SafePellets

Waltraud Emhofer

Publishable Summary Report

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Commercial partner	Firefly AB Laxå Pellets AB Pusch AG AEBIOM-European Biomass Association proPellets Austria PF-Swedish Pellets Association Danske Halmleverandorer DEPV-Deutscher Energieholz- und Pellet-Verband Verdo energy AS DTE-Dansk Traeemballage A/S
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1 Executive Summary

The broadening of the bioenergy fuel resources is a dedicated goal to comply with EU2020 targets. This broadening will also result in the utilization of a wider range of raw materials used in the production of biomass pellets for the heat and energy production sector. However, this increase in production may also lead to an increase in risks from the phenomena of off-gassing and self-heating from biomass pellets and thereby could result in an increase in accidents related to either of the two phenomena. Up to now dedicated methods to assess the off-gassing and/or self-heating potential of biomass pellets and guidelines or standards on how to handle the risks associated with off-gassing and self-heating were not available.

The SafePellets project aimed on the development of methods to provide information about the off-gassing and self-heating potential of biomass pellets and to develop guidelines to give the pellet industry the tools to overcome the risks associated with the two phenomena. To this purpose five RTD partners (BIOENERGY 2020+ GmbH [BE2020], Deutsches Biomasseforschungszentrum [DBFZ], Sveriges Lantbruksuniversitet [SLU], SP Sveriges Tekniska Forskningsinstitut [SP] and the Dansk Technologisk Institut [DTI]), five SME AGs (The European biomass association [AEBIOM], the Austrian pellets association [PPA], the Danish association Danske Halmlevandører [DH], the Swedish pellet association [PF] and the German association Deutscher Energieholz und –pellet Verband [DEPV]), two pellet producers (Laxå Pellets [Laxa] and Dansk Træemballage A/S [DTE], one manufacturer of fire protection equipment (Firefly AB [FF]), one provider of pelletizing equipment (Pusch GmbH [PUSCH]) and one energy provider (Verdo Energy [VERDO]) cooperated within the SafePellets project to investigate, develop and validate test methods for characterizing the off-gassing and self-heating potential of biomass pellets. Furthermore, the results were also utilized for the development of guidelines for pellet industry in “safe” production, transportation and storage of biomass pellets.

In the course of the three year project the partners followed a five-stage approach comprising (1) information gathering and market research, (2) characterization of off-gassing and self-heating from wood pellets, (3) method optimization, (4) measurements and verification in field test experiments and (5) continuous dissemination of the project results to achieve the objectives.

Overall project outcome are the guidelines on safe production, transportation and storage of biomass pellets, which will provide the basis for continuous work within the newly establish WG7 of TC238, which aims to develop 4 international standards related to safety in pellets production, logistics and storage. Furthermore, the project provided a Material Safety Data Sheet for biomass pellets, which will serve as an important tool to allow pellet retailers and consumers to assess safety issues during handling and storage of biomass pellets.

Moreover, measures and technological solutions to prevent self-heating and spontaneous ignition of wood pellets were derived in two ways:

1. By preventive measures in-line (e.g. raw material pre-treatment; minimum age of assortments; adding of antioxidative additives during production) and
2. by end-of-pipe measures (e.g. simple, but reliable sensors for CO and VOCs detection; reliable fire protection system, ventilation of storages).

Last but not least, the SafePellets project has contributed significantly to the deeper understanding of the complex mechanisms of off-gassing and self-heating from biomass pellets, which occurs in both small as well as large-scale handling of pellets. Thus, the findings will definitely help to broaden the applicable fuel resources for heat production.

2 Summary description of project context and objectives

2.1 Project context

Pellets are the most advantageous solid biofuel. This is due to its higher energy density and better defined qualities compared to other solid biofuels. So far, the largest share of the production is made from virgin wood sources. Depending on quality characteristics (wood) pellets are currently used as solid biofuel in large scale power plants, district heating facilities and single household boilers and stoves. Product standards (for wood pellets (EN 14961-2)) are available in Europe ensuring a standard quality of the fuel. First attempts are also undertaken to standardize pellets supply and storage and standards, such as the CEN TS 15234, provide multipart standards including separate quality assurance standards for wood pellets and non-woody pellets. Anyhow, these regulations do not include sufficient safety considerations regarding prevention from self-heating and spontaneous ignition of bulk storages and from off-gassing of toxic emissions like carbon monoxide (CO) and volatile organic compounds. A number of incidents due to spontaneous ignition of wood pellets and accidents due to CO intoxication have been reported. Therefore, both on the CEN (e.g. CEN/TC 335) as well as on the ISO (e.g. ISO/TC 238) level activities must be launched to derive solutions to overcome these threats to industry and customers.

The objectives of the SafePellets project have been derived from the above outlined needs and are listed as follows:

- To identify the origins and quantify the phenomena (1) off-gassing of CO and VOCs and (2) self-heating and spontaneous ignition of wood pellets
- To derive technical solutions to prevent from self-heating and spontaneous ignition of pellets stored in bulk, to provide technical solutions for fire protection
- To provide technical solutions to overcome the threat from off-gassing of formed CO and VOCs in storage systems
- To provide best practice guidelines for quality assurance measures along the whole wood pellets production and supply chain, which shall be the basis for a Europe wide unique standard for quality and safety measures of pellets supply to industrial and private customers

5 SME AGs (The European Biomass Association [AEBIOM], proPellets Austria [PPA], the Swedish Association of Pellet Producers [PF], the German Wood Fuel and Pellet Association [DEPV] and the Danish organization Danske Halmleverandører [DH]), one producer of systems to protect industrial processes against fires and dust explosions (Firefly [FF]), one pellet producer (Laxå Pellets [Laxa]), one company providing know-how and experience for developing operational agrar-pellets heating utilities (Pusch GmbH [Pusch]), one large Danish energy provider (VERDO Energy [Verdo]) and a manufacturer and dealer of transport packaging made from wood (Danske Træemballage A/S [DTE]) cooperate within the

SafePellets project. RTD work is outsourced to a number of RTD institutions in different European countries, with vast experience in the field of characterization of biomass fuels in terms of off-gassing and self-heating properties, test methods and experimental work in laboratory as well as in field test conditions (BIOENERGY 2020+ GmbH [BE2020], Deutsches Biomasseforschungszentrum [DBFZ], Sveriges Lantbruksuniversitet [SLU], SP Sveriges Tekniska Forskningsinstitut [SP] and the Dansk Technologisk Institut [DTI]). Moreover, key personnel involved in the project are also members of standardization groups on a national, European and also international level.

In order to meet the above-described objectives, the project work followed a five-stage approach (1) comprising information gathering and market research, (2) characterization of off-gassing and self-heating from wood pellets, (3) method optimization, (4) measurements and verification in field test experiments and (5) continuous dissemination of the project results Whilst the RTD partners mostly did the scientific part of the work, the associations and the involved industry partners evaluated the proposed methods regarding their practical applicability and helped to develop and disseminate the best practice guidelines for safe handling, storage and transportation of biomass pellets.

2.2 Project objectives according to the individual work packages

WP 2 - Market and risk inventory, and product selection

The work package was divided in two main parts. The first part was focusing on:

(i) the evaluation of:

- market relevance of off-gassing and self-heating based on the current wood and non-wood pellets production and storage capacities in Europe
- available production, logistic and storage technologies

(ii) information on:

- reported incidents related to the phenomena of self-heating and/or off-gassing of biomass pellets
- existing national standards and guidelines for biomass pellets production, logistics and storage

In the second part the selection of relevant pellets to be investigated in the project and standardized sampling and distribution to the project partners was the main focus. Both commercially available pellets and pellets with high potential for the future were to be part of the selection. Furthermore, pellets with defined composition were to be produced to investigate the influence of raw material and production aspects on the off-gassing and self-heating potential.

WP 3 - Characterization of the off-gassing of wood pellets

The objective of this work package has been to study causes for the phenomenon of off-gassing from biomass pellets during storage. Additionally, parameters influencing the off-gassing characteristics have been studied (e.g. pellets moisture, biomass species, etc.). An important aim has been to develop a simple and standardized method to determine off-gassing from pellets. Supplementary comparative emission measurements from biomass pellets from different production processes and batches have been made. The correlation between raw-material variables (e.g. moisture content of pellets) and formation of VOCs (e.g. aldehydes), CO and CO_2 of various pellets has been investigated. Some of these gases are flammable and toxic and will increase the risks during storage of pellets.

WP 4 - Characterization of the self-heating of wood pellets

Within this work package the cause(s) and conditions for the phenomenon self-heating and spontaneous ignition of biomass pellets during storage were examined. Experiments monitoring the propensity for self-heating were carried out in different scales. Different small scale methods have been used to characterize biomass pellets with different properties. A laboratory screening method was developed for determination of self-heating potential of biomass pellets and was used for screening of different types of pellets. The development of a simulation tool for prediction of self-heating risks in storage was initiated. Analyses and measurements in connection with medium scale tests were carried out to compare and verify the results from small scale experiments and simulations. Some comparisons were also made with tests in full scale.

WP 5 - Measurements and verification in real scale storages

The objective of WP5 was to verify the experiments, which were carried out in the previous work packages (WP 3 and WP4) in small laboratory-scale conditions, for real-scale storage of biomass pellets regarding the off-gassing and self-heating potential. The previous data was verified under three representative storage conditions:

1. residential storage (1.000 – 10.000 kg)
2. industrial storage silo (>100.000 kg). and
3. piles in roofed storage (>200.000 kg).

The tests and measurements were designed in cooperation with the industry partners of the project and selected pellets were used to verify the potential of new measures (e.g. ventilation equipment, special sensor equipment,…) to reduce off-gassing and self-heating effects from the pellets.

WP 6 – Measures and recommendations to prevent and handle off-gassing and self-heating

The objective of this work package was twofold:

(1) Validated recommendations and guidelines for the production of pellets with low self-heating and off-gassing potential, as well as recommendations for the safe transportation and storage of pellets were developed.

(2) Together with industrial partners a draft for a Material Safety Data Sheet for biomass pellets was developed, which will provide a basic tool to allow pellet retailers and consumers to assess safety issues during handling and storage of biomass pellets.

2.3 Description of the main S & T results/foregrounds

Overview of actual market situation and predicted further developments for woody and non-woody pellets

The structure of the worldwide pellet production market is very different dependent on the available resources within the individual countries as well as the targeted markets. The market inventory was conducted by data collection on pellet production figures and on projections for the estimated future demands for woody and non-woody pellets (see Figure 1).

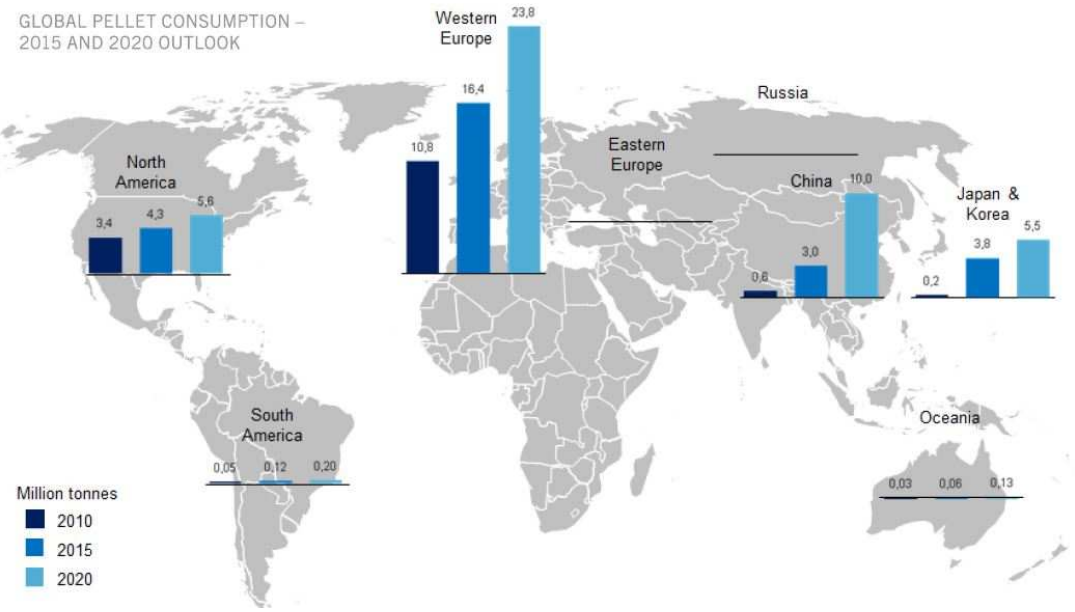

Figure 1: Global pellet consumption and outlook (Pöyry, 2012)

Estimated numbers on current amounts of produced and consumed wood pellets worldwide and within the European Union were also presented (see Figure 2 and Figure 3).

Additionally, information on state-of-the-art pellet production, logistics and storage conditions was collected and presented to allow an overview on current pellet production conditions (information was mainly provided for the 4 participating countries in the project: Germany, Austria, Sweden and Denmark). Also, a detailed description of relevant raw materials used in pellet production is given, followed by a description of commonly used means of transport and shipping of pellets, as well as commonly used storage situations for both industrial and residential purposes. In an extensive public report, available on the project website (Deliverable 2.2 Part A), the data has been summarized.

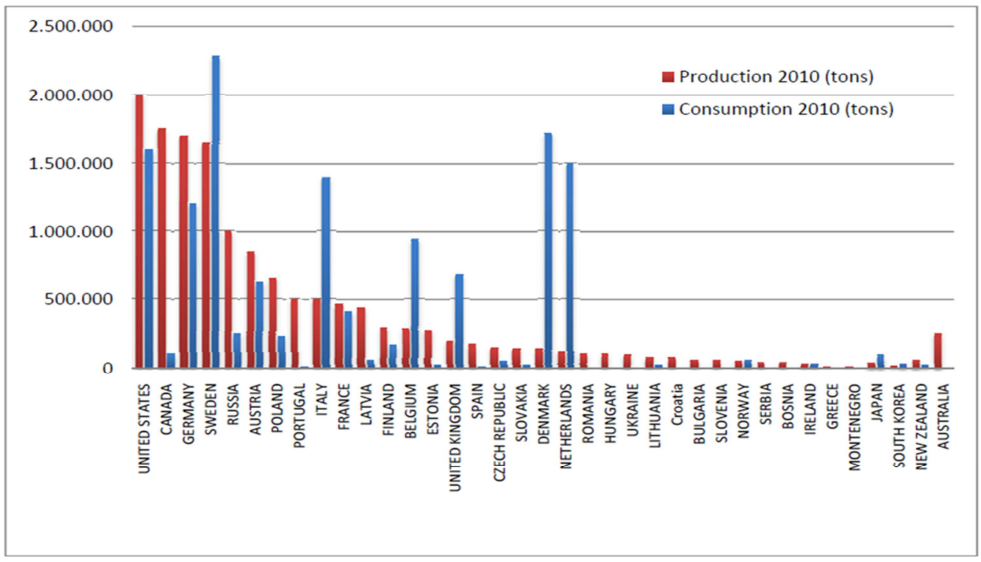

Figure 2: Production and consumption of wood pellets worldwide (Source: IEA 2012)

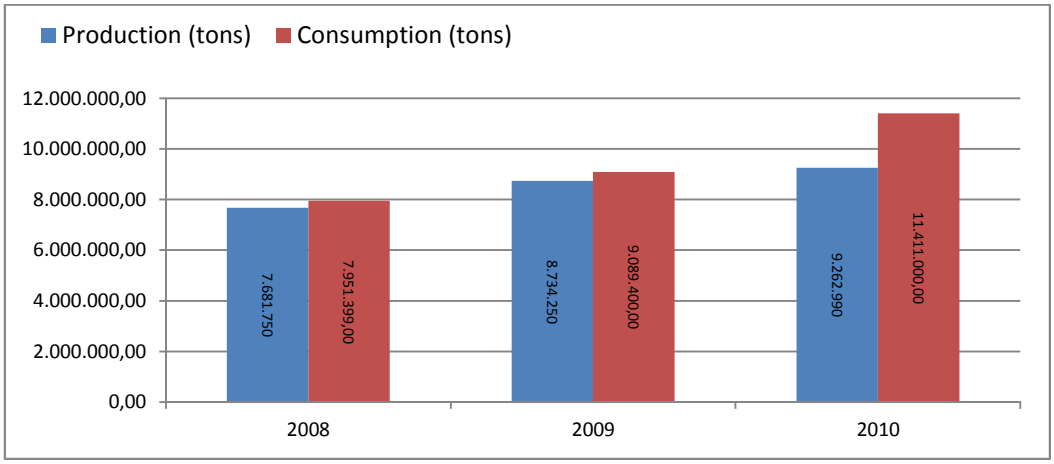

Figure 3: Production and consumption of wood pellets within the European Union (Source: IEA 2012)

Additionally, information on state-of-the-art pellet production, logistics and storage conditions was collected and presented to allow an overview on current pellet production conditions (information was mainly provided for the 4 participating countries in the project: Germany, Austria, Sweden and Denmark). Also, a detailed description of relevant raw materials used in pellet production is given, followed by a description of commonly used means of transport and shipping of pellets, as well as commonly used storage situations for both industrial and residential purposes. In an extensive public report, available on the project website (Deliverable 2.2 Part A), the data has been summarized.

Risk assessment of off-gassing and self-heating/spontaneous ignition of biomass pellets during storage

In a detailed publicly available report, available on the SafePellets webpage, Deliverable 2.2 Part B, the results of the survey on "Problems and Incidents during Pellet Transportation and Storage" related to off-gassing and self-heating along the pellet supply chain are presented. To gather this data a questionnaire was developed and distributed in the partner countries of the SafePellets project (Austria, Denmark, Germany and Sweden). The targeted stakeholders were pellet manufacturers, pellet distributors and industrial scale 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. An overview of the answers received from the participating countries is presented in Table 1.

Table 1: Summary of the answers of the questionnaires on incident reports

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

In total 93 answers have been received and most answers were obtained from manufacturers (38 respondents) and distributors (40 respondents) and a small number of users (15 respondents). The participants were asked whether they had ever experienced any problems with off-gassing and/or smell from pellets or with self-heating from pellets. As shown in Figure 4, 5 and 6, 26 out of 38 manufacturers (about 68 %), 29 out of 40 distributors (about 73 %) and 4 out of 15 users (about 27 %) have experienced problems with smell and off-gassing. Problems with self-heating were reported by 14 out of 38 manufacturers (about 37 %), 16 out of 40 distributers (about 40 %) and 5 out of 15 users (about 33 %) (see Figures 7,8 and 9).

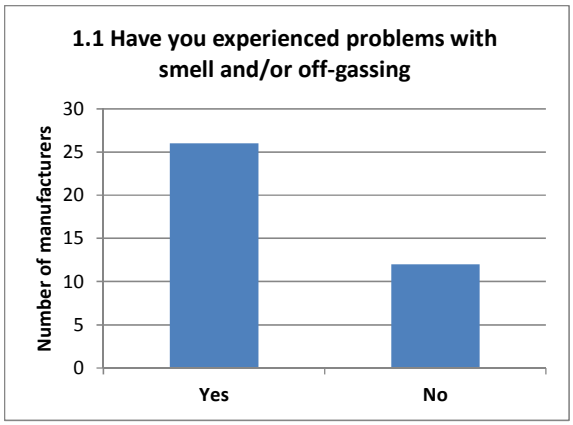

Figure 4: Manufacturers answers related to the overall problem with smell and off-gassing

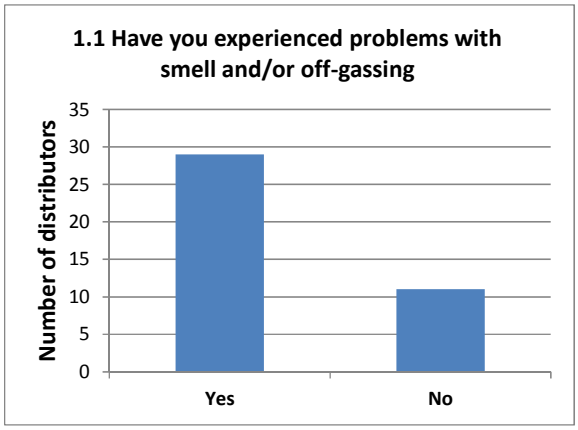

Figure 5: Distributers answers related to the overall problem with smell and off-gassing

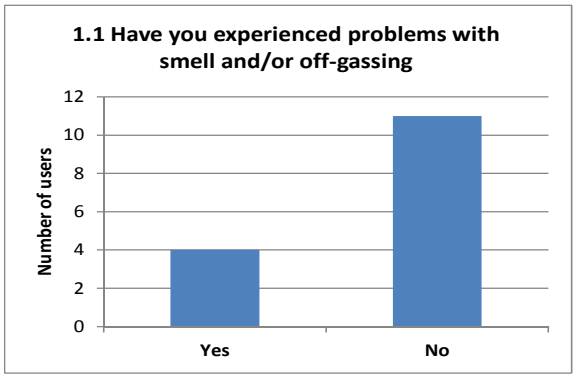

Figure 6: Users answers related to the overall problem with smell and off-gassing

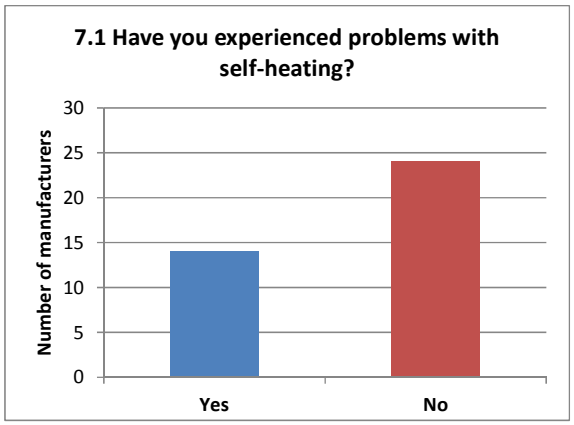

Figure 7: Manufacturers answers related to the overall problem with self-heating

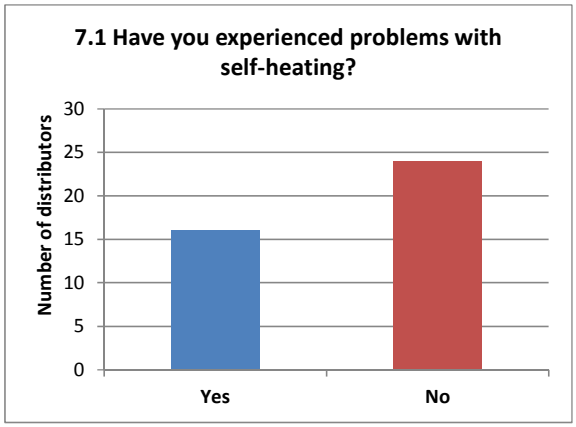

Figure 8: Distributers answers related to the overall problem with self-heating

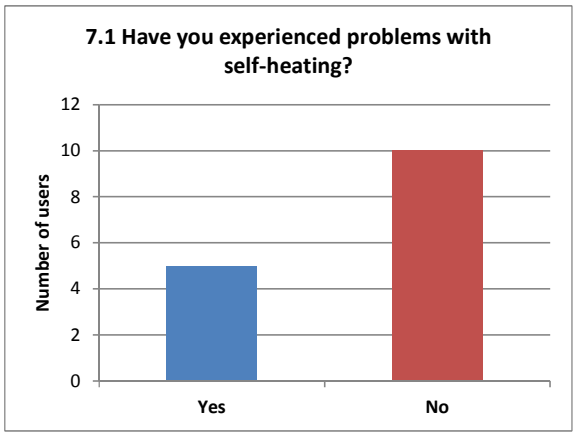

Figure 9: Users answers related to the overall problem with self-heating

Issues for pellet manufacturers

68 % of questioned manufacturers have reported to have experiences problems related to off-gassing and smell from pellets. Out of this group most reported to have experienced problem only on few occasions (22 respondents), while three respondents reported that they have frequent problems. The frequency of off-gassing incidents that caused problems to the employees is relative low, 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. Only one respondent has answered that the experienced 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.

The main causes suspected to be responsible for the smell and off-gassing problems are shown in Figure 10. 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. Furthermore, 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. As a consequence possible measures reported by manufacturers, which can help to avoid the problems of smell and off-gassing are mainly focused on the raw material and production conditions.

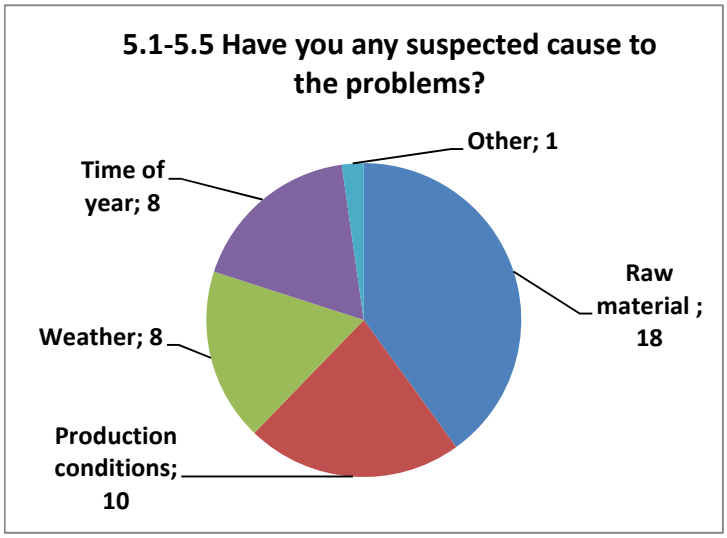

Figure 10: Manufacturers answers to suspected causes for problems with smell and off-gassing

37 % of manufacturers reported to have experienced problems with self-heating and all of them declare that the problems occur on more than one occasions. Three respondents indicated that

they have frequent problems. However, only in a few cases it was reported that there has been need for acute actions to be taken. Most manufacturers declare that they have learnt to handle the problem. The most common actions in case of self-heating are shown in Figure 11. 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 cases other measures were taken as well, however, it was not further specified what exactly was done by the companies. Four manufacturers out of 38 (about 10 %) have experienced fire incidents related to self-heating, however, most respondents answers indicated 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.

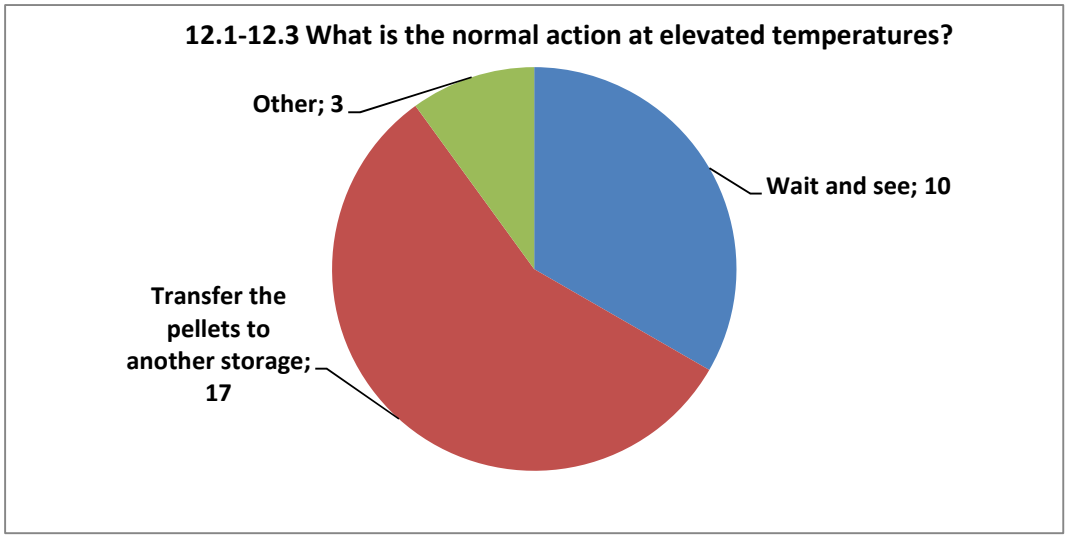

Figure 11: Measures to be taken by manufacturers in case of self-heating incidents

Issues for pellet distributors

Of the responding distributors about 70 % have experienced problems with off-gassing and smell from pellets and all of them are still having problems as often as from 1-10 times per year. Although problems occur a number of times per year, only one respondent reported that their employees have experienced any symptoms from smell and off-gassing. A majority of the problems related to smell and off-gassing was observed by either the end consumer or the employees, but other detection systems were mentioned as well (see Figure 12). The suspected causes of the problems among the distributors are mainly related to raw material, production conditions, weather and time of year, all of which are normally out of their control. The majority of distributers have indicated that they take “other measures” to control the issues related to smell and off-gassing, one respondent mentioned that they carry out frequent controls of O_2 and CO concentrations in combination with good ventilation of the storages.

40 % of distributers reported to have experienced problems with self-heating. Mostly, the problems occurred at only a few occasions, but two respondents indicated that they have frequent problems. Almost 75 % of the answers indicated 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) and that the size of the silos in general is quite small among the distributors. For the pellet 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 (see Figure 13).

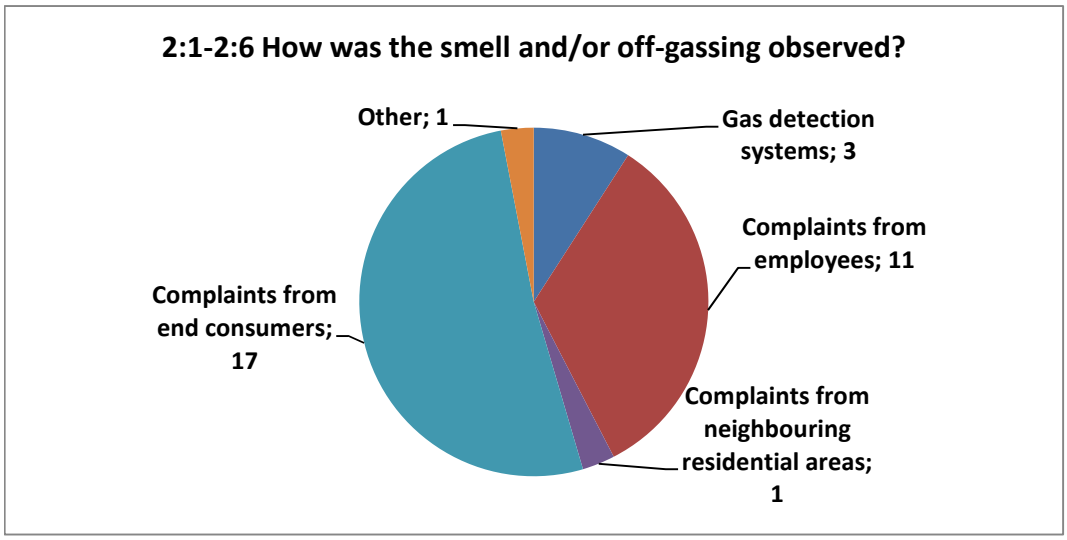

Figure 12: Distributors answers on the detection of smell and/or off-gassing from pellets

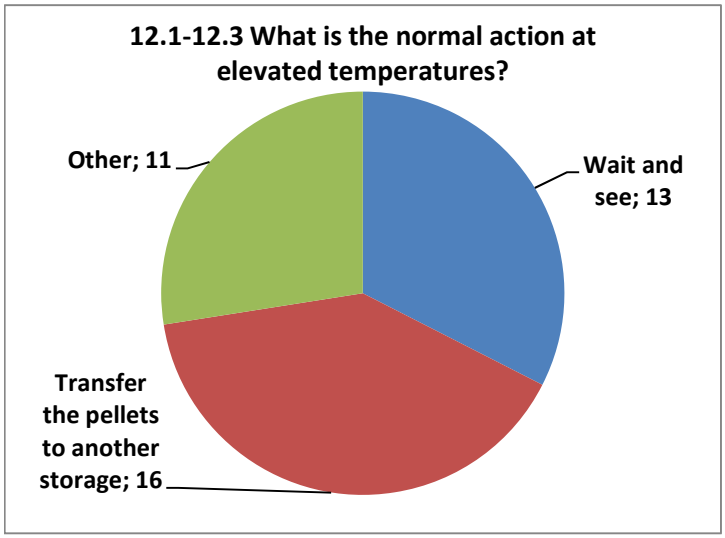

Figure 13: Measures to be taken by distributors in case of self-heating incidents

Contrary to the answers received from the pellet manufacturers, the group of pellet distributors reported have reported a higher frequency of fires related to self-heating. Two respondents have judged their fires as minor incidents while two other 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. Three of these incidents were reported to have occurred in flat storages and one respondent refer to a silo.

Issues for pellet users

About 25 % of questioned users have experienced problems with smell or off-gassing from pellets. 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. All four positive respondents indicated 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. Three out of the four users mentioned that they have learnt to handle the problem by ventilating their silo to get rid of CO during unloading, opening hatches installed in the storage building or by installing fan systems, that can ventilate the storage building, the conveyor system and the maintenance culverts. The main causes suspected by users to be responsible for the smell and off-gassing problems are similar to the answers from manufacturers and distributors.

33 % of users also reported problem with self-heating. When asked about measure on how they handle the self-heating issue, “Other actions” were a more frequent answer among the responding users than the “wait and see”-approach common amongst distributors and manufacturers. One mentioned alternative action was the prioritized combustion of such pellets to get rid of the problem. Other suggestions included the opening of hatches on the walls of the storages to increase ventilation, another is to re-load the pellet stack and try to keep the stack at a low height. 20 % of users have experienced fire incidents due to self-heating, however, similar to the answers from the manufacturers self-heating is not the most common cause of fire incidents occurring.

Overall conclusions

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.

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.

Table 2 gives an overview on the overall percentage of respondents along the chain of supply of pellets indicating problems with smell and off-gassing, self-heating and fires.

Table 2. 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	68	73	27
Self-heating	37	40	33
Fire incidents due to self-heating	10	20	20
Fire incidents, other causes	35	15	35

Mechanisms and quantification of off-gassing (CO, CO_2 and VOCs) in wood pellets production, storage and transportation

The objective of this investigation was to determine the absolute amounts of formed CO, CO_2, CH_4 and VOC during the off-gassing reactions and to quantify the amount of consumed O_2 to gain further information on the underlying kinetics governing the off-gassing behavior of wood pellets in laboratory scale. For this purpose a range of 20 wood pellet samples were tested in sealed storage containers and data regarding the formed amounts of CO, CO_2 and VOC was collected. An overview on the range of emissions formed during the storage experiments is given in Figure 14. The boxplot graphic shows that the range of formed emissions varied significantly from sample to sample and that it is difficult to predict the actual off-gassing potential of a pellet sample purely by knowledge about the raw material used in pellet production. However, it also gives a wide set of data, previously not available to estimate off-gas formation from wood pellets and shows the range from low - to average - to high off-gassing potential, which needs to be anticipated when planning measures capable of handling off-gassing emissions safely (e.g. ventilation measures).

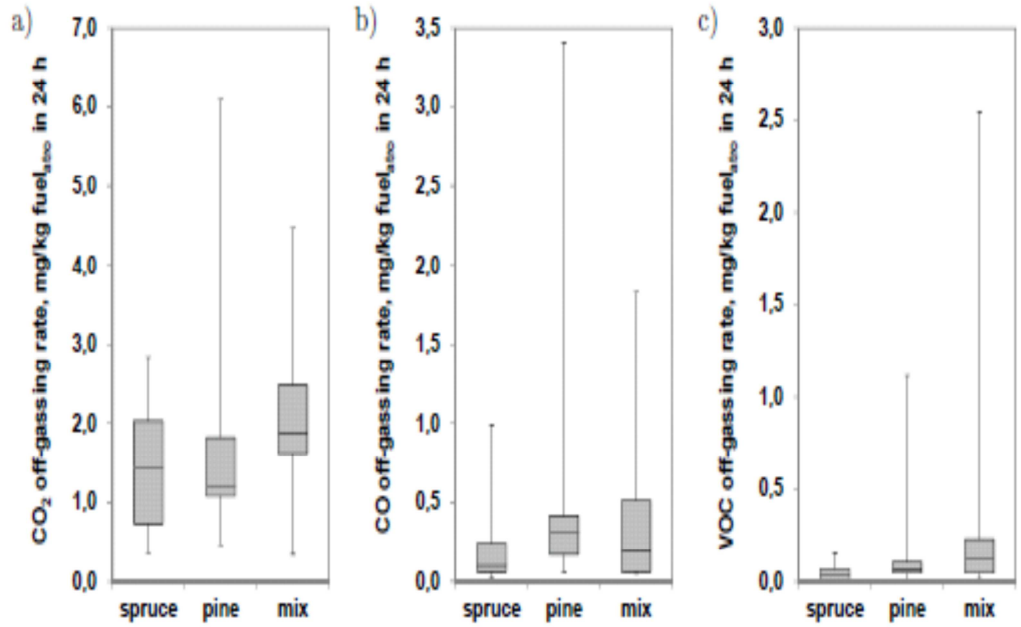

Figure 14: Boxplots for the off-gassing rates of pellets made from spruce, pine and mixtures of both wood species for a) CO_2, b) CO and c) VOC emissions

In the course of the project it could also be proven, that there is a correlation between the amounts of formed emissions from wood pellets during storage and the availability of oxygen in the storage environment. This was investigated via a special kinetic apparatus consisting of a stainless steel storage compartment equipped with temperature sensors and connected to a

gas chromatograph for the analysis of the off-gasses (for a photograph of the apparatus see Figure 15).

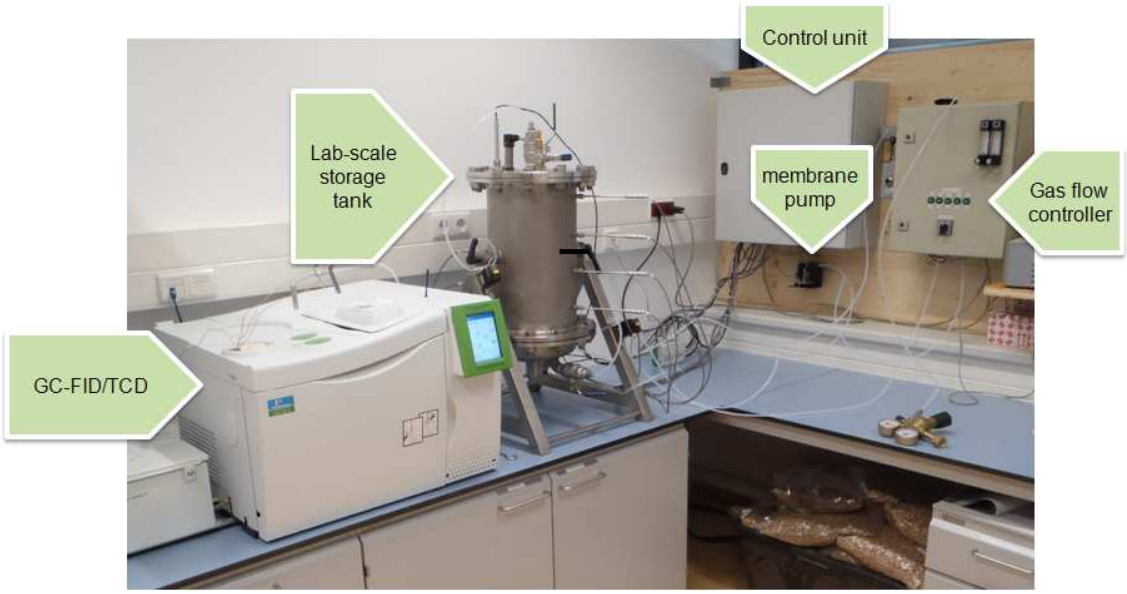

Figure 15: Photograph of the kinetic apparatus

Within this experimental setup it was possible to control the amount of oxygen in the stainless steel storage compartment and thus determine the dependence of off-gassing emission formation to oxygen availability. The development of the off-gassing rates for all detected off-gasses shows a very similar overall trend throughout all storage experiments. CO_2 is the dominating off-gas in every storage situation, followed by CO, VOC and lastly CH4. Over the course of the 20 days storage time the off-gassing rates for CO_2 and CO are clearly dropping more or less continuously, the drop is less significant for the off-gassing rates of VOC and least noticeable for CH_4. The development of the emission factors show an increase of the formation of CO_2 and CO with rising O_2 content in the storage atmosphere while at the same time the emission factors of VOC and CH_4 are decreasing with rising O_2 values (for more detailed results see Figure 16).

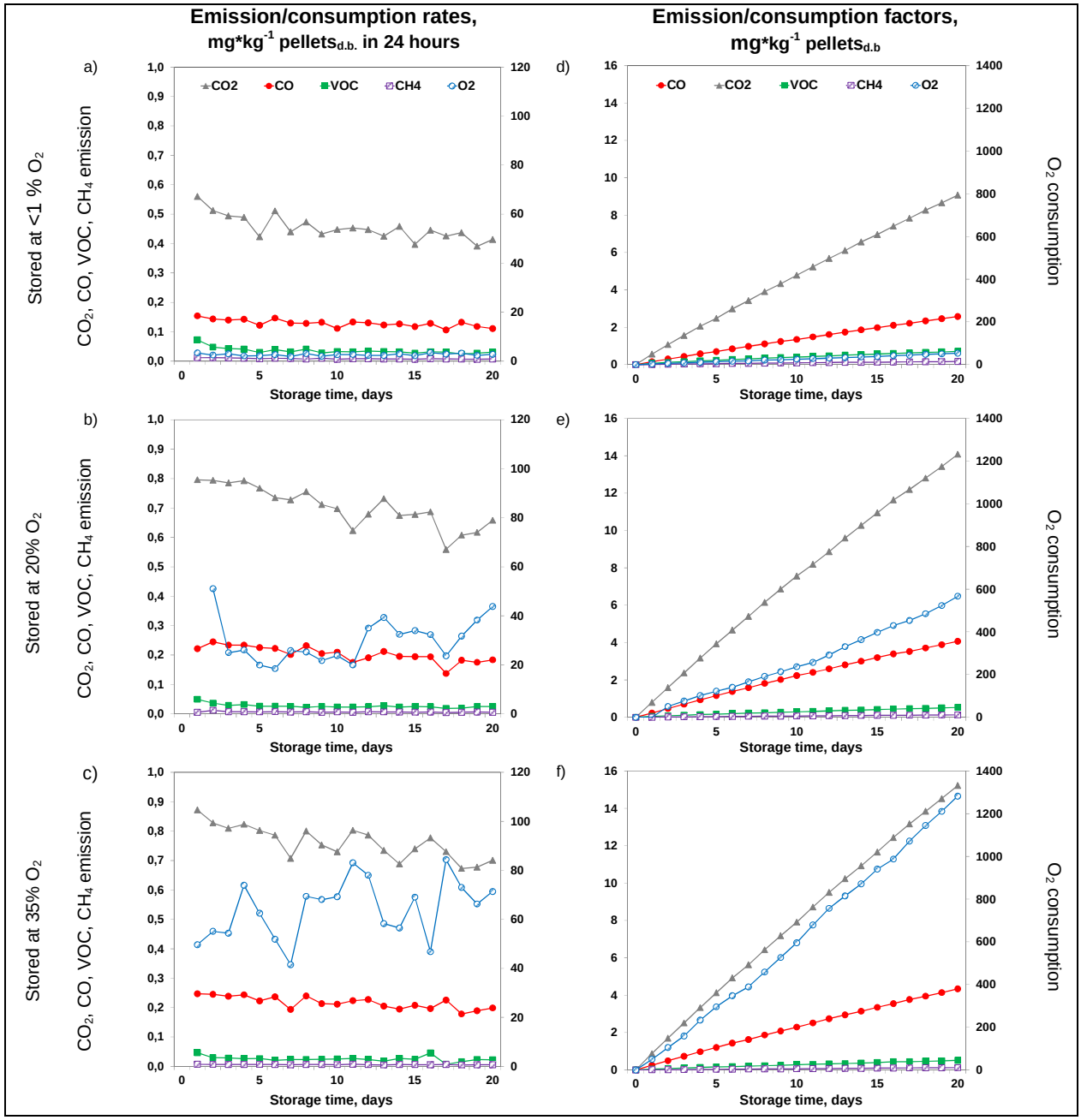

Figure 16: Off-gassing/consumption rates dependent on the oxygen content of the storage atmosphere a) at 0% b) at 20% and c) at 35% O_2; Emission/consumption factors d) at 0% e) at 20% and f) at 35% O_2. The values of the O_2 consumption rates and factors are to be read from the secondary y-axis

Development of practical methods for the characterization of the off-gassing potential from wood pellets

Different existing laboratory methods were compared to verify the results on the off-gassing and self-heating characterization for 18 selected batches of biomass pellets. The chosen methods included the Oxipres method, Micro-calorimetry, Aldehyde emission, Off-gassing in sealed containers, determination of fatty and resin acids and near-infrared spectrometry. The objective of the comparison was twofold. First, the aim was to compare the results from the individual methods in terms of detected off-gassing or self-heating activity from the individual samples. To this purpose the pellets batches were ranked according to their measured activity for the individual methods and afterwards the different rankings were compared to determine, whether the tests presented similar outcomes for the tested pellet batches. From the similar outcomes of the different methods, it could be concluded that there is a link between the off-gassing and self-heating propensity of a wood pellet sample. It could further be established that to some degree all characterization methods deliver similar results to classify the off-gassing/self-heating potential of a specific pellet sample. This information allows pellet industry to test pellet samples with either of the described methods and to get an estimate on the off-gassing and/or self-heating potential of the tested sample (see Figure 17).

Batch no.	BE2020		SP	SLU	
	CO	VOC	Microcalorimetry	CO	Aldehydes
12	1	1	3	1	2
14	2	5	7	2	1
9	3	2	1	3	3
16	4	6	8	7	4
15	5	-	10	6	5
6	6	3	2	4	6
10	7	8	4	5	7
17	8	4	14	13	14
5	9	7	6	10	8
1	10	15	13	16	12
2	11	13	15	14	11
7	12	14	11	11	13
21	13	12	16	-	-
8	14	9	12	12	10
13 – non wood	15	10	9	8	-
22 – non wood	16	17	-	17	-
18 – non wood	17	16	5	9	9
11 – non wood	18	11	17	15	15

Figure 17: Comparison of activity ranking for off-gassing/self-heating potential of pellet samples from different methods

Secondly, the objective was to find the a simplified and SME suitable analytical method for determination of off-gassing from pellets during storage. The evaluated selection criteria, which were used to determine the best method were:

1. Ability to measure high concentrations of CO (beyond 10000ppm)
2. Ability to measure O_2, CO_2 and CH_4
3. Portability, and availability of power supply options for outdoor operations, as well as a suitable working temperature range
4. Cost
5. Robustness, reproducibility of results, and simple operation

Ten gas analyzers were compared, each of them capable of detecting non-condensable emissions from off-gassing, such as CO and CO_2, as well as O_2 and CH_4. The reason for this is that the main gases the SME's need to measure because of their poisonous characteristics in the short term is carbon monoxide and depletion of oxygen. The device complying with the selection criteria best was the ECOM J2KN instrument. The more interesting feature about this instrument is its ability to measure up to 63000 ppm of CO, plus its capability to measure CH_4. Besides, it is portable (approximately 16 kg) and can be operated with a battery.

Development of a practical method for the characterization of the self- heating potential from wood pellets

To test the self-heating properties of pellets in medium scale a new test procedure was developed to create means to assess the self-heating characteristics in a larger scale compared to the laboratory scale methods (micro calorimeter and crossing point method, respectively). All the tests were performed in a 1 m^3 scale set-up (see Figure 18). This was constructed to facilitate verification of results from tests performed in small scale. The initial and wall temperature were varied between the different tests. This set-up made it also possible to vary the ventilation conditions. The main aim of the test series was to study the propensity for self-heating, but also gas emissions (off-gassing) were analyzed during the different tests.

The main conclusions from the test series were:

- The test-configuration has been proved suitable for assessing the propensity for self-heating for different types of biopellets.
- The test configuration allows spontaneous ignition to occur and the fire could be handled with a safe extinguishment procedure.
- An advantage of the test configuration is that critical bulk temperatures found with the test are likely to be similar to real bulk temperatures.
- It was demonstrated that the bulk temperature has a great impact on the rate of self-heating. Significant differences in heating rates were seen in the temperature range 90 – 120 °C.

- It was shown in the tests that ventilation has a large impact on the development of self-heating. This also influenced the results in the medium scale (1 m3) test set-up. A complete sealed and airtight container tends to generate an inert environment, which will slow down or even suppress the self-heating. Too much leakage will cause convection, which will ventilate out gases and cool the pellet bulk. Forced ventilated through an already heated pellet bulk was shown to increase the self-heating significantly and resulted in spontaneous ignition in one test.
- A test procedure with optimal ventilation was designed to allow separation of propensity for self-heating between different types of biomass pellets.
- Further improvements of the test configuration would be to improve the control of the container wall temperature. Also the pre-heating procedure of the bulk could be improved.

Figure 18: Photo of the 1 m^3 test set-up with the insulated test container

Technical and quality management measures to prevent from off-gassing and self-heating and spontaneous combustion and to safely handle formed off-gases and detected self-heating and prevent from fires and smoldering

This objective was tackled from various different starting points. On one hand two approaches were tested that tackled the possibility of changes in the pellet production process to control and/or diminish off-gassing and self-heating from wood pellets. As a first approach special pellets batches were produced using antioxidative additives to suppress autoxidation reaction of fatty acids. The purpose of the experiments was to demonstrate if it is possible to reduce or eliminate off-gassing by adding a relevant amount of a certain antioxidant. Since different antioxidants have different antioxidant capacity and effectivity as well as different mechanisms of blocking oxidation three different additives (named A, B and C for confidentiality reasons)

were chosen to have a higher chance of finding a suitable candidate for this specific purpose. The three tested additives were selected based on a literature studies and their physical properties (i.e. high melting points to avoid melting of antioxidant during pelletizing process). Subsequently, four batches of pine pellets were produced, one without any additives and three more with the three selected antioxidant additives. One of the used additives (additive A) proofed effective in the course of the experiment and thus a proof of concept could be realized. CO emitted from pellets made with this specific additive showed a drastically reduced (about 90 %) emission formation compared to the emission formation from the reference pellets (without antioxidant). That supports (indirectly) the theory that autoxidation is the major reason for spontaneous CO formation from pellets during storage. Furthermore, the pellets with the effective antioxidant additive A also showed little evidence of oxygen depletion in the storage atmosphere, due to less oxidation processes occurring. A long term storage experiment also confirmed that it is possible to store pellets with this particular antioxidant for a period of around two months without reducing the positive effect of the antioxidant addition. Another interesting observation was that temperature of pellets in the container containing the reference pellets increased to ca 35 °C during the early part of the storage time (for 3-4 days) but the temperature of the pellets with additive A in the other container did only increase to max 27 °C and for a shorter period of time (about 1 day). Thereby confirming, that the additive did also positively influence the self-heating potential of the produced pellets.

The other two tested antioxidants B and C seemed to have less effect on autoxidation and thereby showing higher levels of CO off-gassing, potentially due to their different and for biomass pellets less effective blocking mechanisms for oxidation.

In a second approach, pellets made from extract-free sawdust were pelletized. These pellets showed much lower off-gassing and self-heating propensity than pellets produced from a reference material. For example, the level of CO after 30 days (730h) of storage for the pellets produce from extract-free sawdust was only 15 % of the level as detected in the reference batch after same time of storage. Also the measured O_2-level was high (at ca. 19.3 %) in the storage atmosphere around the extracted pellets, whereas the O_2-level in the container with the reference pellets was much lower (at ca. 12 %). The data also show that there are very low total emissions of aldehydes and ketones from the extract-free pellets as compared to a reference. That is as would be expected since the extractive free pellets also had a very low activity regarding off-gassing. This is in accordance with the low levels of fatty/resin acids remaining in the batch after the supercritical fluid extraction. Thereby, the close connection between extractive content and off-gassing/self-heating potential of a pellet sample could be demonstrated.

A different starting point was investigated in the real-scale storage situation of varying sizes (from residential to industrial-scale storages). Here the effectiveness of different technical solutions in overcoming the problems of off-gassing and self-heating were tested. In the residential size storage experiments on the effectiveness of ventilation solutions were investigated, whereas with the industrial storages the trials focused on the verification of gas/fire

detection systems. The aim there was primarily to evaluate if these systems could detect self-heating to prevent accidental fires in real time, but also to observe if they gave false alarms. An overview on all trials conducted is given in Table 3.

Table 3: Overview on real-scale storage experiments

Trial	Pellets			Analyses				Duration
	Type	Tons	Age	T	RH	Gasses	VOC	Months
Underground tank								
Long term x 3 (GEO)	Spruce, ENplus	6	Fresh	X	X	CO		1 - 2
Ventilation x 3 (GEO)		< 1		X		CO/O_2		Hours
Residential storage								
Family house (HDG)	Spruce, ENplus	7	Fresh	X	X	CO		2
Office building (KWB)	Spruce, ENplus	15	6 months	X	X	CO		1
Office building (HDG)	Spruce, ENplus	15	Fresh	X	X	CO		1
Public building (HDG)	Spruce, ENplus	60	Fresh	X	X	CO		1
Silo								
Laxå	Pine spruce mix	3000	Fresh	X	X	X	X	3
Flat storage								
Amagerværket	Straw	2000	6 months	X		X	X	1
Løgumkloster	Spruce	500	6 months	X		X		1
	Spruce	2500	2-3 weeks	X		X	X	3

At the silo site of company partner Laxå the installation of a ventilation fan in top of the Laxå silo showed a rapid and significant decrease in gas concentrations, which were lowered to about a quarter within the first day after installation. Also at the site of Laxå pellets a combination of energy glow/spark sensors at the inlet and outlet of the silo and gas sensors in the silo successfully detected a self-heating process inside the pellet bulk.

At the site of the flat storages no changes in the atmosphere above the pellets were measured during the trials, which confirms the non-alarm functionality of the detector systems. According to company partner Firefly they have gained new information in SafePellets, which will be an input to develop new products in the safety field, as well as which areas/points that needs to be monitored. Furthermore, additional functionality will be added to existing products (specifics can't be given due to confidentiality reasons).

Guidelines and recommendations for the production of "safe" pellets with low self-heating and off-gassing potential, as well as for safe transportation and storage of biomass pellets

Within the SafePellets project guidelines and recommendations for the production of "safe" pellets with low self-heating and off-gassing potential, as well as for safe transportation and

storage of biomass pellets were developed. These will be of significant use for SMEs that do not need to develop methods and safety measures by themselves.

Special attention was paid to safety guidelines for residential pellet users, as this group typically is less knowledgeable about potential health risks associated with the storage of wood pellets. Furthermore, individuals out of this group also typically do not possess the means to install expensive security equipment in their pellet storages to monitor the atmosphere or temperature within. Therefore, it was extremely important to the SafePellets consortium to inform this group of customers about the best way to construct a “safe” pellet storage and to give simple guidelines regarding safety measures to be followed before entering their pellet storage. The basic rules to be followed can be summarized as follows:

1. Humans should keep out of pellet storages except for necessary maintenance activities. Access should not be possible for unauthorized persons. Children should not have access to pellet storages at any time.
2. Before entering or working on pellet storages or storage containers the pellet boiler must be turned off. Follow the time specified in the manufacturer´s instructions.
3. Pellet storages have to be sufficiently ventilated at all times. For small storage systems (<10t) ventilation caps are sufficient for this purpose. In addition, it is recommended to open the door to the pellet storage at least 15 minutes before entering to provide the storage with an extra amount of fresh air.
4. Before entering or working on pellet storages or storage containers an informed second person has to be present outside of the storage.
5. Pellet storage systems that are effectively air-tight and sealed systems, e.g. underground pellet storages made from concrete or plastic or with an installation of a electric ventilator, should only be entered by risk educated service personnel and only after determination of the oxygen and carbon monoxide concentrations inside the storage. This is necessary, as these types of pellet storages are particularly prone to maintain high levels of CO while exhibiting low levels of oxygen at the same time, as there is virtually no air exchange with the outside.

The guidelines for professionals along the pellet supply chains (manufacturers, distributors, etc.) on the other hand contain more complex instructions and more detailed information on safety equipment to be utilized to ensure risk-free handling of pellets. For example a detailed workflow for the “safe” inerting of a silo with nitrogen in case of a self-heating incident is described along with information on personal safety related to CO, CO_2 and O_2 conditions in a silo atmosphere. Furthermore, the benefits and risks from various firefighting tactics in silos such as foam extinguishing, injecting water and ventilation of a silo are being discussed.

These guidelines are also the basis for a European standard related to quality assurance and safety of the wood pellet supply chain aiming to avoid draw backs arising from accidents causing negative public perception in existing markets and to support the establishment of new

markets. The beneficiaries of this type of result from pre-normative research are all actors along the supply chain (pellets producers and suppliers, boiler and stove manufacturers, plant manufacturers and operators, storage system manufacturers and suppliers, safety technology manufacturers and suppliers, and also final (private and industrial) customers. Moreover, the project contributed along the project lifetime and with the results achieved to the establishment of quality and safety along the pellets supply chain to the work of the ISO TC 238/WG7.

Material Safety Data Sheets (MSDS) for biomass pellets

With the development of a Material Safety Data Sheet (MSDS) for biomass pellets a necessary tool for biomass pellet retailers and consumers was introduced, which in addition to commonly used parameters to describe biomass pellets such as heat value or mechanical stability, also allows to assess specific risk from self-heating and off-gassing of biomass pellets during handling and storage and provides information on safety measures to be executed in case risky situation arising from off-gassing or self-heating incidents should occur. The MSDS will be provided by pellet producers to help the pellet distributers and (mainly large-scale) consumers to adequately asses the risk potential of a specific batch of pellets. The MSDS describes the product wood pellets in general and also gives basic information on:

1. First aid measures
2. Firefighting measure
3. Accidental release measures
4. Handling and storage
5. Exposure controls/personal protection
6. Physical and chemical properties
7. Stability and reactivity
8. Toxicological information
9. Ecological information
10. Disposal consideration
11. Transport information

The pellet producer must further provide information on the raw material used in pellet production, as well as state any additives used in the production of the pellets.

A Draft MSDS is publicly available from the project website and will also be promoted and distributed by the SME-Associations partnering in the SafePellets project amongst their members, especially to their members, which are pellet manufacturers and distributors.

Reduced health risks for final customers & Reduced risks of fires in large scale storage systems

Reported concentrations of CO and VOC in private house-owners storages and in industrial scale storages strongly exceed allowed maximum exposure limits and can reach even lethal concentration levels. CO concentrations higher than 500 ppm have been detected in large as well as in small-scale pellet storages and at this height CO levels pose a serious threat to the health of any individual entering a pellet storage. The guidelines for safe storage of pellets in industrial as well as residential scale developed in the SafePellets project provide measures and solutions to secure the health of final customers. In these guidelines final customers are educated to apply simple technical ventilation solutions to their storages suitable to safely remove formed toxic off-gasses from their storages before entering. Furthermore, they are educated about other potential sources of harmful gases, which they might be exposed to when entering the storage (such as harmful gases from incomplete combustion processes due to backfiring from their combustion units). The provision of this knowledge on an easy to access basis and promoted in public by the SME-Associations partnering in the SafePellets project will benefit both customers and professionals having to work in these environments on demand.

Apart from off-gassing of CO and VOC SafePellets also deals with the threats of self-heating and spontaneous ignition of stored pellets, mostly related to larger scale (industrial) storages. Within the SafePellets project two different types of fire detections systems, (1) a combination of energy glow/spark sensor and (2) a multiple gas detector (MGD) were tested. The MGD contains extremely sensitive sensors that reacts fast on the gases released in a very early stage of a fire, even before the presence of visible smoke or flames. The detector is constantly comparing the actual gas pattern with different classified patterns of gas. Based on this the detector can differentiate the actual gas from a fire from other gases in the air coming from other disturbing elements. Both sensor systems were successfully trialed with the help of the projects SME partners and in the case of the MGD, a product of the project partner Firefly, the results from the trials will be used to add additional functionality to the already existing product. With this improved reliable fire protection systems to safely handle once formed smoldering fires in storages it will be possible to decrease the risk for fires in large scale pellet storages and thus reduce the potential threats for human beings (personnel at the industry/storage and from the fire rescue services). The reduction of fires will also have the effect of reduced potentially large economical losses for SME’s due to fires and might possibly reduce insurance costs of pellet manufacturers in the future.

Raised awareness for problems in industry, law making bodies and standardization bodies

The SafePellets project has helped raise awareness of the potential risks and dangers associated with the off-gassing and self-heating phenomena inherent to biomass (especially wood) pellets. It further has achieved to create a safety community within the pellet industry and has managed to implement a know-how exchange between many different stakeholders within the pellet industry. A crucial factor of success to achieve this goal was provided by the first and the second international pellet safety workshops organized in the course of the project. These workshops with a total of more than 120 participants helped to bring to together a large number of knowledgeable industrial stakeholder of the pellets industry from pellet producers, distributors, law making officials, government employees, scientists and technology providers and started an intense knowledge exchange between them. Topics that were discussed in smaller working groups were as follows:

1. Limitation on the size of Biomass Silos?
2. Why and when could self-heating be a problem?
3. Preventive monitoring?
4. How to ensure safety in small-scale pellet storages?
5. How should a silo be prepared for fire fighting?
6. Influence of the production on the off-gassing and self-heating potential of pellets?
7. Best practices in storage?
8. Pellet production
9. Pellet safety certification?
10. What are existing best practice examples for safe pellets production and where are still existing security gaps?
11. Formation of explosive CO atmospheres in pellet plants?
12. How can ignition source in the most efficient way be found and eliminated in pellet production processes?
13. Explosions and Venting
14. Second generation pellets
15. Why would second generation pellets, Black Pellets improve the safety level for large power stations compared with white pellets?
16. Heat treated pellets along supply chains?
17. Pellet transport
18. Complying with working at Heights Directive
19. Pellet Safety in Transportation
20. Dust inhalation – what are the risks and how should they be managed?
21. Human health and safety as it pertains to pellet production
22. Transferring industry needs to research possibilities?
23. How to accurately record, classify and publish incidents of safety in pellet supply chains?

The results of these discussion and comprehensive documentation of both workshops are available in electronic form (and free of charge) after a short web-based registration with links from SafePellets, EPC and AEBIOM websites.

As a direct result of these efforts also a new working group was established within ISO TC 238 /WG 7. Moreover, the project contributed along the project lifetime and with the results achieved to the establishment of quality and safety along the pellets supply chain to the work of this ISO TC 238/WG7.

Nationally organised training programmes to specific topics on safety and quality assurance along the pellet utilization chain

In each country, in which partners participate, a national workshop was organized (Germany, May 2012; Austria, January 2014; Denmark, April 2014; Sweden, June 2014). In the course of these workshops national stakeholders in the pellet industry were invited to be updated on the latest advancements in the knowledge about self-heating and off-gassing research conducted and to join in the discussion on the resulting implications for safety measures.

The first national project workshop focused on pellet standards and took place at partner DBFZ (Deutsches Biomasseforschungszentrum) on May 15th 2012 in Leipzig, Germany. The very successful workshop with around 25 participants was organized in cooperation with the EU project SolidStandards (IEE) .The aim of the workshop: Various players of the pellet industry were informed about the newly introduced European quality standards for wood pellets. Moreover, further developments regarding pellet standards were presented. Sustainability as well as safety related topics concerning pellet storage and transport were talked about. In a common conversation by participants and experts different topics were critically discussed. Therefore information for the further development of practically relevant standards was generated.

The second national workshop took place in Austria in January 2014 during the 4th Central European biomass conference. The SafePellets project together with the AshMelt project, a second project also funded by the European Commission in the frame of FP7, was hosting a workshop on the topics of fuel characterization and the impact on standardization. The very successful workshop could draw the attention of around 45 participants from various players of the pellet industry from all over Europe. A special focus was given to the ongoing activities on the ISO standardization levels with respect to the development of new safety standards for pellet storage and characterization.

The Danish national workshop of the SafePellets Project took place on the 8th of April 2014, in Taastrup, Denmark. Around 40 invited people joined the workshop, which was combined with the dissemination of another project dealing also with safety issues among others. The presented topics included: Sustainability of pellets, sampling techniques for suspended wood

dust, self-heating issues, off-gassing issues, fire protection and prevention on large scale facilities, ATEX and safety regulations, dust and health, potentials for increased use of straw pellets, and ISO standardization work on safety issues. The day ended with a discussion on the challenges to be faced in the future with wood pellet utilization.

Finally, the Swedish National Workshop on safety in relation to handling and storage of pellets took place on 4th of June 2014, in Jönköping, Sweden at Scanic Elmia. The title of the workshop was: “Seminarium om säkehet vid hantering och lagring av pellets” (Seminar on safety in relation to handling and storage of pellets) arranged by PelletsFörbundet, SP Technical Research Institute of Sweden and Swedish University of Agricultural Sciences (SLU). The meeting was arranged in cooperation with the so called Pellets platform (Pelletsplattformen) in Sweden. It was arranged in connection to World Bioenergy 2014, but was not part of that conference. Therefore, during the day studies both from SafePellets and from Pelletsplattformen were presented. In total 29 persons from 14 different organisations participated. In total 14 different presentations were held covering subjects: Introductions to SafePellets, Pelletsplattformen and PelletsFörbundet, results from small-scale tests on additives, off-gassing, and self-heating, respectively, large-scale storage tests, detection, and plans for new ISO standards.

2.4 Potential impact and main dissemination activities and exploitation results

Contribution to the development of new European norms, standards, and quality labels

The guidelines on “safe” production, transport and storage of wood pellets developed in the course of the SafePellets project will be of significant use for SMEs that do not need to develop methods and safety measures by themselves. These guidelines aim to avoid draw backs arising from accidents causing negative public perception in existing markets and to support the establishment of new markets. The beneficiaries of this type of result from pre-normative research are all actors along the supply chain (pellets producers and suppliers, boiler and stove manufacturers, plant manufacturers and operators, storage system manufacturers and suppliers, safety technology manufacturers and suppliers, and also final (private and industrial) customers). The documents are available free-of-charge from the SafePellets webpage and will be promoted by all partnering SME-AGs.

Moreover, the project contributed along the project lifetime and with the results achieved to the establishment of quality and safety along the pellets supply chain to the work of the newly established ISO TC 238/WG7. Within the working group 7 five new work item proposals have been proposed and are on route to be released in the years 2017 to 2018. The titles of the proposed standards are listed below:

1. Solid biofuels — Safety of biofuel pellets – Safe handling and storage in commercial and industrial applications - Part 1: General
2. Solid biofuels — Safety of biofuel pellets – Safe handling and storage in commercial and industrial applications - Part 2: Detection, suppression and management of fire and explosion
3. Solid biofuels — Safety of biofuel pellets – Safe handling and storage of wood pellets in residential and other small-scale applications
4. Solid biofuels — Safety of biofuel pellets - Determination of self-heating
5. Solid biofuels — Safety of biofuel pellets - Determination of off-gassing and oxygen depletion

Furthermore, the partner DBFZ has been involved into the development of the ENplus label owned by the German Pellets Institute (DEPI). From mid of December 2010 AEBIOM was granted a license of the ENplus label. It was possible to provide project results for being integrated into the ENplus on request of the SafePellets SME-AG participants. This input is mainly focused in the ENplus label for pellet traders, which demands that pellet delivery truck drivers with contact to end customers must participate in a training course on the knowhow of smooth pellet delivery and storage. The training material provided has been expanded with

additional information on the dangers in pellet storages associated to off-gassing and self-heating from wood pellets.

Contribution to solving technological problems

SafePellets supported SME-AGs and their members to identify the mechanisms for uncontrolled off-gassing of toxic emissions from wood pellets by carrying out controlled laboratory experiments to detect the underlying mechanism involved in the off-gassing and self-heating reactions of biomass pellets. As a result of the elaborate tests carried out, it could be determined that :

- Large differences in the off-gassing self-heating behavior between different types of pellets
- The tested batches with mixtures of pine/spruce were more reactive than the batches with pure pine or spruce
- Pellets from 100 % pine were more reactive than pellets from 100 % spruce
- Pellets from alternative raw materials (straw, eucalyptus, wine pruning) seem to be less reactive than more traditional wood pellets
- The composition of pellets (pine/spruce/etc.)
  - is not directly correlated to the emissions
  - other production process parameters seems to have impact on the emissions
- Effect of antioxidant additives to added during production confirms the importance of autoxidation of fatty/resin acids for the emission of aldehydes and off-gassing of CO, CO_2 and CH_4

Based on the findings of this elementary research concrete measures and technological solutions to prevent self-heating and spontaneous ignition of wood pellets were derived. For industrial stakeholders along the pellet supply chains, and pellet manufacturers in particular, the effectiveness of sawdust pre-treatment by super critical extraction of fatty and resin acids and the utilization of antioxidant additives in the pellet production process in reducing the off-gassing and self-heating potential of pine pellets has been investigated. Both measures showed some promise in their ability to reduce the off-gassing and self-heating potential of the thus treated pellets, however, both measures require further development before they are reproducibly reliable and economically feasible. The during the project developed end-of-pipe measures (e.g. simple, but reliable sensors for CO and VOCs detection; improved fire protection system, improved silo storage management strategies; ventilation of storages) on the other hand can be immediately implemented and adapted for individual stakeholder along the pellet supply chain and will (if widely implemented) significantly reduce the number of reported off-gassing accident and fire incidents in the pellet industry. For example, the in cooperation with SME partner Firefly tested multiple gas detector (MGD) represents a highly advanced sensor system for early detection of self-heating incidents in a pellet storage. The extremely sensitive sensors reacts fast on the gases released in a very early stage of a fire, even before the presence of visible

smoke or flames. The detector accomplishes this by constantly comparing the actual gas pattern with different classified patterns of gas. Based on this the detector can differentiate the actual gas from a fire from other gases in the air coming from other disturbing elements. Improved reliable fire protection systems, such as the MGD, will help to safely handle once formed smoldering fires in storages. This will decrease the risk for fires in large scale pellet storages and thus reduce the potential threats for human beings (personnel at the industry/storage and from the fire rescue services) and reduce potential economical losses for companies resulting from such incidents.

For residential pellet consumers the focus in the development of measures to overcome off-gassing and self-heating risks was on end-of-pipe measures. Therefore, final customers are educated to apply simple technical ventilation solutions to their storages suitable to safely remove formed toxic off-gasses from their storages before entering. Furthermore, they are educated about other potential sources of harmful gases, which they might be exposed to when entering the storage (such as harmful gases from incomplete combustion processes due to backfiring from their combustion units). The provision of this knowledge on an easy to access basis and will be promoted in public by the SME-Associations partnering in the SafePellets project. The impact of these measures will be noticed over the course of the first five years after the end of the project and will hopefully result in no (or at least fewer) reported accidents related to off-gassing in residential pellet storages.

Finally, a simple, robust analytical method (also applicable in industry) for measurements of off-gassing and emissions of VOC (volatile organic compounds) from pellets was developed in the course of the project. All derived solutions have been made available to the SME-AGs and their members.

Raised awareness for problems in industry, law making bodies and standardization bodies

The SafePellets project has helped raise awareness of the potential risks and dangers associated with the off-gassing and self-heating phenomena inherent to biomass (especially wood) pellets. It further has achieved to create a safety community within the pellet industry and has managed to implement a know-how exchange between many different stakeholders within the pellet industry. A crucial factor of success to achieve this goal was provided by the first and the second international pellet safety workshops organized in the course of the project. These workshops with a total of more than 120 participants helped to bring to together a large number of knowledgeable industrial stakeholder of the pellets industry from pellet producers, distributors, law making officials, government employees, scientists and technology providers and started an intense knowledge exchange between them. Topics that were discussed in smaller working groups centered around know-how exchange in the fields of best practice

routines for safe production of pellets, safe transportation of pellets and safe storage of pellets. The industry partners freely shared their experiences with fire and off-gassing accidents and if and how they were able to overcome any problems they were having. Scientific institutions also freely shared the results from latest research carried out in the field of off-gassing and self-heating research, but also other topics such as health impacts from dust exposure and risks associated with dust explosions were presented. The results of these discussion and comprehensive documentation of both workshops were made available in electronic form (and free of charge) after a short web-based registration with links from SafePellets, EPC and AEBIOM websites.

As a direct result of these efforts also a new working group was established within ISO TC 238 /WG 7. Moreover, the project contributed along the project lifetime and with the results achieved to the establishment of quality and safety along the pellets supply chain to the work of this ISO TC 238/WG7. The titles of the proposed standards are listed below:

1. Solid biofuels — Safety of biofuel pellets – Safe handling and storage in commercial and industrial applications - Part 1: General
2. Solid biofuels — Safety of biofuel pellets – Safe handling and storage in commercial and industrial applications - Part 2: Detection, suppression and management of fire and explosion
3. Solid biofuels — Safety of biofuel pellets – Safe handling and storage of wood pellets in residential and other small-scale applications
4. Solid biofuels — Safety of biofuel pellets - Determination of self-heating
5. Solid biofuels — Safety of biofuel pellets - Determination of off-gassing and oxygen depletion

Benefits for SMEs

Three SME partners were directly involved in the SafePellets project. Laxå Pellets is a Swedish pellet producer. Firefly AB is a Swedish manufacturer of protection systems for fires and dust explosions. Finally, PUSCH AG acts worldwide in the segment of renewable energies developing agropellets on the basis of individual mixtures made from agricultural and forestry residues. The SME partners gained benefits from the project on various different points:

1. Saved expenses for R&D due to transnational cooperation

The outsourced RTD work within SafePellets generally managed to guarantee cooperation between all relevant scientific actors in the field of self-heating and off-gassing research in Europe and thus prevented that many actors continued just doing more of the same without benefitting from each others experiences and results. Joining the highly developed expertise for large scale pellets supply from Scandinavia with the well developed expertise from Central

Europe on domestic scale issues provided an essential added value to the impact and economic benefits of SafePellets to the European pellets industry.

2. Higher security in market development

SMEs will benefit from the introduction of guidelines (and eventually standards) for quality assurance and safety in pellets supply giving security in the establishment of new markets and the growth of existing markets. The former is highly risky without the security of widely accepted guidelines or standards. SafePellets involved SME-AGs from established markets providing their experience and know-how to SME-AGs and SMEs from young emerging markets. Safety and quality assurance measures will gain even more importance in the future, when new resources and mixtures of resources will be used for pellets production.

Estimates from the participating SME AGs indicate potential sales of (small scale) wood pellets boilers between 500.000 and 1 million in 2020. These are tremendous market opportunities, which require maximum security related to technical and legal framework in order to be optimally exploited. Any drawback could cause fatal disturbances to these bright expectations.

3. Reduced time-to-market

The training activities organized in the course of the project will ensure that the developed guidelines and recommendation of the project will be realized in the pellet industry quickly. Furthermore, the in the course of the project developed and improved fire and gas detection systems were tested already within the project from various RTD and SME partners allowing for a minimum possible time-to- market.

4. Maintaining positive image and preventing from drawbacks in public perception

SMEs usually do not have the possibilities to fund cost intensive image campaigns in order to overcome difficult situations after scandalized accidents (e.g. intoxications, fires), but also due to continuous bad customer recognition (e.g. bad smell of pellets). The quality assurance measures and the technical solutions derived by SafePellets will prevent SMEs from such drawbacks in public perception allowing for accessing the tremendous market potential provided from the political framework conditions. The immediate benefit will be a reduction of reclamations due to bad smell of pellets and an increase of satisfied private customers, respectively.

The sensitivity of – above all – private customers has been demonstrated in Central Europe in 2007, where customers practically did not buy any small scale (typical single family house) central boilers anymore in the 2nd half of the year due to sharply risen pellets prices. In Austria this caused an over 60% market break for small scale pellets boilers and respectively little market increase of pellets sales from 2006 to 2007. For some of the acting SMEs (boiler and stove manufacturers) 2007 has been a major economic threat. Strengthening growth of existing

and foundations of new SMEs The young European pellets market is predominated by expanding SMEs and is continuously growing by a large number of newly established SMEs. This is reflected by the >80% (71- 100%) share of SME members represented in the participating SME-AGs and directly benefitting from the technical solutions developed by SafePellets. Together with the fact, that the bioenergy sector is 50 to 100 times as employment intensive in the EU as the fossil fuel branch (COM(2005) 628 final), SafePellets significantly fosters growth and occupational effects within SMEs.

5. Added-value from risk prevention

SMEs also benefit from professional risk assessment and from implemented risk prevention measures as to the reduced probability of fire hazards and consequently by reduced insurance fees. This will basically be the case for pellets producers and pellets suppliers. Moreover, customers will benefit due to reduced costs of the supplied fuel.

6. Licensing technical solutions

The involvement of the SME partner Firefly was aimed to jointly develop new or adapt existing sensor systems for off-gasses and smoldering fire detection for hazard prevention and fire protection, primarily for large scale storage facilities. Firefly will license its technical solutions at best price conditions to members of the participating SME AGs

7. Improved industrial scale storage concepts

The involvement of the SME partner Laxå was aimed to overcome their recurring problem with off-gasses and smoldering fires within their storage silos. In the course of the project it was possible to implement an improved system of storage of freshly produced wood pellets more sensitive to possible dangerous changes in the temperature conditions within their silos system to handle threats from fires in particular earlier. This will significantly reduce the risks for future fires within their production plants.

Dissemination activities

The results of the SafePellets project were disseminated in 3 international and 4 national workshops at premises of biomass conferences and exhibitions or in cooperation with the national RTD partners. Overall more than 300 people participated in these workshops, which centered around topics varying from safety related topics concerning pellet production, transport and storage, developments in fuel based standardization activities, fire protection and prevention on large scale facilities, ATEX and safety regulations, dust and health, potentials for increased use of straw pellets and discussions on discussion on the challenges to be faced in the future with wood pellet utilization.

Furthermore, six journal papers have been submitted or will be submitted to peer-reviewed scientific journals on the major scientific results of the project. One paper is already published. The remaining papers are expected to be published still within 2015 (for details see Table 4). In addition to the journal papers, five contributions published in proceedings of conferences have been published (see Table 5). Also a stunning total of 52 presentations by project partners of the SafePellets project have been held over the course of three project years at events all over Europe and also in the USA and Canada reaching an impressive audience of several hundred important industrial stakeholders and thereby placing the topic of safety related to pellet production, transport and storage firmly in the heads of CEOs and company employees of the pellet industry.

Another important scientific output of the SafePellets project was the publication of two master theses and one doctoral thesis over the course of the project. The titles of the theses are listed below:

1. Experimental investigations and design of a new apparatus for measurements of emissions from stored pellets – Verena Trinkel – Vienna University of Technology
2. Pellet off-gassing during storage: The impact of storage conditions and type of source material – Franziska Meier - University of Natural Resources and Life Sciences, Vienna
3. Emissions from Wood Pellets during Storage – Waltraud Emhofer - Vienna University of Technology

Furthermore, all public deliverables of the project will be available for download at the SafePellets website in summer 2015. The website will be hosted at least until 2017.

Last but not least, the project contributed along the project lifetime and with the results achieved to the establishment of quality and safety along the pellets supply chain to the work of the newly established ISO TC 238/WG7, which aims to release four new standards on the topic by 2019.

3 Publications

Peer reviewed publication

#	DOI	Title	Author(s)	Journal	Volume/ Issue	Date of publication
1	http://dx.doi.org/10.1016/j.fuel.2014.05.088	Direct measurements of thermal properties of wood pellets: Elevated temperatures, fine fractions and moisture content	Johan Sjöström and Per Blomqvist	Fuel	134	15.10.2014
2		A multivariate analysis of the relationship between the fatty and resin acid contents of wood pellets produced on pilot and industrial scales and their emissions of volatile organic compounds, CO, CO_2, and CH_4	Elizabeth Valencia-Reyes, Mehrdad Arshadi* and Paul Geladi	Biomass & Bioenergy		2015 (planned)
3		Green extraction technologies for the production of safer wood pellets for heat and power	Elizabeth Valencia-Reye, Thomas M. Attard, Andrew J. Hunt,* Vitaliy L. Budarin, Mehrdad Arshadi and James H. Clark	Fuel		2015 (planned)
4		Influence of the chemical compostion and mineral content on biomass ignition temperature and reactivity during thermochemical decomposition	Annett Pollex, Frank Döhling	Analytical and applied pyrolysis		04.2015 (planned)
5		The influence of oxygen availability on off-gassing rates of emissions from stored wood pellets	Franziska Meier et al.	Energy & Fuel		07. 2015 (planned)
6		A study on the connection between the self-heating and the off-gassing properties of wood pellets	Waltraud Emhofer et al.	Fuel		08.2015 (planned)

Paper in Proceedings of a Conference / Workshop

#	Title	Author(s)	Proceedings	Date of publication	Start Date	End Date	Publisher
1	CO aus Holzpellets- Bildung, Charakterisierung und Massnahmen	Emhofer, W., Aigenbauer, S.	12. Holzenergie-Symposium	14.09.2012	14.09.2012	14.09.2012	ETH Zürich
2	Assessment of self-heating potential of wood pellets	Larsson, I., Lönnermark, A., Blomqvist, P., Persson, H., Rahm, M.	Eco-Tech 2012, Book of Abstracts	28.11.2012	26.11.2012	28.11.2012	Linneaus University
3	Correlation between CO off-gassing and linoleic fatty acid content of wood chips and pellets	Emhofer Waltraud	21 st European Biomass Conference	06.06.2013	02.06.2013	07.06.2013	European Biomass Conference
4	Small scale screening tests to assess the self-heating potential of wood pellets	Larsson, I., Lönnermark, A., Blomqvist, P., Persson, H., Rahm, M.	Interflam	25.06.2013	24.06.2013	26.05.1013	Interscience Communications
5	Temperature Measurements and Examination of self-heating in large scale storage of wood pellets	Ida Larsson, Anders Lönnermark, Henry Persson and Per Blomqvist	World Bioenergy 2014	27.06.2014	03.06.2014	05.06.2014	Swedish Bioenergy Association

Thesis / Dissertation

#	Thesis/Dissertation	Title	Author(s)	Date of Approval	Institution Name
1	Master thesis	Experimental investigations and design of a new apparatus for measurements of emissions from stored pellets	Verena Trinkel	01.10.2012	Vienna University of Technology
2	Master thesis	Pellet off-gassing during storage: The impact of storage conditions and type of source material	Franziska Meier	04.11.2014	University of Natural Resources and Life Sciences, Vienna
3	Dissertation	Emission from wood pellets during storage	Waltraud Emhofer	16.04.2015	Vienna University of Technology

University Publication/Scientific Monograph

#	Title	Author(s)	Title of the Monograph	Date of publication	Publisher
1	Health and Safety Aspects of Solid Biomass Storage, Transportation and Feeding	Koppejan, J., Lönnermark, A., Persson, H., Larsson, I., Blomqvist, P., Arshadi, M., Valencia-Reyes, E., Melin, S., Howes, P., Wheeler, P., Baxter, D., Nikolaisen, L.	IEA Bioenergy Task 32, 36, 37 and 40	01.05.2013	IEA Bioenergy
2	Lagring av biobränsle och avfall - Statistik och erfarenheter från incidenter och bränder (in Swedish)	Persson, H., Leandersson, A., Amen, M. P., Lönnermark, A.	SP Report 2014:55	2014	SP Technical Research Institute of Sweden

4 Dissemination Activities

Organisation of a workshop

#	Main Leader	Title	Date	Place	Type of audience	Size of Audience	Countries addressed
1	DBFZ	Pellet standards workshop	15.05.2012	Leipzig, Germany	Scientific community, industry, policy makers	22	Germany
2	AEBIOM	1st international Workshop on Pellet Safety	04. – 06.03. 2013	Fügen, Austria	Scientific community, industry, policy makers	70	International
3	BE2020+	Pellet workshop	17.01.2014	Graz, Austria	Scientific community, industry, policy makers	45	Austria, Germany
4	DTI	Danish National Workshop of the SafePellets Project	08.04.2014	Taastrup, Denmark	Scientific community, industry,	30	Denmark
5	AEBIOM	2nd international Workshop on Pellet Safety	05. – 7.05.2014	Fügen, Austria	Scientific community, industry, policy makers	50	International
6	SLU	Swedish National Workshop on safety in relation to handling and storage of pellets	04.06.2014	Jönköping, Sweden	Scientific community, industry, policy makers	29	Sweden
7	AEBIOM	3rd international SafePellets workshop	15.10.2014	Berlin, Germany	Scientific community, industry, policy makers	120	International

Web sites / Applications

#	Main Leader	Title	Date	Place	Type of audience	Countries addressed
1	AEBIOM	SafePellets website	01.02.2013	www.safepellets.eu	Scientific, industry, civil society, policy makers, medias	Europe

Press Releases

No.	Main leader	Title	Date/Period	Place	Type of audience	Countries addressed
1	BE2020+	EU research project SafePellets started	01.02.2012	www.bioenergy2020.eu; APA	Civil society, industry	Europe

Articles published in the popular press

#	Main leader	Title	Date/ Period	Place	Type of audience	Countries addressed
1	SP	Large stockpiles: si-lower the fire risks	01.06.2012	Bioenergy Insight	Industry	Sweden
2	SP	Ökade brandrisker med större lagringsvolymer av fasta biobränslen	01.03.2013	Energimagasinet	Industry	Sweden
3	BE2020 +	Off-gassing from wood pellets - how to improve safety in pellet production and logistics	01.07.2014	VGP Powertech Journal	Industry	international

Videos

#	Main leader	Title	Date/ Period	Place	Type of audience
1	AEBIOM	Project SafePellets - Safety and quality assurance measures along the pellet supply chain	28.10.2014	https://www.youtube.com/watch?v=qfz1A1-HTM8 www.safepellets.eu; www.bioenergy2020.eu	scientific, industry
2	AEBIOM	SafePellets - a few words about wood pellets	28.10.2014	https://www.youtube.com/watch?v=PikGKPNkbLw www.safepellets.eu; www.bioenergy2020.eu	Civil society, industry

Interviews

No.	Main Leader	Title	Date	Place	Type of audience	Countries addressed
1	SLU	SafePellets project	01.06.2012	News at TV4	Civil society	Sweden

Media Briefings

#	Main Leader	Title	Date	Place	Type of audience	Countries addressed
1	SLU	SafePellets project	01.07.2012	Umeå	Scientific community, Industry, Civil Society, Policy makers, Medias	Sweden

Presentations

#	Main Leader	Title	Date	Place	Type of audience	Size of Audience	Countries addressed
1	SLU	Safety and quality assurance measures along the biomass pellets supply chain	01.02.2012	Stockholm, Sweden	Scientific community, Industry		Sweden
2	BE2020+	CO off-gassing from pellets: Impact of raw material choice and storage conditions - Implications for pellet standardization	30.05.2012	Jönköping, Sweden	scientific, industry, policy makers	100	International
3	SLU	Problems associated with storage of wood pellets and some proposed practical solutions	29.05.2012	Jönköping, Sweden	scientific, industry, policy makers, medias	100	International
4	BE2020+	CO aus Holzpellets: Bildung, Charakterisierung und Massnahmen	14.09.2012	Zurich, Switzerland	scientific, industry, policy makers	350	Austria, Germany, Switzerland
5	DTI	Characterizing self-heating and off-gassing potential of wood pellets in storage and shipping	29.10.2012	New Orleans, USA	scientific, industry, policy makers		UsA, International
6	SP	Brandsäkerhet vid lagring av biobränslen och avfall	13.11.2012	Stockholm, Sweden	Industry		Sweden
7	SP	SafePellets - Förbättrad och säkrare lagring av pellets	29.01.2013	Falun, Sweden	Industry		Sweden
8	SLU	Safety and quality assurance measures along the pellets supply chain	06.06.2013	Antwerp, Belgium	scientific, industry,		International

#	Main Leader	Title	Date	Place	Type of audience	Size of Audience	Countries addressed
9	SP	Säkrare lagring av biobränsle - Statistik över och erfarenheter från incidenter och bränder	21.02.2013	Umeå, Sweden	industry		Sweden
10	SP	How should a silo be prepared for fire fighting	05.03.2013	Fügen, Austria	scientific, industry	70	International
11	BE2020+	Correlation between CO off-gassing and linoleic fatty acid content of wood chips and pellets	06.06.2013	Copenhagen, Denmark	scientific, industry, policy makers	350	International
12	SP	Fire safety aspects during storage and handling of solid biofuels	01.10.2013	Birmingham, United Kingdom	scientific, industry,		Europe
13	SP	Brandsäkerhet i samband med lagring av pellets	10.10.2013	Ulriceham, Sweden	industry		Sweden
14	SP	Fire fighting in silos	14.11.2013	Berlin, Germany	Scientific community, industry,		Europe
15	SLU	Storage of wood pellets	19.11.2013	Vancouver, Canada	Scientific community, industry,		Canada, USA
16	SP	Fire safety aspects during storage and handling of solid biofuels	17.01.2014	Greenwich, United Kingdom	Industry		United Kingdom
17	DTI	Activities within safety and wood pellet handling at large utilities	17.01.2014	Greenwich, United Kingdom	Industry		United Kingdom
18	BE2020+	Off-gassing – Safety issues related with emissions from wood pellets along the pellet supply chain	17.01.2014	Graz, Austria	Scientific community, industry, policy makers	45	Austria, Germany

#	Main Leader	Title	Date	Place	Type of audience	Size of Audience	Countries addressed
19	DTI	Characterization of self-heating of wood pellets	17.01.2014	Graz, Austria	Scientific community, industry, policy makers	45	Austria, Germany
20	Pusch AG	The importance of standardization and certification for small scale pellet producers	17.01.2014	Graz, Austria	Scientific community, industry, policy makers	45	Austria, Germany
21	DEPV	Safety issues - impact on pellet industry	17.01.2014	Graz, Austria	Scientific community, industry, policy makers	45	Austria, Germany
22	SP	Emissioner från träpellets	04.02.2014	Stockholm, Sweden	Scientific community, Industry		Sweden
23	SP	SafePellets – Enhanced and safer storage of pellets	04.02.2014	Jönköping, Sweden	Scientific community, Industry		Sweden
24	SP	Fire safety aspects during storage and handling of solid biofuels	01.04.2014	Helsinki, Finland	Scientific community, Industry		Finland, Sweden
25	BE2020+	Off-gassing – Safety issues related with harmful emissions from wood pellets	05.05.2014	Fügen, Austria	Scientific community, industry	50	International
26	SP	The self-heating phenomenon –from micro scale to real scale storage	05.05.2014	Fügen, Austria	Scientific community, industry	50	International
27	DTI	Preliminary results from SafePellets on studies of selfheating in biopellets storages	05.05.2014	Fügen, Austria	Scientific community, industry	50	International
28	SP	Prevention and fire fighting in silo	06.05.2014	Fügen, Austria	Scientific community, industry	50	International
29	SP	SafePellets – WP4 and WP 5 Self-heating experiments with pellets	06.05.2014	Fügen, Austria	Scientific community, industry	50	International

#	Main Leader	Title	Date	Place	Type of audience	Size of Audience	Countries addressed
30	DEPV	Safety issues -impact on pellet production and traders-results from a market survey on safety incidents	07.05.2014	Fügen, Austria	Scientific community, industry, policy makers	50	International
31	DTI	Large scale storage trials with pellets - Flat storages - Approach and setup	04.06.2014	Jönköping, Sweden	Scientific community, industry	29	Sweden
32	SLU	Monitoring of off-gassing during storage of wood pellets – Full scale silo experiment	04.06.2014	Jönköping, Sweden	Scientific community, Industry		Sweden
33	SLU	Mätning av emissioner under lagring av pellets - Fullskalig lagringsförsök,	04.06.2014	Jönköping, Sweden	Scientific community, industry	29	Sweden
34	SLU	avgasning	04.06.2014	Jönköping, Sweden	Scientific community, industry	29	Sweden
35	SP	Statistik och erfarenheter från brandincidenter	04.06.2014	Jönköping, Sweden	Scientific community, industry	29	Sweden
36	SP	Introduktion till SafePellets	04.06.2014	Jönköping, Sweden	Scientific community, industry	29	Sweden
37	SP	Guidelines och förslag på ISO-standarder	04.06.2014	Jönköping, Sweden	Scientific community, industry	29	Sweden
38	SP	Additivers påverkan på träpellets potential för självuppvärmning	04.06.2014	Jönköping, Sweden	Scientific community, industry	29	Sweden
39	SP	Temperaturmätningar och undersökning av självuppvärmning i storskalig silo vid lagring av träpellets	04.06.2014	Jönköping, Sweden	Scientific community, industry	29	Sweden

#	Main Leader	Title	Date	Place	Type of audience	Size of Audience	Countries addressed
40	SP	Mätning av självuppvärmning i träpellets i liten skala	04.06.2014	Jönköping, Sweden	Scientific community, industry	29	Sweden
41	SP	Självuppvärmningsförsök i mellanskala	04.06.2014	Jönköping, Sweden	Scientific community, industry	29	Sweden
42	BE2020+	Sicherheit bei der Lagerung von Pellets	11.06.2014	Vienna, Austria	scientific, industry, policy makers	80	Austria
43	DBFZ	No pellet is like the other	15.10.2014	Berlin	Scientific community, industry, policy makers	120	International
44	SLU	Monitoring and reducing emissions from wood pellets	15.10.2014	Berlin	Scientific community, industry, policy makers	120	International
45	SP	Self-heating of biomass pellets	15.10.2014	Berlin	Scientific community, industry, policy makers	120	International
46	DTI	Results from verification tests of self-heating and off-gassing in small and large scale storages	15.10.2014	Berlin	Scientific community, industry, policy makers	120	International
47	BE2020+	Relation between off-gassing and self-heating from biomass pellets – will it impact the work of the pellet industry?	15.10.2014	Berlin	Scientific community, industry, policy makers	120	International
48	DEPI	Ausgasungs- und Selbsterwärmungsrisiken bei Pellets – neue Erkenntnisse	20.10.2014	Fulda, Germany	Industry	27	Germany
49	DEPI	Ausgasungs- und Selbsterwärmungsrisiken bei Pellets – neue Erkenntnisse	30.10.2014	Hannover, Germany	Industry	18	Germany

#	Main Leader	Title	Date	Place	Type of audience	Size of Audience	Countries addressed
50	DEPI	Ausgasungs- und Selbsterwärmungsrisiken bei Pellets – neue Erkenntnisse	19.11.2014	Ulm, Gemany	Industry	23	Germany
51	BE2020+	Ergebnisbericht aus dem SafePellets-Projekt	20.03.2015	Vienna, Austria	Industry	50	Austria
52	DBFZ	Sicherheit bei der Lagerung und Handhabung von Holzpellets	01.05.2015	Fulda, Germany	Scientific community, industry, policy makers	30	Germany

Poster

#	Main Leader	Title	Date	Place	Type of audience	Size of Audience	Countries addressed
1	BE2020+	A preliminary study on the influence of the pelletizing process on the off-gassing behavior of wood pellets	02.06.2012	Vienna, Austria	scientific, industry	500	international
2	SLU	Safety and quality assurance measures along the pellets supply chain, the SafePellets project	31.05.2012	Jönköping, Sweden	scientific, industry, policy makers, medias	100	International
3	SLU	Problems associated with storage of wood pellets and some proposed practical solutions	29.05.2012	Jönköping, Sweden	scientific, industry, policy makers, medias	100	International
4	SLU	Monitoring of off-gassing during storage of wood pellets – Full scale silo experiment	04.06.2014	Jönköping, Sweden	Scientific community, Industry		Sweden