ASSESSMENT OF FIRE SAFETY REQUIREMENTS TO UPHOLSTERED FURNITURE AND MATTRESSES

Anne Steen-Hansen[1] and Bjarne Kristoffersen[2]
[1]Norwegian University of Science and Technology
[2]SINTEF NBL as

ABSTRACT

The Norwegian authorities responsible for product safety have started a revision of the present regulations to fire behaviour of mattresses and upholstered furniture. This paper presents results from a project aimed at collecting and analysing international and national knowledge and experience on this subject to create a decision basis for the Norwegian authorities. Statistics from fires in prisons and psychiatric institutions have been studied, and the evaluation shows that incendiary fires in these institutions often start in furniture. Data from domestic fatal fires show that fires starting in furniture represent a high fatality risk. These results are supported by findings from an extensive literature study, and leads to the conclusion that fire safe furniture is a highly effective fire countermeasure, both in selected public areas and in private homes.

INTRODUCTION

Modern homes contain relatively large amounts of upholstered furniture and mattresses. Such furniture is also a common part of the furnishing in hotels, hospitals, nursing homes, health institutions and prisons. In cinemas and theatres there are numerous rows of comfortable upholstered seats. In several of these buildings, the escape time in case of fire may be considerably long. It is therefore crucial that both the surface materials and the materials in the furniture do not contribute significantly to development and spread of the fire, neither concerning heat release, flame spread nor smoke production.

Mattresses and upholstered furniture are constructed from several different components, where the padding material constitutes a large part of both volume and mass. The predominant padding material is polyurethane foam with varying density and additives, but other materials as cellulosic- and polyester battings are also used[1]. Padding material that is not treated or modified to become more resistant to fire, is normally easily ignitable, and may produce large amounts of both heat and smoke during combustion. Polyurethane foams have a theoretical heat of combustion value between 26.1 and 31.6 MJ/kg [2]. In the European test program *Combustion Behaviour of Upholstered Furniture* (CBUF) one of the test series was made to investigate the effect of different fabric/padding variations[3]. Chairs with different combinations of foam and cover materials were tested, and the results show that the effective heat of combustion for the items containing High Resilliant (HR) polyurethane foam was in the range 14.5-18.2 MJ/kg. The measured peak heat release rate for these items were ranging from 832 kW to 1325 kW. This is a considerable amount of energy released in a short time. The smoke production and production of toxic gases were also high for these chairs. The CBUF-program was one of several studies during the last 30 years which all point towards the same conclusion: upholstered furniture and mattresses represent a large fire risk in many buildings today if not modified to control their contribution to fire. This fact has lead many nations to consider their requirements to fire safety of such items.

The Norwegian authorities responsible for product safety have started a revision of the present regulations to fire behaviour of mattresses and upholstered furniture. This paper presents results from a project aimed at collecting and analysing international and national knowledge and experience on

this subject to create the needed decision basis for the Norwegian authorities' revision of their regulations.

METHOD AND MATERIAL

Definition of important problems to be addressed and assessments of the present status and possible improvements of the safety level are based on an extensive literature study. The number of papers, scientific reports and internet contribution in the field of fire safety of mattresses and upholstered furniture is overwhelming, and covers several fields of expertise: fire engineering, statistics, chemistry, risk assessment, environmental sciences, regulations, fire testing etc.

Fire statistics from the Norwegian Directorate for Civil Protection and Emergency Planning (DSB) have also been analysed to quantify the fire risk in relation to furniture as the first item ignited in both *psychiatric institutions* and *prisons*. Results reported from earlier analyses of fatal domestic fires in Norway have been used to assess the risk in private homes.

WHY DO WE NEED FIRE SAFE FURNITURE?

There is a vast amount of international publications concerning furniture and fire. One overall conclusion is that unmodified mattresses and upholstered furniture, i.e. items not designed to be fire safe to any degree, represent a high fire risk in buildings. Such objects are often readily ignitable and produce large amounts of heat, smoke and toxic gases when burning. Fire statistics from the USA show that mattresses and upholstered furniture are the first items to be ignited in about 10 % of all domestic fires. These fires cause, however, as many as about 35 % of the domestic fire deaths[1]. During the 1980's and 90's several Norwegian research projects were conducted in this field, but until now, the only requirement to mattresses and upholstered furniture on the Norwegian market is resistance against ignition by a smouldering cigarette. Internationally, there is a trend towards introducing more fire safe furniture in different application areas, and the time may be due to revise the regulations in Norway as well. Fire safe furniture should also be considered as a fire countermeasure when fulfilling requirements in performance based building codes.

Studies of full scale behaviour of furniture have shown that the heat release from a single chair may exceed 1 MW. This means that ignition of one single item is sufficient to cause flashover in a small room[3]. The assumption that upholstered furniture is a major contributor in fires unless it has been modified with respect to its reaction-to-fire properties after ignition is therefore realistic. Fires in modern houses may develop very rapidly, produce high levels of heat and smoke during the first phase of a fire – and thereby the available time to escape may be very short. This will especially be critical in buildings where long evacuation times are required, but does also represent a major risk in domestic buildings where people may be asleep or handicapped. Evaluation of fire statistics may give a picture of the risk related to mattresses and upholstered furniture in different application areas.

Fatal domestic fires starting in mattresses and in upholstered furniture

The number of domestic fires in Norway has been at a constantly high level for a rather long time. The annual number of domestic fires over the period 2001-2005 was over 1600. 58 % of all building fires in 2005 where fire brigades were alarmed took place in private homes[4]. The number of fire fatalities each year varies between 50 and 70 (11-15.5 per million inhabitants), and this level has been unchanged over a long period. However, it has been shown by a SINTEF-study that changes in the Norwegian society should have lead to a higher number of fatalities, given that the fire safety level has been unchanged[5]. Significant changes are the increasing share of elderly people, and the increasing number of single-person households.

Norwegian fire statistics give only rarely information about first item ignited in fires. However, fatal fires are thoroughly investigated by the police, and by studying police report and reports from the fire brigades it is possible to get more detailed information about these cases.

A SINTEF analysis of police reports from 306 fatal fires in Norway during the period 1970-1979, investigated the first item ignited[6]. Upholstered furniture and bedding components were two of the items studied. In a subsequent project, fatal fires from the period 1978-1992 were analysed[7]. As shown in Figure 1 there was a clear reduction in fires starting in bedding items from the first 10 years to the last 10 years. There was no such evident reduction in fires starting in upholstered furniture over the same period.

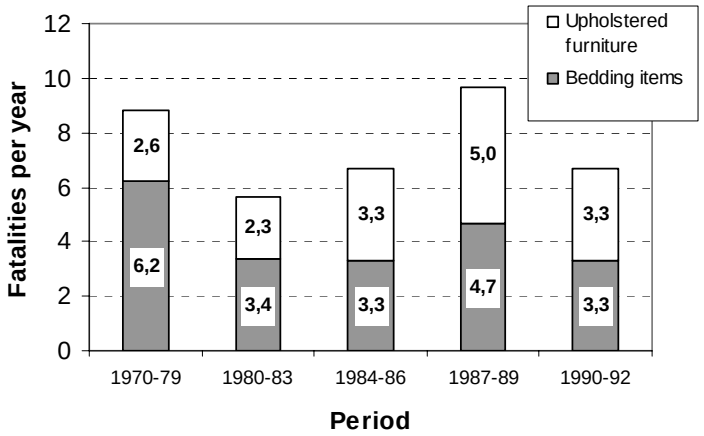

Figure 1 Annual fatalities in Norwegian building fires where bedding items or upholstered furniture are assumed to be the material first ignited. Note the different number of years in the analysed periods.

It must be taken into account that the uncertainty connected to assessment of the first material ignited is relatively large. The number of fatal fires is low, and the required information in the reports is partly insufficient. The statistics is, however, indicating that fires starting in bed became less common during the 1980's. There may be several reasons for this. A change in smoking habits among the Norwegian people may be one of the reasons, but the connection may not be obvious. In an analysis of the effects of increased fire counter-measures in UK[8,9], it was concluded that changes in smoking habits in the population did not significantly affect the trends in fire statistics since the introduction of the UK Furniture Fire Regulations in 1988[10]. Several studies have pointed out that the fire risk is higher in financially and socially challenged households. The number of smokers will also be highest in these parts of the society.

In a master thesis from 2005, Norwegian domestic fatal fires in the period 2000-2004 were analysed[11]. Only fires with origin in the living room or bedroom were included, because these are the areas where mattresses and upholstered furniture most likely will be found. Fires where mattresses or upholstered furniture was the first item ignited were studied; the project did not investigate how the furniture contributed to fire development or fire spread. In the studied fires, 67 persons died in living rooms and 21 in bedrooms. These fires constitute 0.4 % of all domestic fires in the same period, and their total number of fatalities about 15 % of all fire fatalities over these five years. An overview over the fire causes is given in Table 1.

Table 1 Causes for Norwegian fatal fires where the origin was in the living room or bedroom during the period 2000-2004[11].

Fire cause	Living room		Bedroom		Total	
	Number	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**
Open flames[*)]	40	59,7 %	8	38,1 %	48	54,5 %
Electrical fault	4	6,0 %	2	9,5 %	6	6,8 %
Electrical equipment	2	3,0 %	3	14,3 %	5	5,7 %
Incendiary fire	3	4,5 %	4	19,0 %	7	8,0 %
Unknown	18	26,8 %	3	14,3 %	21	23,9 %
Other causes	0	0 %	1	4,8 %	1	1,1 %
Total number of fatalities	**67**	**100 %**	**21**	**100 %**	**88**	**100 %**

[*)] About half of these cases were caused by smoker's material (cigarettes or matches).

59 % of the victims were between 31 and 60 years old, while 22 % were older than 70. There were no children under 15 years among the victims. 63 % of the victims were asleep when the fire started, and 16 % were intoxicated by alcohol or drugs. The thesis shows that mattresses and upholstered furniture is a significant factor in Norwegian fatal fires, and that smoker's material and flaming ignition sources caused most of these fires. This is in full agreement with international fire statistics[1].

Fires in Norwegian prisons and psychiatric institutions

Fires in prisons and psychiatric institutions represent a very high risk. The occupants have restricted freedom of mobility, and some of them may be confined to their beds. According to the fire statistics, arson fires have a high probability in both these types of buildings. In a SINTEF-study of arson fires, it was found that there were more than 25 arson fires per 1000 prisons in 1996-97[12]. In the same period, the number of arson fires in buildings for health care was 4.3 per 1000 buildings. Most of the fires in the latter category were started by occupants with different psychiatric disorders. Neither Statistics Norway nor the SINTEF-study distinguish between psychiatric institutions and other types of hospitals, so it is reasonable to assume that the number of arson fires in psychiatric hospitals is far higher than 4.3 per 1000 buildings. For comparison, there were 40 incendiary school fires in 1996-97, that is a number of 1.5 per 1000 school buildings. This means that the probabilityof an incendiary fire in a prison is 17 times higher than in a school.

Fire statistics obtained from the Directorate for Civil Protection and Emergency Planning in Norway were analysed to find the frequency of fires in Norwegian prisons and psychiatric institutions, and also the frequency of incendiary fires in these building categories. The data investigated covered 13 years, from 1993 to 2005.

Prisons: Fire causes

115 fires in Norwegian prisons were reported from 1993 to 2005. 68 of them were incendiary fires, while 16 fires were caused by open flames, faults in electrical wiring etc. The causes of the remaining 31 fires were unknown. Mattresses or bedding items were assumed to be the first item ignited in 17 % of all these 115 fires, and was the first item ignited in 28 % of the intentional fires. Only one of the 115 fires was known to have started unintentionally by smoking in bed. The distribution of causes for the prison fires is shown in Figure 2.

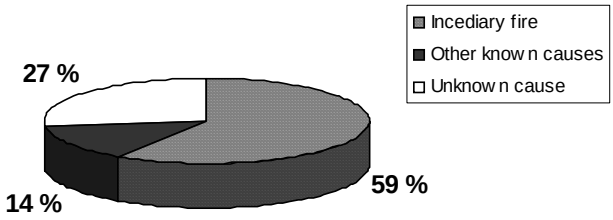

Figure 2 Distribution of causes for the 115 reported prison fires in Norway in the period 1993-2005.

The number of prison fires varied from year to year, see Figure 3.

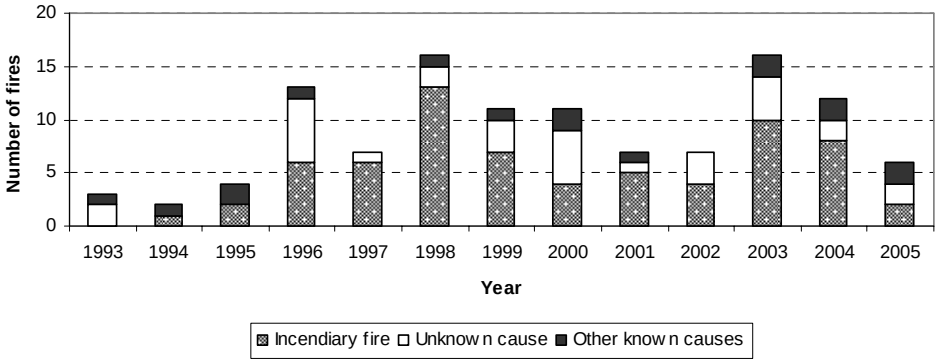

Figure 3 Annual number of fires and fire causes in Norwegian prisons during the period 1993-2005.

In both 1998 and 2003 there were relatively high numbers of fires, mostly due to a high number of arson fires. Provided that the number of prisons in Norway has been kept constant from 1993 to 2005, the statistics lead to an annual number of 22 incendiary fires per 1000 prisons.

Prisons: Injuries and fatalities

40 of the prison fires resulted in a total of 55 persons injured, and only one person died. 30 of the 40 fires with person injuries were intentional fires, i.e. 75 %. Only 3 of these fires had other known causes, while 7 are recorded with an unknown cause of fire.

Prisons: Damage costs

As shown in Figure 4 most of the prison fires had a very limited damage extension. The three fires with the largest damage had unknown cause of fire.

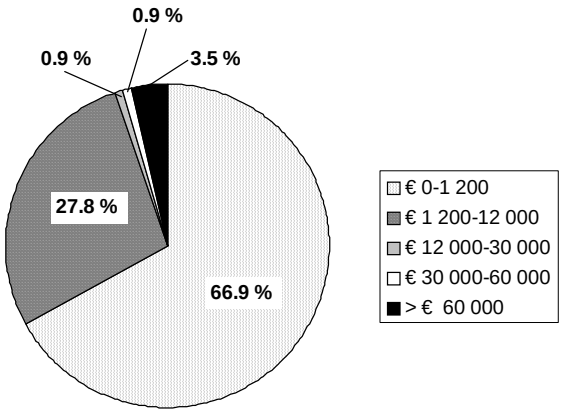

Figure 4 Damage costs in Euros for prison fires in Norway in the period 1993-2005. Loss levels were estimated by the fire brigades.

Psychiatric institutions: Fire causes

390 fires in psychiatric institutions were reported during 1993-2005. 210 were intentional fires, while 39 are reported with other known causes. The fire cause was unknown in the resulting 141 fires. Mattresses or bedding items were assumed to be the first item ignited in 25 % of all these 390 fires, and was the first item ignited in 30 % of the intentional fires. The distribution of fire causes over the 13 analysed years is shown in Figure 5.

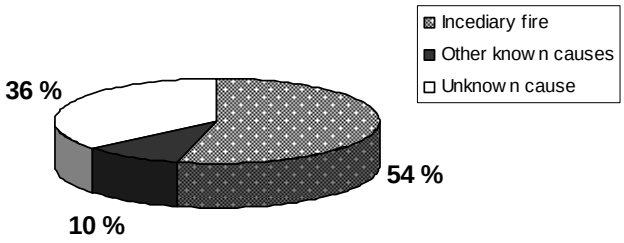

Figure 5 Distribution of causes for the 390 reported fires in psychiatric institutions in Norway during the period 1993 to 2005.

As Figure 6 shows, most fires in psychiatric institutions were intentional fires. The number of fires with unknown cause was reduced during the period, while the number of fires with other known cause than arson increased. This change may be a result of the authorities' stronger focus on fire investigation.

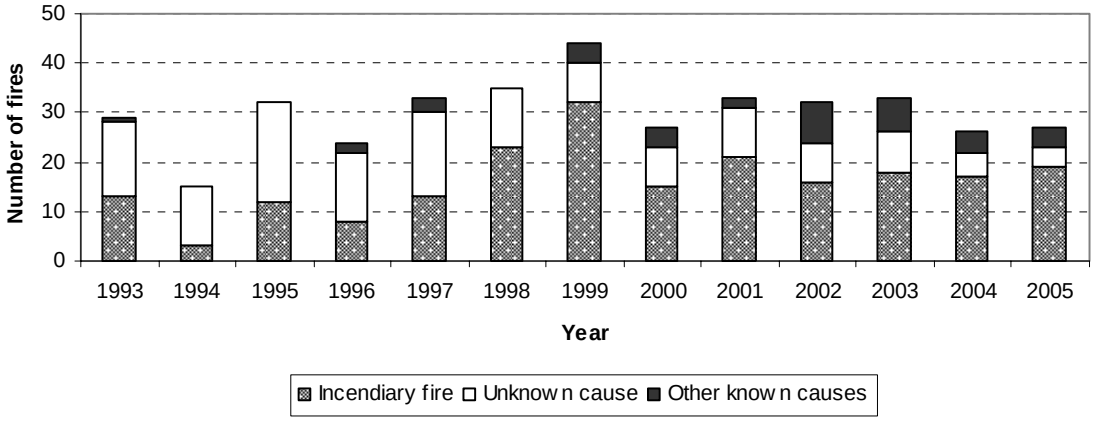

Figure 6 Annual number of fires in Norwegian psychiatric institutions during the period 1993-2005.

Psychiatric institutions: Injured persons and fatalities

26 persons were injured in a total of 19 fires. There was only one fatality among the victims. 12 of the fires with injured persons were arson fires, but the fatal fire was not an incendiary fire.

Psychiatric institutions: Damage costs

The damage in most of the fires in psychiatric institutions were very limited, see Figure 7. The 3 fires with the largest loss of property had unknown cause of fire.

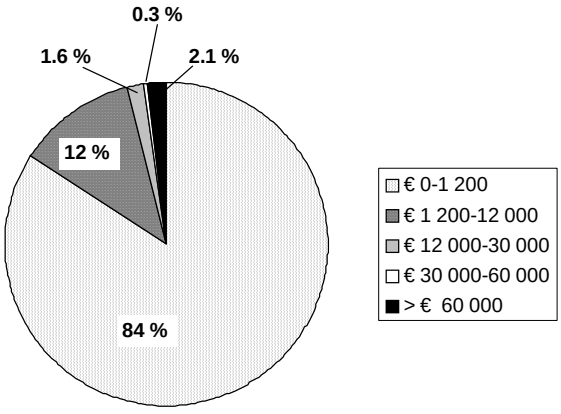

Figure 7 Damage costs for fires in psychiatric institutions in Norway in the period 1993-2005. The damage extent was estimated by the fire brigades.

During the analysed period of 13 years, there were annually 9 fires in prisons and 30 fires in psychiatric institutions. More than half of these fires were intentional. In the fire report forms used by the fire brigades and the police, there is a field for free comments. The comments give the impression that the personnel in both prisons and psychiatric institutions are well trained to handle fire situations. It is often stated that the personnel extinguished the fire, and that they behaved correctly in the fire situation. The contribution from the personnel is most probably the main reason that the number of fatalities and injured persons is low, and also that the economical loss normally is low.

REGULATION OF FIRE BEHAVIOUR OF FURNITURE

Current Norwegian regulations

The Norwegian requirements for ignitability of mattresses and upholstered furniture[13] are regulated by the European Product Safety Directive[14], and state as follows:

> *Mattresses and upholstered furniture shall resist ignition by a smouldering cigarette in accordance with specific criteria given in recognised standards.*

The regulations refer to the European test standards EN 1021-1 for furniture[15], and EN 597-1 for mattresses[16]. These requirements are set to all mattresses and items of upholstered furniture sold on the Norwegian market, regardless of application area.

There are no indications that there exist products on the Norwegian market that do not fulfill the criteria to resistance against ignition by a smouldering cigarette. However, this level of ignition resistance does not guarantee that the object will not be ignited by flaming sources, and gives no information about how the object will behave after ignition.

Regulations in Europe

In Europe, furniture and mattresses are regulated by the European Product Safety Directive. In the early 1990's a draft directive concerning the fire behaviour of upholstered furniture was prepared, but this draft has not been finished later. The European Product Safety directive gives no specific instructions on how to control fire properties of upholstered furniture and mattresses. Each member state in the European Union and the European Economic Area must therefore consider if and how fire safety of such items should be assessed, and different options have been chosen in different countries. There are variants of requirements with regard to ignition resistance, which type of furniture that is regulated, and areas where requirements apply, as shown in Table 2. The information in the table is not complete, but covers a large part of the European Economic Area. UK and Ireland have the most severe regulations in Europe, and requires resistance against smouldering cigarettes, as well as match flame and the relatively severe flaming source called crib 5[17,18] for all appliances.

Table 2 Regulation of fire safety of mattresses and upholstered furniture in some European countries[19].

Country	Type of building	Object	Ignition source	Method	Class
UK and Ireland	Domestic	Seats/mattress escovering Padding.	Cigarette Match flame Crib 5	EN 1021-1 EN 1021-2 BS 5852	pass/fail pass/fail pass/fail
	Public	Seats	Cigarette Match flame Larger flaming sources.	EN 1021-1 EN 1021-2 BS 5852	pass/fail pass/fail pass/fail
		Mattresses	Cigarette Match flame Larger flaming sources.	EN 597-1 EN 597-2 BS 6807	pass/fail pass/fail pass/fail
Italy	Public	Seats Mattresses	40 mm flame applied for 20 s 80 s 140 s	CSE RF 4/83	 3IM 2IM 1IM
Germany	Public	Seats	Cigarette Match flame	EN 1021-1 EN 1021-2	pass/fail pass/fail
Finland	Domestic	Seats	Cigarette	EN 1021-1	pass/fail
	Public	Seats	Cigarette Match flame	EN 1021-1 EN 1021-2	pass/fail pass/fail
Sweden (recommendations only)	All	Seats Mattresses	Cigarette Cigarette	EN 1021-1 EN 597-1	pass/fail pass/fail
	Public (health-care institutions)	Mattresses	Match flame	NT FIRE 037	pass/fail
	Public (in high-risk institutions)	Mattresses	Larger flaming source	SS8760010	pass/fail
	Public (restaurants, hotels, boarding homes etc.)	Seats Mattresses	Match flame Match flame	EN 1021-2 EN 597-2	pass/fail pass/fail
Norway	All	Seats Matresses	Cigarette Cigarette	EN 1021-1 EN 597-1	pass/fail pass/fail
France	Health institutions	Mattresses	Cigarette	EN 597-1	pass/fail
	Theatres etc.	Seats	20 g paper cushion	NF D 60013	pass/fail
	Prisons	Mattresses	Cigarette Match flame Larger flaming sources.	EN 597-1 EN 597-2 GPEM DI 90	E D A,B,C
Spain	As France				
Portugal	As France				

Some countries set high fire safety requirements

Some countries have higher requirements to fire behaviour of furniture than others. UK introduced a high fire safety level for upholstered furniture in 1988[10], and the requirements were extended to apply also for indoors and outdoors furniture, beds, pillows and mattresses[20]. From 1993 the fire regulations also covered retail store second-hand furniture. An analysis of fire statistics in UK shows a significant decline in the number of serious domestic fires after 1988[8,9,] The furniture regulations are probably a major reason for this decrease, but other factors as an increase in installed domestic smoke detectors and a change in smoking habits in the populations may also have affected the statistics positively. However, fire safety may be just as much a social issue as a technical one, and persons with a low income and social problems may have a relatively high probability to experience a domestic fire. The analysis report concludes therefore that changes in smoking habits have not affected the fire statistics significantly. It is estimated that the regulations have lead to a reduction of more than 44 000 domestic fires in UK from 1988 to 2002, and that more than 4 000 lives have been saved. 1 150 of these lives were saved because a higher fire safety level has prevented fire start in mattresses and upholstered furniture. The total material cost savings over the same period is estimated to be
£182 million, in addition there are saved costs connected to saved lives and reduced number of injuries. It is estimated that there annually would be 850 saved lives in EU if countermeasures as fire safe furniture and smoke detectors had been introduced.

California has enforced fire requirements to furniture and mattresses for more than 20 years, regulations concern both cigarette- small flame- and large flame resistance for different applications areas[21]. Ten years after the introduction of cigarette- and small flame ignition standards, upholstered furniture fires were reduced by 50 %[1]. A part of the reduction was ascribed to increased installation of smoke detectors and a decreased percentage of smokers in the population, but much of the reduction is assumed to be caused by the furniture regulations.

Sweden has no legal regulations regarding fire safe furniture, but the Swedish Rescue Services Agency has published recommended fire requirements for furniture[22]. After a mattress fire in a hospital where two persons died, it is now recommended that mattresses in high-risk institutions are tested according to Swedish Standard SS 876 00 10, which implies exposure to a 30 kW ignition source[23].

Recommended strategy for revision of the Norwegian regulations

From Table 2 we see that countries in the European Economic Area have chosen different strategies with respect to fire safety of mattresses and upholstered furniture. Requirements range from no regulation at all, via resistance to ignition by a smouldering cigarette in selected types of buildings, to the British regulations requiring resistance to a larger flaming ignition source.

There are several aspects to be considered when assessing the fire regulations for upholstered furniture and mattresses to a fire, some of them are listed below.

- **Ignitability.** The first barrier to be set is resistance against the most common ignition sources for these items, like smouldering cigarettes and match flame. There are several tests designed to document this level of reaction to fire. However, larger ignition sources should also be considered. If materials in pillows and bedcovers are ignited, the mattress beneath must be able to resist a much larger ignition source than fire testing by cigarettes or small flames simulates. A burning TV in a living room may ignite a sofa. Arson fires are not uncommon in some high-risk areas, like in prisons and health-care institutions, and a high fire safety level is necessary, also including fire safe furniture.

- **Contribution to development and spread of fire.** Some tests are designed to study how the tested object contributes to a fire after ignition. Different test results may be reported, like time to ignition, flame spread, heat release, melting and flaming material, mass loss, smoke production and production of toxic gas species.
- **Different criteria for different end use applications** may be required depending on a fire risk analysis.
- **Environmental adverse effects** related to use of FR chemicals should be assessed to ensure that higher fire requirements are beneficial in a wider perspective.
- **Effects for suppliers and consumers.** Factors to be considered are the economical impact of changes in the regulations, and how properties like design and comfort may be affected.

DISCUSSION AND CONCLUSIONS

For revision of the Norwegian regulations we recommend that mattresses and upholstered furniture in buildings where the fire risk may be assessed to be high should have a higher fire safety level than today's cigarette resistance. The analysed fire statistics from prisons and psychiatric institutions show that intended fires is a significant problem in these types of buildings, and that mattresses and bedding items are the first objects ignited in around 30 % of all incendiary fires in these institutions. Upholstered furniture in high-risk buildings like these ones should therefore obviously be resistant to larger flaming ignition sources, in addition to resistance against a smouldering cigarette. Requirements should also be set to the amount of heat and smoke the objects release in a fire, because the required time to escape may be high. Other public high-risk areas where a high level of fire safety should be required may be different categories of health-care institutions, hotels, boarding homes, restaurants, theatres and cinemas etc. Sheltered housings for elderly or handicapped persons are also buildings where a high fire safety level is needed.

We also believe that it is possible to regulate reaction-to-fire properties of furniture in private homes to the same level as in public buildings. The UK regulations, the Californian regulations, and also the introduction of new federal regulations to mattresses in the USA in 2007 are examples that demonstrate that this will be manageable, and we recommend that this option also is considered by the Norwegian authorities.

Table 2 shows a variety of available test standards, and in the literature and in standards we find even more test procedures for furniture products. Appropriate test procedures are available to measure a variety of different reaction-to-fire properties for furniture, there should be no need to invent new ones. The question is rather to define relevant design fire scenarios for the furniture and then choose a test procedure that is able to measure the furniture's contribution to the fire. Important properties to test are ignition resistance (to both cigarette and flaming ignition source(s)) as well as post-ignition heat- and smoke production. The Norwegian market has some experience with testing according to BS 5852, and also according to NORDTEST method NT FIRE 032. These methods should therefore be considered in addition to other relevant test methods.

A concern connected to increased fire requirements to furniture is that it may lead to an increased use of environmentally hostile fire retardant (FR) chemicals. Such chemicals may represent a risk for both human health and the local and global environment. FR chemicals may be released at different stages of the furniture's lifecycle: during production, during use and after use – i.e. in recycling, incineration or as deposits in landfill. And of course, a fire situation at different stages in the lifecycle will also lead to emissions of unwanted species. SP in Sweden has performed a life cycle analysis study of furniture, and concluded that FR treated furniture will give less environmental adverse effects that non-FR furniture[24], one of the causes being a reduced number of fires. Looking at the savings connected to a lower number of deaths and injuries, the benefits from FR treated furniture are even higher. There are relatively environment-friendly treatments of both padding materials and fabrics available today, and ongoing research seeks to find even better solutions

Another concern may be that Norwegian manufacturers may have problems to produce comfortable and attractive furniture with better fire properties than today. The costs connected to production of more fire safe furniture will be higher than today's production, and one may worry that the increased costs may be unacceptable to the consumers. Through contact with the Norwegian furniture manufacturers, we were informed that many of them produce furniture and mattresses for the British market today, and therefore already comply with the UK requirements. The increased costs per item are also said to be moderate, and will probably not affect the furniture manufacturers' access to the Norwegian market negatively.

The study of Norwegian fire statistics clearly tells us that upholstered furniture and mattresses represent a fire risk in prisons, psychiatric institutions as well as in private homes. If furniture were more resistant to ignition, many fires would probably have been prevented, and many lives would have been saved, especially in domestic fires.

We therefore recommend that the fire safety requirements to mattresses and upholstered furniture on the Norwegian market should be increased. A more strict regulation is especially important for high-risk applications as described earlier in this paper, but the beneficial effects of improved fire safety in private homes will also be considerable.

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