBAB	Överklinten	30.000	10.000	30.000	20.000
Smålandspellets	Korsberga	30.000	10.000		
Ystad Pellets	Ystad	90.000	10.000		
Alfta Skogstekniska	Alfta	3.000	3.000	3.000	3.000
Norrlands Trä	Älandsbro	12.000	8.500	12.000	9.500
Ölmstad Träförädling	Ölmstad	8.000	7.000	8.000	8.000

Table (continued)

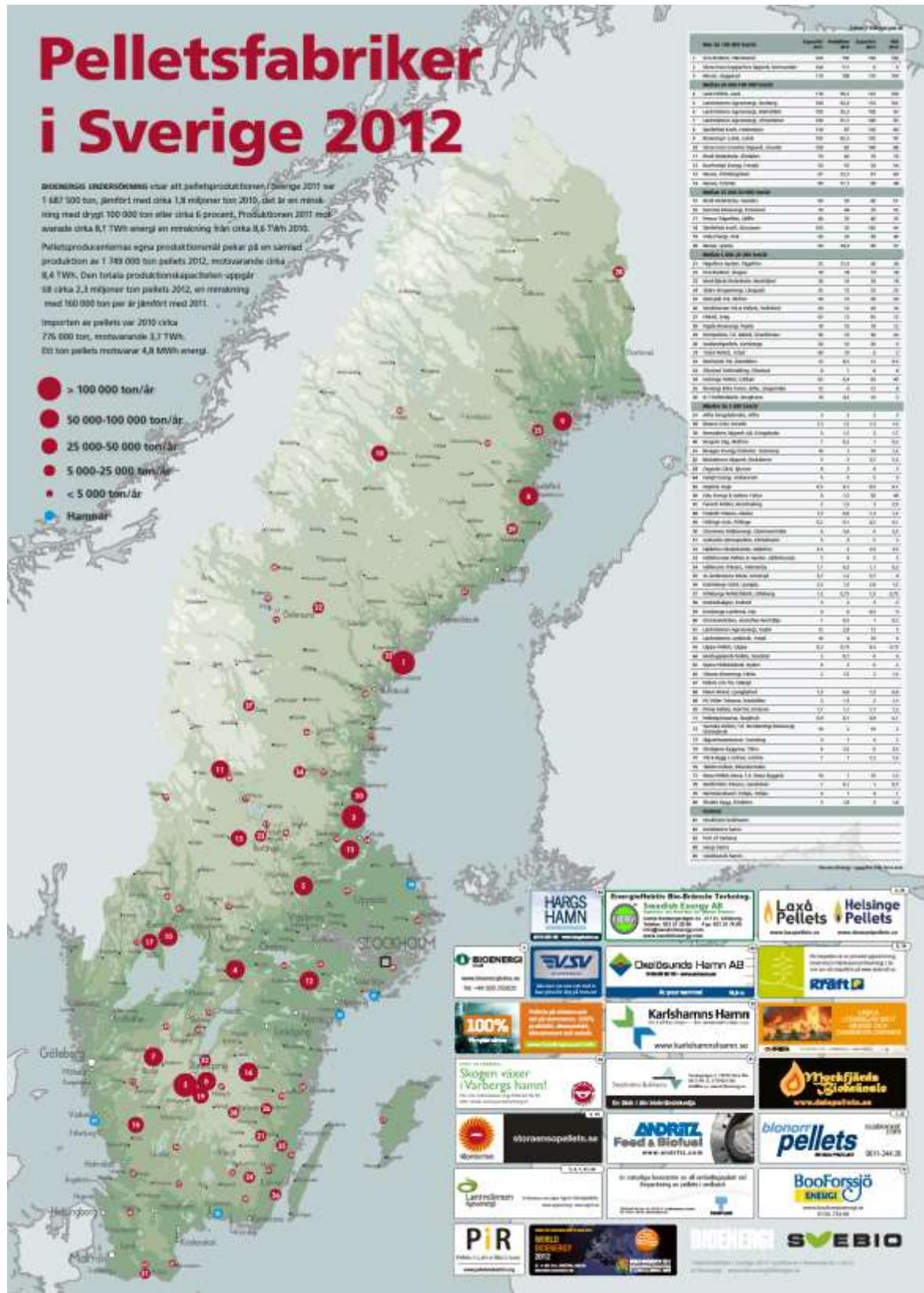
Company	Location	Capacity	Production	Capacity	Production
		2011 [tons/year]	2011 [tons/year]	2012 [tons/year]	2012 [tons/year]
Helsinge Pellets	Edsbyn	65.000	6.400	65.000	40.000
Bionergi Böta Kvarn	Böte	12.000	6.000	12.000	8.000
	Långemåla				
N T Pelletsfabrik	Bergkvara	10.000	4.500	10.000	3.000
BaseEo Golv	Sorsele	1.300	1.200	1.300	1.200
Bennsätters Sågverk AB	Eringsboda	3.000	1.700	3.000	1.700
Bergom Såg	Matfors	1.000	200	1.000	200
Bioagro Energy Österlen	Tommarp	10.000	1.000	10.000	1.500
BäEkebrons Sågverk	BäEkebron	5.000	5.000	5.500	5.500
Dagsnäs Gård	Bjurum	6.000	3.000	6.000	3.000
Dalsjö Energi	Dnkarsrum	5.000	3.000	5.000	3.000
Dejesträ	Deje	500	100	500	100
Falu Energi & Vatten	Falun	0	1.500	50.000	40.000
Femett Pellets	Nordmaling	2.000	1.500	3.000	2.500
Fredells Trävaru	NaEka	1.300	900	1.300	1.200
Föllinge Golv	Föllinge	200	100	200	100
Glommers Miljöenergi	Glommersträsk	6.000	3.600	6.000	3.500
Gotlands Värmepellets	Klintehamn	5.000	3.000	5.000	3.000
Hällefors Ekobriketter	Hällefors	3.500	3.000	3.500	3.500
Hälleforsnäs Pellets & Hyvleri	Hälleforsnäs	5.000	4.000	5.000	5.000
Hällerums Trävaru	Vimmerby	1.100	300	1.100	300
JG Anderssons Söner	Linneryd	3.700	1.200		
Kastebergs Gård	Ljungby	2.500	1.500	2.800	1.500
Killebergs Pelletsfabrik	Killeberg	1.500	750	1.500	750
Knäredssågen	Knäred	3.000	2.000	3.000	2.000
Korsberga Lantbruk	Hjo	0	0		
Kriminalvården	Norrtälje	1.000	500	1.000	500
Lantmännen Agroenergi	Insjön	12.000	2.900	12.000	3.000
Lantmännen Lantbruk	Ystad	10.000	4.000	10.000	4.000
Läppe Pellets	Läppe	300	150	300	150
Nordupplands Pellets	Skutskär	3.000	700		
Nybro Pelletsfabrik	Nybro	6.000	2.000	6.000	2.000
Olssons Bioenergi	Färila	2.000	1.500	2.000	1.500
Pellets oEh Flis i Nässjö	Nässjö	0	0		
Plane Wood	Ljungbyhed	1.500	600	1.500	600
PO Hiller Trävaror	Runhällen	2.000	1.300	2.000	1.300



Table (continued)

Company	Location	Capacity	Production	Capacity	Production
		2011	2011	2012	2012
		[tons/year]	[tons/year]	[tons/year]	[tons/year]
Prima Pellets Norrträ	Krokom	1.700	1.100	1.700	1.300
Pelletspressarna	Skephult	900	100	900	100
Svenska Pellets f.d.	Strömsbruk	10.000	2.000	10.000	2.000
Nordanstigs Bioenergi					
SågverksassistanEe	Svanskog	4.000	1.000	4.000	2.000
Sörsågens Byggross	Tibro	6.000	3.500	6.000	3.500
Trä & Bygg i LoEkne	LoEkne	1.000	1.000	1.200	1.200
Tålebo Pellets	Blomstermåla	0	0		
Wasa Pellets Mora f.d. Wasa	Byggträ	10.000	1.000	10.000	1.500
Wallströms Trävaru	Sandviken	1.000	100	1.000	500
Wermlandsved i Höljes	Höljes	4.000	1.000	4.000	1.000
Älvdals Bygg	Älvdalen	3.000	1.800	3.000	1.800
<b>Sum</b>	<b>72</b>	<b>2.483.000</b>	<b>1.685.500</b>	<b>2.304.500</b>	<b>1.747.000</b>
	<b>production sites</b>				

## 10.6 Map of Swedish Pellet Producer





## 10.7 Industrial Wood Pellets Specifications from WPBI

WOOD PELLETS SPECIFICATIONS		Initiative Wood Pellets Buyers: Industrial wood pellets specifications				Remarks
27.04.2012	EN	11 industrial	12 industrial	13 industrial	Check performed by	
PARAMETERS AND REJECTION LIMITS 4	Standard	11 Forest, plantation and other virgin wood, 1.2.1.1 chemically untreated wood residues	12 Forest, plantation and other virgin wood, 1.2.1.1 Forest, plantation and other virgin wood, 1.2.1.1 chemically untreated wood residues	13 Forest, plantation and other virgin wood, 1.2.1.1 chemically untreated wood residues		
Origin and source	EN 14961-1	1.1 Forest, plantation and other virgin wood, 1.2.1.1 chemically untreated wood residues	1.1 Forest, plantation and other virgin wood, 1.2.1.1 Forest, plantation and other virgin wood, 1.2.1.1 chemically untreated wood residues	1.1 Forest, plantation and other virgin wood, 1.2.1.1 Forest, plantation and other virgin wood, 1.2.1.1 chemically untreated wood residues	insp & lab	
Sampling	EN 14778				insp	
Quality check	EN 14780				insp	
No water damage		None	None	None	insp	
No burned/charred pellets		None	None	None	insp	
Additives (composition, mass)	EN 14961	< 3% additives	< 3% additives	< 3% additives	insp	type and quantity to be stated
	OFGEM	sustainability proven for UK	sustainability proven for UK	sustainability proven for UK	declared by seller	
Physical parameters		Limit	Limit	Limit		
Diameter	EN16127	6 to 8	6 to 10	6 to 12	insp & lab	
Length ≤60 mm	EN16127	99.9%	99.9%	99.9%	insp & lab	
Length ≤40 mm	EN16127	99%	99%	99%	insp & lab	
Water content	EN14774	≤ 10 %	0.5% absolute	0.5% absolute	insp & lab	
Bulk (apparent) density	EN15103	≥ 600	≥ 600	≥ 600	insp & lab	
Maximum bulk temperature	EN15234-2	≤ 60	1°C	1°C	insp	Bulk maximal temperature to be checked when the pellets leave the final point of loading for delivery to the end-user, i.e. leaving the final storage point or the factory. This is the maximum temperature measured at any spot.
Net calorific value at constant pressure	EN14918	≥ 16.5	0.3 GJ/ton	0.3 GJ/ton	lab	
Ash content	EN14775	≤ 1.0%	10% of limit	10% of limit	lab	
Elementary composition						
Cl	EN15289	≤ 0.03%	0.01% absolute	0.01% absolute	lab	
N	EN15104	≤ 0.3%	0.05% absolute	0.05% absolute	lab	
S	EN15289	≤ 0.15 %	0.01% absolute	0.01% absolute	lab	
Trace elements						
As	EN15297	≤ 2	0.064 absolute	0.064 absolute	lab	
Cd	EN15297	≤ 1	0.06 absolute	0.06 absolute	lab	
Cr	EN15297	≤ 15	0.032 absolute	0.032 absolute	lab	
Cu	EN15297	≤ 20	0.043 absolute	0.043 absolute	lab	
Pb	EN15297	≤ 20	0.033 absolute	0.033 absolute	lab	
Hg	EN15297	≤ 0.1	0.0046 absolute	0.0046 absolute	lab	
Zn	EN15297	≤ 200	5.43 absolute	5.43 absolute	lab	
Fines ≤ 3.15 mm (round hole sieves)	EN15210-1	≤ 4 %	1% absolute	1% absolute	insp & lab	
Durability	EN15210	97.5-99%	0.5% absolute	0.5% absolute	lab	
Particle size distribution (square hole sieves)					lab	
% < 3.15 mm	EN16126	>99%	1% absolute	1% absolute	lab	
% < 2.0 mm	EN16126	>95%	2% absolute	2% absolute	lab	
% < 1.0 mm	EN16126	>60%	5% absolute	5% absolute	lab	
<b>Tolerance: instances where ISO doesn't have a tolerance</b>						
<b>Notes:</b>						
Generic wording to be included to cover water damage and burned pellets						
Performed by: -Lab: analyses will be performed by the independent laboratory; -Insp: test will be performed by the inspection company;						
-Insp & lab: means a field test will be performed by the inspection company, the final value will be analyzed by the lab						

## 10.8 MSDS for Bulk Pellets

**LOGO**

Company name (full legal name)

Issued May 5, 2009

**MATERIAL SAFETY DATA SHEET****WOOD PELLETS IN BULK**

For Wood Pellets in Bags, see  
**MATERIAL SAFETY DATA SHEET for Wood Pellets in Bags**  
 issued by the producer

**1. Product Identification and Use**

Product name/trade name: Wood Pellets  
 Producer's Product Code: XXXXXXXXXXXX  
 Synonyms: Wood Pellets, Fuel Pellets, Whitewood Pellets, Softwood Pellets, Hardwood Pellets, Bark Pellets  
 Product appearance: Light to dark blond or chocolate brown, glossy to semi-glossy, cylinder with ¼ inch diameter (6.35 mm referred to as 6 mm pellets) and 5 to 25 mm in length.  
 Product use: Fuel for conversion to energy, animal bedding, absorbent  
 HS Product Code: 44013090  
 United Nations Number: Not allocated  
 Hazchem: Not allocated  
 IMO Safety Code: Material Hazardous in Bulk (MHB) Group B (IMO-260E)

**Manufacturer:** Name of company (full legal name with no abbreviations)  
 Visiting address  
 Place and postal code  
 Canada  
 Tel (switchboard): 001-XXX-XXX-XXXX  
 Fax: 001-XXX-XXX-XXXX  
 Website: WWW.XXXXXXXXXXXXXXXXXX  
 Email: XXXXXXXXXXXX@XXXXXXXXX

**Emergency contact:** Tel (direct): 001-XXX-XXX-XXXX  
 Tel (mobile): 001-XXX-XXX-XXXX  
 Fax: 001-XXX-XXX-XXXX

**II. Composition and Physical Properties**

Wood Pellets are manufactured from ligno-cellulosic saw dust, planer shavings or bark by means of one or any combination of the following operations; drying, size reduction, densification, cooling and dust removal. The chemical composition of Wood Pellets varies between species of raw material, components of the wood, soil conditions and age of the tree. Wood Pellets are typically manufactured from a blend of feedstock with the following composition;



**LOGO**

Company name (full legal name)

Issued May 5, 2009

Feedstock	Oxygenated compounds (indicative composition in % of weight)		
		Cellulose	30 - 40
		Hemi-cellulose	25 - 30
		Lignin	30 - 45
		Extractives (terpene, fatty acids, phenols)	3 - 5
Additives	None except as stated in Wood Pellets Product Specification		
Binders	None except as stated in Wood Pellets Product Specification		

Classification as per CEN/TC 14961 Standard; D06/M10/A0.7/S0.05/DU97.5/F1.0/N0.3

Many pellet products consist of a blend of white wood and bark feedstock which may affect the characteristics of the pellets. For more detailed information about the properties, see the latest version of Wood Pellets Product Specification issued by the manufacturer. This MSDS includes the major differences in the characteristics of the Dust from pure whitewood and pure bark pellets.

**III. Health Hazard Data**

Wood Pellets emit dust and gaseous invisible substances during handling and storage as part of the normal degradation of all biological materials. Ambient oxygen is typically depleted during such degradation. The sizes of the particulate matter range from crumbs to extremely fine airborne dust. The dust normally settles on surfaces over time. Emitted gases are immediately diluted by the air in the containment and escape with ventilation air. If the Wood Pellets are stored in a containment which is not ventilated (naturally or forced) the concentration of emitted gases, or the oxygen depletion, may pose a health threat for humans present in the containment and the containment should be ventilated and precautions should be taken as specified in this MSDS. Section IX includes a method of estimating the concentration of gases. The gases emitted at normal indoor temperature include carbon-monoxide (CO), carbon-dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and hydrocarbons with Permissible Exposure Levels (PEL) and symptoms as follows;

Entry	Substance	Permissible Exposure Level and symptom	Remedial action	
Swallow	Dust	Dry sensation, see Section IX.	Rinse mouth thoroughly with water. Do not induce vomiting.	
Inhale	Dust	Coughing, dry throat. For toxicological data, see Section X.	Rinse mouth thoroughly with water. Do not induce vomiting.	
	Carbon monoxide (CO)	Toxic invisible and odorless gas. Living space TLV-TWA 9 ppmv (ASHRAE). Work space TLV-TWA 25 ppmv (OSHA).	If hygiene level is exceeded, evacuate and ventilate thoroughly, see Section IX for estimation of ventilation requirement.	
		50 ppmv	Max 15 minutes.	
		200	Mild headache.	Evacuate.
		400	Serious headache.	Evacuate and seek medical attention.
		800	Dizziness, convulsion, unconscious in 2 hours, death in 2-3 hours.	Evacuate and seek medical attention.
		1,600	Dizziness, convulsion, unconscious, death in 1 - 2 hours.	Evacuate and seek medical attention.
		3,200	Dizziness, convulsion, unconscious, death in 1 hour.	Evacuate and seek medical attention.
6,400	Dizziness, convulsion, unconscious,	Evacuate and seek medical attention.		



Member of Wood Pellet Association of Canada (WPAC)

**LOGO**

Company name (full legal name)

Issued May 5, 2009

			death in 25 minutes.	
		12,800	Dizziness, convulsion, unconscious, death in 1 – 3 minutes.	Evacuate and seek medical attention.
	Carbon dioxide (CO <sub>2</sub> )	Asphyxiating invisible and odorless gas. Occupational TLV-TWA 5,000 ppmv (OSHA)		If hygiene level is exceeded, ventilate thoroughly, see Section IX for estimation of ventilation requirement.
	Methane (CH <sub>4</sub> )	Asphyxiating invisible and odorless gas.		Ventilate
	Hydrocarbons	See Section IX. Odor.		Ventilate
	Oxygen depleted air	Oxygen level is normally 20.9 % at sea level in well ventilated space. Minimum hygiene level is 19.5 % in work space (NIOSH)		If oxygen level is less than hygiene level, evacuate and ventilate thoroughly.
Skin contact	Dust	Itching for some people. For toxicological data, see Section X.		Remove contaminated clothing. Rinse skin thoroughly with water.
Eye contact	Dust	Tearing, burning. For toxicological data, see Section X.		Flush with water and sweep out particles inward towards the nose

**IV. First Aid Procedures**

Wood Pellets are considered a benign product for most people. However, individuals with a propensity for allergic reactions may experience reactions and should contact their physician to establish the best remedial action to take if reaction occurs.

In case Wood Pellets are not handled or stored in accordance with recommendations in Section VII the risk of harmful exposure increases, particularly exposure to concentration of CO higher than stipulated PEL in Section III. In case of exposure it is important to quickly remove the victim from the contaminated area. Unconscious persons should immediately be given oxygen and artificial respiration. The administration of oxygen at an elevated pressure has shown to be beneficial, as has treatment in a hyperbaric chamber. The physician should be informed that the patient has inhaled toxic quantities of carbon monoxide. Rescue personnel should be equipped with self-contained breathing apparatus when entering enclosed spaces with gas.

Carbon monoxide is highly toxic by means of binding with the hemoglobin in the blood to form carboxyhemoglobin which can not take part in normal oxygen transport, greatly reducing the blood's ability to transport oxygen to vital organs such as the brain.

Asphyxiating gases like carbon dioxide and methane (sometimes called simple asphyxiant) are primarily hazardous by means of replacing the air and thereby depriving the space of oxygen. Person exposed to oxygen depleted conditions should be treated the same as a person exposed to carbon monoxide.

**V. Fire and Explosion Measures**

Wood Pellets is a fuel and by nature is prone to catch fire when exposed to heat or fire. During handling of Wood Pellets there are three phases with various levels of stability, reactivity (see section IX) and decomposition products:

- solid intact Wood Pellets
- crumbs or dust
- non-condensable (primarily CO, CO<sub>2</sub> and CH<sub>4</sub>) and condensable gases (primarily aldehydes, acetone, methanol, formic acid)

Extinguishing a fire in Wood Pellets require special methods to be successful as follows;



Member of Wood Pellet Association of Canada (WPAC)



**LOGO**

Company name (full legal name)

Issued May 5, 2009

State of Wood Pellets	Extinguishing measures	Additional information
General	Restrict oxygen from entering the space where the Wood Pellets are stored.	
	Cover exposed pellets with foam or sand to limit exposure to air.	
	Be prepared for an extended period of extinguishing work. An industrial size silo may take a week to fully bring under control.	
Storage in enclosed space	Seal openings, slots or cracks where Wood Pellets may be exposed to air.	
	Inject nitrogen (N <sub>2</sub> ) or carbon dioxide (CO <sub>2</sub> ) in gaseous form at the bottom or in the middle of the pile of Wood Pellets or as close as possible to the fire if exposed. N <sub>2</sub> is preferred. Dosage of gas depends on the severity of the fire (how early detection is made). Recommended injection speed is 5 – 10 kg/m <sup>2</sup> /hour (m <sup>2</sup> refers to the cross section of the storage containment such as a silo) with a total injected volume throughout the extinguishing activity of 5 – 15 kg/m <sup>3</sup> for less severe fires and 30 – 40 kg/m <sup>3</sup> for more advanced fires.	Recommended values developed by SP Technical Research Institute of Sweden  Specific volume for N <sub>2</sub> is 0.862 m <sup>3</sup> /kg and for CO <sub>2</sub> 0.547 m <sup>3</sup> /kg (at NTP)
Storage in open flat storage	Cover the pile of Wood Pellets with foam or sand if available or spray water. Dig out the pile to reach the heart of the fire and remove effected material.	
During handling	Restrict oxygen from entering the space where the Wood Pellets are present	
	Cover the Wood Pellets with foam or sand if available or spray water. Dig out the material to reach the heart of the fire and remove effected material.	

**VI. Accidental Release Measures**

If Wood Pellets are released in a populated area, the material should be removed by sweeping or vacuuming as soon as possible. Wood Pellets are a fuel and should preferably be disposed of by means of burning. Deposition of Wood Pellets or related dust should be such that gas from the material does not accumulate. Wear a protective mask to prevent inhaling of dust during cleanup (see Section VIII).

**VII. Safe Handling and Storage**

Precautionary measures are recommended to avoid hazardous conditions by the reactivity as outlined in Section IX developing when handling Wood Pellets.

State of Wood Pellets	Precautionary measures	Additional information
General	Always store Wood Pellets in containment with a minimum of one (1) air exchange per 24 hours at + 20°C and a minimum of two (2) air exchanges per 24 hours at + 30°C and above.	One air exchange corresponds to the volume of the containment.
	For long period storage in large bulk containment shall be as air tight as possible. Fires tend to migrate towards air (oxygen) supply. For shorter period open storage, ventilate to eliminate gas and odor.	Early warning sensors for heat and gas detection enhances the safety of storing Wood Pellets

## LOGO

Company name (full legal name)

Issued May 5, 2009

	Protect the Wood Pellets from contact with water and moisture to avoid swelling, increased off-gassing, increased microbial activity and subsequent self-heating.	For large enclosed storage, label the points of entry to storage containment or communicating spaces containing Wood Pellets with a sign such as "Low Oxygen Risk Area, Ventilate thoroughly before Entry".
	Always protect Wood Pellets and dust from exposure to heat radiators, halogen lamps and exposed electrical circuitry which may generate ignition energy and set off a fire or explosion.	See Section IX Explosibility and applicable ATEX directives.
	Always segregate the Wood Pellets from oxidizing agents (e.g. poly-oxides capable of transferring oxygen molecules such as permanganate, perchlorate) or reducing agent (e.g. chemical compounds which includes atoms with low electro-negativity such as ferrous ions (rust), sodium ions (dissolved sea salt)).	Schedule for Wood Pellets, Code of Safe Practice for Solid Bulk Cargoes, 2004, IMO 260E.
	Do not expose Wood Pellets to rain.	
	Do not smoke or extinguish cigarettes in the vicinity of Wood Pellets or wood dust.	Install heat and gas detectors with visible and audible alarm.
Storage in enclosed space	For large enclosed storage entry should be prohibited by means of secured lock and a well established written approval process for entry, only AFTER ventilation has been concluded and measurement with gas meter has confirmed safe atmosphere in the space. Alternatively, use self-contained breathing apparatus when entering space. Always make sure backup personnel are in the immediate vicinity monitoring the entry.	Label points of entry to enclosed storage areas containing Wood Pellets with "Carbon monoxide Risk Area, Ventilate thoroughly before Entry".
	Install N <sub>2</sub> or CO <sub>2</sub> sprinklers as per applicable fire regulations.	A Shipper Cargo Information Sheet (SCIS) must be used when shipping Wood Pellets in ocean vessels as per international regulations issued by IMO, see SCIS issued by Producer.
Storage in open space	For large storage spaces install water sprinklers. For smaller storage spaces, contact your local fire department for recommendations.	Sand or foam has proven to be effective to limit access of oxygen in case of fire.
During handling	Avoid breakage caused by dropping the Wood Pellets. Be aware of potential dust generation during high pressure pneumatic handling of pellets.	Monitor temperature at bearings, pulleys, augers or other heat generating machinery.
	Avoid friction generated by rough surfaces such as worn out conveyor belts as much as possible.	
	Suppress dust generation and accumulation at transfer points and in areas close to mechanical moving parts which may dissipate heat.	
	Apparatus exposed to dust generated during the handling should be rated according to applicable safety standards, see ATEX directives. Warning signs should be posted in areas where dust tends to remain suspended in air or settle on hot surfaces, see Section IX Explosibility.	Example of labels and pictogram: HIGH DUST CONCENTRATION OR ACCUMULATION ON SURFACES MAY CAUSE EXPLOSIONS OR FIRES.  VENTILATE AND KEEP SURFACES CLEAN.



**LOGO**

Company name (full legal name)

Issued May 5, 2009

--	--	--	--

**VIII. Exposure Control and Personal Protection**

The following precautionary measures shall be taken for personal protection:

Activity	Precautionary measure	Additional information
Entering space containing Wood Pellets	Ventilate thoroughly all communicating spaces before entering.	For estimation of ventilation requirement, see Section IX.
	In the event the space is enclosed, always measure both level of carbon monoxide and oxygen.	Oxygen level at sea level shall be 20.9 % in well ventilated space. Space with carbon monoxide level > 25 ppmv shall not be entered into without caution, see Section III.
	When door to space is labeled with warning sign, make sure to follow instructions and obtain permit in writing to enter.	Examples of labels and pictogram: LOW OXYGEN RISK AREA. VENTILATE BEFORE ENTRY. ALWAYS MEASURE CARBONMONOXIDE AND OXYGEN.
	Use self-contained breathing apparatus if entry is required before proper ventilation has been completed.	CARBONMONOXIDE RISK AREA. VENTILATE BEFORE ENTRY. ALWAYS MEASURE CARBONMONOXIDE AND OXYGEN.  
Exposure to dust from Wood Pellets	Wear protective glasses and dust respirator. Wear gloves during continuous or repetitious penetration.	

**IX. Stability and Reactivity Data**

The stability and reactivity properties of Wood Pellets are as follows:

Parameter	Measure	Value
Odor	°C	Above + 5 °C, fresh Wood Pellets in bulk smells like aldehydes in poorly ventilated space and more like fresh softwood in ventilated space.

## LOGO

Company name (full legal name)

Issued May 5, 2009

Off-gassing	Emission Factor (g/tonne)	Emission of CO, CO <sub>2</sub> and CH <sub>4</sub> from Wood Pellets contained in a space is a function of temperature, ambient air pressure, bulk density, void in Wood Pellets, access to oxygen, relative humidity in air (if ventilated) as well as the age and composition of the raw material (unique for the product as specified in the Wood Pellet Product Specification). The emission rate in grams (g) of off-gassing per tonne of stored Wood Pellets given below are from measurements of gas generated within a sealed containment filled with Wood Pellets at approximately constant pressure without ventilation over a period of > 20 days. The emission factors values are only valid for sealed containment without sufficient oxygen available to support oxidation of the Wood Pellets (see Oxidation in this Section). The numbers should not at any time be substituted for actual measurements. The following examples illustrate how the emission factors can be used for estimating a rough order of magnitude of the gas concentration in a non-ventilated as well as a ventilated containment with Wood Pellets, assuming the ambient air pressure is constant.		
		<b>Non-ventilated (sealed) containment</b>		
		Gas species	Temperature °C	Emission factor (±10 %) g/tonne/>20 days
		Carbon-monoxide (CO)	+ 20	12
			+ 30	15
			+ 40	16
			+ 50	17
			+ 55	17
		Carbon-dioxide (CO <sub>2</sub> )	+ 20	20
			+ 30	54
			+ 40	80
			+ 50	84
			+ 55	106
		Methane (CH <sub>4</sub> )	+ 20	0.2
			+ 30	1.0
			+ 40	1.3
			+ 50	1.5
			+ 55	1.9
		<b>Example A.</b>		
		<ul style="list-style-type: none"> <li>- Mass of Wood Pellets = 1000 tonne</li> <li>- Bulk density of Wood Pellets = 700 kg/m<sup>3</sup> (0.7 tonne/m<sup>3</sup>)</li> <li>- Solids in bulk Wood Pellets including 0.5 % fines = 50 %</li> <li>- Size of containment = 2800 m<sup>3</sup></li> <li>- Temperature = +20 °C (constant)</li> <li>- Emission factor for CO (&gt;20 days storage time) = 12 g/tonne (see table above)</li> </ul>		
		<b>Calculation of concentration of CO (g/m<sup>3</sup>) in containment;</b> $12 \text{ (g/tonne)} * 1000 \text{ (tonne)} / [2800 \text{ (m}^3\text{)} - 50\% * 1000 \text{ (tonne)} / 0.7 \text{ (tonne/m}^3\text{)}]$ $= 5.8 \text{ g/m}^3$		
		<b>Calculation of concentration of CO (ppmv) in containment</b> <ul style="list-style-type: none"> <li>- Ambient pressure = 101.325 kPa (1 atm)</li> <li>- Molecular weight of CO (Mwt) = 28 (g/mol)</li> </ul>		
		$(\text{g/m}^3) * (20\text{°C} + 273.1\text{°C}) / \text{Mwt(g/mol)} / 0.012 = 5.8 * 293.1 / 28 / 0.012 =$ <u>5060 ppmv after &gt; 20 days of storage in sealed containment.</u>		



**LOGO**

Company name (full legal name)

Issued May 5, 2009

		<p>PEL (TLV-TWA = 15 minutes, See Section III) = 50 ppmv which means a person shall not be exposed to the atmosphere in the non-ventilated containment.</p>																																				
		<p><b>Ventilated containment</b></p>																																				
		<table border="1"> <thead> <tr> <th>Gas species</th> <th>Temperature °C</th> <th>Emission rate factor (±10 %) g/tonne/day</th> </tr> </thead> <tbody> <tr> <td rowspan="5">Carbon-monoxide (CO)</td> <td>+ 20</td> <td>0.9</td> </tr> <tr> <td>+ 30</td> <td>2.2</td> </tr> <tr> <td>+ 40</td> <td>8.0</td> </tr> <tr> <td>+ 50</td> <td>18.0</td> </tr> <tr> <td>+ 55</td> <td>25.0</td> </tr> <tr> <td rowspan="5">Carbon-dioxide (CO<sub>2</sub>)</td> <td>+ 20</td> <td>1.3</td> </tr> <tr> <td>+ 30</td> <td>4.8</td> </tr> <tr> <td>+ 40</td> <td>17.0</td> </tr> <tr> <td>+ 50</td> <td>29.0</td> </tr> <tr> <td>+ 55</td> <td>119.0</td> </tr> <tr> <td rowspan="5">Methane (CH<sub>4</sub>)</td> <td>+ 20</td> <td>0.01</td> </tr> <tr> <td>+ 30</td> <td>0.04</td> </tr> <tr> <td>+ 40</td> <td>0.18</td> </tr> <tr> <td>+ 50</td> <td>0.38</td> </tr> <tr> <td>+ 55</td> <td>1.10</td> </tr> </tbody> </table>	Gas species	Temperature °C	Emission rate factor (±10 %) g/tonne/day	Carbon-monoxide (CO)	+ 20	0.9	+ 30	2.2	+ 40	8.0	+ 50	18.0	+ 55	25.0	Carbon-dioxide (CO <sub>2</sub> )	+ 20	1.3	+ 30	4.8	+ 40	17.0	+ 50	29.0	+ 55	119.0	Methane (CH <sub>4</sub> )	+ 20	0.01	+ 30	0.04	+ 40	0.18	+ 50	0.38	+ 55	1.10
Gas species	Temperature °C	Emission rate factor (±10 %) g/tonne/day																																				
Carbon-monoxide (CO)	+ 20	0.9																																				
	+ 30	2.2																																				
	+ 40	8.0																																				
	+ 50	18.0																																				
	+ 55	25.0																																				
Carbon-dioxide (CO <sub>2</sub> )	+ 20	1.3																																				
	+ 30	4.8																																				
	+ 40	17.0																																				
	+ 50	29.0																																				
	+ 55	119.0																																				
Methane (CH <sub>4</sub> )	+ 20	0.01																																				
	+ 30	0.04																																				
	+ 40	0.18																																				
	+ 50	0.38																																				
	+ 55	1.10																																				
		<p><b>Example B</b></p> <ul style="list-style-type: none"> <li>- Volume of Wood Pellets = 1000 tonne</li> <li>- Size of containment = 2800 m<sup>3</sup></li> <li>- Storage time = 5 days</li> <li>- Temperature = +20°C (constant)</li> <li>- Ambient pressure = 101.325 kPa (1 atm)</li> <li>- Emission of CO = 0.9 g/tonne/day (see Table above)</li> <li>- Ventilation rate = 1 air exchanges (2800 m<sup>3</sup>) /day</li> <li>- Molecular weight of CO (Mwt) = 28 (g/mol)</li> <li>- Conversion factor (g/m<sup>3</sup> to ppmv) = 0.012</li> </ul> <p><b>Calculation of concentration of CO:</b>  <math>0.9 \text{ (g/tonne/day)} * 1000 \text{ (tonne)} / [2800 \text{ (m}^3\text{/day)} * [1 - \exp(-2800 \text{ (m}^3\text{/day)} / 2800 \text{ (m}^3\text{)} * 5 \text{ (days)})] = 0.32 \text{ g/m}^3</math></p> <p><b>Conversion to ppmv:</b>  <math>(\text{g/tonne}) * (T + 273.1 \text{ (C}^\circ\text{)}) / \text{Mwt (g/mol)} / 0.012 = 0.32 * 293.1 / 28 / 0.012 = 279 \text{ ppmv}</math></p> <p>To keep the concentration below PEL the containment needs to be ventilated with more than one air exchange per day.</p> <p>For more accurate estimation of gas concentrations in containment with variations in temperature and pressure, see "Report on Off-gassing from Wood Pellets" to be issued by Wood Pellet Association of Canada (<a href="http://www.pellet.org">www.pellet.org</a>) when results from on-going research becomes available.</p>																																				
Oxidization	Rate	<p>It is believed oxidation of fatty acids contained in the woody material is the primary cause for depletion of oxygen and emission of gas species as exemplified above during storage of Wood Pellets or related dust. The depletion ratio is a function of temperature, pressure, bulk density, void in Wood Pellets, relative humidity in air (if ventilated) as well as the age and composition of the raw material (unique for the product as specified in the Wood Pellet Product Specification). The numbers below are from</p>																																				

## LOGO

Company name (full legal name)

Issued May 5, 2009

		measurements of gas generated within the space of the Wood Pellets at approximately constant pressure. The numbers should not at any time be substituted for actual measurements.
	Temperature °C	(±10 %) Depletion of oxygen in %/24h
	+ 20	0.7 – 1.2
	+ 30	
	+ 40	1.5 – 2.5
	+ 50	
	+ 55	
		For more accurate estimation of oxygen concentrations in containment with variations in temperature and pressure, see "Report on Off-gassing from Wood Pellets" issued by Wood Pellet Association of Canada ( <a href="http://www.pellet.org">www.pellet.org</a> ) when results from on-going research becomes available.
Melting temperature	-	Not applicable.
Vaporization	-	Emit hydrocarbons as vapors above + 5 °C.
Boiling temperature	-	Not applicable.
Flash point temperature	-	Not applicable.
Auto-ignition temperature	°C	Auto-ignite of Wood Pellets at temperatures > + 260 °C in the presence of oxygen. For dust, see Section Explosibility Dust deflagration below.
Pyrophorocity	Rate	Wood Pellets or dust are not classified as pyrophoric solids as defined by UN MTC Rev.3, 2000, Class 4.2 Test N.4.
Flammability	Rate	Wood Pellets or dust are not classified as flammable solids as defined by UN MTC Rev. 3, 2000, Class 4.1 Test N.1. (Burning rate < 200 mm/2 min.) Burning rate; Airborne Wood Pellet Dust = 20 mm/2 min. Airborne Bark Pellet Dust = 22 mm/2 min.
Self-heating	Rate	Propensity to start self-heating in presence of oxygen.
Bio-degradability	%	100.
Corrosivity		Not applicable.
pH		The potential for Hydrogen ions (pH) varies depending on species of wood.
Solubility	%	If penetrated by water Wood Pellets will dissolve into its feedstock fractions.
Mechanical stability	-	If exposed to wear and shock Wood Pellets will disintegrate into smaller fractions and dust.
Incompatibility	-	Always segregate the Wood Pellets from oxidizing agents (e.g. poly-oxides capable of transferring oxygen molecules such as permanganate, perchlorate) or reducing agent (e.g. chemical compounds which includes atoms with low electro-negativity such as ferrous ions (rust), sodium ions (dissolved sea salt)). (See Schedule for Wood Pellets, Code of Safe Practice for Solid Bulk Cargoes, 2004, IMO 260E), see Section VII.
Swelling	Rate	If penetrated by water Wood Pellets will swell about 3 to 4 times in volume.
Shock	Rate	The mechanical integrity of Wood Pellets will degrade if exposed to an external force as a result of for example a drop in height.
Mechanical ware	Rate	Wood Pellets are sensitive to friction between the Wood Pellets and a transportation causeway or conveyor belt and may generate dust.
Explosibility	Dust deflagration	Sieving of dust for testing purposes; 230 mesh < 63 µm. Moisture content for whitewood pellets dust = 5.6 % of weight. Moisture content for bark pellets dust = 7.9 % of weight. ASTM E11-04 Standard.

9



**LOGO**

Company name (full legal name)

Issued May 5, 2009

	<p>The following data is not necessarily intrinsic material constants for Dust from Wood Pellets.</p> <p>Minimum Ignition Temperature for dust cloud (<math>T_{IC}</math>)          Whitewood dust = + 450 °C.          Bark dust = + 450 °C.          ASTM E 1491 Standard.</p> <p>Minimum Ignition Temperature for dust layer 5 mm (<math>T_{L5}</math>)          Whitewood dust = + 300 °C.          Bark dust = + 310 °C.          ASTM E 2021 Standard.</p> <p>Minimum Ignition Temperature for dust layer 19 mm (<math>T_{L19}</math>)          Whitewood dust = + 260 °C.          Bark dust = 250 °C.          ASTM E 2021 Standard.</p> <p>Auto - Ignition Temperature for dust layer (<math>T_{AUTO}</math>)          Whitewood dust = +225 °C.          Bark dust = +215 °C.          US Bureau of Mines RI 5624 Standard.</p> <p>Minimum Ignition Energy for dust cloud (<math>MIE_c</math>)          Whitewood dust = 17 mJ.          Bark dust = 17 mJ.          ASTM E 2019 Standard.</p> <p>Maximum Explosion Pressure of dust cloud (<math>P_{max}</math>)          Whitewood dust = 8.1 bar (gauge).          Bark dust = 8.4 bar (gauge).          ASTM E 1226 Standard.</p> <p>Maximum Explosion Pressure Rate of dust cloud (<math>dP/dt_{max}</math>)          Whitewood dust = 537 bar/sec.          Bark dust = 595 bar/sec.          ASTM E 1226 Standard.</p> <p>Specific Dust Constant (<math>KSt</math>)          Whitewood dust = 146 bar.m/sec.          Bark dust = 162 ba.m/sec.          ASTM E 1226 Standard.</p> <p>Explosion Class (<math>St</math>)          Whitewood dust = St 1. (&gt; 0 to 200 bar.m/sec).          Bark dust = St 1. (&gt; 0 to 200 bar.m/sec).          ASTM E 1226 Standard.</p> <p>Minimum Explosible Concentration for dust cloud (<math>MEC_{dc}</math>)          Whitewood dust = 70 g/m<sup>3</sup>          Bark dust = 70 g/m<sup>3</sup>          ASTM E 1515 Standard.</p> <p>Limiting Oxygen Concentration for dust cloud (<math>LOC_c</math>)          Whitewood dust = 10.5 %.          Bark dust = 10.5 %.          ASTM E 1515 Standard (modified).</p>
Gas	<p>Carbon monoxide (CO) is potentially explosive in concentration &gt; 12 % by volume (120,000 ppmv) when mixed with air. Wood Pellets are not known to generate this level of concentration.</p> <p>Methane (CH<sub>4</sub>) is flammable in concentration &gt; 20 % (LFL 20) by volume (200,000 ppmv) when mixed with air. Solid Wood Pellets are not known to generate this level of concentration.</p>

**LOGO**

Company name (full legal name)

Issued May 5, 2009

**X. Exposure and Toxicological Data**

The feedstock is the basis of the toxicological characteristics of Wood Pellets. The available data does not make a clear distinction between whitewood and bark material. The toxicological data applies primarily to the material in form of dust.

Feedstock	PEL (OSHA)	REL (NIOSH)	TLV (ACGIH)	Health Effects
Softwood such as fir, pine, spruce and hemlock.	15 mg/m <sup>3</sup> Total Dust 5 mg/m <sup>3</sup> Respirable Dust	TWA = 1 mg/m <sup>3</sup> for 10 hours @ 40 hours week	TWA = 5 mg/m <sup>3</sup> for 8 hours @ 40 hours week  STEL = 10 mg/m <sup>3</sup> for 15 minutes, max 4 times/day, each episode max 60 minutes	Acute or chronic dermatitis, asthma, erythema, blistering, scaling and itching (ACGIH).
Hardwood such as alder, aspen, cottonwood, hickory, maple and poplar.	15 mg/m <sup>3</sup> Total Dust 5 mg/m <sup>3</sup> Respirable Dust	TWA = 1 mg/m <sup>3</sup> for 10 hours @ 40 hours week	TWA = 5 mg/m <sup>3</sup> for 8 hours @ 40 hours week  STEL = 10 mg/m <sup>3</sup> for 15 minutes, max 4 times/day, each episode max 60 minutes	Acute or chronic dermatitis, asthma, erythema, blistering, scaling and itching (ACGIH). Suspected tumorigenic at site of penetration (IARC).
Oak, walnut and beech.	15 mg/m <sup>3</sup> Total Dust 5 mg/m <sup>3</sup> Respirable Dust	TWA = 1 mg/m <sup>3</sup> for 10 hours @ 40 hours week	TWA = 1 mg/m <sup>3</sup> for 8 hours @ 40 hours week	Suspected tumorigenic at site of penetration (ACGIH).
Western Red Cedar.	15 mg/m <sup>3</sup> Total Dust 5 mg/m <sup>3</sup> Respirable Dust	TWA = 1 mg/m <sup>3</sup> for 10 hours @ 40 hours week  TWA = 1 mg/m <sup>3</sup> for 10 hours @ 40 hours week	TWA = 5 mg/m <sup>3</sup> for 8 hours @ 40 hours week  STEL = 10 mg/m <sup>3</sup> for 15 minutes, max 4 times/day, each episode max 60 minutes	Acute or chronic rhinitis, dermatitis, asthma (ACGIH).

Respirable Dust means particles with an AED < 10 µm capable of deposition in nasal, thoracic and respiratory regions.

Dust from certain hardwoods has been identified by IARC as a positive human carcinogen. An excess risk of nasal adeno-carcinoma has been reported mainly in those workers in this industry exposed to wood dusts. Some studies suggest workers in the sawmilling, pulp and paper and secondary wood industries may have an increased incidence of nasal cancers and Hodgkin's disease. However, IARC concludes that the epidemiological data does not permit a definite assessment.

Dust from Western Red Cedar is considered a "Nuisance Dust" (= containing less than 1% silicates (OSHA)) with no documented respiratory carcinogenic health effects (ACGIH). Cedar oil is a skin and respiratory irritant.

**XI. Notice to Reader**

The information contained in this MSDS is based on consensus by occupational health and safety professionals, manufacturers of Wood Pellets and other sources believed to be accurate or otherwise technically correct. It is the Reader's responsibility to determine if this information is applicable. This MSDS is updated from time to time, and the reader has the responsibility to make sure the latest version is used. We do not have an obligation to immediately update the information in the MSDS.

Product data available from the manufacturer of the Wood Pellets includes;

- MSDS for Wood Pellets Packaged in Bag Smaller than 25 kg



## LOGO

Company name (full legal name)

Issued May 5, 2009

- MSDS for Wood Pellets in Bulk
- Wood Pellet Product Specification
- Shipper Cargo Information Sheet (SCIS)

Contact the manufacturer to order the latest version of these documents.

Notice that some of the information in this MSDS applies only to Wood Pellets manufactured by the Manufacturer identified on the first page of this MSDS and may not necessarily be applicable to products manufactured by other producers.

While we have attempted to ensure that the information contained in this MSDS is accurate, we are not responsible for any error or omissions, or for the results obtained from the use of this information.

We are not responsible for any direct, indirect, special, incidental, or consequential damage, or any other damages whatsoever and however caused, arising out of or in connection with the use of the information in this MSDS, or in reliance on that information, whether the action is in contract, tort (including negligence) or other tortious action. We disclaim any liability for unauthorized use or reproduction of any portion of this information in this MSDS.

## XII. Abbreviations Used in This Document

ACGIH	American Conference of Governmental Industrial Hygienists
AED	Aerodynamic Equivalent Diameter
ASHRAE	American Society of Heating Refrigerating and Air-conditioning Engineers
ATEX	ATmosphere EXplosible
atm	atmosphere pressure
bar	$10^5$ Pascal (Pa) or 100 kPa or 0.9869 atm
CCOHS	Canadian Center for Occupational Health and Safety
CEN/TC	European Committee for Standardization/Technical Committee Comité Européen De Normalisation
g	gram = 0.001 kg
mg	milligram = 0.000001 kg
HS	Harmonized System Code
IARC	International Agency for Research on Cancer
IMO	International Maritime Organization (UN)
m <sup>3</sup>	cubic meter
µm	micrometer = 0.000001 meter
MSDS	Material Safety Data Sheet
NTP	National Toxicology Program
LEL	Lower Explosible Limit (MEC=LFL=LEL)
LFL	Lean Flammability Limit (MEC=LFL=LEL)
MEC	Minimum Explosible Concentration (MEC=LFL=LEL)
NFPA	National Fire Protection Association (USA)
NIOSH	National Institute for Occupational Safety and Health (USA)
NTP	Normal Temperature and Pressure (+20°C, 101.325 kPa or 1 atm)
OSHA	Occupational Safety and Health Administration (USA)

**LOGO****Company name (full legal name)****Issued May 5, 2009**

PEL	Permissible Exposure Level
ppmv	parts per million on a volume basis. For example, 5,000 ppmv means 5,000 molecules per 1 million molecules of gas, which also corresponds to 0.5 %. A concentration of 10,000 ppmv corresponds to 1 % of volume
REL	Recommended Exposure Limit
SCIS	Shipper Cargo Information Sheet
sec	second
STEL	Short Term Exposure Limit
STP	Standard Temperature and Pressure (0°C, 101.325 kPa or 1 atm)
TLV	Threshold Limit Value
tonne	1000 kg
TWA	Time weighted Average
WPAC	Wood Pellet Association of Canada



## 10.9 Questionnaire for Sector Data

**Feedstock for pellets**

1.1	What assortments of feedstock material are used?	Amount (t/a)
	stemwood with bark	
	stemwood without bark	
	forest residues	
	sawmill residues	
	other wood based material	
	stalk-type biomass (straw etc.)	
	other biomass	

1.2	What basic feedstock material is used?	Percentage (%)
	pine	
	spruce	
	other coniferous wood	
	beech	
	other hardwood	
	non-woody biomass	

1.3	Where does the basic raw material come from?	Percentage (%)
	national origin	
	import from Europe (EU)	
	extra-European imports (worldwide)	

1.4	How is the raw material stored?	Size (m <sup>3</sup> )
	free	
	roof covered	
	closed store house	
	silo	
	other kind of storage (which?)	



## Pellet-production und logistics

2.1	What is the total national pellet production	Amount (t)
	in 2011	
	in 2012 (projection)	
	In 2013 (projection)	
	in 2015 (projection)	
	in 2020 (projection)	

2.2	What is the theoretical production potential	Amount (t)
	in 2011	
	in 2012 (estimation)	
	in 2015 (estimation)	
	in 2020 (estimation)	

2.3	In 2011 the national pelletindustry had	Amount
	how many companies?	
	how many production sites?	
	how many employees?	
	what total turnover? (in million euro)	

2.4	What quality where produced in 2011?	Amount (t)
	premium quality pellets (loose bulk goods)	
	premium quality pellets (in bags)	
	pellets for industry use	
	specific requirements for export	

2.5	Which certificates are fulfilled by pellet producers?	Percentage (%)
	ENplus	
	DINplus	
	Svebio	
	other	

2.6	What kind of transportation is used for pellets?	Percentage (%)
	truck (walking floor, dumper truck, container)	
	silo wagen	
	railway	
	ship	

## Pellet-customers and security guidelines

3.1	How many pellet-stoves are used	Amount
	in the private sector?	
	in the public sector?	
	in the commercial/industriel sector?	

3.2	What total power do pellet-stoves have	Total power (MW)
	in the private sector?	
	in the public sector?	
	in the commercial/industriel sector?	

3.3	What average power output range have pellet-stoves	Power output range (KW)
	in the private sector?	
	in the public sector?	
	in the commercial/industriel sector?	

3.4	During <u>loading /unloading</u> pellets compliance with following safety guidelines is recommended / required:

3.5	During <u>transport</u> of pellets <u>by truck</u> compliance with following safety guidelines is recommended / required:

3.6	During <u>transport</u> of pellets <u>by ship</u> compliance with following safety guidelines is recommended / required:

3.7	During <u>transport</u> of pellets <u>by train</u> compliance with following safety guidelines is recommended / required:

d



Henry Persson  
Anders Lönnermark  
Alexander Claesson  
Johan Lindström

## Project Report

Report on questionnaire regarding self-heating and off-gassing

Version	Final
Date	28 June 2013
Deliverable	2.2 (Part B)
Grant Agreement Number	287026
Project manager	Waltraud Emhofer Waltraud.emhofer@bioenergy2020.eu
Scientific partner	DTI, DBFZ, BE2020, SLU, SP
Commercial partner	AEBIOM – European Biomass Association, Danish Straw Association, DEPV – German Pellets Association, PF – Swedish Pellets Association, PPA – ProPellets Austria, Firefly AB (SE), Laxå Pellets AB (SE), Pusch AG (DE), Dansk Træemballage AS (DK), Verdo Energy AS (DK)
Project duration	1 January 2012 – 31 December 2014
Supported by	Research for the benefit of specific groups/ Research for SME associations/groupings within the Seventh Framework Programme of the European Union (FP7-SME-2011 287026-Safepellets)





## Table of Content

<b>1</b>	<b>Introduction</b>	<b>5</b>
<b>2</b>	<b>Description of questionnaire</b>	<b>6</b>
2.1	Questions in Part 1	6
2.1.1	Pellet manufacturers - Information regarding production and storage	6
2.1.2	Pellet distributors - Information regarding pellet supply, storage and delivery	7
2.1.3	Pellet users - Information regarding pellet supply and storage	7
2.2	Questions in Part 2	8
2.2.1	Questions related to problems with smell and/or off-gassing	8
2.2.2	Questions related to self-heating and fire incidents	9
2.3	Distribution and response	11
<b>3</b>	<b>Evaluation of the answers</b>	<b>12</b>
3.1	Interpretation of each questionnaire	12
3.2	Evaluation of the answers in Part 2	14
3.2.1	Problems related to smell and/or off-gassing (Q1-Q6)	14
3.2.2	Problem related to self-heating and fire incidents (Q7-Q15)	14
<b>4</b>	<b>Results</b>	<b>16</b>
4.1	Manufacturers	16
4.1.1	General information about the responding manufacturers	16
4.1.2	Summary of the manufacturers answers to the specific questions	20
4.1.2.1	Results related to smell and/or off-gassing (Q1-Q6)	20
4.1.2.2	Answers related to self-heating (Q7, 9 and 12)	23
4.1.2.3	Questions related to fire incidents (Q8, Q13)	25
4.2	Distributors	30
4.2.1	General information about the responding distributors	31
4.2.2	Summary of the distributors answers to the specific questions	34
4.2.2.1	Results related to smell and/or off-gassing (Q1-Q6)	34
4.2.2.2	Answers related to self-heating (Q7, 9 and 12)	37
4.2.2.3	Questions related to fire incidents	38
4.3	Users	40
4.3.1	General information about the responding users	40
4.3.2	Summary of the users answers to the specific questions	43
4.3.2.1	Results related to smell and/or off-gassing (Q1-Q6)	43
4.3.2.2	Answers related to self-heating (Q7, 9 and 12)	46
4.3.2.3	Questions related to fire incidents (Q8, Q13)	47
<b>5</b>	<b>Experience from real accidents</b>	<b>50</b>

5.1	Accidents related to off-gassing	50
5.1.1	Wood pellets incidents	50
5.1.2	Other materials than wood pellets	51
5.2	Fire incidents related to self-heating	51
5.2.1	Silo fires	52
5.2.2	Flat storage fires	57
<b>6</b>	<b>Summary</b>	<b>58</b>
6.1	Handling and storage	58
6.2	Problems related to smell, off-gassing and self-heating	60
6.3	Problems with fire incidents	61
<b>7</b>	<b>Conclusions and discussion</b>	<b>63</b>
<b>8</b>	<b>References</b>	<b>65</b>



# 1 Introduction

SafePellets (Safety and quality assurance measures along the pellets supply chain) is performed and funded under the Research for the Benefit of SMEs activity of the Seventh Framework Programme (FP7) of the European Union. The consortium consists of SME-industry partners and research institutes coming from five EU member states, in total 15 partners.

The objective of the project is the development of guidelines for quality assurance measures along the pellets supply chain and solutions for safe handling and storage of pellets. In the course of the project methods for the assessment of off-gassing and self-heating shall be developed.

Work Package 2 (WP2) of the SafePellets project involves a market and risk inventory, and product selection. The part related to risk inventory is covered in Task 2.2 which aims to collect information about incidents related to self-heating and/or off-gassing of wood pellets. The work includes the following parts:

- Characterization of known incidents in the partner countries, e.g. type of incident; time, date and location; frequency of occurrence; storage technique and degree of damage
- Investigation of the causes for the incidents if known, e.g. caused by persons or technical reasons
- In-depth analysis of selected relevant incidents specifically related to off-gassing or self-heating will be made by SLU and SP.

This report summarizes the results of a questionnaire and is focused on pellet manufacturers, distributors and end-users in the countries of the participating partners, Austria, Denmark, Germany and Sweden.

The report also includes some examples of experience from real, more serious accidents related to off-gassing and self-heating. As the questionnaire only provided some very few incident reports, the description of accidents are mainly based on information published in the open literature, on internet and/or through direct contacts with relevant sources.

## 2 Description of questionnaire

In order to collect the information on the problems related to off-gassing and self-heating along the pellet supply chain, a questionnaire was developed to be distributed in the partner countries of the SafePellets project, i.e. Austria, Denmark, Germany and Sweden. The targeted stakeholders were pellet manufacturers, pellet distributors and pellet users.

The questionnaire was divided into two parts, the first part including questions about specific responders activities, and their handling and storage of pellets and was, therefore, slightly different for the manufacturers, distributors and users. The second part focused on specific questions related to off-gassing, self-heating and possible fire incidents and was the same in all questionnaires.

As it was a relatively small group of respondents, it was decided to distribute the questionnaire in the form of a Word-document making it possible for the respondents to answer, either by editing directly in the document or to make a print out and fill in manually.

Template questionnaires were prepared by SP in cooperation with the other involved scientific partners, which were then translated into Danish, German and Swedish before sent out in the partner countries.

The questions in Part 1 were so called open questions where the respondent had to answer with his own descriptions. This means that no pre-defined alternatives were given.

In Part 2 all questions followed by statements were supposed to be answered by “yes” or “no”. In addition, there was a possibility to provide additional comments to each question.

### 2.1 Questions in Part 1

The questions in part 1 aimed to get an understanding of the activities for each individual responder as this might influence to what extent they have observed any problems during their handling of pellets. As the type of activities and handling depends on where in the pellets supply chain a specific company is active, the relevant questions become somewhat different. In chapter 2.1.1 - 2.1.3, a list is provided of the questions asked to pellet manufacturers, pellet distributors and pellet users, respectively.

#### 2.1.1 Pellet manufacturers - Information regarding production and storage

The following nine questions (designated 0.1 - 0.9) were asked to pellet manufacturers regarding their business activities.



- 0.1 When was the operations started (year)?
- 0.2 Maximum production capacity/year (ton, m<sup>3</sup>)
- 0.3 Current production/year (ton, m<sup>3</sup>)
- 0.4 Raw material (e.g. proportion of spruce, pine, energy wood, waste wood, dry raw material, others)
- 0.5 Type of storage for fresh produced pellets (flat storage, silo, big bag, others)
- 0.6 Storage capacity (ton, m<sup>3</sup>)
- 0.7 Normal storage time (months)
- 0.8 Maximum storage time (months)
- 0.9 Delivery of pellets (approx. proportion (%) in bulk, big bag, sacks for private consumer use)

### 2.1.2 Pellet distributors - Information regarding pellet supply, storage and delivery

The following twelve questions (designated 0.1 - 0.12) were asked to pellet distributors regarding their business activities.

- 0.1 Type of customers (power plant, local heating station, private consumer)
- 0.2 When was the operations started (year)?
- 0.3 Turnover of pellets/year (ton, m<sup>3</sup>)
- 0.4 Type of storage (flat storage, silo, others)
- 0.5 Storage capacity (ton, m<sup>3</sup>)
- 0.6 Normal storage time (months)
- 0.7 Maximum storage time (months)
- 0.8 Method of pellet supply (truck, rail, ship, others)
- 0.9 Normal supply volumes (ton, m<sup>3</sup>)
- 0.10 Origin of pellets (country/countries, manufacturer)
- 0.11 Delivery methods to customer, (approx. proportion (%) in bulk, big bag, sacks for private consumer use)
- 0.12 Typical delivery volumes in bulk to single consumers (min/normal/max (ton, m<sup>3</sup>))

### 2.1.3 Pellet users - Information regarding pellet supply and storage

The following ten questions (designated 0.1 - 0.10) were asked to pellet users regarding their business activities. It should be noted that the questions were focussing on medium and large scale users and not small scale users, e.g. private households.

- 0.1 Type of user (power plant, local heating station, private consumer)
- 0.2 When was the operations/handling of pellets started (year)?
- 0.3 Consumption/year (ton, m<sup>3</sup>)
- 0.4 Type of storage (flat storage, silo, others)
- 0.5 Storage capacity (ton, m<sup>3</sup>)
- 0.6 Normal storage time (months)

- 0.7 Maximum storage time (months)
- 0.8 Method of supply (truck, rail, ship, others)
- 0.9 Normal supply volumes (ton, m<sup>3</sup>)
- 0.10 Origin of pellets (country/countries, manufacturer)

## 2.2 Questions in Part 2

In total 15 main questions were given in Part 2 of the questionnaire. Six of these (no 1-6) were related specifically to smell and/or off-gassing, while nine questions (no 7-15) were related to self-heating and fire incidents.

Each main question had two to six more specific statements where the responder had to agree or not by answering yes or no to these statements. After each statement, there was also a possibility to provide additional comments. After some statements, there was also a follow up question to be answered in the comment column.

Below are all the questions and statements listed. In order to be able to make reference to each question and statement, the questions are numbered 1-15 and each statement is numbered with both the question number followed by the statement number (e.g. 1.3, 8.5).

At the end of the questionnaire, after the numbered questions, there was also space for additional comments.

### 2.2.1 Questions related to problems with smell and/or off-gassing

1. Have you experienced problems with smell and/or off-gassing?

- 1.1 Never
- 1.2 At some few occasions (approx. no/year)
- 1.3 We have learnt how to handle the problems by specific measures. (which measures?)
- 1.4 We have frequent problems
- 1.5 We have had incidents resulting in acute, company internal actions (approx. no/year)
- 1.6 We have had serious incidents resulting in response from the emergency medical care or the fire and rescue services (number of these serious incidents in total?)

2. How was the smell and/or off-gassing observed?

- 2.1 Gas detection systems
- 2.2 Complaints from employees
- 2.3 Complaints from neighbouring facilities
- 2.4 Complaints from neighbouring residential areas



2.5 Complaints from end consumers

2.6 Others

3. Is there any "statistics" available?

3.1 Internal complaints

3.2 External complaints

3.3 End users

4. Have any of your employees showed any symptoms which might be related to smell/off-gassing?

4.1 Problems related to smell

4.2 Symptoms related to off-gassing

5. Have you any suspected cause to the problems?

5.1 Raw material

5.2 Production conditions

5.3 Weather

5.4 Time of year

5.5 Other

6. Have you made any measures to possibly reduce the problems?

6.1 Raw material

6.2 Production conditions

6.3 Other

2.2.2 Questions related to self-heating and fire incidents

7. Have you experienced problems with self-heating?

7.1 Never

7.2 We have noticed self-heating at some few occasions (approx. how many or how often?)

7.3 We have learnt how to handle the self-heating problems by specific measures. (which measures?)

7.4 We have frequent problems with self-heating

7.5 We have had self-heating incidents resulting in acute, company internal actions (number of incidents in total?)

8. Have you experienced problems resulting in fire incidents?

8.1 Never

8.2 Minor fire incidents at some few occasions (number of fires in total?)

8.3 We have had fire incidents resulting in acute, company internal actions (number of fires in total?)

8.4 We have had serious fire incidents resulting in response from the fire and rescue services (number of fires in total?)

8.5 We have had fires but where the cause of fire has not been spontaneous ignition due to self-heating (where did the fires occur, what was the cause?)

9. Where do you mainly experience self-heating problems?

9.1 Flat storage

9.2 Silos

9.3 Other

10. What kind of fixed system do you have to detect self-heating and fire?

10.1 Single point gas detectors in the ceiling

10.2 Sampling gas detection system

10.3 Vertically suspended temperature sensors measuring in the bulk

10.4 Other types of system (e.g. IR-detectors)

11. How was the fire detected?

11.1 Smell

11.2 Smoke

11.3 Temperature detection system

11.4 Gas detection system

11.5 Open flames

11.6 Other

12. What is the normal action at elevated temperatures?

12.1 Wait and see

12.2 Transfer the pellets to another storage

12.3 Other

13. Where has spontaneous ignition occurred?

13.1 Flat storage

13.2 Silos

13.3 Other storages (what type?)

14. How did you respond to the fire?

14.1 Own personnel

14.2 Fire and rescue services

14.3 Other



15. Is there any incident report available? (If “yes”, please provide contact information)

15.1 Internal report

15.2 Fire and rescue services report

15.3 Third party fire investigation

15.4 Other

## 2.3 Distribution and response

The final distribution list in each country was defined by the scientific partner in each country in cooperation with their national pellet association.

In Austria and Germany, pellets users are to a large extent private households or small users. As the questions were aimed for larger users (medium/large scale power plants), it was decided by the national pellets associations not to send out the questionnaire to users in Austria Germany. In case of any consumer problems, it was also assumed that any complaints would be reported back to the manufacturer or supplier.

In Germany, it was also decided to exclude some of the questions in the questionnaire towards pellet distributors. The reason was that many distributors are quite small and the questionnaire was considered too long, and the intention was to simplify to receive a better response. The excluded questions were 2.3 and the entire questions 6, 8, 11, 13 and 15.

In both Part 1 and Part 2, there was no possibility to control that the respondent answered all questions/statements. Some respondents have been very reluctant to answer the questionnaire and in some cases there were only some few answers given to all the specific questions. Whether this is due to lack of time to fill in the questionnaire, lack of interest for the SafePellets project or if it was a fear of announcing any kind of off-gassing or fire related problems is not known. After further contacts with these companies additional information has been obtained to such extent that the quality of the overall answer could be considered acceptable. However, based on a common decision among the SafePellets scientific partners, the “answer” from one respondent has been excluded as the uncertainty was considered unacceptable.

The fact that there was a lot of information lacking in certain cases caused a lot of extra work and made it necessary to make our own interpretations of the answers received (see chapter 3). However, the interpretations has been discussed and checked by each scientific partner to ensure that the overall interpretation of the all the questionnaires could be considered to represent the situation in the pellets supply chain.

### 3 Evaluation of the answers

The respondents sent back their answers to each national contact point, i.e. in this case the scientific partner in SafePellets (SP, BE2020, DBFZ, and DTI)

Each returned questionnaire got an identification code with a country code (A-Austria, D-Denmark, G-Germany, S-Sweden), a code for type of activity (M-Manufacturer, D-Distributor, U-User) and a consecutive number (e.g. A-D1, D-U5, S-M15).

A template document was prepared by SP in Excel where all the answers on a national basis could be transferred to. This work was made by the scientific partner in each country and during this process, the specific company names were excluded in order to keep this information confidential to the rest of the project consortium. However, these identifications are not used in the report and all answers are just referring to a respondent number without any identification of nationality.

#### 3.1 Interpretation of each questionnaire

As it was not possible to “force” the respondents to answer all the questions, which is possible in a web based questionnaire where each question have to be answered before it is possible to go to the next question, there is a large number of questions/statements that has not been given an answer. To a large extent, we believe that this is depending on how the respondent answered to some of the main questions, as they thereby felt that they indirectly answered the subsequent questions. In order to make an evaluation of the answers on a common basis, it has therefore been necessary to make interpretations of the answers and give an assumed answer to all questions/statements that was not answered. The interpretations have been checked by the responsible scientific partner in each country and in selected cases they have also validated the interpretation by subsequent phone calls to the respondent in question.

In Figure 1 an overview of the results compiled into the Excel file is shown as an example. The figure shows the answers to question (Q) 1-6 with their corresponding statements (horizontal direction) where the answers from each respondent are summarized on one row giving their answer (Yes or No). All the white cells represent a given answer by the respondent while the yellow marked cells indicate that no answer was given and the result (Yes or No) in the cell is based on our interpretation.

A typical situation is that the respondent has answered Yes to Q.1.1 (1. Have you experienced problems with smell and/or off-gassing? - 1.1 Never). Following this answer, the respondent did not answer to the following statements in the same question as they seem not relevant. This might also translate to Q2 to Q6, as if there has not been any problems, these questions might not seem relevant to answer. The same pattern can also be noticed for Q7 and Q8 and the related questions/statements in Q9-Q15.



Respondent	1. Have you experienced problems with smell and/or off-gassing?						2. How was the smell and/or off-gassing observed?						3. Is there any "statistics" on available?		4. Have any of your employees showed any symptoms which might be related to smell/off-gassing?		5. How do you say suspected causes to the problem?		6. Have you made any measures to possibly reduce the		
	Have you experienced problems with smell and/or off-gassing?	Do you know how to handle the problems with smell and/or off-gassing?	Do you have a procedure for handling the problems with smell and/or off-gassing?	Do you have had somebody contacted to solve the problem with smell and/or off-gassing?	Do you have had somebody contacted to solve the problem with smell and/or off-gassing?	Do you have had somebody contacted to solve the problem with smell and/or off-gassing?	How often?	Where?	How long?	How often?	How long?	How often?	How long?	How often?	How long?	How often?	How long?	How often?	How long?	How often?	How long?
S-0001	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0002	uncertain	no	uncertain	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0003	uncertain	no	uncertain	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0004	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0005	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0006	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0007	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0008	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0009	uncertain	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0010	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0011	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0012	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0013	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0014	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0015	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0016	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0017	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0018	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0019	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0020	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0021	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0022	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0023	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0024	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0025	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0026	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0027	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0028	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0029	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0030	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0031	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0032	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0033	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0034	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0035	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0036	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no
S-0037	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Figure 1 An overview of the respondents answers to some of the questions compiled in an Excel file. The white marked cells represents answers ("yes" or "no") which were given specifically by the respondent while the yellow marked represent our interpreted answers. During the evaluation process, there were in some cases uncertainties for specific answers which needed to be checked ("Uncertain"- green marked). In most cases these uncertainties have be possible to solve, but in some cases the answer "Uncertain" still occurs. (Note: The figure is included as an illustration and the text in the figure is not meant to be readable)

For some questions, we have also realized that the statement and corresponding alternatives could be misinterpreted. Once again, looking at Q1.1 and a respondent that have not had any problems, the correct answer would be **Yes** which refer to the statement **Never**. However, if the respondent is referring to the main question rather than the statement, he would then answer No. As there are a number of respondents that has answered No to Q1.1 but then not answered, or answered No to the following statements in Q1-Q6, we have interpreted this as a mistake and adjusted accordingly.

In some answers, the opposite situation occurs as the respondent has answered Yes to Q.1.1 but then indicated that there have been problems by answering Yes to some of the following questions/statements in Q1-Q6.

In some situations it has not been possible to interpret the answer and during the interpretation process such answers were marked "uncertain" (green cells in Figure 1) and those respondents were contacted to confirm their answers.

By making a careful interpretation of all answers from each respondent considering these aspects and possible miss-interpretation by the respondent, followed by a check made by the

responsible scientific partner in each country, it is our belief that the compiled information from the questionnaire gives a true picture of the respondents' situation.

## 3.2 Evaluation of the answers in Part 2

The received answers contain a lot of information and can be evaluated in various ways. The "main" questions (Q1, Q7 and Q8) provide statistics of how frequent the problems with smell/off-gassing, self-heating and fire are along the pellet distribution chain. Based on the answers to the various statements in these questions and following related questions/statements, further detailed information can be extracted.

The strategy of the evaluation is described more in detail below.

### 3.2.1 Problems related to smell and/or off-gassing (Q1-Q6)

The answers has been evaluated in the following sequence which firstly provide some statistics about how common these problems are, what are the consequences, how has the problems been detected, what are the causes and what measures has been done.

Q1.1 Gives an answer if the respondent have any problem or not with smell and/or off-gassing.

Q1.2 and Q1.4 provides the frequency of the problems today.

Q4.1 and Q4.2 provides information about the consequences of the problems.

Q1.5 to Q1.6 provides information about how serious consequences the problems have caused.

Q2.1 to Q2.6 indicates how the problems have been detected.

Q1.3 and Q5.1 to Q5.5 and Q6.1 to Q6.3 is related to the respondents experience to handle the problems, the suspected cause and what measures that might have been made to reduce the problems.

Q3.1 to Q3.3 (combined with Q15.1 to Q15.3) indicated if there are any statistics or additional information available on the problem.

### 3.2.2 Problem related to self-heating and fire incidents (Q7-Q15)

Q7.1 Gives an answer if the respondent have any problem or not with self-heating.

Q7.2 and Q7.4 provides the frequency of the problems today.

Q9.1 to Q9.3 provides information about where the problems occurred

Q7.3 and Q7.5 provides some additional information about how many have learnt to handle the problems and if they have experienced serious incidents resulting in internal company actions.

Q12.1 to Q12.3 provides information about actions normally taken when self-heating is observed.



Q8.1 gives an answer if the respondent has any fire incidents or not related to self-heating.

Q8.2 to Q8.4 provides information about how serious the fire incidents have been.

Q8.5 indicates the relative number of fire incidents that has not been caused by self-heating and is thereby a free-standing question from Q8.1-Q8.4 but still reported together.

Q13.1 to Q13.3 provides information about where the fires occurred.

Q10.1 to Q10.4 indicates what kind of fixed system the respondent have for detection of self-heating and fire (smoke detectors were not specifically mentioned as an alternative to gas detection, which might have caused confusion in answering Q10 and Q11).

Q11.1 to Q11.6 indicates how the fire incidents were actually detected (we have noticed that some respondents answered how they planned to detect a fire as they answered this question although they had not had any fire).

Q14.1 to 14.3 provides information about how the fire was handled.

Q15.1 to Q15.3 indicates if there are any incidents reports or additional information available.

## 4 Results

An overview of the answers received from the participating countries is presented in Table 1. In total 93 answers have been received and most answers are obtained from manufacturers and distributors.

*Table 1 Summary of the answers of the questionnaires.*

	<b>Sweden</b>	<b>Denmark</b>	<b>Austria</b>	<b>Germany</b>	<b>Total</b>
Manufacturer	17	5	10	6	38
Distributor	4	8	10	18	40
User	11	4	0	0	15
Total	32	17	20	24	93

From the SafePellets project perspective, the answers from the pellet manufacturers are in some respects the most interesting as this is the beginning of the pellet supply chain, where we can find the best and knowledgeable information about the pellets composition, the production process and how these relates to observed problems. It is also known that the problems related to smell, off-gassing and self-heating are more pronounced for freshly made pellets and thereby provide a reference for evaluation of the answers received further down the supply chain.

However, also the results obtained from the distributors and users, are interesting as these could indicate if the problems might be transferred to the distributors or even the end user under certain circumstances and in some cases perhaps cause more severe problems than at the manufacturer's site.

### 4.1 Manufacturers

#### 4.1.1 General information about the responding manufacturers

As shown in Table 1, 38 answers have been received from the pellet manufacturers. The size of the plants varies significantly and Figure 2 provides an overview of their maximum production capacity. There are 14 manufacturers with a capacity of max 50 000 ton/year, 14 manufacturers with a capacity of 50 000-100 000 ton/year and 10 having a capacity of more than 100 000 ton/year. The smallest manufacturers have a capacity of 3 000 ton/year while the largest single manufacturer has a capacity of 300 000 ton/year. Respondent 37 have a total capacity of 260 000 ton/year, representing 2 production plants, corresponding to an average capacity of 125 000-130 000 ton/year per plant. This means also that the questionnaire represents in total 39 separate production plants.

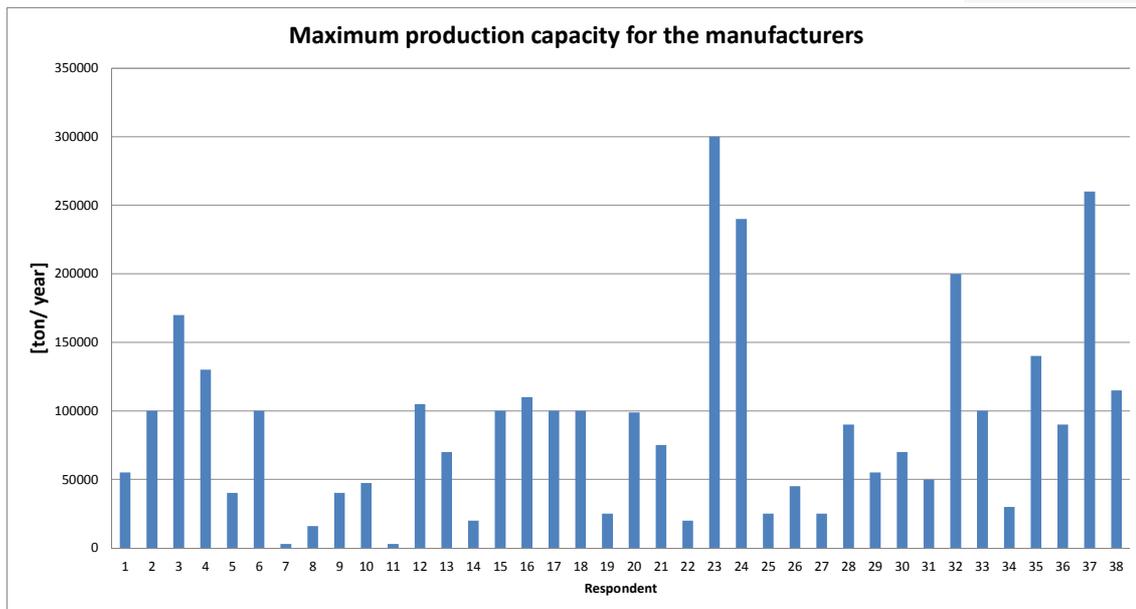


Figure 2 Maximum production capacities for the pellet manufacturers represented in the questionnaire. Note that the capacity for respondent no 37 represents two production plants.

The types of storage used by the manufacturers are summarized in Table 2. About 47 % of all the respondents (18) have silos and about 32 % have flat storage (12). Four respondents (11 %) declare that they are using both silo and flat storage. The smallest manufacturers use only big-bag and/or sacks for their storage. It should be noted that the table only provide information of the type of storage, not information about the number or capacity of the various types of storage. Unfortunately the answers do not provide full information on such figures. However, there is some information given by some respondents. The capacity of flat storage seem to be in the range of 20 000-45 000 ton although there is one example of a flat storage with a capacity of 6 000 ton. The provided figures on the capacity of silos vary from 500 to 8 000 ton.

Table 2 Summary of the types of storage represented in the questionnaire.

Type of storage	Flat storage	Silo	Flat storage and silo	Big-bag or sacks	No Information
	12	18	4	2	2

The fraction of raw material used by the manufacturers for their pellet production is shown in Figure 3. Although not specifically mentioned, we assume that the figures are given on a yearly basis and that there could be some variations. According to the information received, the most common raw material seem to be saw dust and in some cases wood chips and the use of spruce or a mixture of spruce and pine is dominating. Other raw materials are also used among some manufacturers, e.g. wood chips from “energy wood” (mixture of various leaf trees, both

softwood and hardwood). In most cases, the raw material seems to be moist, but some manufacturers also use a mixture including some dry matter, e.g. wood shavings, saw dust and wood residue from furniture manufacturing, etc. One responding manufacturer (no 20) use 94 % wheat straw mixed with 6 % wood and another manufacturer (no 22) use 100 % residue from Shea nuts for their pellet production.

In Sweden (respondents 1-17), the raw material mixture varies normally depending on the location of the pellet plant, as spruce is dominant in the southern part of Sweden while pine is most common in the north. As an average over the country, the spruce/pine mixture is about 60/40 %. However, looking at single manufacturers, there is a wide range spanning from 100 % spruce to 100 % pine. In Austria and Germany (respondents 23-38), the use of spruce seem to be more dominating although there are some manufacturers including small portions of pine or other materials. Information on raw material is also missing from in total 5 respondents.

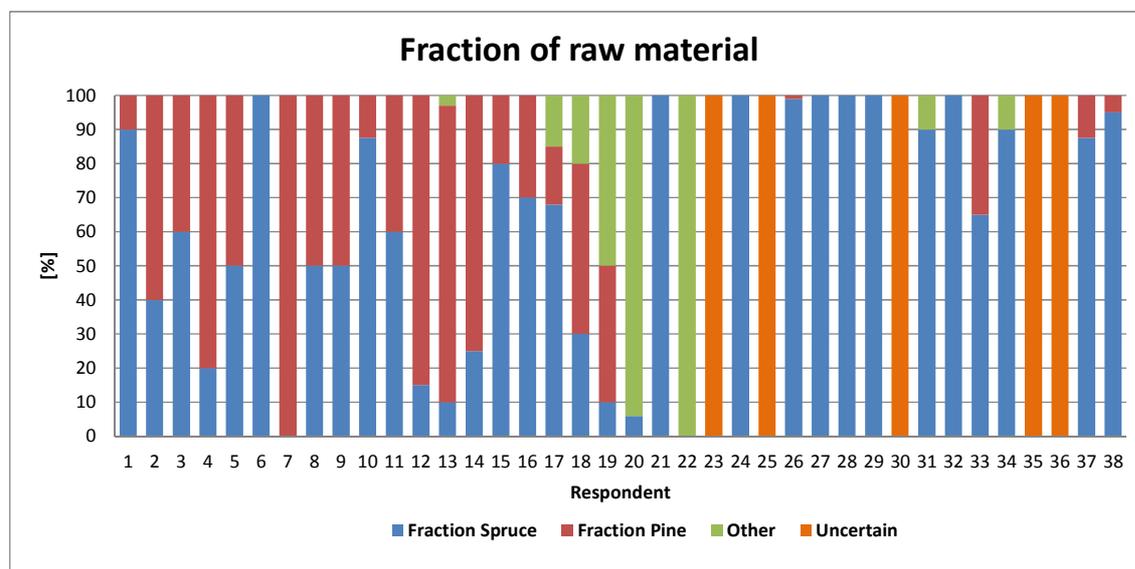


Figure 3 Fractions of different raw material used for pellet production.

More detailed information from respondent 16 gives an example of how the fraction of raw material might differ during the season. The basic raw material is saw dust and the mixture fraction is normally in the span of 60-80 % spruce and 20-40 % pine in their mixture due to local supply of saw dust. Depending on availability, the manufacturer may in some situations replace some of the saw dust mixture with cutter shavings or energy wood. On a yearly basis they add about 20 % of cutter shavings to the spruce/pine saw dust mixture, although the amount may vary from 10-70 %. The cutter shavings could be either from spruce or pine or a mixture of these, depending on the raw material handled in the planning mills.

In Figure 4 the normal and maximum storage time at the pellet manufacturers are shown. For about 87 % of the manufacturers, the normal storage time is less than 6 months and only 8 % store 6-12 months. None have indicated a normal storage time exceeding 12 months. The



maximum storage time varies more, but still about 50 % of the manufacturers does not exceed 6 month. However, about 16 % might have a maximum storage time of 12 - 24 months. It should be noted that the answers at the “boarder lines” are put into the lower group, e.g. if someone have answered 6 months, the answer will be found in the group 3-6 months.

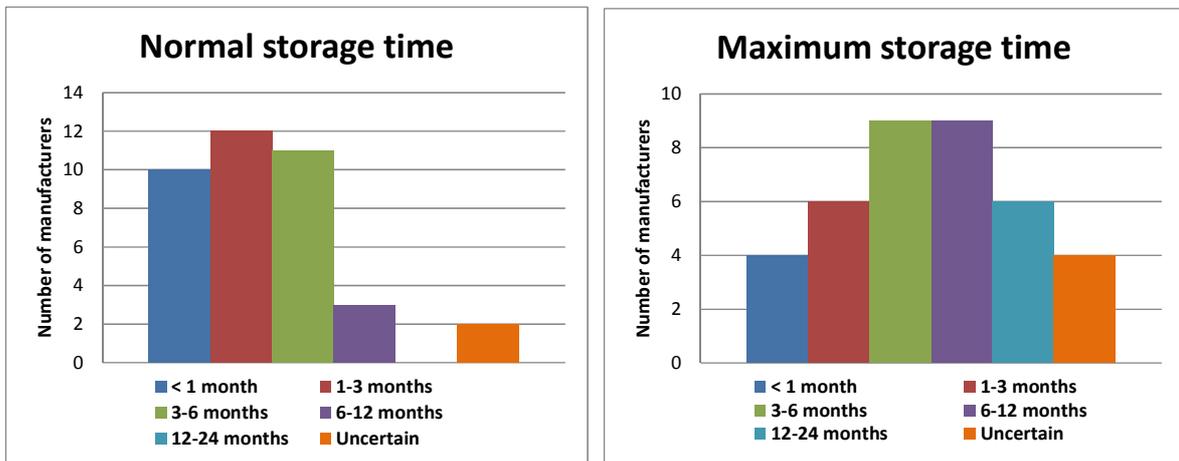


Figure 4 Normal and maximum storage time among the pellet manufacturers.

A summary of the various ways of delivery from the manufacturers are shown in Figure 5. As can be noted from the diagram, there is a large variation depending on the specific manufacturer. Nine manufacturers deliver 100 % of their production as bulk material while, on the other hand, there are two manufacturers delivering 85 % and 95 %, respectively, in sacks. Overall, the delivery in big bags is not that frequent, although one manufacturer (no 8) delivers about 80 % in big bag and the remaining part in bulk. For those manufacturers quoted “Uncertain”, no information has been obtained from the respondent.

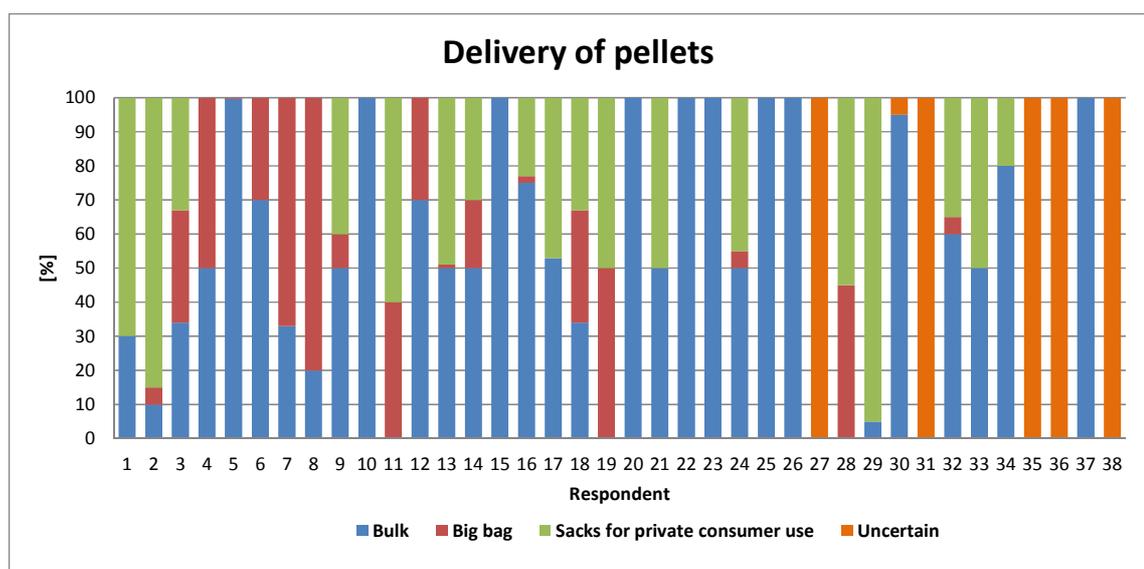


Figure 5 Form of delivery from the various manufacturers.

#### 4.1.2 Summary of the manufacturers answers to the specific questions

As previously described, in total 15 questions were included in the questionnaire and in chapter 4.1.2.1 to 4.1.2.3, a summary of the results is presented. In some cases, the respondents have provided additional comments which are then summarized under each relevant question.

##### 4.1.2.1 Results related to smell and/or off-gassing (Q1-Q6)

As shown in Figure 6, 26 out of 38 (about 68 %) have experienced problems with smell and off-gassing. For those having some kind of problem, it seems to occur only at some few occasions (22 respondents) while it is only three respondents that have frequent problems.

In the comments provided among the “yes-answers” to Q1.1, one respondent mentioned that problem occur in storage with no ventilation. Another mentioned that they have no problem at the manufacturing plant.

Among those that have answered “At some few occasions” in Q1.2, there are a number of comments about what the actual frequency is, and these are ranging from “once during a test round” to “10 times”. As an average estimation based on the comments, it indicates that “at some few occasions” correspond to about 1-3 times per year. There are also two comments specifically regarding pine. One respondent indicates problems when handling saw dust from pine in the wrong way and another respondent says that problem occur when there is too high fraction of pine in the pellets. One respondent is also claiming that the problems are related to their large silo.

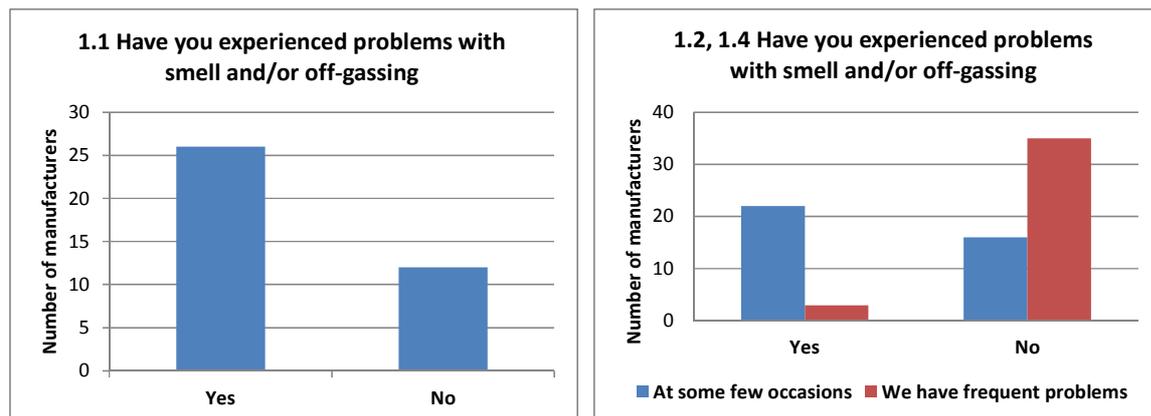


Figure 6 Answers related to the overall problem with smell and off-gassing and the frequency among those having experienced problems.

The frequency of off-gassing incidents that caused problems to the employees is relative low (see Figure 7). Only three respondents in total have either had employees showing any



symptoms related to smell (1 respondent) or off-gassing (1 respondent) or both (1 respondent). One respondent has mentioned “dizzines” as symptom.

Looking at the more serious consequences, it is only one respondent that has answered that the problems have generated some form of acute internal company actions. There is no information available about what kind of action was taken. There has been no reported situation where the emergency medical care or the fire rescue services had to be involved in connection with off-gassing incidents.

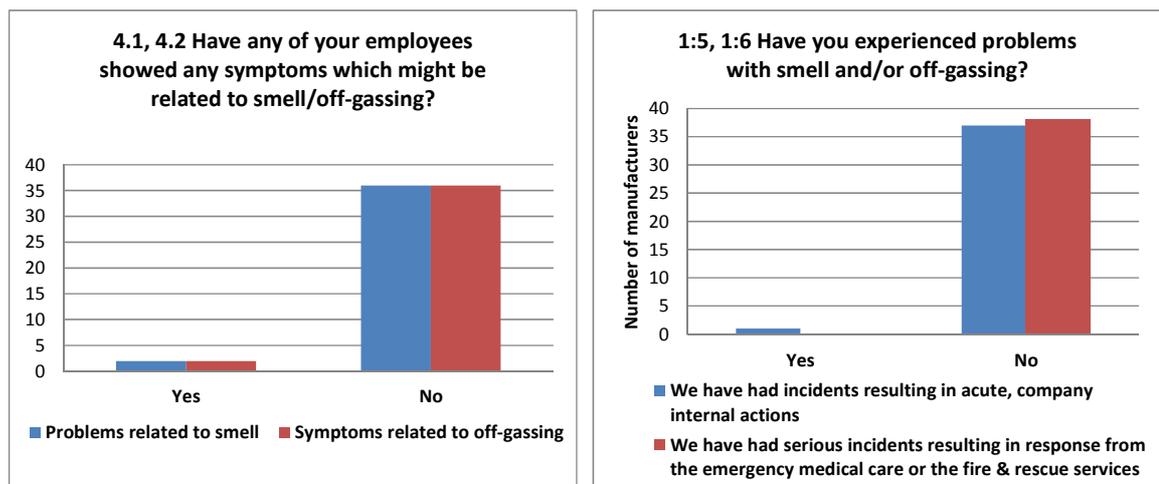


Figure 7 Answers related to the consequences of the smell and off-gassing problems.

In about 1/3 of the cases, the problems were observed by the pellet manufacturer personnel, see Figure 8. It is also relatively common that there are complaints from end-users. The problems might also be detected by gas detection systems or various other ways. However, it seems to be a local problem as there are no complaints reported from either neighbouring facilities or residential areas. One respondent comment that problem with smell (for the employees) occur when the pellets are warm.

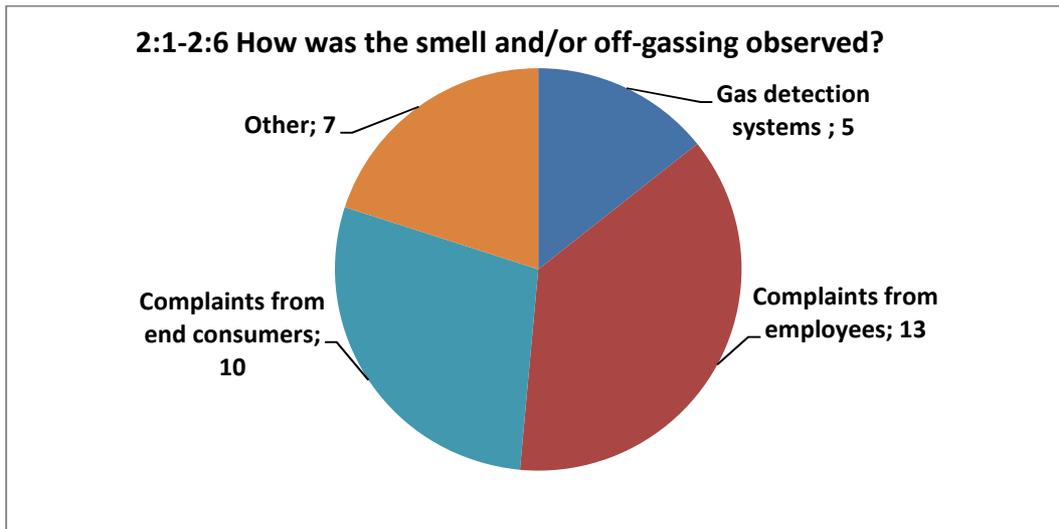


Figure 8 Answers related to how the smell and off-gassing problems were observed.

The questionnaire also included some questions related to what measures that have been made to reduce the problem. As shown in Figure 9, 50 % of the respondents (about 75 % of those indicating that they have or have had problems) have found various ways to handle the problem.

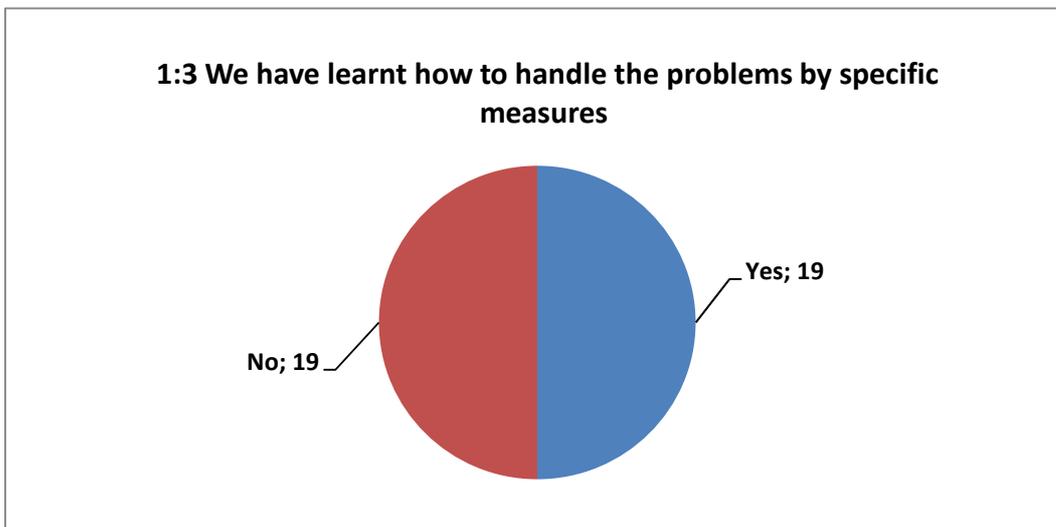


Figure 9 About 50 % declare that they have learnt to handle the problem with smell and off-gassing.

The main causes suspected to be responsible for the smell and off-gassing problems are shown in Figure 10 (left). The quality of the raw material is the most frequent suspected cause but also production conditions, weather and time of year seem to be important. It should be noticed that there are 45 “yes” answers from 22 responders which means that there are in average two proposals from each respondent.



In the comments to Q5.1-5.5, an increased fraction of pine as raw material in the pellets is pointed out to cause problems by five respondents. Two respondents comment the need to cool the pellets and two mentioned that the weather and time of year (high ambient temperature) cause problems to cool the pellets enough.

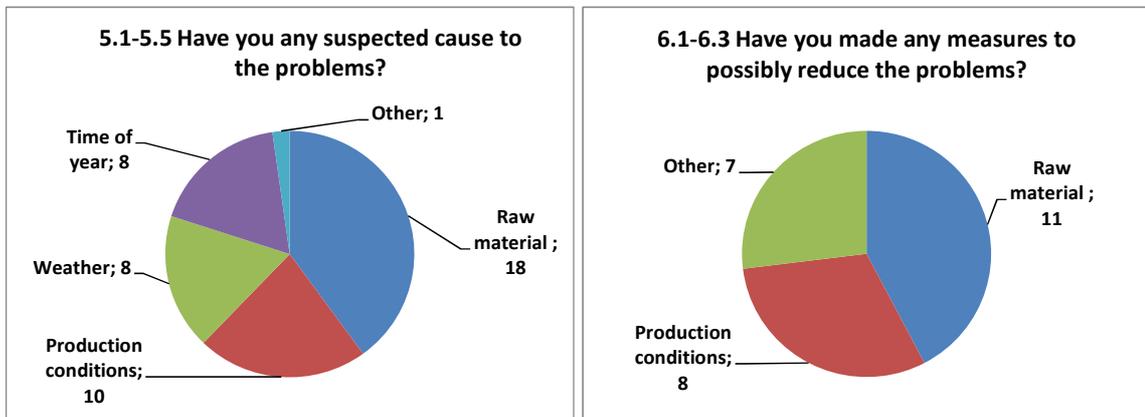


Figure 10 Information about possible causes for the problems and what measures that have been taken to reduce the problems.

As shown in Figure 10 (right) the measures to avoid the problems are mainly focused on the raw material and production conditions, but there also seem to be a number of other measures that can be made. Also in this question there were more than one answer in each category, 17 respondents have given 26 “yes” answers, which indicates that a number of respondents have answered in more than one category.

In the comments to Q1.3 and Q6.1-6.3, examples are given such as “storing the pine saw dust 4-6 week before pelleting”, “cooling + longer pre-storage time”, “optimum cooling and extended cooling times”, “service door to pellets silo kept open to cool pellets”, “reduce the amount of pine and cooling the pellets” and “mix pine with other materials”. Three respondents mentioned that they have excluded the use of pine.

Comments related to “other measures” suggest “air drying and increased ventilation”, “ventilation before entering the silo” and “install cooling at silos”.

#### 4.1.2.2 Answers related to self-heating (Q7, 9 and 12)

As shown in Figure 11, 14 out of 38 (about 37 %) have experienced problems with self-heating and all of them declare that the problems occur at some few occasions. Based on the answers of Q7.3, 12 manufacturers that they have learned how to handle the problem and in Q7.5, 3 manufacturers answer that they have experienced self-heating incidents which have resulted in internal acute actions.

In the comments, one respondent mentioned that they have had self-heating problems twice, another has experienced self-heating problems 10 times, and a third mentioned a couple of

times per year. Another respondent mentioned that self-heating problems mainly occur during summer time when the turn-over of the storage is low. One respondent mentioned that they once had a self-ignition in a silo which then also spread to a flat storage. In the comments to Q7.3 (We have learnt to handle the problem), one respondent mentioned that they spread the pellets after production and another mentioned that the problems disappeared after the moisture content was set to less than 14 %.

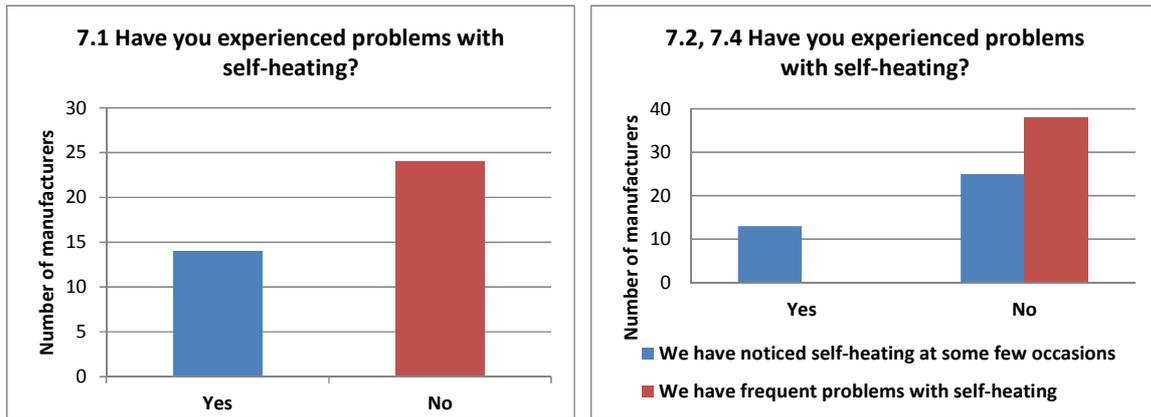


Figure 11 Answers related to the overall problem with self-heating and the frequency among those having experienced problems.

As shown in Figure 12, nine of the manufacturers have experienced self-heating in flat storage while the remaining four mentioned problems in silos. No other types of storage areas are mentioned to give problems. It should be noticed that there are 13 “yes” answers from 12 responders which means that there is one manufacturer that have problem in both flat storage and silos. To give an answer to the reason for the difference between flat storage and silos would require a further and more detailed evaluation.

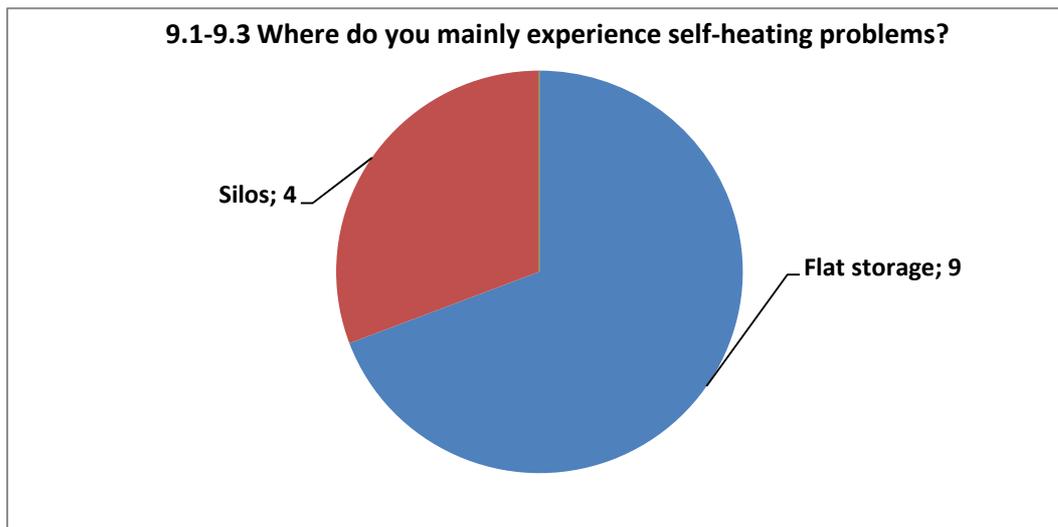


Figure 12 Answers related to where the self-heating problems occur.



The most common actions in case of self-heating are shown in Figure 13. In total there are 22 respondents that have given 30 “yes” answers, which mean that there are a number of respondents who answered in more than one category. The most common action is to transfer the pellets to another storage, but the most probable combination is to first wait and see, and if necessary transfer the material. In some few cases, there seem to be other possibilities as well.

In the comments, one respondent mentioned that they use manual heat detection and another mentioned that they cool the pellets, however, there is no information how this is done.

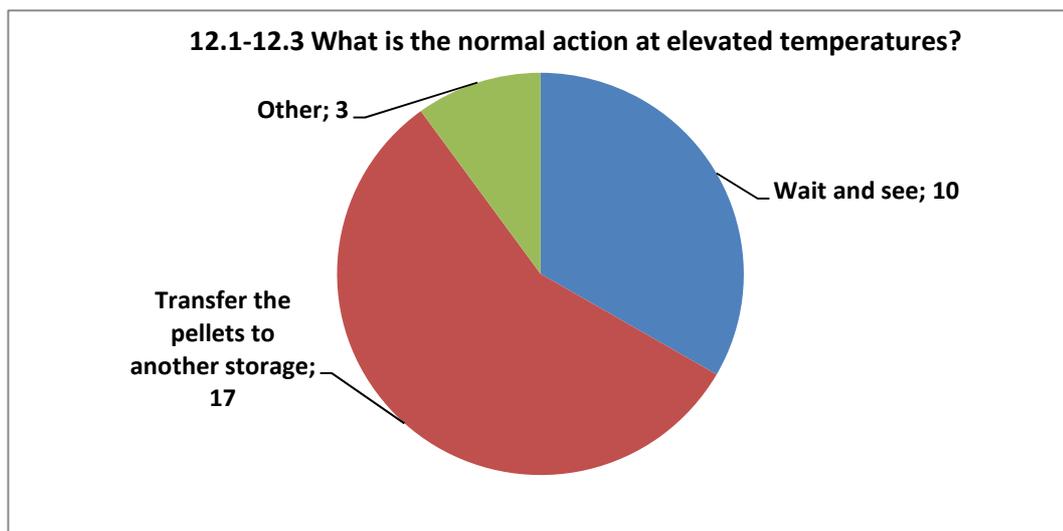


Figure 13 Common actions in case of self-heating.

#### 4.1.2.3 Questions related to fire incidents (Q8, Q13)

As shown in Figure 14, 4 manufacturers out of 38 (about 10 %) have experienced fire incidents related to self-heating. Two additional respondents had answered “yes” to this but then commented that it was not due to self-ignition and these answers are, therefore, reported in Q8.5.



Figure 14 Answers related to the overall problem with fire incidents related to self-ignition.

In Figure 15, more detailed information is provided about these fire incidents. In some cases, there are only minor incidents but it seems that when a fire occurs it involves actions both by the company and the fire brigade. This seems reasonable as even a small fire incident have the possibility to escalate very quickly in case prompt actions are not taken. One of the two respondents to Q8.2 (“minor fire incidents at some few occasions”) comment that they have had in total 4 fire incidents in dust silos and one incident in the pellet cooler.

Except for these two “yes” responders to Q8.2, one respondent mentioned that they have had fires in a silo in the past due to self-ignition, but today they only have flat storage without any self-heating problems. Another respondent mentioned that they have had self-ignition at one occasion in a storage of wood briquettes but not in pellets. A third mentioned that they experienced self-ignition both in a silo and a flat storage. Although these respondents do not feel they have problems today, all these fires resulted in both internal actions and response from the fire brigade and are thereby included in Q8.3 and Q8.4.

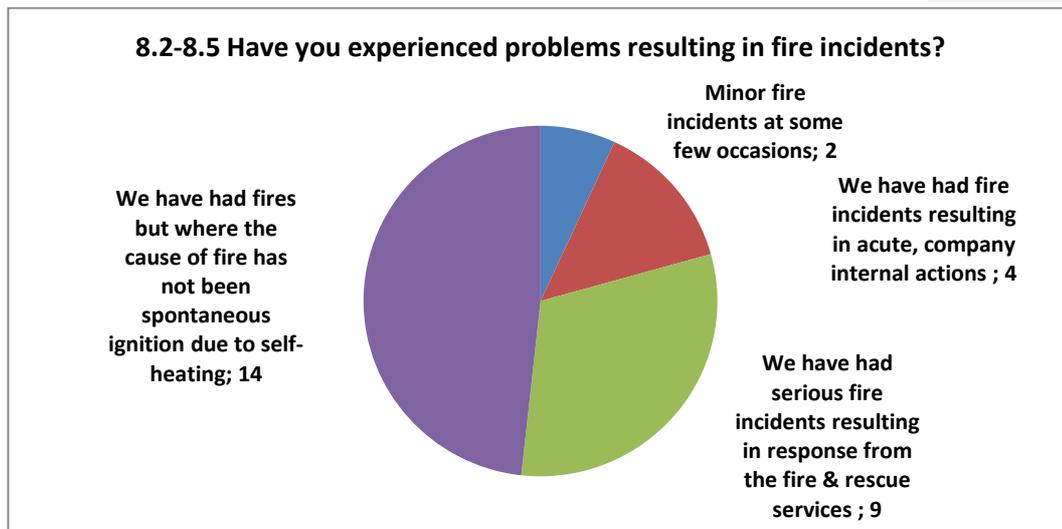


Figure 15 Frequency and consequences of reported fire incidents both related to self-heating and spontaneous ignition but also fires due to other reasons.

The answers thereby indicate that spontaneous ignition is probably not the most common cause for fire incidents as 14 manufacturers have experienced fire incidents not caused by self-heating. Some descriptions of the type of fire incidents have been obtained and are shown below.

- Three fire incidents has been experienced, one in a paper shredding equipment, one in a pelleting machine due to over-heating and one in a mill due to break down of a bearing causing over-heating and sparks.
- A number of fires in the powder silos before the pellet press. Cause is unknown, probably sparks from the process. Also a fire in briquette storage in 1995, probably due to self-ignition (Note: Answer included in Q8.5 as the fire was not including wood pellets)
- Two fires in powder silos, one probably due to self-heating, one due to a bearing breakdown in a transport screw causing a dust explosion at the silo inlet also resulting in a fire spread to two additional powder silos.
- Conveyor system
- Broken bearing in conveyor motor caused dust explosion
- Many places, but often in the hammer mills
- Machinery breakdown press/dryer
- Twice, electrical failure

Based on the comments given, it is obvious that the cause of fires seem to be related to the production process and related equipment such as the drying system, the mill and the pellet press system, but also conveyor systems seem to be frequently involved, e.g. due to breakdown of bearings. It is also shown that these primary ignition sources might cause dust

explosions resulting in fire spread into e.g. silos. It is also shown that self-ignition might occur in powder silos before the pellet press.

The answers related to the location of the spontaneous ignition are shown in Figure 16. The answers indicate no difference in fire statistics between flat storage and silos. However, the number of answers is limited so one should be very careful to make any specific statements based on these figures.

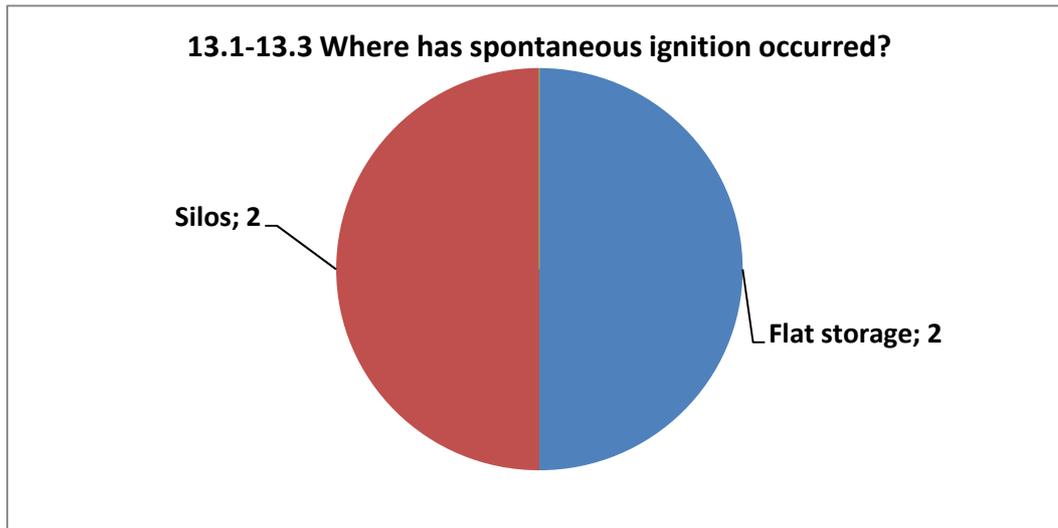


Figure 16 Location of fires caused by self-heating.

In order to reduce the consequences of a fire incident, an early detection is very important. Figure 17 provide information about what kind of fixed fire detection systems that is installed in the facilities. It could be noted that there are answers from 26 respondents and 36 "yes" answers which indicates that a number of respondents have more than one type of fire detection system installed.

Based on the comments to Q 10.4 (Other types), five respondents mentioned that they have spark detection systems in the transport system, one respondent use manual temperature measurements and another have installed an aspirating smoke detection system combined with heat detectors. Although this respondent has mentioned the aspirating smoke detection under Q10.4, we believe that there might also be such systems in the answers of Q10.2 as it was not clearly defined the difference between sampling (aspirating) gas and smoke detection systems.

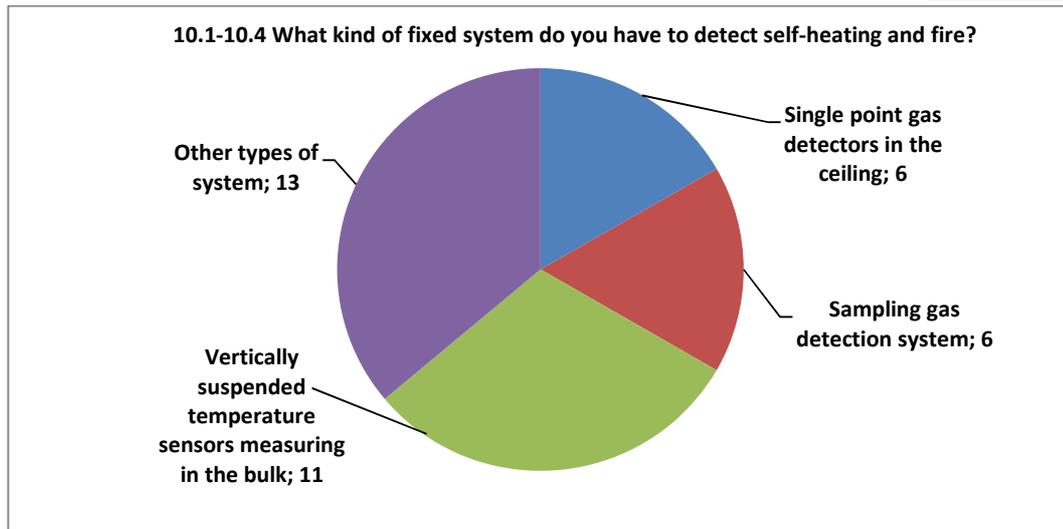


Figure 17 Type of fixed fire detections systems that the respondents have installed in their facilities

Although it seems that fixed fire detection systems are frequently used in the plants, Figure 18 indicate that smell, smoke and open flames are the most common ways to detect fires. Two respondents have mentioned temperature detection systems. It should also be noticed that there are answers from 13 respondents and 22 “yes” answers which means that there are a number of occasions where the fires at a certain respondent has been detected in more than one way. It could also be noted that no gas detection system has been reported to detect a fire.

In the comments, several respondents indicate that smell or smoke often has been the first indication but in some cases, the actual detection of the fire has been a combination of visible smoke, flames or explosion.

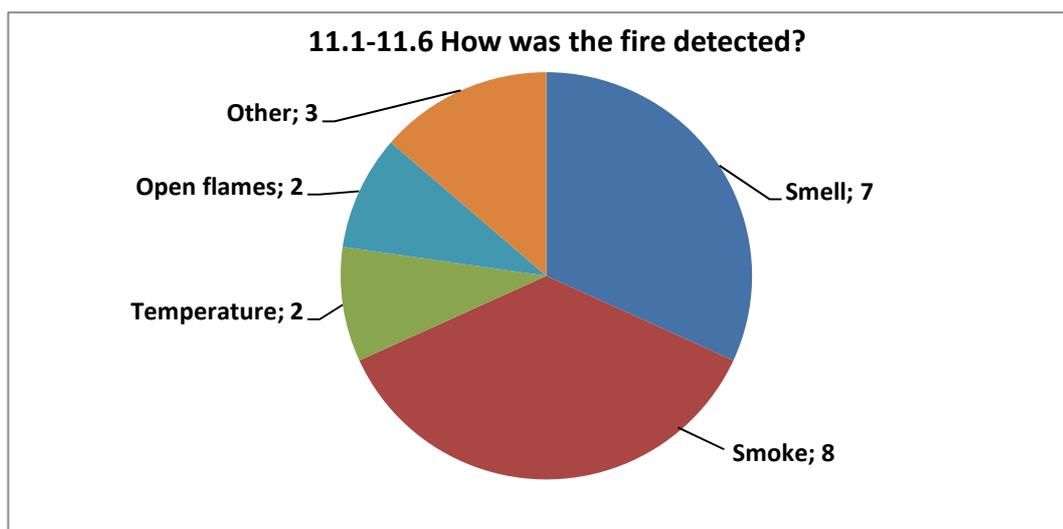


Figure 18 Answers related to how the fire incidents were detected. In some cases we know that this question also involves answers related to fires not caused by self-ignition (Q8.5).

Figure 19 shows how the manufacturers responded to the fire incidents. There are 10 respondents and 23 “yes” answers which mean that there are a number of respondents who answered in more than one category. Our interpretation is that a fire situation is judged as a very serious event and all possible resources are used to fight the fire as efficiently as possible.

Based on the comments, the answers in Q14.3 (Other) seem to relate to installed sprinkler system that has been activated by the personnel or the fire and rescue services.

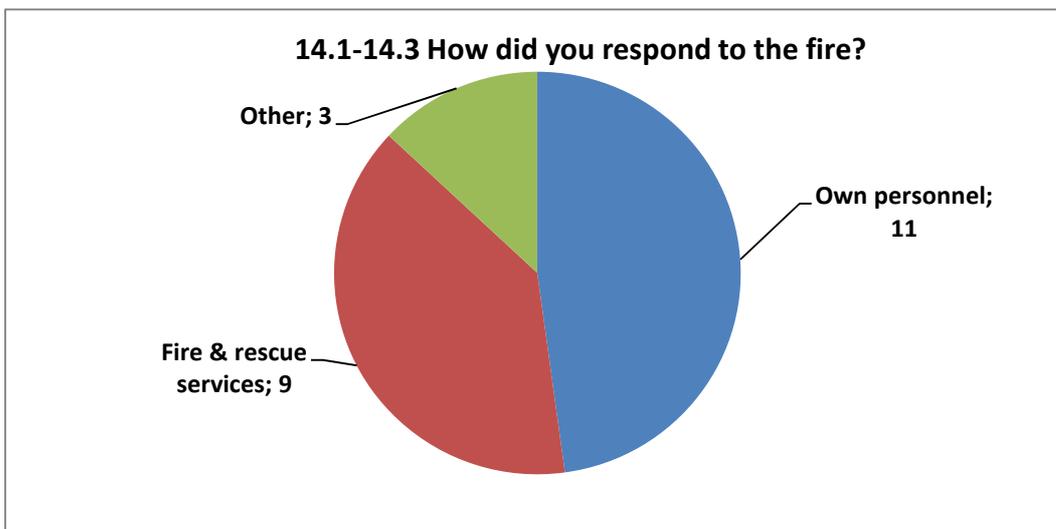


Figure 19 Answers related to how the manufacturers responded to the fire incidents.

## 4.2 Distributors

In total, 40 answers have been obtained from various pellet distributors, 4 from Sweden, 8 from Denmark, 10 from Austria and 18 from Germany. As all German distributors are relatively small, the German pellet association decided not to include all questions in the distributed questionnaire. The excluded questions were 2.3 and the entire questions 6, 8, 11, 13 and 15, which influence the answers from these respondents.

It could also be noted that from Swedish point of view, small distributors selling pellets from Swedish pellet manufacturers to the residential market in small bags was not included in the distribution list. These distributors are mostly only a shipping point between the manufacturer and the final customer and any problems were expected to be covered in the answers from the manufacturers.



#### 4.2.1 General information about the responding distributors

The distributor's turnover of pellets is shown in Figure 20 and as the size of these companies varies from 1 500 ton/year up to 1 000 000 ton/year, the figures are presented in two diagrams with various scale. The upper diagram in Figure 20 is showing all answers in the scale from 0 to 1 200 000 ton/year while the lower diagram has the scale limited to 100 000 ton/year. All Swedish distributors (respondents 1-4) are handling imported pellets and three of the four responding Swedish distributors are actually ports handling import of pellets supplying one or several heating plants.

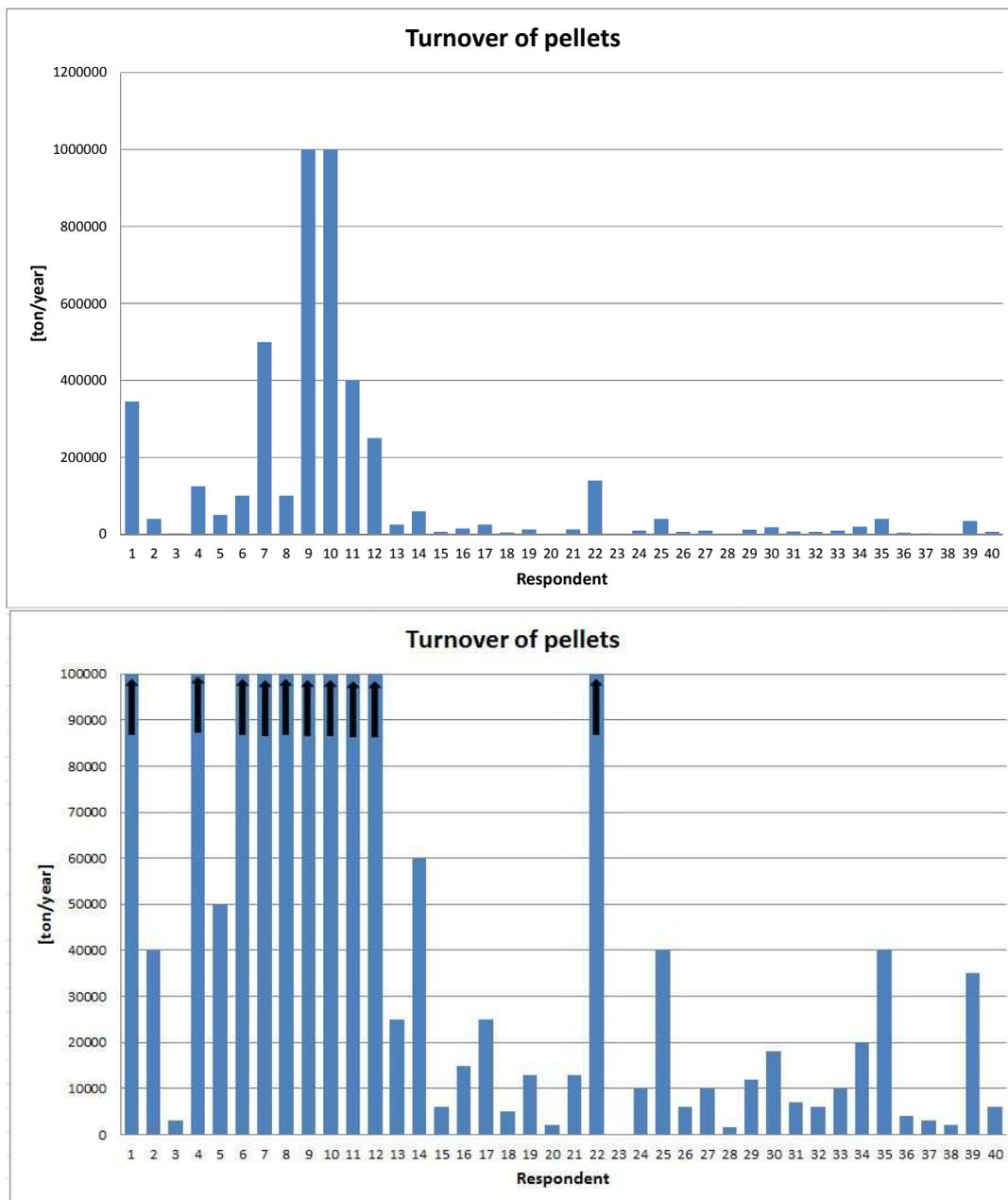


Figure 20 Turnover of pellets per year for responding distributors (lower diagram showing the figures in increased scale).

All Danish distributors (no 5-12) except one have a turnover equal to or larger than 100 000 ton/year. Two respondents (no 9-10) are actually shipping companies and are handling about 1 000 000 ton/year. It should also be noticed that respondent no 11 is only an inspection company, their turnover represent the quantity inspected (400 000 ton/year).

Most of the Austrian and German distributors handle less than 20 000 ton/year but there are some larger distributors with the largest one (no 22) handling 140 000 ton/year. Two respondents (no 27 and 40) have answered “more than 10 000 and 6 000 ton”, respectively) but in the diagrams, these are still represented by these figures.

Table 3 shows a summary of the type of storage used among the responding distributors. Flat storage is the most common form of storage but there are also a number of respondents using both flat storage and silos. In the comments, one responder mentioned that they will build a silo in 2013. There are also some distributors that only trade with pellets without having any storage on their own. For the two shipping companies, the storage facility is actually the cargo holds during loading, transport and unloading.

*Table 3 Summary of the types of storage among the distributors represented in the questionnaire.*

Type of storage	Flat storage	Silo	Flat storage and silo	Big-bag or sacks	Cargo holds	No storage
	18	5	6	1	2	8

Just like the large variation in turnover, there is also a large variation in storage capacity as shown in Figure 21. Of those respondents having their own storage, 18 have a storage capacity less or equal to 5000 ton and ranges then up to 400 000 ton. For the shipping companies, the storage capacity is 30 000 tons which is the capacity of their ships.

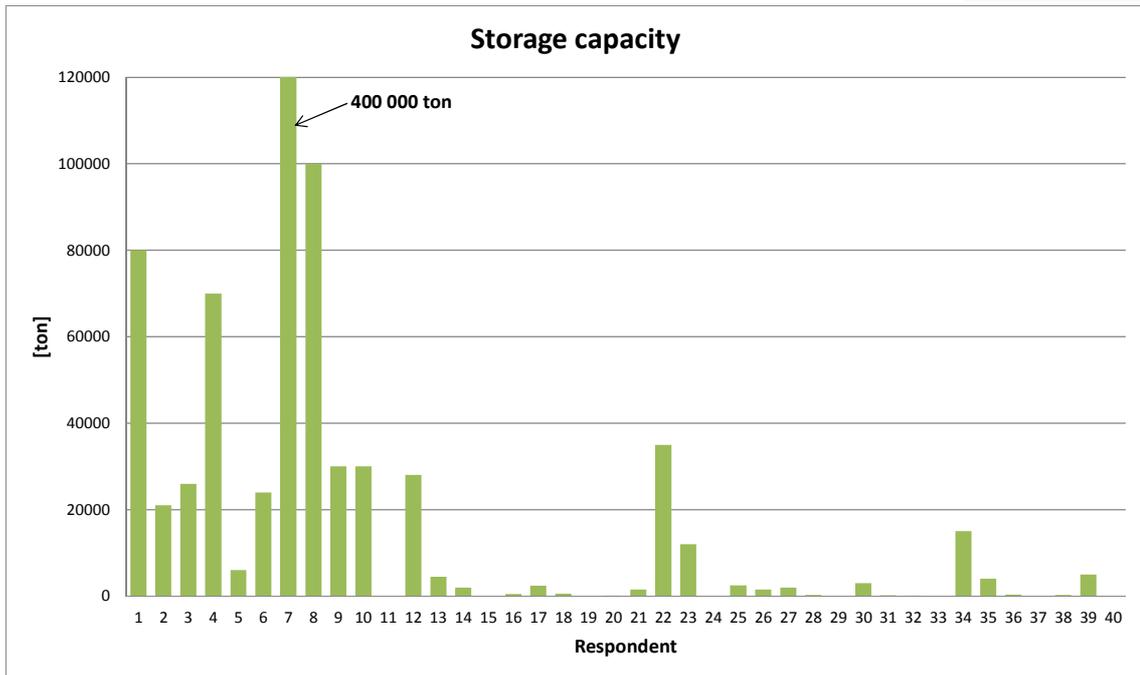


Figure 21 Range of storage capacity among the distributors (respondent no 7 have a storage capacity of 400 000 ton).

The normal and maximum storage time for the distributors is shown in Figure 22. For the distributors having storage, 19 of 32 respondents have a normal storage time of 1-3 months. The declared maximum storage time varies more but, except for one respondent, the storage time is less than 12 months.

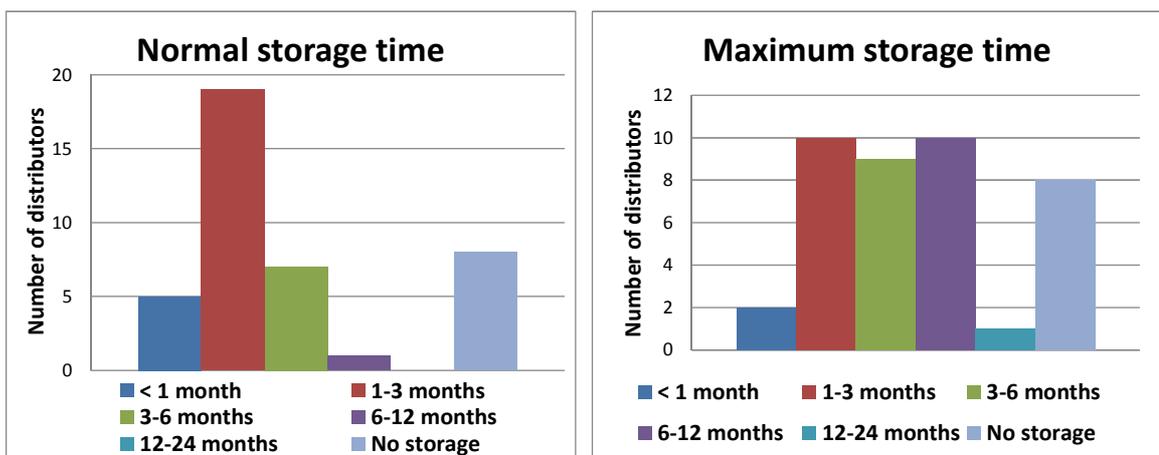


Figure 22 Normal and maximum storage time at distributors.

A summary of the various ways of delivery for the distributors is shown in Figure 23. Bulk handling is very dominant and there are 12 distributors that only handle the pellets in bulk. All

the remaining distributors have also a handling of sacks for consumer use but the amount is in most cases below 25 %. There are only 7 distributors that have indicated handling in big-bags. There are two distributors (8, 11) where the answer is indicated “100 % uncertain” as we do not have information about the proportions of delivery. However, we know that respondent 8 handles both bulk and sacks and that respondent 11 mentioned that wood pellets can be packed both in big-bags or sacks before delivery to the customer.

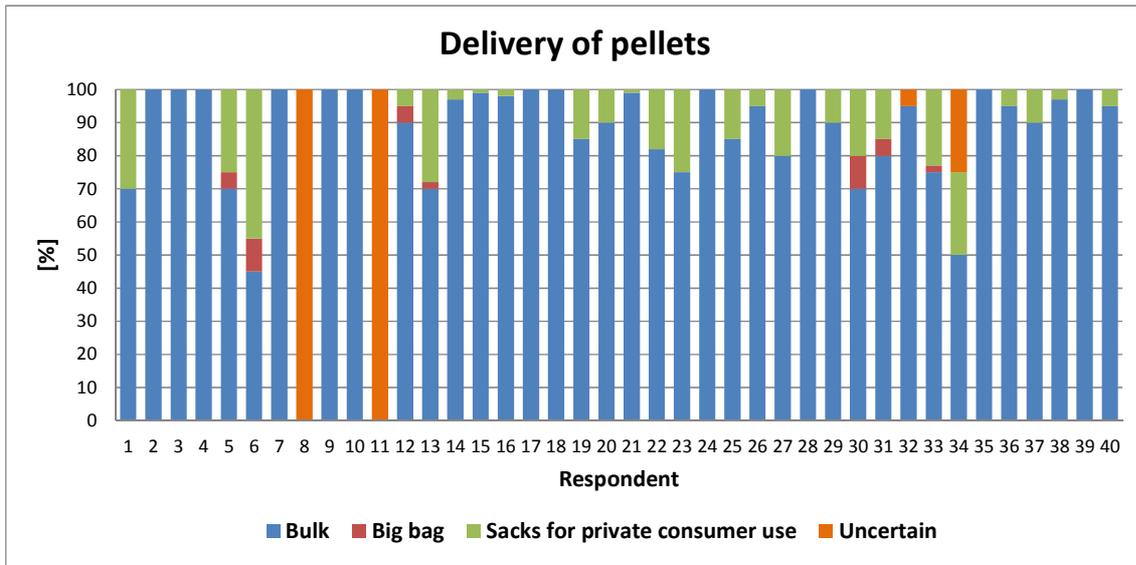


Figure 23 Form of delivery from the various distributors.

#### 4.2.2 Summary of the distributors answers to the specific questions

As previously mentioned, there were 40 responding distributors and in chapter 4.2.2.1 to 4.2.2.3 a summary of the results is presented. Some specific questions were not given to the German distributors and in these cases there are only 22 respondents representing the answers presented. In some cases, the respondents have provided additional comments which are then summarized under each relevant question.

##### 4.2.2.1 Results related to smell and/or off-gassing (Q1-Q6)

As shown in Figure 24, 29 out of 40 respondents have experienced problems with smell and off-gassing and all these respondents are also indicating that they have these problems at some few occasions while none indicate to have frequent problems.

In the comments made to Q1.2 from a number of respondents, the actual frequency of the problem seems to vary from once per year to ten times per year. One respondent mentioned that the problem is specifically related to fresh pellets.

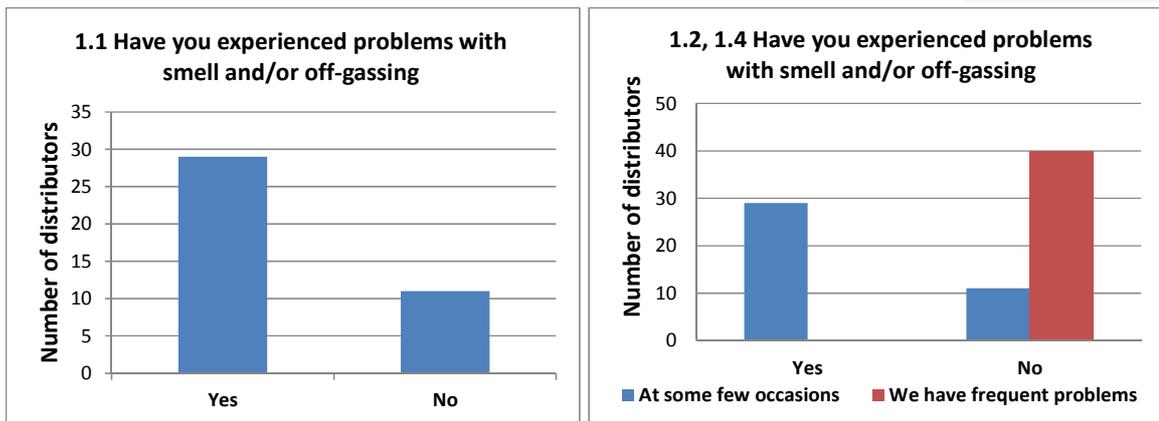


Figure 24 Answers related to overall problems with smell and off-gassing and the frequency among those having experienced problems.

Although problems occur a number of times per year, there is only one respondent where their employees have experienced any symptoms regarding smell and off-gassing, see Figure 25. One respondent commented that they measure both O<sub>2</sub> and CO before the work starts in the storage. However, according to Q1.5 and Q1.6, the consequences seem to have caused both internal company actions and the response from the emergency medical care or the fire rescue. The interpretation could be that there have been some serious problems in the past but in almost all cases without causing any problems for the employees.

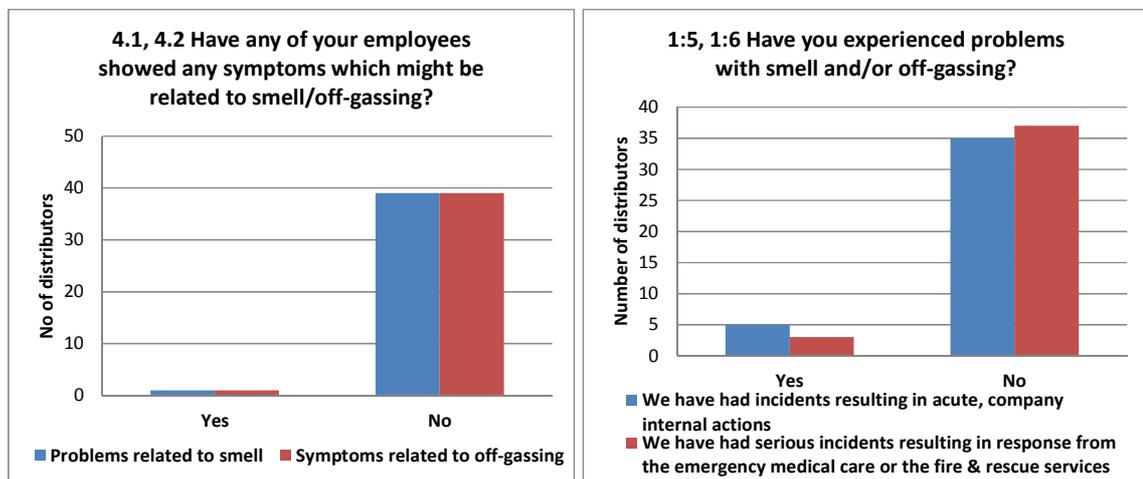


Figure 25 Answers related to the consequences of smell and off-gassing problems.

As shown in Figure 26, a majority of the problems related to smell and off-gassing was observed by either the end consumer or the employees. Question 2.3 (complaints from neighbouring facilities) was not included in the German questionnaire but this has most likely not influenced the overall result.

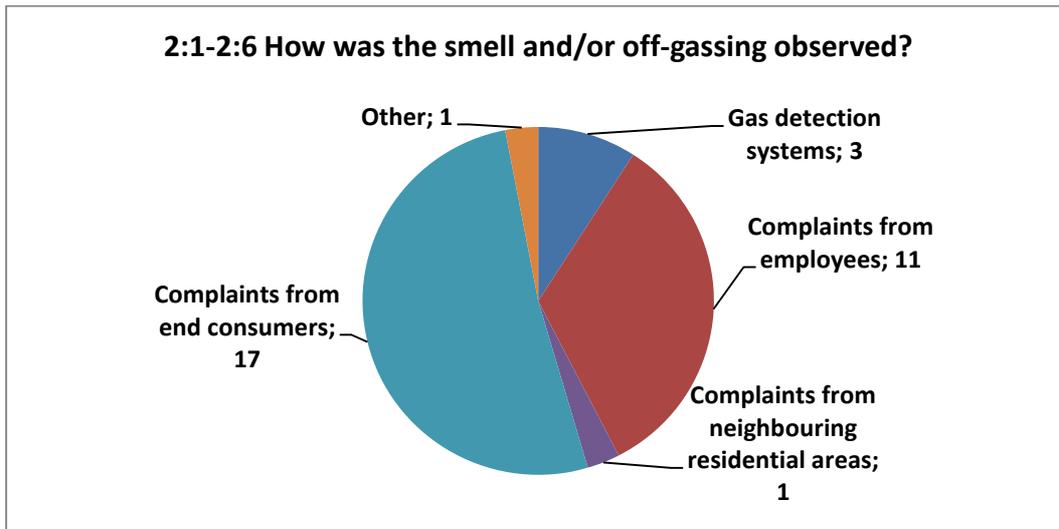


Figure 26 Answers related to how the smell and off-gassing was observed (Q2.3-complaints from neighbouring facilities was not asked in Germany).

As shown in Figure 27, about 17 of the 29 respondents claim to have problems at some few occasions (Q1.2), mentioned that they have learned to handle the problems. One respondent mentioned that they have increased the ventilation. Our interpretation is that the remaining 12 respondents have accepted that smell and off-gassing occur but have not been able to really solve the problem.

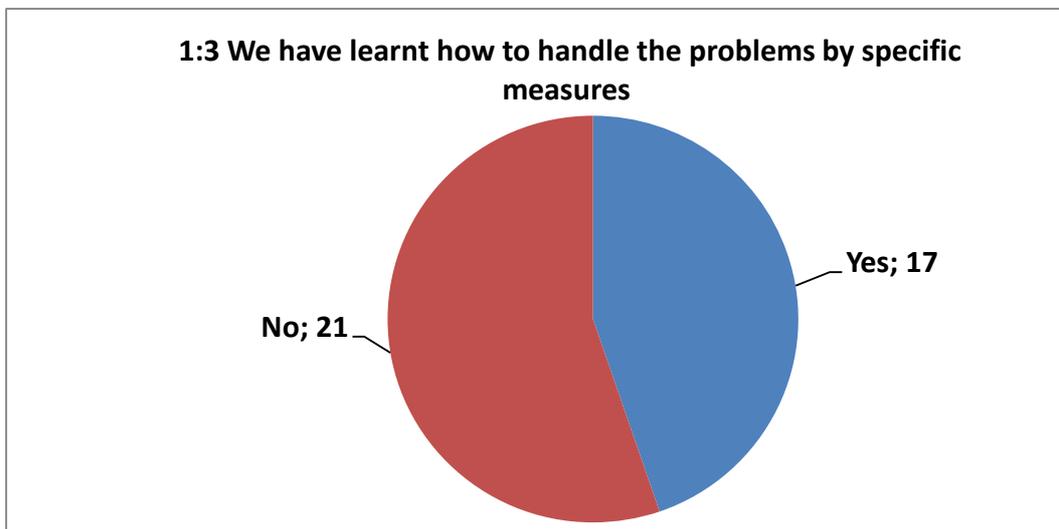


Figure 27. 17 of the 29 respondents having problems at some few occasions declare that they have learnt how to handle the problem with smell and off-gassing.

The suspected causes of the problems among the distributors are mainly related to raw material and production conditions, which are normally out of their control, see Figure 28 (left). The same relates to weather and time of year. One respondent mentioned a combination of low



pressure and no wind, as a typical weather condition causing problem. It should be noted that there are 51 “yes” answers from 28 respondents, indicating that many respondents believe there could be several reasons for the problems.

Question 6 (Figure 28, right) relates to any measures and was not included in the German questionnaire. However, the answers received indicate that some of them have made changes to raw material or production process, probably via a good communication with the pellet manufacturer. The majority have indicated “other measures” and one respondent mentioned frequent control of O<sub>2</sub> and CO concentrations in combination with good ventilation.

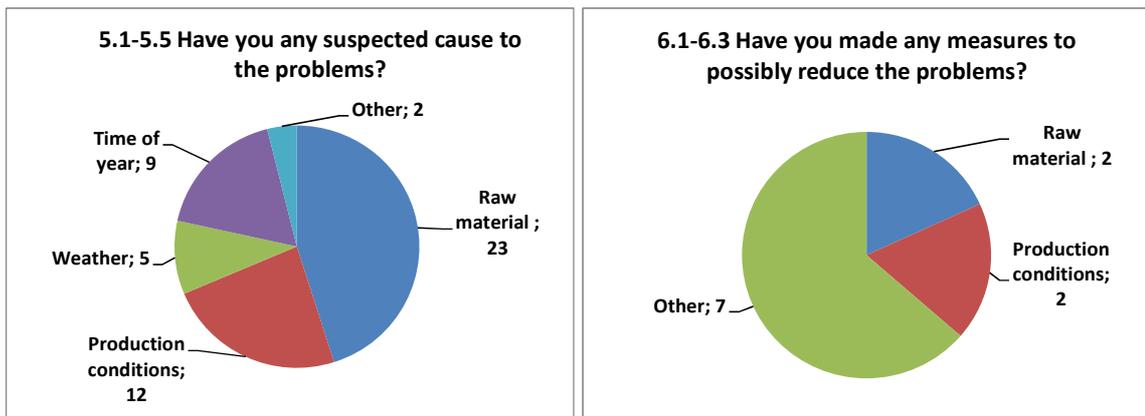


Figure 28 Information about possible causes for the problems and what measures that have been made to reduce the problems (Q6 not answered in Germany).

#### 4.2.2.2 Answers related to self-heating (Q7, 9 and 12)

As shown in Figure 29, 16 out of 40 respondents have experienced problems with self-heating. Mostly, the problems occur at some few occasions, but two respondents indicate that they have frequent problems.

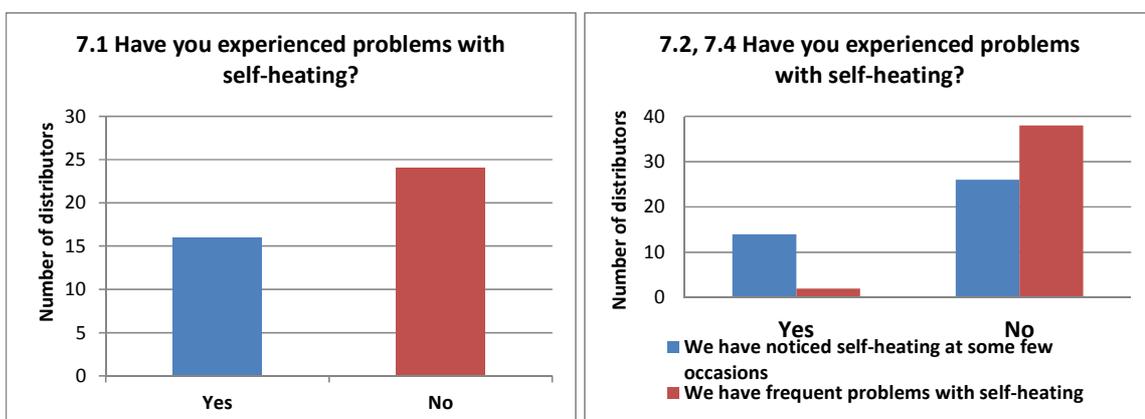


Figure 29 Answers related to the overall problem with self-heating and the frequency among those having experienced problems.

As shown in Figure 30 (left), almost 75 % of the answers indicate that the problem is mainly related to flat storage. A possible explanation could be that the majority of the respondents have flat storage (24 out of 30 respondents storing pellets onshore, see Table 3) and that the size of the silos in general is quite small among the distributors.

There is really no dominating type of action in case of self-heating, but the answers could be interpreted as the first thing to do, is to follow the development of the situation and if necessary, transfer the pellets to another storage.

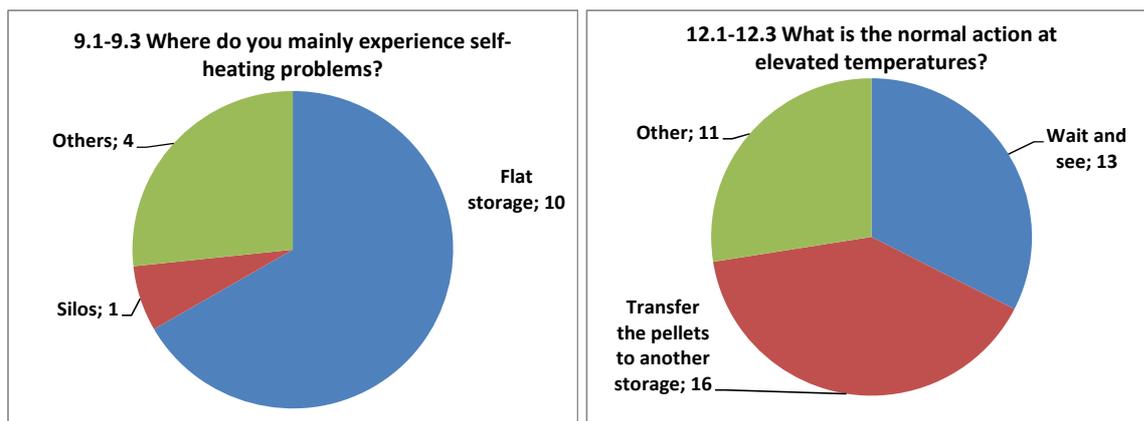


Figure 30 Answers related to where the self-heating problems occur and common actions.

#### 4.2.2.3 Questions related to fire incidents

The following part of the report relates to answers regarding fire incidents for distributors. Some of the questions (Q8, 11, 13 and 15) were not included in the German questionnaire which means that the number of respondents is only 22 for those questions.

According to the received answers on Q8, 4 out of the 22 respondents have experienced fires related to self-heating and Figure 31 provides some more information about these incidents. Two respondents have judged the fires as minor incidents while two respondents indicate more serious fires which resulted in response by the fire and rescues services. One respondent gives an example of an incident, where they had to empty a storage facility due to a fire and part of the storage building was damaged. According to Q13, three respondents answered that the fires occurred in flat storage and one respondent refer to a silo.

In addition, three respondents have experienced fire incidents not related to self-heating.

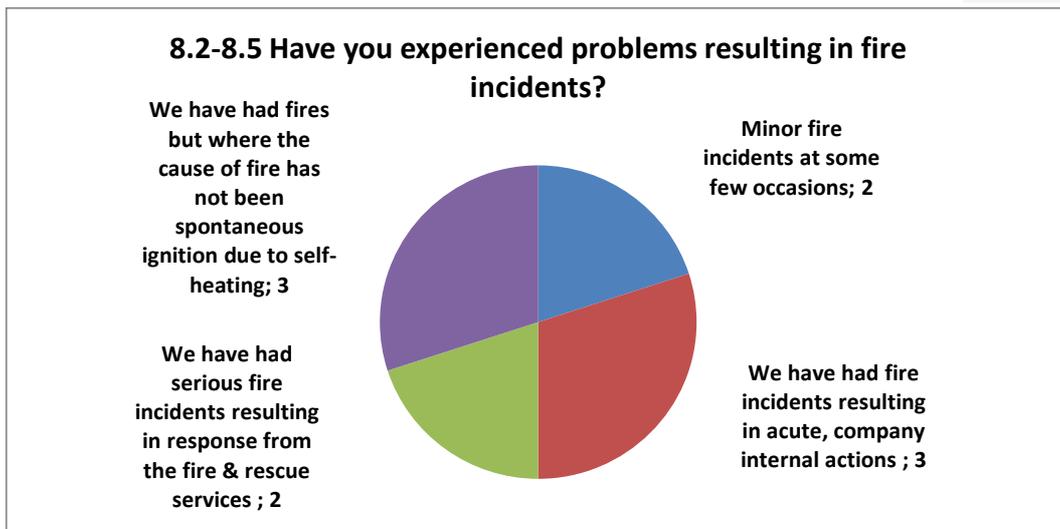


Figure 31 Frequency and consequences of reported fire incidents both related to self-heating and spontaneous ignition but also fires due to other reasons (Germany not included).

The various types of fixed fire detection systems installed at the distributors are shown in Figure 32. Among the 20 respondents who indicated to have some form of detection system, the single most common system is vertically suspended temperature sensors. These are most common in silo storage and as the majority of the distributors seem to use flat storage, the use of “other types of system” seems logic. Unfortunately, there are no comments on what kind of systems that are used. It could be noted that none have indicated that they have a sampling gas detection system.

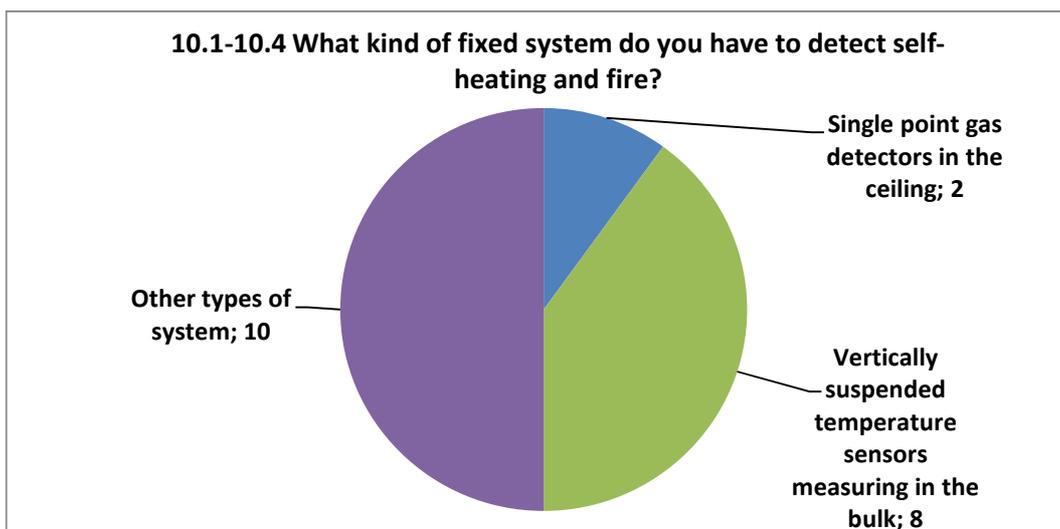


Figure 32 Type of fixed fire detection systems that the responders have installed in their facilities.

In spite that 20 distributors have some form of fire detection system, Figure 33 shows that the most common way to detect a fire is still by observation of smell and smoke. It should be noted that there are 7 respondents that have provided 11 “Yes” answers, indicating that fires at a specific respondent could be detected in more than one way. It should also be noted that these answers also includes the reported fires that was not caused by self-ignition.

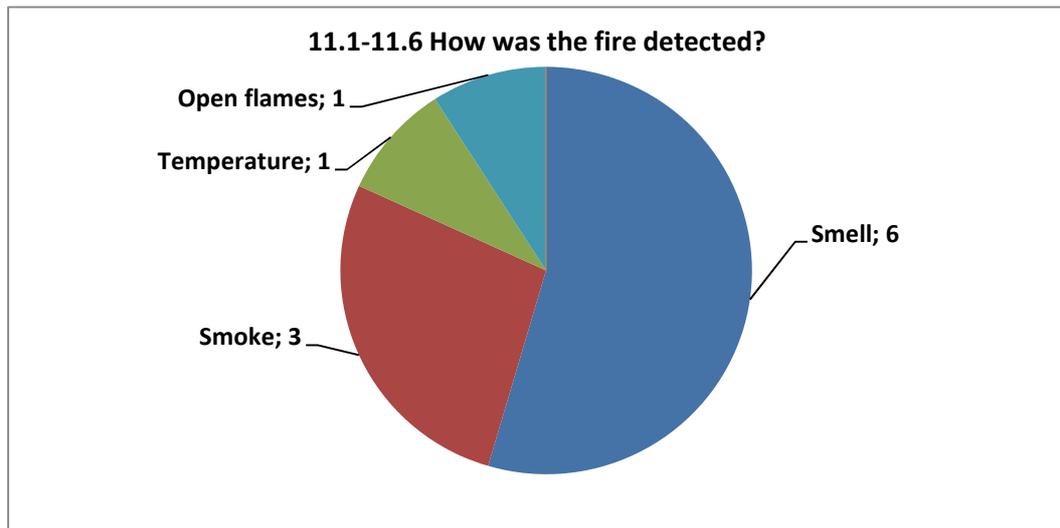


Figure 33 Answers related to how the fire incident was detected (Germany not included). The answers also include incidents not caused by self-ignition.

5 respondents have answered Q14, “How did you respond to the fire?”, and all five have involved their own personnel. Two respondents mentioned that the fire and rescue services have also been involved and one respondent also indicate “other measures”.

## 4.3 Users

In total, 15 answers have been obtained from various pellet users, 11 from Sweden and 4 from Denmark. As most Austrian and German users are relatively small, the Austrian and German pellet associations decided not to distribute the questionnaire to any users.

### 4.3.1 General information about the responding users

The questionnaires in Sweden and Denmark have been distributed to heating/power plants that was identified as users of wood pellets. There is also one industrial user of wood pellet for steam generation in their manufacturing process.

As shown in Figure 34, the pellet consumption vary significantly, from 290 ton/year to 700 000 ton/year. The smaller consumers are using the pellets at small local heating plants, in some cases just to handle peaks in heat consumption during the winter time while other have a



consumption of pellets all year round. The larger consumers are all CHPs (combined heat and power generating plants) including the single industrial user.

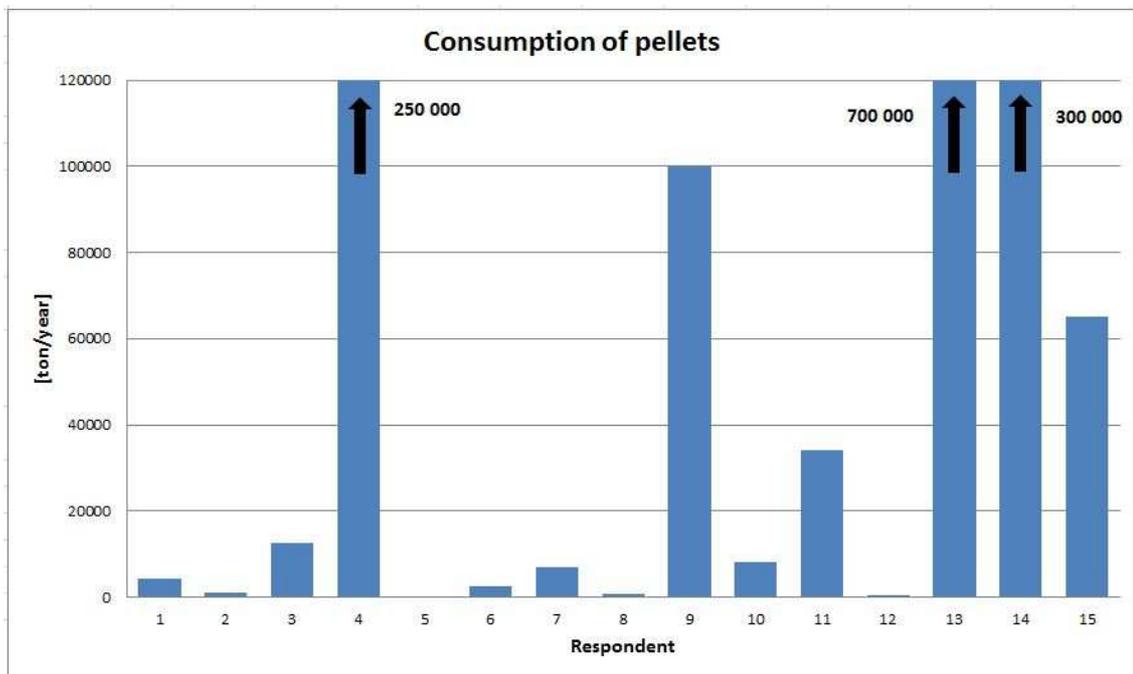


Figure 34 Pellet consumption for the users represented in the questionnaire. Respondent 6 has a capacity up to 40 000 ton/year.

Table 4 provides an overview of the respondents and their type of storage. Respondent 4, 6, 9, and 13-15 are all CHPs, while respondent 11 is an industrial user, and they are all large pellet consumers. It could be noted that respondent no 6 can use up to 40 000 ton/year but the consumption was only 2500 ton in 2012. Among these users, both flat storage and silos are represented and their total storage capacity varies from 500 ton up to 130 000 ton.

The table also shows that the respondents representing a heating plant usually have several facilities which mean that the use of pellets and storage capacity is relatively small. Although there is no exact number of flat storages and silos, respectively, silo storage seems to be the dominant storage method for this type of heating plants and the size of the silos seem to vary from 20 m<sup>3</sup> up to about 300 m<sup>3</sup>.

Table 4 Summary of the types of storage represented in the questionnaire.

Respondent	No of plants	Flat storage	Silo	Flat storage and silo	Approx. total storage capacity (ton)
1	3		3		200
2	2		2		50
3	4			X	600
4	1 (CHP)	2			10 000
5	1		1		50
6	1 (CHP)		1		500
7	5		5		700
8	2		2		65
9	1 (CHP)	1			30 000
10	2		2		300
11	1		1		7000
12	1			X	30
13	1 (CHP)			X	130 000
14	1 (CHP)			X	50 000
15	1 (CHP)		1		3000
Total	27	3	17	4	

Note: "X" indicates that the respondent have both flat storage and silos at their plants, however information is lacking on the specific number of each type of storage.

In Figure 35, the normal and maximum storage time is indicated and as shown, 12 of the 15 respondents indicate a normal storage time of less than 1 month while the remaining three respondents have a normal storage time of 1-3 months. This storage time represent the conditions during the period of heat and power production. As many of the plants are small heating plants, those will have a much lower consumption or even be closed during the summer season. The consequence is that the storage time increase as some pellets might be stored until next heating season. Based on this, the estimated maximum storage time is commonly in the span of 1 to 6 months, but two respondents indicate that the storage time might even be up to 12 months.

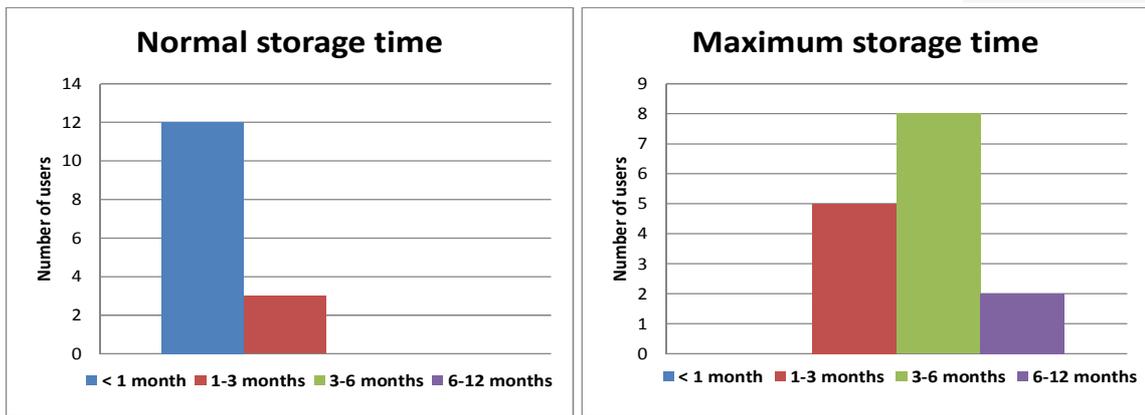


Figure 35 Normal and maximum storage time among the pellet users.

#### 4.3.2 Summary of the users answers to the specific questions

As previously mentioned, there were 15 responding distributors from Sweden and Denmark and in chapter 4.3.2.1 to 4.3.2.3 a summary of the results is presented. In some cases, the respondents have provided additional comments which are then summarized under each relevant question.

##### 4.3.2.1 Results related to smell and/or off-gassing (Q1-Q6)

As shown in Figure 36, 4 of the 15 respondents have experienced problems with smell and off-gassing. One respondent indicated that they have problems at some few occasions (6-8 times/year) and one mentioned that they have frequent problems, without mentioning how frequent those problems are. According to the comments from the first respondent, the problems relate normally both to high CO concentrations and “terpene” smell.

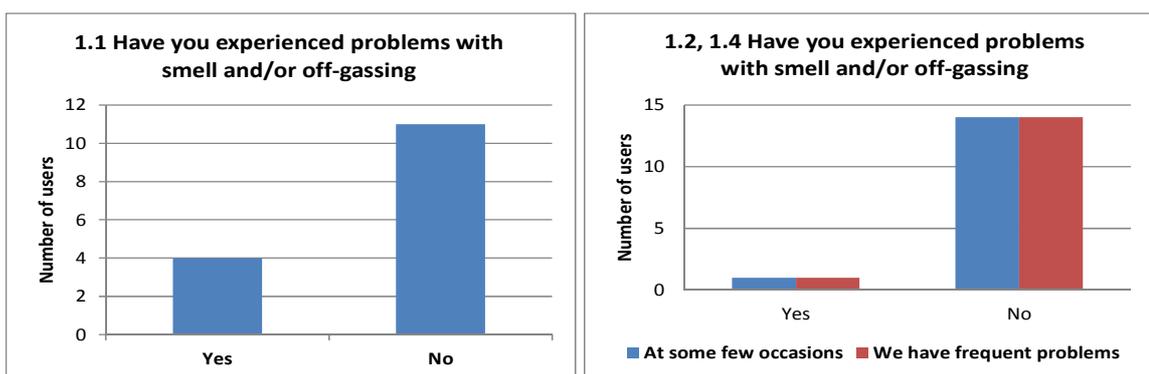


Figure 36 Answers related to the overall problems with smell and off-gassing and the frequency among those having experienced problems.

As shown in Figure 37 and the answers to Q4, only one respondent has declared that any of their employees have showed symptoms related to off-gassing while none have had any

symptoms related to smell. According to the provided comments, the respondent mentioned that symptoms were headache and respiratory disorders due to dust inhalation.

However, despite the previous answers to Q4, one respondent mentioned that they have had incidents resulting in acute internal company actions and two respondents have had serious accidents resulting in response from the fire and rescue services.

According to the comments received to Q1.5 and Q1.6, one respondent mentioned that that problems might occur about once a year due to moist pellets and that they had actions from the fire and rescue services twice. The second respondent mentioned two cases of suspected occupational diseases that might have developed because of handling of pellets or because of work inside a silo. In one case, there was asthma-like symptoms and in another case skin allergy symptom. Both cases have been reported to department of occupational medicine at the nearby hospital.



Figure 37 Answers related to the consequences of the smell and off-gassing problems.

As shown in Figure 38, all four respondents indicate that they have used a gas detection system combined with some other observation when they have noticed the problems. One respondent mentioned that they have gas detectors in the storage building, over the conveyor system and in the maintenance culverts. Another example mentioned that personnel have observed strong smell during patrolling. Another respondent mentioned that one of their employees had read about the fatal accident on-board a ship in Helsingborg [1] and therefore made measurements in their silo discovering problems with off-gassing.

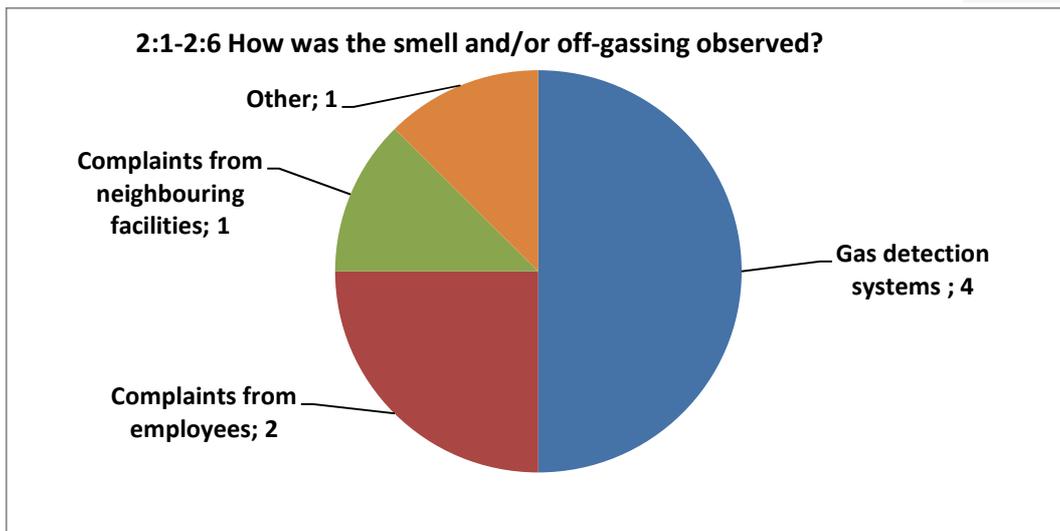


Figure 38 Answers related to how the smell and off-gassing problems were observed.

According to Q1.3, three respondents mentioned that they have learnt to handle the problem. Looking at the specific answers, one respondent seems to have solved the problems and do not have any problems today. According to their comments, they ventilate their silo to get rid of CO during unloading. One respondent still have problems at some few occasions but can control the situation by opening hatches installed in the storage building. There is also a fan system that can ventilate the storage building, the conveyor system and the maintenance culverts. The third respondent claims that they have frequent problems. According to our interpretation, this means that they have also learnt how to handle their problems.

The main causes suspected to be responsible for the smell and off-gassing problems are summarized in Figure 39. Four respondents have provided seven possible causes to the problems, however, there is really no clear trend in the answers. One respondent mentioned the drying process using smoke gases as a factor. He also mentioned that especially fresh pellets smell a lot of terpene, are often warm and might cause condensation in the storage. Also long time storage might cause problems. Another respondent mentioned that it might depend on how they handle the pellets and how they maintain the silo. A third respondent mentioned that the pellets were wetted due to rain during the unloading of a ship.

Looking into the measures made to reduce the problems, there has been attempts to change the production conditions and one respondent have declared to the pellet manufacturer that they do not want warm pellets or pellets generating high CO concentrations. Other respondents mentioned other measures, e.g. patrolling and making routine measurements in the storage to quickly detect any problems, using respiratory equipment and particle filters and avoiding unloading during rainy conditions.

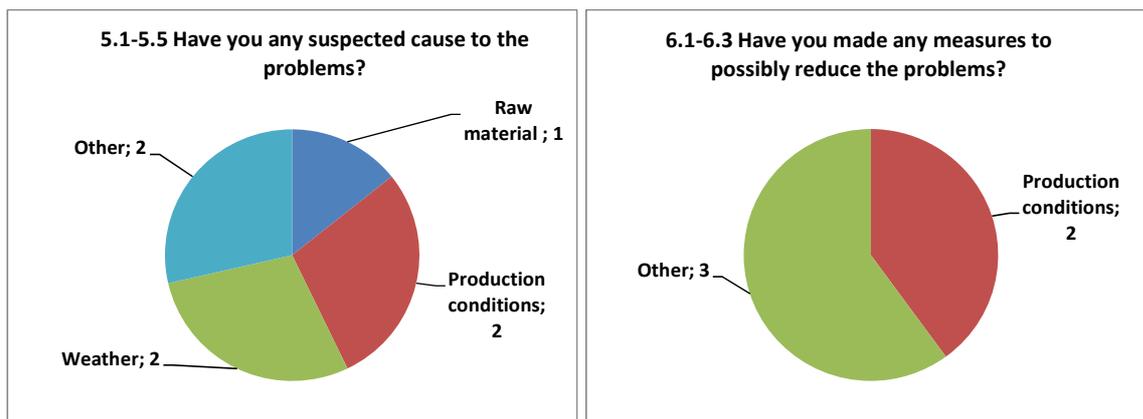


Figure 39 Information about possible causes for the problems and what measures that have been made to reduce the problems.

#### 4.3.2.2 Answers related to self-heating (Q7, 9 and 12)

As shown in Figure 40, 5 respondents have experienced problems with self-heating and 4 of these claim that they still have some problems at some few occasions. Two examples of the frequency are given in the provided comments, “about 6 times in the 19 years we have handled pellets” and “2-3 times of small magnitude”. One of the respondents also mentioned that “this problem must constantly be taken into account.”

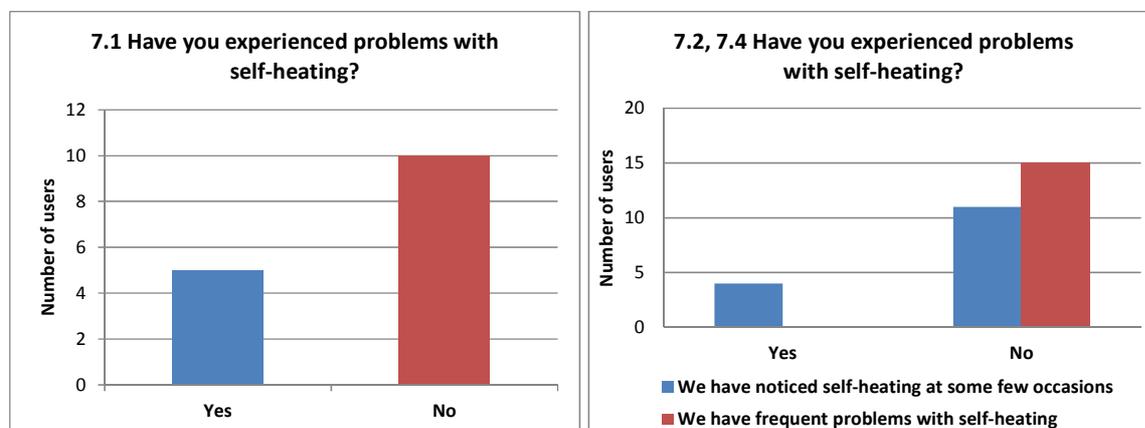


Figure 40 Answers related to the overall problem with self-heating.

According to the answers to Q9 “Where do you mainly experience problem with self-heating?”, the respondents indicated that problems are both related to silos (3 “yes”) and flat storage (2 “yes”). In the comments, one of the respondents mentioned that condensation is their biggest problem and one mentioned that the problems are mainly related to the fuel bunkers before the pellets enter the boiler.

In total 6 respondents have answered Q12 “What is the normal action at elevated temperatures?” and have given in total 10 answers, 3 “wait and see”, 2 “transfer to another



storage” and 5 have suggested “other actions”. Two respondents mentioned that there are no routines, one respondent mentioned that the stored pellets are consumed in about 3 ½ days during full load which solves the problem. Another responder mentioned the possibility to cut a hole in the silo and remove the pellets with a wheel loader in cooperation with the fire and rescue services. Two of the respondents have also provided examples on how to handle the problem, one is to open hatches on the walls and increase ventilation, another is to re-load the pellet stack and try to keep the stack at a low height.

#### 4.3.2.3 Questions related to fire incidents (Q8, Q13)

The following part of the report relates to the answers regarding fire incidents from pellet users and according to the received answers, 3 out of the 15 respondents have experienced fires related to self-heating. As shown in Figure 41, three respondents experience minor fire incidents at some few occasions and five respondents have experienced fires which have been caused by other reasons than self-heating and subsequent spontaneous ignition. Altogether, two respondents declare that the fire and rescue services have responded to the fires while the remaining fires seem to have been handled within the companies.

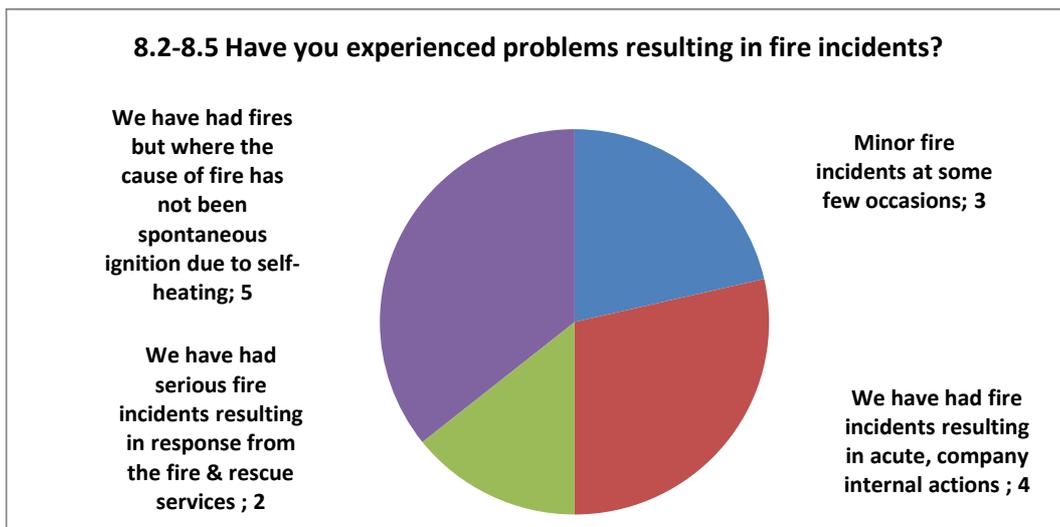


Figure 41 Frequency and consequences of reported fire incidents both related to self-heating and spontaneous ignition but also fires due to other reasons.

Looking into the comments received to Q8, these provide more detailed information. One of the respondents mentioned that they have had fires twice due to self-ignition in their flat storage, and that they have emptied their storage a couple of times. They have also had in total seven fires not caused by self-ignition, five large and two small. The cause of ignition has been friction heat from a belt conveyor, a ripped cable over the belt conveyor causing sparks and friction heat due to a bearing failure in a transport screw. The cause of the four remaining fires has not been possible to establish. Another respondent mentioned that they have had fires twice due to overheating in a belt conveyor and a third respondent also mentioned problems with conveyor belt bearings.

There are two answers related to Q13 “Where did the spontaneous ignition occur?”, indicating problems both in flat storage and silos. In the comments, the respondent with the flat storage fires actually mentioned that the cause of the fire could not be established in all cases. Regarding the silo fires, the respondent mentioned that they have in total six fuel bunkers before the boilers with a size from 90-150 m<sup>3</sup> which seem to be the most common location for the fires.

Figure 42 shows what kind of fixed fire detection systems the responding users have installed. In total 15 answers have been received from 9 respondents, indicating that some of them have more than one type of system. The most common seem to be some form of gas detections system, either as a single point gas detector or a sampling system. Only one respondent have a fixed system for temperature measurements in the bulk while there are 6 answers related to the use of some other kind of detection system.

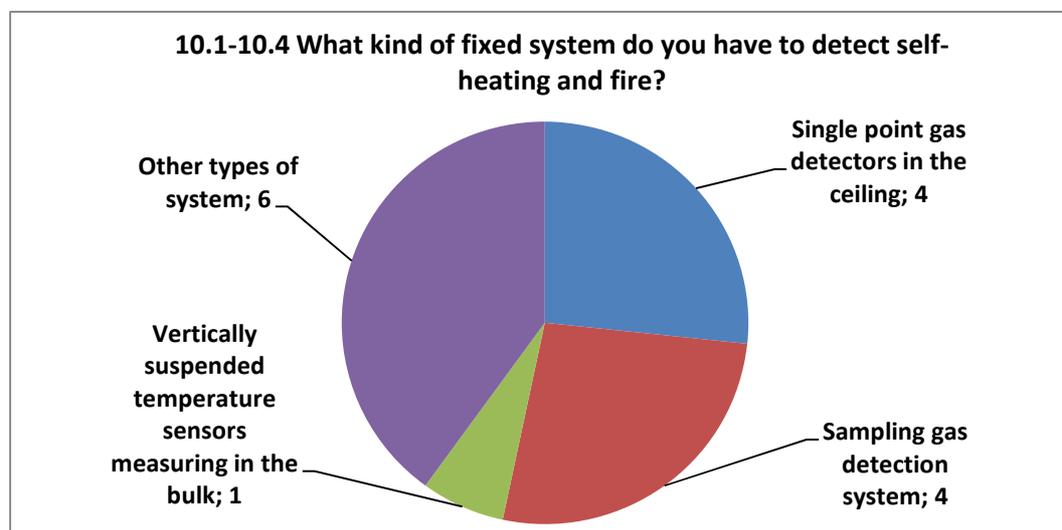


Figure 42 Type of fixed fire detection systems that the respondents have installed in their facilities.

The comments provide some further information and one respondent mentioned that they have CO detectors installed in the conveyor belts ducts and maintenance ducts and sampling gas detectors inside the flat storage and along the conveyor belts inside the storage. Several respondents mentioned the use of IR-detectors, e.g. at the transfer point between conveyors or at the inlet to a silo. One respondent mentioned that they have no fixed system but perform daily inspections making temperature measurements with an IR-camera.

Figure 43 shows how the reported fires have actually been detected, and the three respondents answering this question have provided 10 answers, indicating that the fires have been detected in several ways. All respondents mentioned smell and smoke. In two cases the gas detection system have also provided some form of alarm and in two cases open flames has been observed as well. None of the respondent mentioned temperature detection or some other systems.



The comments provide some additional information and one respondent mention that when sampling system or smoke detectors have triggered because of smoke or fire, the alarm has been confirmed by smell. The respondent also confirms that when the CO-detectors have triggered, they have found smouldering fires. One respondent also mentioned that a sprinkler system activated shortly after a smoke detector gave alarm.

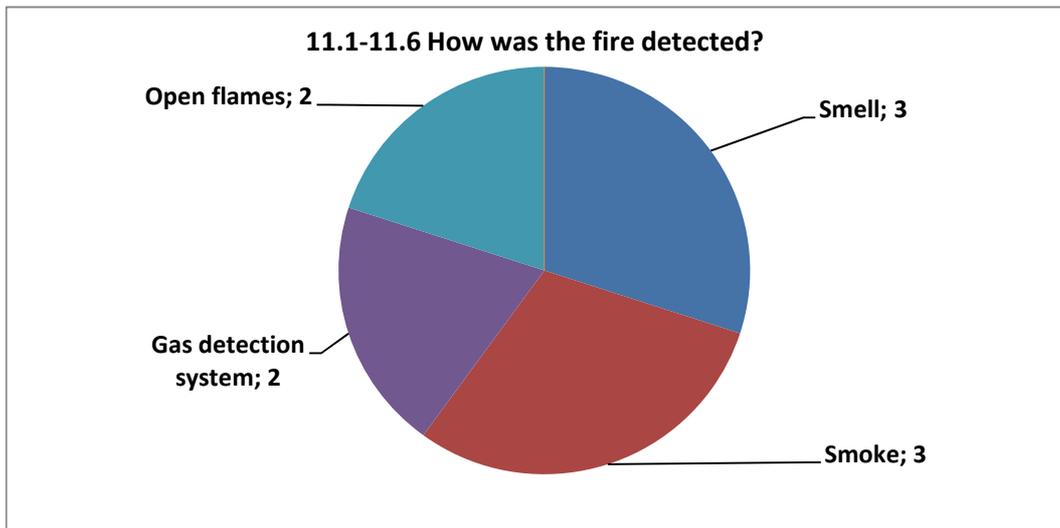


Figure 43 Answers related to how the fire incidents were detected.

All three respondents mentioned in Q14 “How did you respond to the fire?”, that both their own personnel and the fire and rescue services have responded to the fire. In the comments one respondent mentioned that the fire and rescue services was alerted but that there was also a fixed sprinkler system activated. It is also mentioned that the pellets have been covered with foam at two occasions. Another respondent mentioned their use of an IR camera and having front loaders ready for removal of pellets if necessary.

## 5 Experience from real accidents

In the following chapter, a summary is made of reported accidents related to off-gassing and fires. Most of the information has been gained from public literature and the reported accidents are in most cases not directly related to the responders of this questionnaire.

### 5.1 Accidents related to off-gassing

As shown in the questionnaire, there are many producers, distributors and users that declare that they have problems with smell and off-gassing at some few occasions. However, the consequences are often very limited and it is only in some few cases where it has resulted in acute measures or need for medical treatment.

However, the off-gassing has a potential of causing very dangerous situations in case the problems are not known or the problem is not handled seriously and if relevant precautions are not taken.

To show the potential danger, below is a summary of eight accidents dealing with CO poisoning of wood pellets and four accidents dealing with other wood commodities during storage, which have been reported in the period 2002-2012.

It should be noted that in some of the cases, there is not a full agreement whether the accidents were caused by off-gassing or by “back-gassing” from the furnace via the conveyor system into the pellet storage. The information below is based on published literature.

#### 5.1.1 Wood pellets incidents

**2002.** Port of Rotterdam, The Netherlands. One person died of CO poisoning after entering a cargo hold of an ocean vessel loaded in Vancouver with wood pellets. Two other persons were severely injured [2, 3].

**2006.** Port of Helsingborg, Sweden. An ocean vessel transporting wood pellets from British Columbia was the setting for a fatal accident. The accident occurred in the morning, after the gases had built up in the cargo hold during the night, as the doors were closed due to the risk of rain. The usual routine consisted of taking air measurements for oxygen level prior to entering the stairway. That day no air measurements were taken. One worker died, one worker was seriously injured, and several rescuers were slightly injured. Measurements of gases two days after the accident from an undisturbed cargo hold from the vessel on which the accident took place, revealed levels of CO 5850 ppm, CO<sub>2</sub> 9340 ppm, CH<sub>4</sub> 614 ppm [1].

**2007.** One person died in Finland after entering a pellets storeroom of about 10 ton [4].

**2008.** One person died in Finland after entering a pellets storeroom of about 10 ton [4].



**2009.** Bornholm, Denmark. Two persons died on the ship *Amirante* after going down the stairways next to the cargo holds. Wood pellets had been loaded the day before [4].

**2010.** A fatal accident occurred in Germany. A 43-year-old man died after entering the storeroom to fix a problem with the filling level gauge. The 155 ton wood pellet bunker supplied around 700 households. A second worker was slightly injured, but was still able to call the emergency services [3].

**2010.** One person died in Dublin, Ireland, after entering a household storeroom containing approximately 7 ton wood pellets [4].

**2011.** A 28-years-old pregnant woman died of CO poisoning in an 82 m<sup>3</sup> wood pellet storeroom which supplied 60 households in Luzern, Switzerland. There was a problem with the conveyor, so she entered the storeroom to inspect it. The storeroom was one-third full of its capacity and a CO concentration of 7500 ppm was measured after 2 h of ventilating the room [3].

#### 5.1.2 Other materials than wood pellets

**2003.** One person died in the United States in a cargo hold transporting timber [3].

Similar fatal accidents also occurred in Sweden;

- August 2005 (cargo hold transporting pulpwood in Gruvön),
- December 2006 (cargo hold transporting wood chips in Skelleftehamn)
- May 2007 (cargo hold transporting timber in Timrå).

The accidents have all in common that the victims had entered inadequately ventilated stairways communicating with cargo holds [4, 5]. Unfortunately, this long list of accidents may not be complete as there may be more that were not reported. According to Svedberg and Knutsson, a review of accidents in international shipping show 93 reported deaths in confined spaces since 1998 [4].

## 5.2 Fire incidents related to self-heating

Below is a summary of some fire incidents during storage of wood pellets in silos and flat storage. The incidents cover the time period from 1998 to 2012 and are in most cases not directly related to the responders of this questionnaire. Most of the reported fires are related to Scandinavia, mainly because the information has been publicly available. One of the incidents (Avedöre 2012) was not caused by self-heating but is included as it is an example of a complex fire situation caused by a fire in a conveyor system. However, the fire is also of interest as the fire fighting operation inside the affected silos would meet the same challenges also in case of a fire caused by self-heating.

### 5.2.1 Silo fires

**1998.** On the 5<sup>th</sup> of November 1998, a fire started in a large silo complex in Esbjerg, Denmark [6]. The silo complex was originally built for storage of grain and pelletized animal feed and was 85 m high and contained 23 separate silo cells of about 2000 m<sup>3</sup> each. At the time for the fire, 17 cells were filled with material, and part of the silo complex was also used for storage of wood pellets. The fire started in a cell filled with wood pellets, most likely due to self-ignition, and then caused fire spread to two adjacent cells also containing wood pellets. This was the start of a very long and complex fire situation which lasted for about 9 months. During the fire there were several attempts to discharge the material from the burning silo cells, to extinguish the fire with inert gas and foam application. However, during the work, several problems occurred due to a lack of understanding of silo fire fighting, which influenced the fire situation and made the fire involve the entire silo complex.

The main mistake was to try to discharge the first involved silo cell by opening up the side of the silo wall to discharge the pellets out on the ground. However, pyrolysis gases inside the silo cell was ignited when mixed with air causing both smoke gas and dust explosions and during the second attempt, the fire spread to the superstructure on top of the silo complex causing further fire spread into adjacent silo cells. The extinguishing operation was then changed to try to control the fire mainly by use of carbon dioxide and foam application and then discharge the content in a more controlled way which turned out to be a long term operation. The fire was officially declared extinguished on the 24<sup>th</sup> of August 1999. The entire silo complex was then demolished by blasting on the 16<sup>th</sup> of April 2000.

**2004.** In Härnösand, Sweden, 2004, a concrete silo complex consisting of five separate silo cells was involved in a fire [7]. The silos were 34 m high, three silo cells were 11.5 m in diameter and two were 8 m in diameter, corresponding to an effective storage volume of 2700 m<sup>3</sup> and 1350 m<sup>3</sup>, respectively. The silos were used by a nearby pellet manufacturer for storage of wood pellets, as their normal storage capacity (A-frame storage) did not provide storage capacity enough. The silos were started to be filled during the period from the 4<sup>th</sup> to the 23<sup>rd</sup> of August and the filling time of each individual silo cell varied from 7 to 25 days. On the 7<sup>th</sup> of September, a smell was noticed in the area close to the silos and in the morning on the next day heavy smoke and a “rain” of tar particles was observed from silo no 4. Smouldering pellets were observed as the discharge equipment was started and the discharge was therefore immediately stopped again. As the heavy smoke was moving directly towards the city centre causing severe problems, it was decided to use the combined tactics of foam application at the top, CO<sub>2</sub> injection at the bottom and discharge of pellets by making an opening in the silo wall. From experience it was recognised that large water monitors should be used to control the fire in discharged material.

At midnight (8-9<sup>th</sup>), foam was applied into the silo top and at about 05:30 (9<sup>th</sup>), CO<sub>2</sub> was injected through a lance close to the silo bottom. There were significant problems as ice formation in the pellets blocked further gas injection. At about 06:00, a 1-1.5 m<sup>2</sup> opening was made in the silo



wall and undamaged pellets started to flow out. After about 2 hours, dark coloured and partly smouldering pellets were observed and at 10:20, the pyrolysis gases formed due to the increased ventilation were ignited in the silo top, which spread to the entire superstructure on top of the silos. Due to the high level of water application, the fire in the opening and in the discharged pellets could be controlled and the silo was emptied at about 08:00 on the 10<sup>th</sup>. In order to prevent similar situations in the other silos, it was decided to inject CO<sub>2</sub> in the four other silos at well. However, on the morning of the 11<sup>th</sup>, heavy smoke was observed from the top of silo 5 and some “activity” was also observed in silo 1 and 2. The same procedure (water monitors and discharging through an opening made in the silo wall) was also used for silo 5 and also later on for silo 1. During the extinguishing operation, several gas explosions occurred in the silo wall openings and at the discharge opening at the bottom of the silo 1; in some cases flames jetting more than 50 m were observed. Fortunately, no injuries occurred. The three silos, the building construction and conveyor system at the silo top were completely destroyed and the silos were later demolished. Most of the pellets were destroyed as a result of the use of water.

**2007.** In September 2007, auto ignition occurred in a silo in Kristinehamn [8]. The silo was 47 m high and 8 m in diameter, filled to about 40 m with wood pellets. Elevated temperatures had been noted for some period of time and it was planned to empty the silo if the temperatures did not decrease within the next few days. However, before this decision was taken, smoke was noted from the top of the silo on the 29<sup>th</sup> and the fire brigade was called to the location. A first extinguishing attempt was made by intermittent application (due to freezing problems) of CO<sub>2</sub> in liquid phase into the silo headspace. During approximately 18 h, about 35 ton of CO<sub>2</sub> was applied. The application seemed to control the fire but there was no possibility of verifying the extinguishing effect of the CO<sub>2</sub> application.

Preparations were, therefore, made to inject nitrogen close to the silo bottom according to the recommendations from the silo experiments in 2006 [9]. A gas tank with liquefied nitrogen and a vaporization unit was ordered. A hole was drilled close to the bottom of the silo and a lance was manufactured which was introduced into the hole. In order to control the effect of the gas injection, temperatures and the concentrations of CO, CO<sub>2</sub> and O<sub>2</sub> were measured in the silo top. The gas measurements were started in the afternoon on the 1<sup>st</sup> of October, just before the start of nitrogen injection. The measurements indicated a very high concentration of CO (>10 %), a sign of on-going pyrolysis activity. After about 3.5 hours, the first indication of a decreasing CO concentration was observed. In the morning of October 2<sup>nd</sup>, the CO concentration had been reduced to about 2 % and the O<sub>2</sub> concentration was 0 %, and it was decided to start the discharge of the silo content. This work continued until 05:00 on October 4<sup>th</sup> when the silo was declared empty and during this work, there was a continuous injection of nitrogen. The unloading work had to be stopped at times for safety reasons due to high temperatures and increasing oxygen concentration in the silo top. This was probably due to the fact that the seat of the fire was exposed.

The gas injection continued for almost 65 hours without interruption. In total, approximately 14 ton of nitrogen was used, which corresponds to an average injection rate of about 4 kg/m<sup>2</sup> h. The gross volume of the silo was about 2500 m<sup>3</sup>, which gives a total gas consumption of 5.6 kg/m<sup>3</sup>. The use of the 35 ton of CO<sub>2</sub> gas in the beginning of the operation corresponds to 14 kg/m<sup>3</sup>. The gas injection rate and the total gas consumption during the nitrogen inerting operation were reasonably in line with the recommendations given in the report. Only a small portion of the pellets were damaged by the fire.

**2010.** On the 5<sup>th</sup> of July 2010, a fire occurred in a silo at a pellet manufacturing plant in Norway [10]. The silo was 24 m in diameter and had a volume of about 7750 m<sup>3</sup> and was used for storage of the produced pellets. At the time of fire, the silo contained about 3500 m<sup>3</sup> of pellets having a moisture content of about 8 %. The silo was equipped with 6 temperature sensor cables having 9 sensors each, hanging from the silo roof about 3 m from the silo wall.

Just after midnight on the 5<sup>th</sup> of July, the fire brigade was called as the temperature had increased from 30 °C to 60 °C and a CO alarm was activated. Liquefied nitrogen was ordered to be used to inert the silo. To start with, the gas company offered 22 CO<sub>2</sub> bottles (corresponding to 220 m<sup>3</sup> of CO<sub>2</sub> gas) as the delivery of nitrogen was expected to take some time due to the distance. Two hours later, smoke started to become visible at the top of the silo. At 06:35 the CO<sub>2</sub>-bottles arrived and it was decided to apply the gas through a hatch in the silo top in order to control the situation as the delivery of the nitrogen was not expected until the afternoon. The CO<sub>2</sub> filling started at about 8:40 from a platform on the silo top and the plan was to fill 6-8 bottles into the silo. When bottle no 5 was discharged (about 8:41), a fire/explosion occurred, lifting the ceiling about 0.5-1 m and pushed flames during 1-2 seconds a couple of meters side wards along the ceiling circumference. The two fire fighters were hit by the flames but thanks to their full protective clothing none of them was seriously hurt. As the silo now was damaged and considered to be "lost", it was decided to make a hole in the silo wall and discharge the content with an excavator and front loaders in combination with water application.

It could be noticed that although the silo roof was equipped with explosion panels, none of these opened, instead the entire silo roof (weighing 27 ton) lifted from the silo construction. It was also believed that the temperature sensor cables had been pushed outwards during filling, resulting in that temperatures were not measured deep into the bulk where spontaneous ignition is most likely, but rather measuring the temperature very close to the wall. The cause of the gas explosion could not be determined but one likely possibility is electrostatic sparks at the CO<sub>2</sub> nozzle igniting the pyrolysis gases inside the silo.

**2010 and 2012.** Two fires occurred at a Swedish pellet manufacturer in 2010 and 2012. In both cases, the cause of the fire was suspected to be spontaneous ignition. The company have three silos for the storage of produced pellets and the silo involved in the fire had a diameter of 20 m and had a storage capacity of about 3500 ton.



During the first fire in 2010, a smouldering fire was discovered in the end of June [11]. Attempts were made to empty the silo through the normal discharge system (conveyor system below the three silos) but the discharge was stopped as the openings and conveyors were blocked by clumps of charred material. After about 5 days it was decided to open up the silo as this was seen as the only possible solution. An opening was made in the silo wall and the discharge process started by unloading the pellets with a front loader in combination with extinguishing the smouldering pellets. After about 5 hours, a severe explosion occurred, due to formation of a flammable gas in a void volume at the bottom of the silo. As a result of the explosion, two large steel doors in the silo wall were thrown away, one more than 80 m before stopped and bent around a steel beam and the second door was thrown about 250 m. The silo construction itself (walls and roof) was made of 6-12 mm steel which was also heavily deformed due to the explosion. Fortunately no person was injured. The silo was completely destroyed and pellets for about SEK 8 million were also destroyed.

A new silo made of corrugated steel plates was built on the same location and with the same size. The new silo was equipped with temperature sensor lines enabling to monitor the bulk temperature. Almost exactly two years after the first fire, a new fire occurred in the silo [12]. Personnel noticed a smell of fire and some white smoke was visible at the top of the silo. The temperature sensor system still showed about 45 °C which had been the indicated temperature for some weeks. The decision was taken to start discharging the silo at maximum capacity, about 35-40 ton/h. After about 2 hours of discharge, a severe explosion occurred in an elevator being a part of the discharge conveyor system. Based on discussions with the local fire brigade, it was decided to try to inert the silo with nitrogen and nitrogen was ordered. As the message was that the delivery might take a number of hours, the fire brigade started to cool the silo walls. As the silo was not prepared for an inerting process, the personnel at the pellet plant started to make penetrations in the silo wall close to the bottom to enable the injection of nitrogen through steel lances. However, the drill to the drilling machine was broken and the worker left to fetch a new one. Just after this, an explosion occurred and a part of the roof (about 1/8) was thrown away and landed almost at the place where the drilling had taken place. It could be noted that none of the explosion vents mounted on the silo roof opened. As the nitrogen delivery seemed to be further delayed and the silo roof was partly destroyed, the fire brigade started to extinguish the open flames in the silo with a water monitor. About 30 minutes after the explosion the remaining part of the silo roof collapsed. In the morning the day after, the situation seem to be under control, there were no open flames from the silo top and the temperature of the silo wall was measured to about 150 °C just above the pellet surface. A couple of hours later, a loud "bang" was heard and it could be noticed that the entire silo wall had been ripped open due to the forces of the swelling pellets. The discharge operation using front loaders in combination with water application continued for several days. The silo and the about 2000 ton of pellets in the silo was completely destroyed. In the investigation after the fire, it was concluded that the temperature monitoring system probably had been damaged during a thunder storm about 2 weeks before the fire and therefore did not display correct temperatures. The new silo that will

be taken into operation during 2013 has now been prepared with a pipe system at the silo bottom for gas injection.

**2011.** A self-heating incident occurred after delivery of premium wood pellets certified according to ÖNORM and DINplus [13]. When loaded onto the truck, the pellets still had a temperature of 45 °C. The delivery day was a rather warm day in May with temperatures up to 25 °C. The delivery had to be done through a 36 meter tube. (The delivery documents note: No liability based on supply distance >30 meters.) Thus, mechanical stress during the delivery might have contributed to the incident by heating the pellets up on the way through the tube. The pellets exhibited a considerable smell of thinning agent. When the smell increased in the evening of the day after the delivery in concert with a noticeable increased temperature, the customer called the fire brigade. According to their measurements, the silo contained more than 660 ppm carbon monoxide. The temperature of the pellets was at least 54 °C. The fire fighters used forced ventilation to reduce the CO level. However, this caused a significant temperature increase to about 140 °C within 3 hours. It was thus decided to empty the silo into a container which was subsequently done. Accordingly, the temperature in the silo decreased to 28 °C at a filling level of 20 %. From the removed pellets a sample was taken and analysed. According to the analysis report, the pellets had an increased formaldehyde level. Furthermore, the headspace was analysed with a GC-MS and a list of identified compounds was reported.

**2012.** In August 2012, a fire in a conveyor system caused a fire in two silos at the Avedøre power plant in Copenhagen, Denmark [14]. Two employees at the power plant observed smoke from a conveyor connected to the top of two large silos (45 000 m<sup>3</sup> and 100 000 m<sup>3</sup>, respectively) used for pellets storage. The fire and rescue services was called, but as the conveyor was located at 30 m height above the ground, the fire fighting operation became very difficult and the fire spread into the smaller silo, causing a surface fire. Attempts to extinguish the fire were made using water nozzles and water monitors, but the fire could not be extinguished as it had already created a deep seated fire. Due to the heating of the silo construction and the use of water causing the pellets to swell, it was considered there could be a risk that the silo would collapse and it was decided to empty the silo as quickly as possible using large dozers. This work was finalized about 12 days later.

In order to prevent fire spread to the large silo, large resources were deployed to protect this silo during the first part of the fire fighting operation. Unfortunately, although the damper between the conveyor and the silo was closed, some glowing embers made its way into the silo. In order to protect the silo and extinguish the fires in the pellet bulk, inert gas, both nitrogen and CO<sub>2</sub> were injected into the silo. Large amounts of gas were used and delivery of gas was obtained from Denmark and Sweden. A decision was made to discharge the silo by continuously combusting the discharged pellets in the power plant and this operation was estimated to take about 4 weeks.

The fire fighting operation was very complex, involving a lot of personnel and equipment, both from various fire brigades, the power plant and chartered companies. During the entire



operation, priority was given to safety aspects and considerations about the risk for gas and/or dust explosions, collapse of constructions, etc. had to be made continuously. The cause of the fire in the conveyor system is still under investigation and an overall evaluation of the fire fighting operation is on-going.

### 5.2.2 Flat storage fires

**2005.** In 2005, a flat storage in Ramvik, Sweden, containing 9 000 ton of wood pellets ignited due to self-heating [15]. The building was about 150 m × 50 m. The fire fighting operation was started by applying water by firemen wearing SCBA equipment in combination with moving the stacks to an outdoor area using five wheel loaders. During the operation, it was observed that one steel column was heavily affected by heat and the work with the wheel loaders was interrupted. As the building was completely filled with smoke making further visual observations impossible, an excavator was used to open up the walls to improve visibility and enable fire fighting from the outside using both water and foam. When the smoke was cleared, the decision was made to start the use of the wheel loaders again as the risk for building collapse was not considered acute. The fire fighting operation lasted for about 30 hours. Both the building and the pellets were destroyed.

**2009.** In the middle of September 2009, a fire incident occurred in a flat storage (A-frame building) at a pellet manufacturer in Luleå, Sweden [16, 17]. The storage building was about 100 m × 20 m with a maximum storage height of about 8 m, corresponding to a storage capacity of 8 000 ton. At the time of the incident, the storage contained about 5 000 ton. No pellets had been put onto the pile involved in the incident since midsummer. A wheel loader was operating in the storage building at about 20:00 at some distance from the pile but the driver did not notice anything strange. At 21:30, an internal alarm was set off by the aspirating smoke detection system inside the building. Smoke was observed and the fire brigade called. The seat of the fire seemed to be high up in the pile, some meters from the edge. In order to prevent a dust explosion, the area was sprayed with water. Also some beams with dust deposits were sprayed. When the situation was deemed to be under control, the pellets were moved outdoor using wheel loaders. In total 1 800 ton was moved and the work was finished at about 03:00 the following morning without any further damage to the building or the adjacent piles of pellets. All pellets that were moved out of the building were damaged by the water application but no open flames were noticed during the operation. The volume that had been involved in the smouldering fire was estimated to be only about 1 m<sup>3</sup> and was located a couple of meters below the surface.

The cause of the fire is not fully clear. One theory is that slag or embers caused by an accident at a nearby steel mill could have penetrated the roof and started the fire. Another theory is that a small leakage in the roof could have caused wetting of the pile, causing self-heating and spontaneous ignition.

## 6 Summary

In total 93 respondents, consisting of 38 manufacturers, 40 distributors and 15 users, from Austria, Denmark, Germany and Sweden have answered the questionnaire. The Austrian and German pellet associations decided not to distribute the questionnaire to any users as these are relatively small, explaining the lower number of respondents. The responding users in Denmark and Sweden were all representing users on an “industrial” scale.

The respondents thereby represent the entire chain of pellet supply, except for private end users, and the respondents handling tonnage per year range from less than 5 000 ton up to 1 000 000 ton.

### 6.1 Handling and storage

The maximum production capacity for the 38 responding manufacturers varies from a maximum of 300 000 ton/year, to a minimum of 3 000 ton/year which means that both large and small manufacturers are represented. Among the manufacturers, 14 respondents have a capacity of max 50 000 ton/year, 14 respondents have a capacity of 50 000-100 000 ton/year and 10 respondents have a capacity of more than 100 000 ton/year.

On the distribution side, the yearly turnover for the 40 distributors varies from a maximum of 1 000 000 ton, to a minimum of 1 500 ton. Among the distributors, 10 respondents had a turnover exceeding 100 000 ton/year, while 27 respondents handled less than 50 000 ton/year.

On the user side, the yearly pellet consumption from the 15 responding users varied from a maximum of 700 000 ton/year to a minimum of less than 1 000 ton/year. Among the users, 3 respondents had a consumption exceeding 100 000 ton/year, 3 respondents were in the range of 20-100 000 ton/year and 9 respondents consumed less than 20 000 ton/year.

In Table 5, the type of storage for various respondent categories is shown. It should be noted that the table does not provide any information about the total number of each type of storage, as the respondents in many cases might have several flat storages or silos on the plant.

*Table 5 Summary of the type of storage used by the respondents*

Type of storage	Flat storage	Silo	Flat storage and silo	Big-bag or sacks	Cargo holds	No storage
Manufacturers	12	18	4	2	-	-
Distributors	18	5	6	1	2	8
Users*)	3	18	4	--	-	-

\*) The 15 responding users are representing 27 separate plants.



The more dominant use of silos among the users seems reasonable as there is an advantage to have a more mechanised storage at fuel plants.

Looking more into details, the manufacturers have a wide representation of both flat storage and silos with various sizes ranging from 6 000 to 45 000 ton for flat storage and 500 to 8 000 ton in silos.

The storage capacity for the large distributors is in the range from 20 000 ton to 100 000 ton with one respondent having a capacity of 400 000 ton, while the smaller distributors generally have a storage capacity well below 10 000 ton.

The large users are often CHP (combined heat and power generating plants) which use pellets all year in large quantities which also mean that they need large storages. The largest user have a total storage capacity of 130 000 ton which includes both flat storage and large silos while the smallest users have a storage capacity of less than 100 ton.

Small users, in the form of e.g. local heating plants are receiving the pellets by trucks and need a storage capacity of at least 30 to 40 ton to handle such delivery. However, both the large distributors and large users are normally receiving their pellets by ships. For the Baltic sea region, a typical shipment contain about 3 000 to 4 000 ton but for the transatlantic transports a typical load is about 30 000 ton with some ships having a capacity close to 50 000 ton. This means that the receiver must have a storage capacity exceeding these volumes.

Today flat storage normally have a higher capacity than silos but there has been a clear trend in recent years to build very large silos, and there are now silos having a storage volumes of about 100 000 m<sup>3</sup>, corresponding to about 65 000 ton.

The normal storage time is also influenced by the type of respondent. For the manufacturers, about 85 % have a storage time of less than 6 months. About 75 % of the distributors have a storage time of less than 3 month and 100 % of the users have a normal storage time of less than 3 month. The maximum storage time are usually less than 12 months for all respondents but some few manufacturers and one distributor have indicated a maximum storage time up to 24 months.

The type of delivery of the pellets varies significantly among the manufacturers and about 25 % of the respondents have just bulk delivery. However, a large portion of the manufacturers deliver also in sacks, in some cases more than 80 % of their total production. The delivery in big-bag is not that frequent but there are three examples where the manufacturers deliver 50 % or more in big-bags.

Bulk handling is very dominant among the distributors and there are 12 distributors only handling pellets in bulk. All the remaining distributors also have handling of sacks for consumer use but the amount is in most cases below 25 %. Only 7 distributors indicate handling in big-bags which is less than 10 % of their turnover.

All 15 users responding to the questionnaire receive pellets in bulk, 10 respondents by truck, 4 by boat and finally one respondent receiving about 80 % by boat and 20 % by truck.

Based on the pellet manufacturers questionnaires, there is also some information about the raw materials used for pellet production. The most common raw material seem to be saw dust and in some cases wood chips from spruce and pine. As an average for Sweden, the spruce/pine mixture is about 60/40 % but there is a wide range spanning from 100 % spruce to 100 % pine. In Austria and Germany, the use of spruce seem to be more dominating among the responding manufacturers although there are some respondents including small portions of pine or other materials.

Examples of other types of raw materials used among some manufacturers are e.g. wood chips from “energy wood” (mixture of various leaf trees, both softwood and hardwood). In most cases, the raw material seems to be moist, but some manufacturers also use a mixture including some dry matter, e.g. wood shavings, saw dust and wood residue from furniture manufacturing, etc. Among the respondents, there is also one manufacturer using about 95 % wheat straw and another manufacturer using 100 % residue from Shea nuts for their pellet production.

## 6.2 Problems related to smell, off-gassing and self-heating

Based on the answers given and our best possible interpretation of the answers, it is clear that about 70 % (26 out of 38 respondents) of the manufacturers have experienced problems with smell and off-gassing although there are only in some few cases that there have been needs for acute actions. Most manufacturers have learnt to handle the problem and only experience problems at some few occasions per year (22 respondents). Three respondents indicate that they have frequent problems.

Of the responding distributors, 29 out of 40 (about 70 %) have experienced problems and all of them are still having problems at some few occasions. Based on the comments received, these indicate that problems might occur from 1-10 times per year.

Among the users, 4 out of 15 respondents (about 25 %) have experienced problems and two of these respondents indicate to have frequent problems and two respondents have problems at some few occasions. In some cases, these problems have resulted in some form of internal acute actions and in some cases also involving medical care.

In most cases the problems with smell/off-gassing are observed by employees or the customer. However, among the users, gas detection systems were declared to have provided information about off-gassing in 50 % of the situations.

The suspected cause of the problem was mainly related to the raw material followed by production conditions and weather conditions/time of year among the manufacturers and



distributors. However, the responding users indicated to a larger portion the weather conditions and “other” factors to cause the problems.

Looking at the comments from the manufacturers, five respondents specifically related the smell and off-gassing problem to the use of pine as raw material. Three respondents mentioned that they had excluded the use of pine. The need for better cooling after production was mentioned by several respondents, and here the weather conditions/time of year becomes an important factor as an effective cooling can be very difficult to obtain during hot summer periods.

Looking at problems with self-heating, about 35 % of the manufacturers (14 out of 38 respondents) have experienced problems and all 14 declare that the problem occur at some few occasions per year. Based on the answers, self-heating seem to be more frequent in flat storage compared to silos.

Among the distributors, 16 out of 40 respondents (40 %) have experienced self-heating, mostly (14) at some few occasions but 2 respondents indicate frequent problems. Also here the problems seem to be more related to flat storage compared to silos.

Of the 15 responding end-users, 5 (about 35 %) have experienced self-heating problems and 4 still indicate to have problems at some few occasions.

For manufacturers and distributors, the most common actions when self-heating is observed is to “wait and see” and “transfer to another storage”, and this is probably made in this order. “Other actions” are more frequent among the responding users, and one such action could actually be to prioritize the combustion of such pellets to get rid of the problem.

### 6.3 Problems with fire incidents

Among the manufacturers, fire incidents due to self-heating are experienced by about 10 % (4 out of 38) of the respondents. In some cases, they indicate only minor incidents at some few occasions, but there are also fires involving actions both by the company and the fire and rescue services.

As the questions related to fire incidents were not included in the German questionnaire to distributors, there are only 22 responding distributors. Of these, 4 respondents (about 20 %) have experienced fire incidents due to self-heating. As for the manufacturers, some of these are characterized as minor incidents, but in many cases it results in both internal actions and the response of the fire and rescue services.

Among the users, 3 (20 %) of the 15 respondents have experienced fire incidents due to self-heating and as for the manufacturers and distributors, it is a mixture of minor incidents and more severe incidents.

The questionnaire also shows that fires not related to self-heating problems, e.g. in the productions or transport systems are even more common. This is perhaps not surprising considering all the process equipment and handling systems used during pellet production and along the supply chain. In total 14 responding manufacturers (about 35 %), 3 distributors (about 15 %) and 5 users (about 35 %) have also experienced this kind of fire situations. Based on the comments provided with the questionnaire, the incidents are often linked to the process equipment, e.g. dryers and hammer mills, conveyor systems due over-heating, e.g. to broken bearings and electrical failures. The conclusion is that a continuous maintenance and supervision of such systems is vital to avoid fire incidents.

Although many of the respondents have various types of fixed detections systems installed, most fires are observed by smell and/or visual smoke or flames. However, in some comments, examples are mentioned that the first indication could be an alarm from a detector system and the fire is the confirmed by visual observations.



## 7 Conclusions and discussion

Based on the questionnaire, it can be shown that there are problems with smell and off-gassing, self-heating and fire incidents along the chain of supply of pellets. As shown in Table 6, the most frequent problems are related to smell and off-gassing and the problem frequency is then decreasing for self-heating and fire incidents. However, when evaluating the answers related to fire incidents, it is important to notice that these figures do not represent the number of actual fire incidents. In several cases, the comments given by the respondents indicate that their answer might be representing several fire incidents.

*Table 6. Overall percentage of respondents along the chain of supply of pellets indicating problems with smell and off-gassing, self-heating and fires*

Type of problem	Manufacturers (%)	Distributors (%)	Users (%)
Smell and off-gassing	70	70	25
Self-heating	35	40	35
Fire incidents due to self-heating	10	20	20
Fire incidents, other causes	35	15	35

It is difficult to judge how representative the answers from the questionnaire are, but as an example, the 18 Swedish manufacturers who have answered the questionnaire have a total production capacity of approx. 1.2 million ton/year while the theoretical capacity for all pellet manufacturers in Sweden according to SVEBIO is estimated to about 2.3 million ton/year. This means that the responding Swedish manufacturers represent more than 50 % of the Swedish pellet production capacity.

According to the answers, the respondents have in most cases learnt how to handle problems with smell/off-gassing and self-heating but problems still exist and many respondents indicate that there are problems at some few occasions per year. A small number of manufacturers also report to have frequent problems. Although there is normally no serious problems related to off-gassing, there are a number of reported fatal accidents showing the potential for very severe incidents if the problem is not taken seriously. For the user of pellets having the pellet storage connected to a furnace, it is also important to consider the risk of toxic gases inside the storage room/silo caused by “back gassing” from the furnace via the conveyor system. In all cases when there is a need to enter closed pellet storage, an accurate ventilation of the storage combined with measurements of CO is vital before entering. It should also be noticed that O<sub>2</sub> measurements only, does not guarantee a safe entry.

Also the figures on fire incidents related to self-heating indicate that the industry have learnt to handle the problem resulting in lower figures. However, fire incidents often cause significant damage, both to the stored pellets but also to the storage facility, e.g. destroyed silos. It is also clear that fires in pellet plants do not only occur due to self-heating. Also the production

process, conveyor systems, etc. are the cause of many fires and must also be considered in the preventative safety work. Whatever the reason for the fire is, it is also important to consider the possible effects of secondary damage, such as business interruption or problems for third parties, especially for larger manufacturers or larger handling and storage plants. Further efforts to reduce the frequency of fires are therefore essential.

As previously shown in Table 5, the questionnaire indicates that the use of silo and flat storage are in the same order at manufacturing plants. Flat storage is dominant among distributors and silo storage is dominant among users. Based on the answers, self-heating seems to be more frequent in flat storage compared to silos, but there might be other factors, e.g. the individual size of the storage, storage time, etc., that influence these figures and a further and more detailed evaluation would be needed to provide an explanation.

An improved understanding of the influence of various types of storage and storage size on the risk for self-heating and fire incidents will for sure be even more important in the future as there is a clear trend towards an increased use of biomass pellets for large scale energy production to replace the use of fossil fuels, in particular coal. The consequence of an incident might be much larger due to more complex handling systems, very large storage facilities, in many cases in the form of large silos or domes, and large conveyor systems that are critical for the entire operation. At these facilities, the experience is based on a long term use of coal and it is important to realize and consider the difference between coal and wood pellets.

When completed, the SafePellets project will provide much important information with respect to these questions. However, there are also some recent publications compiled on the initiative of IEA Bioenergy Task Group 32 [18, 19], summarising the present state of art regarding wood pellets and other types of biofuels.

Prevention of incidents should of course be given highest priority, however, a relevant preparedness for fire incidents and fire fighting operations is also vital, both in the form of preparatory measures and pre-planning of various incident operations.

Silo fires are one very challenging scenario due to lack of access to the storage volume which in many cases have caused severe problems for fire brigades and resulted in large damages. The Swedish Civil Contingencies Agency (MSB), published in 2012 some guidelines, "Silo Fires- Fire extinguishing and preventative and preparatory measures" (in Swedish, translation to English is on-going) [20], providing useful recommendations.

However, it should be noted that present experience is limited to relatively small silos, and possible influence of scaling factors when dramatically increasing the size of silos, are important to consider, both regarding self-heating and the risk for spontaneous ignition, the fire development and the fire fighting operation. The research within the SafePellets project is, therefore, very important in combination with detailed evaluation of real, large scale fire incidents.



## 8 References

1. Svedberg, U., Samuelsson, J., and Melin, S., "Hazardous Off-Gassing of Carbon Monoxide and Oxygen Depletion during Ocean Transportation of Wood Pellets", *Ann. occup. Hyg.*, 2008.
2. Melin, S., "Review of Off-gassing from Wood Pellets A Canadian Perspective", Wood Pellet Association of Canada, 2010.
3. Gauthier, S., Grass, H., Lory, M., Kraemer, T., Thali, M., and Bartsch, C., "Lethal Carbon Monoxide Poisoning in Wood Pellet Storerooms -Two Cases and a Review of the Literature", *Annals of Occupational Hygiene*, **56**, 7, 755-763, 2012.
4. Svedberg, U., and Knutsson, A., "Faror och hälsorisker vid förvaring och transport av träpellets, träflis och timmer i slutna utrymmen", Arbets- och miljömedicinska kliniken, Sundsvalls Sjukhus, 2011:2, Sundsvall, Mars, 2011.
5. Svedberg, U., Petrini, C., and Johanson, G., "Oxygen depletion and formation of toxic gases following sea transportation of logs and wood chips", *Annals of Occupational Hygiene*, **53**, 8, 779-787, 2009.
6. Beredskapsstyrelsen, *Silobranden på Esbjerg Havn den 5. november 1998*, Beredskapsstyrelsen, 2001.
7. "Rapport Silobrand Härnösand 8-13 september 2004. En beskrivning av olycksförloppet, olycksorsaken och våra erfarenheter från insatsen", Räddningstjänsten Höga Kusten-Ådalen (in Swedish), 2004.
8. Persson, H., Blom, J., and Modin, P., "Forskningserfarenheter avgörande vid släckning av silobrand", In *BrandPosten*, 2007.
9. Persson, H., Blomqvist, P., and Yan, Z., "Brand och brandsläckning i siloanläggningar - en experimentell studie", SP Sveriges Provnings- och Forskningsinstitut, SP Rapport 2006:47, Borås, 2006.
10. Botnen, D., "Rapport, Hallingdal trepellets 5 juli 2010", Hallingdal brann- og redningstjeneste iks, 2010.
11. Nilsson, M. T., "Kraftig explosion i silo", *Nerikes Allehanda*, 2 July, 2010.
12. Isaksson, O., "Silo fire incident-Personal communication", 2012.
13. Pollex, A., "Self-heating incident, Personal communication", 2013.
14. Weinreich, E., "Farlig cocktail af risici", *Brandvesen*, 7, 10-19, 2012.
15. "Insatsrapport - Brand i stort magasin med pellets, avser insats med eget larmnummer 2005/00881", Räddningstjänsten Höga Kusten-Ådalen, 2005-10-08.
16. Persson, U., "Rådig insats begränsade skadorna vid pelletsbrand", In *Norrländska Socialdemokraten* 2009-09-16.
17. Stenberg, L., and Sundberg, L.-O., "Pelletsbrand i Luleå 2009-09-14", Personal communication with Stenberg (2009-09-21) and Sundberg (2009-10-28), 2009.
18. Obernberger, I., and Thek, G., Eds., "The Pellet Handbook - The production and thermal utilisation of biomass pellets," BIOS BIOENERGIESYSTEME GmbH, Austria, 2010.
19. Koppejan, J., "Health and Safety Aspects of Solid Biomass Storage, Transportation and Feeding", IEA Bioenergy, May 2013.
20. Persson, H., *Brand i silo, Brandsläckning samt förebyggande och förberedande åtgärder*, MSB386-oktober 2012 ed., Myndigheten för samhällsskydd och beredskap (MSB), 2012.