Office for Product Safety & Standards

Characteristics of modern domestic fires and the implications for product performance testing

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Acknowledgements

This independent research report was produced by a team comprising members of the Fire Safety Group and the Fire Investigation Group, BRE Global.

The views expressed in this report are those of the authors, not necessarily those of the Office for Product Safety and Standards or the Department for Business, Energy & Industrial Strategy (nor do they reflect Government policy).

A Project Stakeholder Group was established at the start of the project. The Project Stakeholder Group met twice. The first meeting was held on 4 March 2019 to present the finalised scope and secure early engagement and input to the project. The second meeting was held on 13 May 2019 to present and discuss the findings of the project.

The following organisations were represented on the Project Stakeholder Group:

- Office for Product Safety and Standards, Department for Business, Energy & Industrial Strategy
- BRE Global (project team)
- Home Office
- Ministry of Housing, Communities and Local Government
- Scottish Building Standards
- Welsh Government
- Association of Manufacturers of Domestic Appliances
- British Furniture Confederation
- British Furniture Manufacturers Association
- British Standards Institution
- Electrical Safety First
- Furniture Industry Research Association
- London Fire Brigade
- National Fire Chiefs Council
- Scottish Fire and Rescue Service
- Tech UK
- The National Bed Federation
- University of Edinburgh, BRE Centre for Fire Safety Engineering
- UK Association of Fire Investigators
- Zurich Insurance

One to one consultations were carried out by telephone and follow up e-mails with selected participants. A total of eleven interviews (involving 10 organisations) were carried out.

Individuals from the following organisations participated in the one to one consultations:

- Association of Manufacturers of Domestic Appliances
- British Furniture Confederation
- British Furniture Manufacturers Association
- Electrical Safety First
- Furniture Industry Research Association
- London Fire Brigade
- Royal Society for the Prevention of Accidents
- Tech UK
- The National Bed Federation
- Which?

Other information was provided as follows.

- The Home Office provided extracted fire statistics for England for BRE Global to analyse for this study.
- The Ministry of Housing, Communities and Local Government gave permission for BRE Global to interrogate the collected information from the ‘Investigation of real fires’ project.
- British Standards Institution, in addition to various one to one consultees, assisted with identifying British Standards relevant to the flammability fire tests and fire hazard tests of consumer products.

Contents

Executive summary

Domestic homes in the UK have changed in recent decades, due to their design, the materials used in their construction and the various new products that people place inside them. These changes have an impact on the physical properties of a domestic fire. As well as new materials, new sources of ignition in domestic dwellings, such as e-cigarettes, batteries and space heaters, are also likely to have changed the characteristics of modern domestic fires.

The aim of this project was to understand how changes in the composition of products in the modern home have changed the ignition sources and characteristics of modern domestic fires. The findings of this work are expected to help identify what changes to safety standards (particularly product flammability fire testing) and product design would be necessary to protect against these new ignition sources and characteristics.

This desk-based study comprised: a review of published literature; reviews and analyses of fire statistics, real fire incidents and consumer product recalls; a review of flammability fire tests of consumer products and one to one consultations.

Review of fires in modern homes

The IRS Home Office Fire Statistics for England has shown that the number of dwelling fires has fallen from a maximum of 58,280 in 1999/2000, to about 30,000 fires attended by the Fire and Rescue Services in each of the last five years. Roughly 90% of these fires are accidental. Over 50% of fires start in the kitchen, followed by bedroom and living room (approximately 10% each). These proportions have remained constant since 2010/2011.

Different types of material ignited may be associated with different types of ignition sources. Different fire types result in different areas of damage. Of the commonest types, furniture fires have the largest average area of damage. Cooking fires are much smaller in extent, on average.

Although fire statistics are available for recent years, relevant literature on the heat release rate and fire risk of consumer products is dated, generally of the order of 20 years old. This is unlikely to represent the fire risk of modern consumer products. Relevant published literature on this issue is also mostly based on overseas data, which may also not be representative of the UK.

The literature review has identified relevant ongoing research on the fire risk of lithium-ion battery consumer products (i.e. laptops, mobile phones, e-cigarettes). This research has identified the processes leading to fire incidents attributed to an exothermic reaction to ‘thermal runaway’ of this type of consumer product, and potential changes to lithium-ion battery design to mitigate the fire risk.

The review has identified changes in the characteristics of modern home design compared to legacy home design, with a trend for living areas to be more open plan and the increased use of Modern Methods of Construction involving the use of combustible materials. Literature on changes in the expected fire dynamics between a modern and legacy dwelling fire is, however, very limited and based on overseas data that may not represent changes to modern dwelling fires in the UK.

The current fire load energy density values assumed for dwelling fires in the UK are based on work carried out in the mid-1980's and may not be representative of modern dwelling fires in the UK. Although more recent data is available overseas, variation in the methodologies used to determine fire load density between different countries, makes comparison between them very difficult, if not impossible.

Consultation with the furniture industry revealed that fillings within domestic upholstered furniture have not changed (with polyurethane foam still being the main filling used); however, covering materials have become more customisable by the consumer and are changed more frequently in the modern home. It was also noted that materials used in the construction of furniture, such as timber and plastics, have also changed over the years. There are also more foam-only mattresses for beds in the modern home than previously.

Consumers are now seeking to buy cheaper, short-term products, which may be inherently/naturally less flame retardant, rather than more expensive long-term products that were previously being bought.

Over the last few decades there has been an increase in the number and types of electrical products inside the home, as well a rapid rise in the use of lithium ion battery powered electrical items that require periodic charging. The consumer is not well informed to identify poor quality and counterfeit appliances, which are more likely to cause fires than appliances from reputable manufacturers.

Trends in ignition sources

Annual trends in the fire statistics for common ignition sources show that:

- Washing machines, tumble dryers, personal computers and battery chargers account for an increasing proportion of fires.
- Television sets, 'other' appliance, matches, and naked flame account for a decreasing proportion of fires.
- The proportion of fires caused by smoking materials has remained unchanged during the period 2010 to 2018.

The largest obstacle to identifying novel ignition sources from trends in the fire statistics is probably that the different people entering data do not recognise that an item is 'new' and therefore worthy of special mention under the 'other' category text field, rather than using an existing standard category. As an example, e-cigarettes could be classed as 'smoking materials' or 'battery charger' rather than being explicitly mentioned.

Despite the difficulty in identifying novel sources of ignition from the fire statistics, from such analysis as has been possible, it seems reasonable to conclude that e-cigarettes have a significantly reduced likelihood of starting a fire, compared to the risk from conventional cigarettes.

Review of real fire incident data, originally collected by BRE Global on behalf of Ministry of Housing, Communities and Local Government and concentrated on fires which have aspects of relevance to the Building Regulations, has shown that there has been a noticeable rise in the number of fires in domestic dwellings caused by battery chargers since 2014; including faulty electronic cigarettes and counterfeit charging devices.

There has also been a rise in the number of fires involving white goods in domestic dwellings since 2015; which triggered campaigns for a product recall database to record the number of real fire incidents attributed to white goods. As a result, the British Standards Institution published a code of practice for the procedure regarding product recalls (PAS 7100).

Examination of product recall databases revealed that defective wiring, cabling and plugs were the most entries, along with overheating appliances, followed by battery overheating and then insufficient electrical insulation.

The correlation between the numbers of items recalled, of a given type, and the number of fires started by items of the same type, is not particularly good. However, it is still worth examining product recall databases as these may show some potentially new sources of ignition.

Changes in product design may introduce new ignition sources and fire risks, for example furniture containing accessories such as electrical charging ports, white goods such as washing machines containing noise dampening (polyurethane foam) which may increase the risk of a fire developing, and flame retardants (added to plastic foams) being withdrawn from the market as combustion products are carcinogenic.

Flammability testing

Whilst there are many standards for the multitude of different products, only a limited number of fire tests are referenced by these standards. These include:

- Cigarette test (furniture) (BS 5852: Part 1)
- Match test (furniture) (BS 5852: Part 2)
- Glow wire test (electrical products) (BS EN 60695-1-10, BS EN 60695-1-11)
- Needle flame test (electrical products) (BS EN 60695-11-5)

The cigarette test is described in Schedule 4 of the Furniture and Furnishings Regulations. Currently, only reduced ignition propensity (RIP) cigarettes are available in the UK and EU; these do not meet the requirements of the cigarette test.

Suggestions for further practical work to support product flammability tests

The general consensus from consultations with the furniture industry was that the Furniture and Furnishings (Fire Safety) Regulations 1988 (as amended) need to be updated to reflect the change in the environment seen in the modern home. In particular, there should be consideration of alternative smouldering sources of ignition in the modern home. The cigarette test requires use of a non-RIP cigarette as an ignition source, an item which is no longer commercially available. Research into modern sources of smouldering ignition would be beneficial, possibly leading to the development of an alternative smouldering ignition source to use in testing.

Another suggestion was the review of the ‘worst-case’ filling which can be used in the testing of upholstery composites if the filling to be used is unknown. Currently, there is no prescribed standard for material to be used, and it was suggested that the ‘worst-case’ filling could be standardised to ensure alignment across the furniture industry.

The main fire safety risk in the modern home with regards to furniture and furnishings was agreed by consultees to be imported products which have an unknown level of fire safety. It was suggested that such products should undergo routine testing to identify products which are non-compliant with regulations.

Consultees noted the speed at which electrical product technologies are emerging results in old standards being applied to new technologies. Some of the series of standards for electrical products could be simplified and a more consistent and more onerous test could be applied across the range of products covered. The standardisation process could be simplified to ensure that the products are tested more effectively and are available in the market sooner.

Product design changes to improve product safety, including suggestions for further practical work

In general, there was a lack of relevant literature on consumer product design and fire risks. However, an exception is the ongoing research on the fire risk of lithium-ion battery consumer products, and the potential changes to lithium-ion battery design to mitigate the fire risk. Literature was also available on proposed changes to fridge-freezer design to reduce the risks of fire.

The product recall databases do not contain a large enough sample for robust conclusions to be drawn. However, a common failing in wiring, cabling and plugs and battery chargers was insufficient insulation. For wiring, cabling and plugs, a second common problem was overheating. In PC equipment, the most common problem was battery overheating.

It would be of great benefit for consumers to only have to refer to one website to identify if any product in their home has been recalled. If it was easier for the consumers to identify recalled products, they could ensure they deal with them appropriately.

Feedback from consultations with the furniture industry highlighted that there could be a greater focus on the selection of materials used for coverings of furniture, and to increase the use of inherently/naturally flame retardant materials, as this could have an impact on product safety. It was noted that use and misuse testing of electrical products could also be beneficial in the selection of materials for furniture coverings.

Concern around the use of fire retardants in furniture in the modern home was also highlighted during consultations, and it was suggested that research into how to maintain the fire safety of products while reducing the quantity of fire retardant in furniture would be beneficial to product safety.

Introduction

Background

Domestic homes in the UK have changed in recent decades, due to their design, the materials used in their construction and the various new products that people place inside them. These changes have an impact on the physical properties of a domestic fire. As well as new materials, new sources of ignition in domestic dwellings such as e-cigarettes, batteries and space heaters, are also likely to have changed the characteristics of modern domestic fires.

It is important that the Office for Product Safety and Standards (OPSS), as the organisation with responsibility for consumer product safety, understands the types of fires that modern consumer products are likely to experience so that the regulations that govern their performance are adequate to protect the consumer. It is also useful to understand what changes in product design might be possible to improve their safety in a modern domestic fire scenario.

Aim and objectives

The aim of this project was to understand how changes in the composition of products in the modern home have changed the ignition sources and characteristics of modern domestic fires. The findings of this work help to identify what changes to safety standards and product design would be necessary to protect against these new ignition sources and characteristics.

The project objectives were:

1. To review the impact of changes in the contents and the design of the home on fire characteristics.
2. To review the impact of new sources of ignition, such as e-cigarettes, batteries and space heaters on product flammability fire testing.
3. To identify any follow-on practical work for product flammability fire performance testing in order to make recommendations on the design of revised standards that are representative of modern fire scenarios.
4. To make suggestions as to how modern designs of consumer products can be amended to improve their safety in a modern domestic fire. To identify any practical follow-on work required in order to verify these suggestions.

General approach

The research essentially comprised desk-based reviews and one to one consultations addressing the project objectives 1 to 4.

The desk-based reviews comprised the following:

- Review of published literature (primarily objectives 1 and 4).
- Review and analysis of fire statistics (primarily objectives 1 and 2).
- Review and analysis of real fire incidents (primarily objectives 1 and 2).
- Review and analysis of consumer product recalls (primarily objectives 2 and 3).
- Review of flammability fire tests of consumer products (primarily objectives 2 and 3).

The intent of this review of published literature was to define the project landscape. Relevant literature sources have been reviewed from academic journal papers, international conference proceedings, the British Library catalogue, internet searches and any other relevant publications.

The research has also involved one to one telephone consultations with selected stakeholders who have provided specialist advice.

This work has also involved review and input from a project Stakeholder Group.

Project scope

Construction products and solar powered photovoltaic panel systems and their components were explicitly excluded from the project scope. However, it is recognised that construction products have a bearing on the domestic fire scenario.

It should be noted that a previous BEIS-funded research project 'Fire incidents involving solar power' has examined the fire risks of PV panel systems, with recommendations for the photovoltaic industry to reduce the risks[1].

[1] Fire incidents involving solar power. Research reports are available at https://www.bre.co.uk/nsc/page.jsp?id=3676. Last accessed 24 January 2019.

Literature review

The literature review assisted in meeting project objectives 1 and 4.

1. To review the impact on fire characteristics of the changes in the content of the home, and in the design of homes.
4. To make suggestions as to how modern designs of consumer products can be amended to improve their safety in a modern domestic fire.

The literature review concentrates on published analyses of fire statistics for dwellings, the experimental determination of the heat release rate from various consumer products on fire, and some issues with consumer product design. Additional sections on modern home design and fire load density have been included for completeness (both topics could form a research project in their own right), with a few selected references rather than a comprehensive list.

Note that Figures 1 to 15 have been redrawn and adapted by BRE Global from the figures in the referenced sources.

Fire statistics for dwellings

Over recent years, public knowledge and awareness of fire has significantly increased, which has led to the general reduction of dwelling fires attended by the Fire and Rescue Service within Great Britain. Over the past 10 years, the total number of dwelling fires attended by Fire and Rescue Services has reduced from 50,382 in 2007/2008 to 37,732 in 2017/2018[2]. However, over the past five years, the number of dwelling fires attended has been relatively consistent, ranging from 39,152 in 2013/2014 to 37,732 in 2017/2018.

According to the Home Office[3], cookers (including ovens) were the most likely type of domestic appliance to be the source of ignition with an average of 9,204 fires between the years 2010/2011 and 2017/2018 in England. The average number of fires due to domestic appliances in England between the years 2010/2011 and 2017/2018 was 17,480. The second most likely type of domestic appliance to be the source of ignition over the same period was grills/toasters with an average of 1,921, followed by ring/hot plates with an average of 1,870 fires.

Note that the above figures are for all causes of fire, including cooking, misuse or negligence, as well as faults. Supplementary analysis by BRE Global of the Home Office Fire Statistics for England 2010/2011 to 2017/2018 shows the number of fires per year caused by faults in appliances or their power supply were 389 for cookers (including ovens), 140 for grills/toasters, and 44 for ring/hot plate (separate appliance). The domestic appliances causing most fires due to faults were washing machines (508 fires per year) and tumble dryers (451 fires per year). Overall, 22% of all fires were caused by faults in equipment, with 2,316 fires per year caused by faults in the electricity supply – wiring, cabling or plugs.

[2] FIRE0201: Dwelling fires attended by fire and rescue services by motive population and nation. Available from https://www.gov.uk/government/statistical-data-sets/fire-statistics-data-tables. Last accessed 23 January 2019.

[3] Home Office Fire Statistics team. Publishing Incident Recording System data on the fire and rescue service at an Incident Level: Domestic Appliance Fires datasheet guidance, first publication: 27 April 2017, update 6 September 2018.

The English Housing Survey 2016 to 2017[4] shows that of the fires that started in dwellings, two thirds (67%) started in the kitchen. Fires in dwellings were most commonly caused by cooking related activities, such as a grill or chip pan catching fire. Electrical equipment/wiring (including electric blankets) was recorded as the cause of fire by 17% of households.

Manes and Rush[5] [6] describe analysis of data from the Incident Recording System (IRS) in England, in comparison with the equivalent USA and New Zealand incident databases, between April 2014 and March 2015. Manes and Rush[5] state that 44% (31,329 fires) of all fires reported by the Fire and Rescue Service in England (a total of 71,089 fires) occurred in dwellings. The vast majority of these dwelling fires (90%) were accidental.

Manes and Rush[6] describe that the primary cause of fire in dwellings in England was due to the misuse of equipment of appliances (36%), followed by faulty appliance and leads, and placing articles too close to heat.

Manes and Rush[6] also state that the items first ignited were food (25%), followed by textiles, upholstery and furnishings (23%), and then by structure and fittings (20%).

Holborn, Nolan and Golt[7] describe an analysis of fatal unintentional dwelling fires investigated by the London Fire Brigade from 1996 to 2000 (259 fires). Due to this literature being dated, the relevance of the detailed findings to modern domestic fires is doubtful, and so is not presented here. However, this work gave the general finding that fatal fires investigated in London were dependent on a number of factors that are likely to be applicable to modern domestic fires, namely:

- Smoking
- Elderly and very young
- Children playing with fire
- Living alone
- Disability, ill health or mental illness
- Alcohol
- Not having a working smoke alarm
- Social deprivation.

Holborn, Nolan and Golt[7] state that many of these factors were thought to have acted in combination to increase the risk of death due to an unintentional dwelling fire.

4 Ministry of Housing, Communities and Local Government. English Housing Survey, Fire and fire safety, 2016-17, July 2018.

5 Manes M and Rush D. Meta-analysis of UK, USA and New Zealand fire statistics databases with respect to damage and financial loss. Applications of Fire Engineering: Proceedings of the International Conference of Applications of Structural Fire Engineering (ASFE 2017), 179–188.

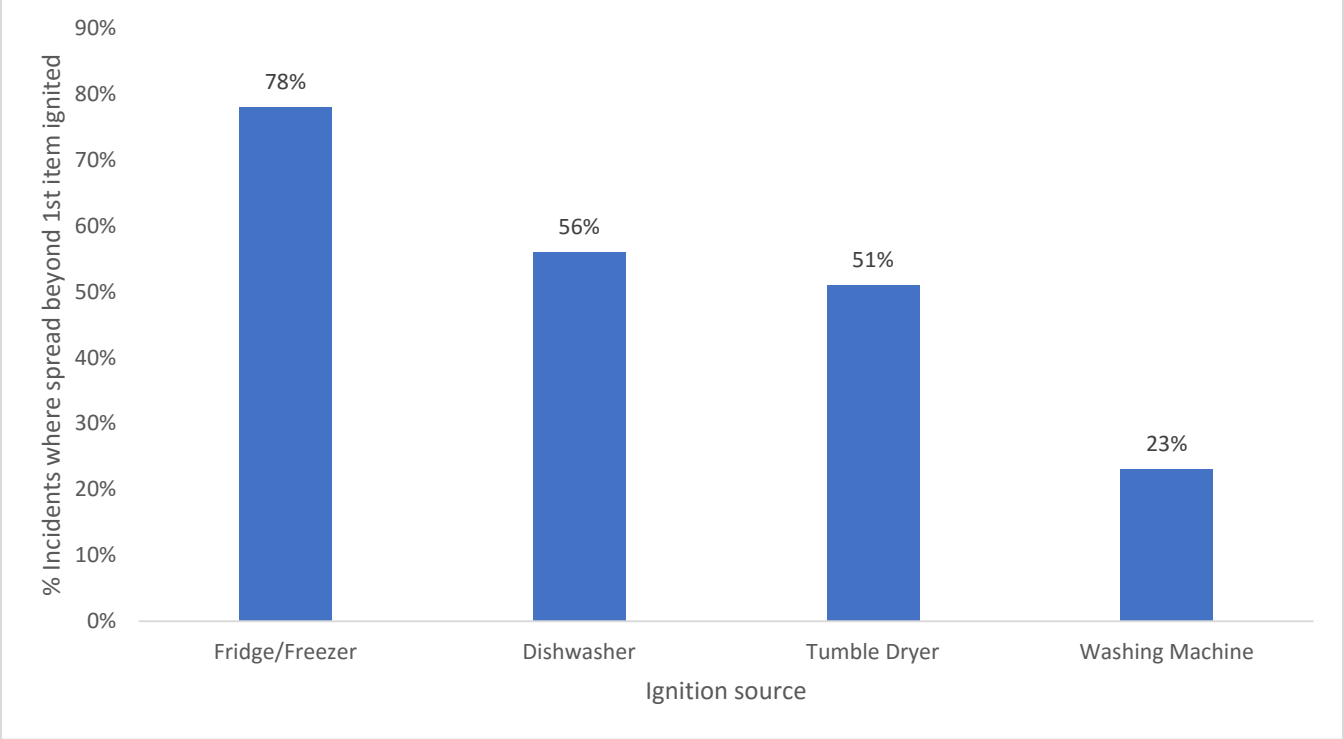
6 Manes M and Rush D. Meta-analysis of response times and safety systems to the fire size, growth and damage, based on UK, USA and New Zealand fire statistics databases. Second International Conference on Structural Safety under Fire and Blast Loading (CONFAB 17), 108–117.

7 Holborn P G, Nolan P F and Golt J. An analysis of fatal unintentional dwelling fires investigated by London Fire Brigade between 1996 and 2000. Fire Safety Journal, 38, 2003, 1-42.

Beasley et al.[8] examined causes and consequences of fridge/freezer fires in dwellings from London Fire Brigade fire investigation data from 2011 to 2015. The general findings were as follows.

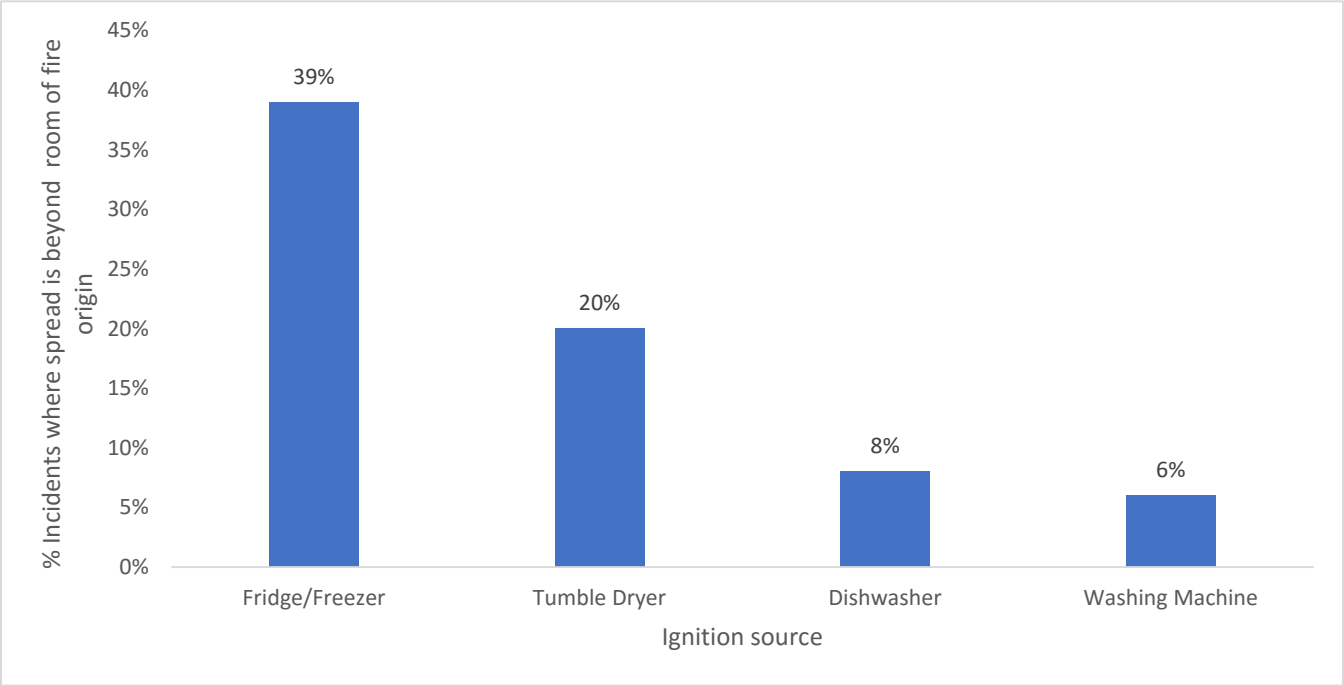
- The probability of fire occurrence in fridge/freezers (1.5×10^{-5} fires per appliance per year) is around half that for dishwashers and tumble dryers (3.1×10^{-5} fires per appliance per year).
- Once ignition occurs, fires caused by fridge/freezers are more likely to exhibit a higher degree of fire spread and damage than other types of white goods appliance (i.e. washing machine, dishwasher or tumble dryer).
- Nearly 80% of fires with fridge/freezers as the source of ignition caused fire spread beyond the first item involved, see Figure 1, whilst almost 40% spread beyond the room of fire origin, see Figure 2. These figures are for London; supplementary analysis by BRE Global of the Home Office Fire Statistics for England 2010/2011 to 2017/2018 shows the same trend but lower values (e.g. fridge/freezer, 71% of fires spread beyond first item ignited and 28% spread beyond room of fire origin).
- Fires involving fridge/freezers displayed a higher casualty rate (335 casualties per 1,000 fires) than for other types of white goods appliance.
- Failure modes leading to the ignition of fridge/freezers were identified.
- Starter relay failures, mechanical defrost switch failures, capacitor failures, solenoid valve failures, etc.

Figure 1: Different appliance types ranked according to % of incidents where fire spread is beyond first item ignited[8]



[8] Beasley M G, Holborn P G, Ingram J M and Maidment C G. Causes, consequences and prevention of refrigeration fires in residential dwellings. Fire Safety Journal, 102, 2019, 66-76.

Figure 2: Different appliance types ranked according to % of incidents where fire spread is beyond room of fire origin[8]



Heat release and fire risk of consumer products

Since the misuse of equipment and appliances, and faulty appliances and leads, was one of the main causes for fires in dwellings described by Manes and Rush[6], this section reviews published work on heat release rate and the fire risk of consumer products obtained from experimental testing.

Household electrical appliances

Hietaniemi, Mangs and Hakkarainen[9] identified there was very little quantitative information available on the fire development involving fridge/freezers, washing machines and dishwashers. In contrast to TV products used in Europe, for which a literature set was available both for experimental data (Babrauskas et al.[10], Simonson et al.[11] and Troitzsch[12]) and frequency of occurrence (De Poortere, Schonbach and Simonson[13]).

Hietaniemi, Mangs and Hakkarainen[9] carried out 14 experiments to characterise fire development of household electrical appliances, involving three television sets, three washing machines, four dishwashers and four fridge/freezers used in the European market. The tests examined free burning situations and burning inside a cupboard, replicating domestic integrated units. The ignition source was a 1 kW propane gas burner; other ignition sources, e.g. smouldering combustion, were not tested. The flame impinged directly onto the product, of

9 Hietaniemi J, Mangs J and Hakkarainen T. Burning of electrical household appliances: An experimental study. VTT Research Note 2084, 2001.

10 Babrauskas V, Harris R H, Gann R G, Levin B C, Lee B T, Peacock R D, Paabo M, Twilley W H, Yoklavich M F and Clark H M. Fire Hazard Comparison of Fire-Retarded and Non-Fire-Retarded Products. NBS Special Publication 749, 1988.

11 Simonson M, Blomqvist P, Boldizar A, Möller K, Rosell L and Sundqvist J O. Fire-LCA Model: TV Case Study, SP Report 2000:13.

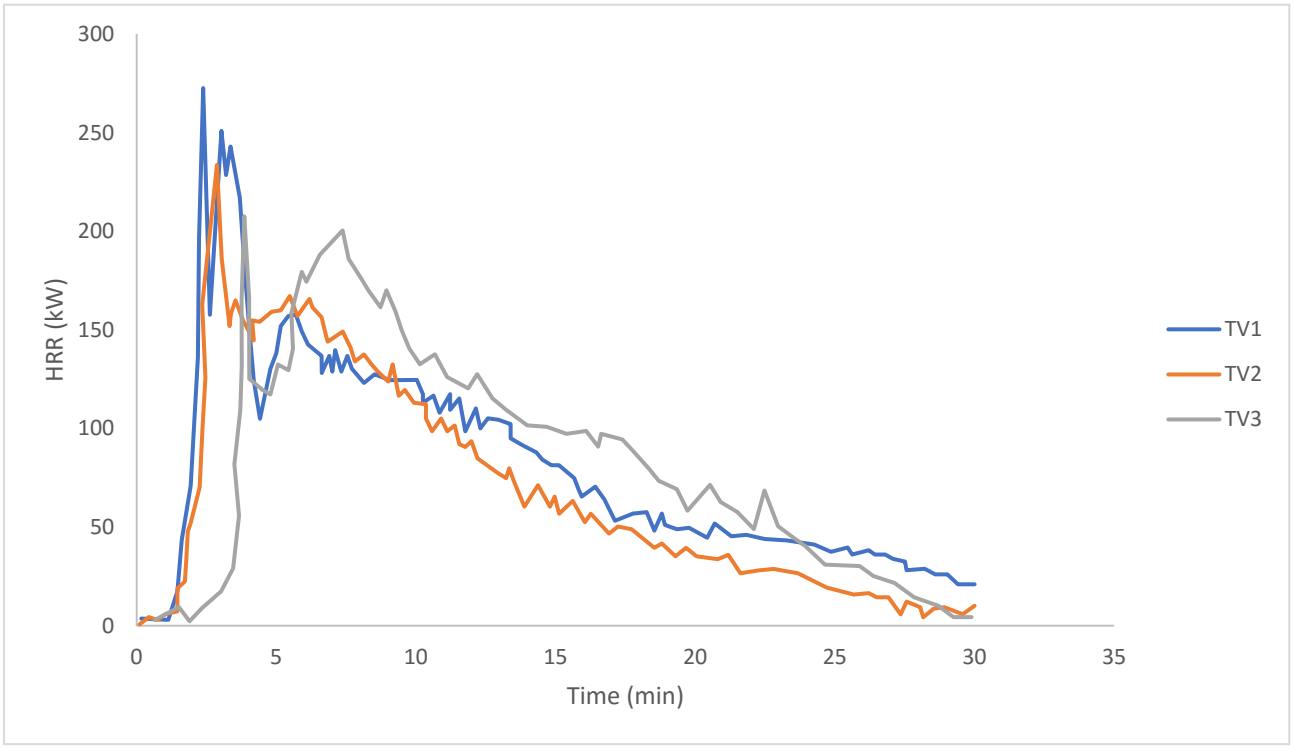
12 Troitzsch J H. Flammability and Fire Behaviour of TV Sets. Fire Safety Science - Proceedings of the sixth international symposium, 1999, 979–990.

13 De Poortere M, Schonbach C and Simonson M. The fire safety of TV set enclosure materials, a survey of European statistics. Fire and Materials, 24(1), 2000, 53–60.

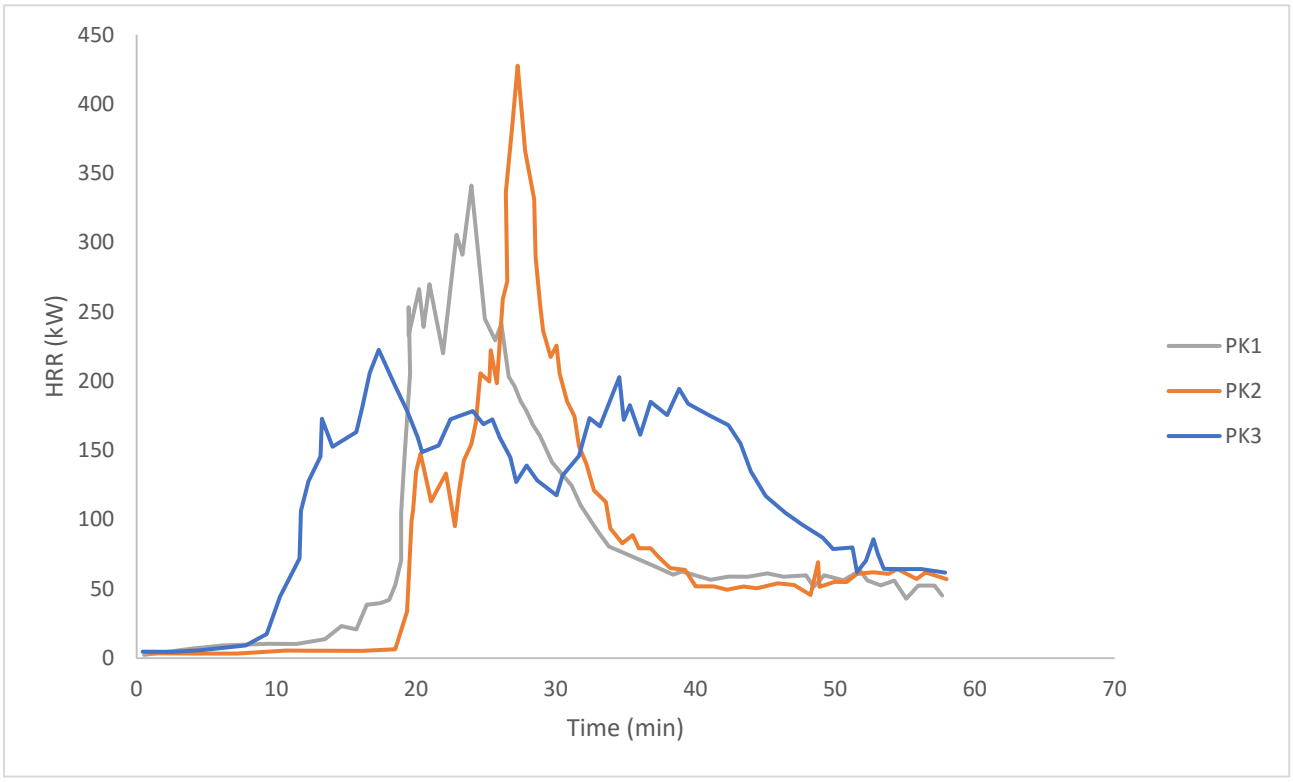
location chosen in a way to replicate realistic scenarios. The various Heat Release Rate (HRR) fire curves from the experiments are shown in Figure 3 (a) to (d).

Figure 3: Heat Release Rates[9]

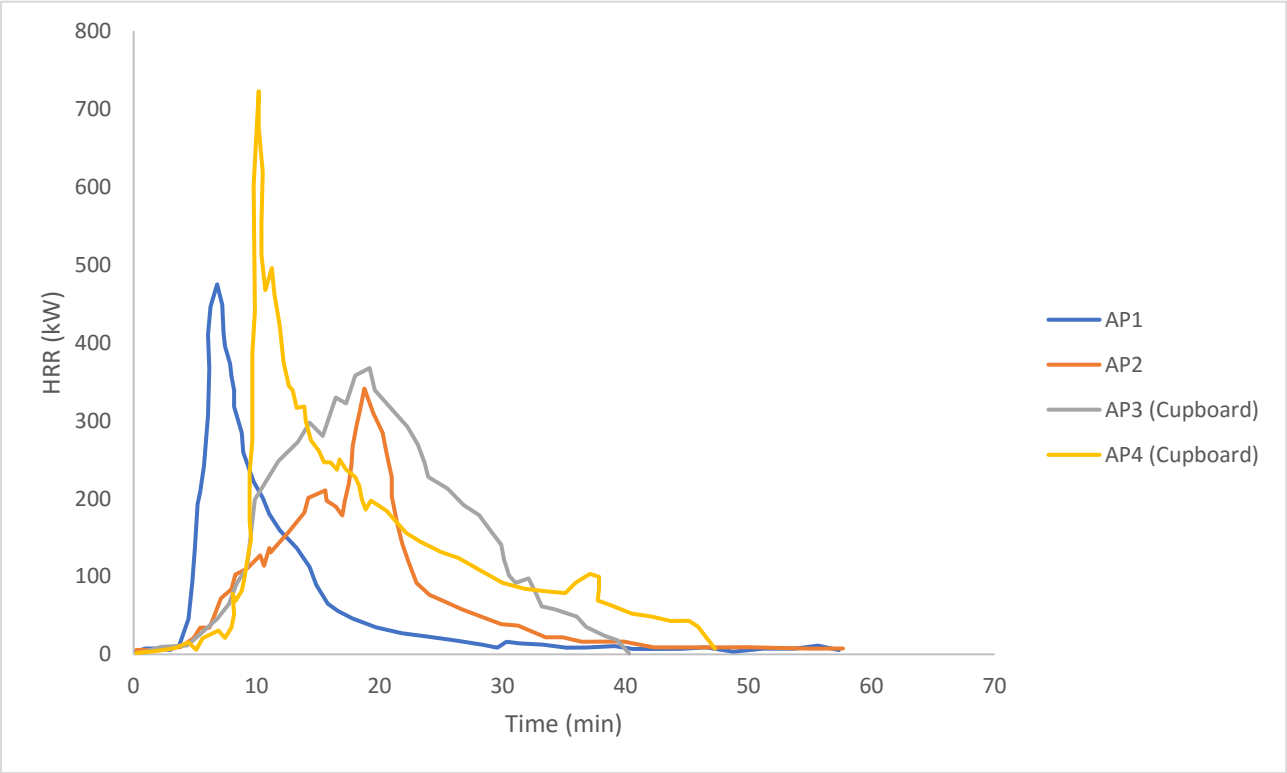
(a) Three television sets



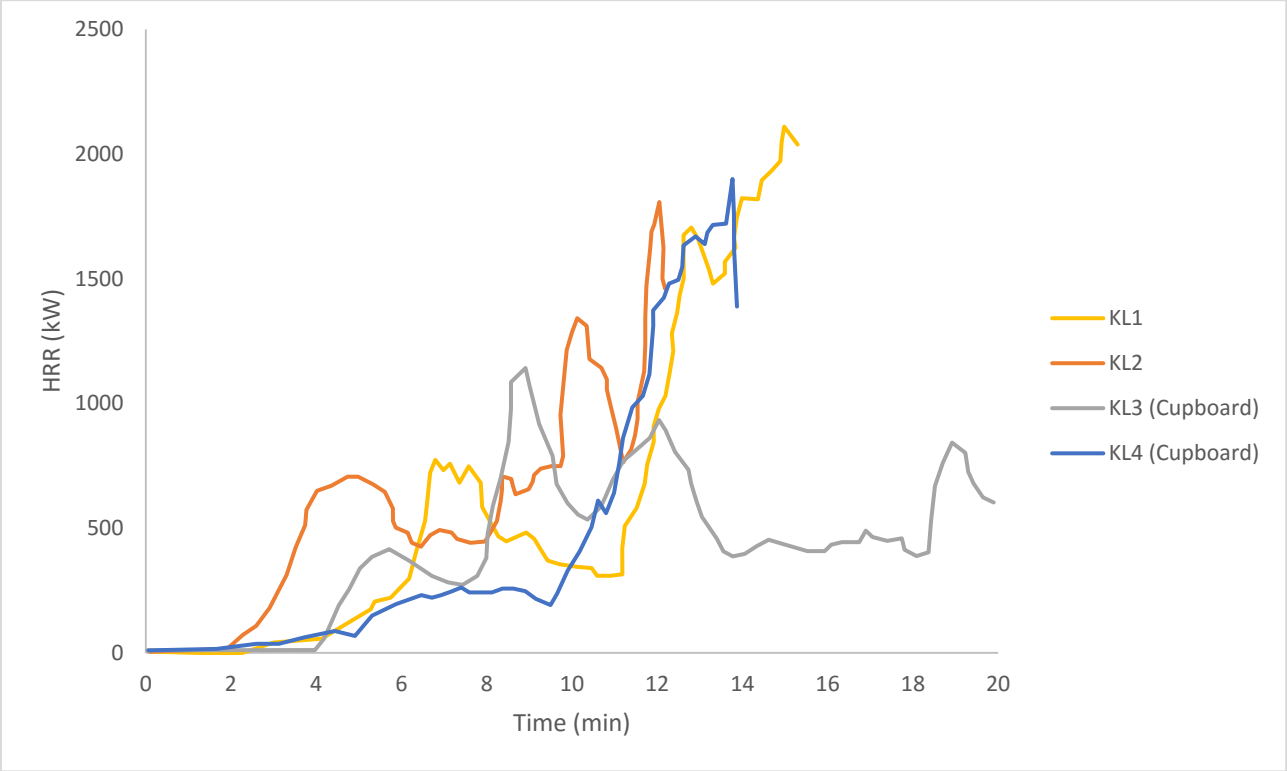
(b) Three washing machines



(c) Four dishwashers



(d) Four fridge/freezers



The following conclusions were made by Hietaniemi, Mangs and Hakkaraineni[9]:

> *"Among the electrical household appliances studied, the highest rates of heat release were found in the experiments with refrigerator-freezers. Rates of heat release rising up to 2000 kW were observed, which is a very large heat production as compared to the size of a typical kitchen."*

"The experiments with refrigerator-freezers were interrupted by extinguishing by water. If the experiments had not been stopped it is probable that even higher rates of heat release than 2000 kW would have been observed."

"For dishwashers, rather high HRR levels were measured reaching peak values of 350–750 kW."

"Burning washing machines produced peak RHR levels of 300–450 kW; however, in relation to the typical, rather small, bath and washing room spaces that these appliances are used, such HRR levels are rather high."

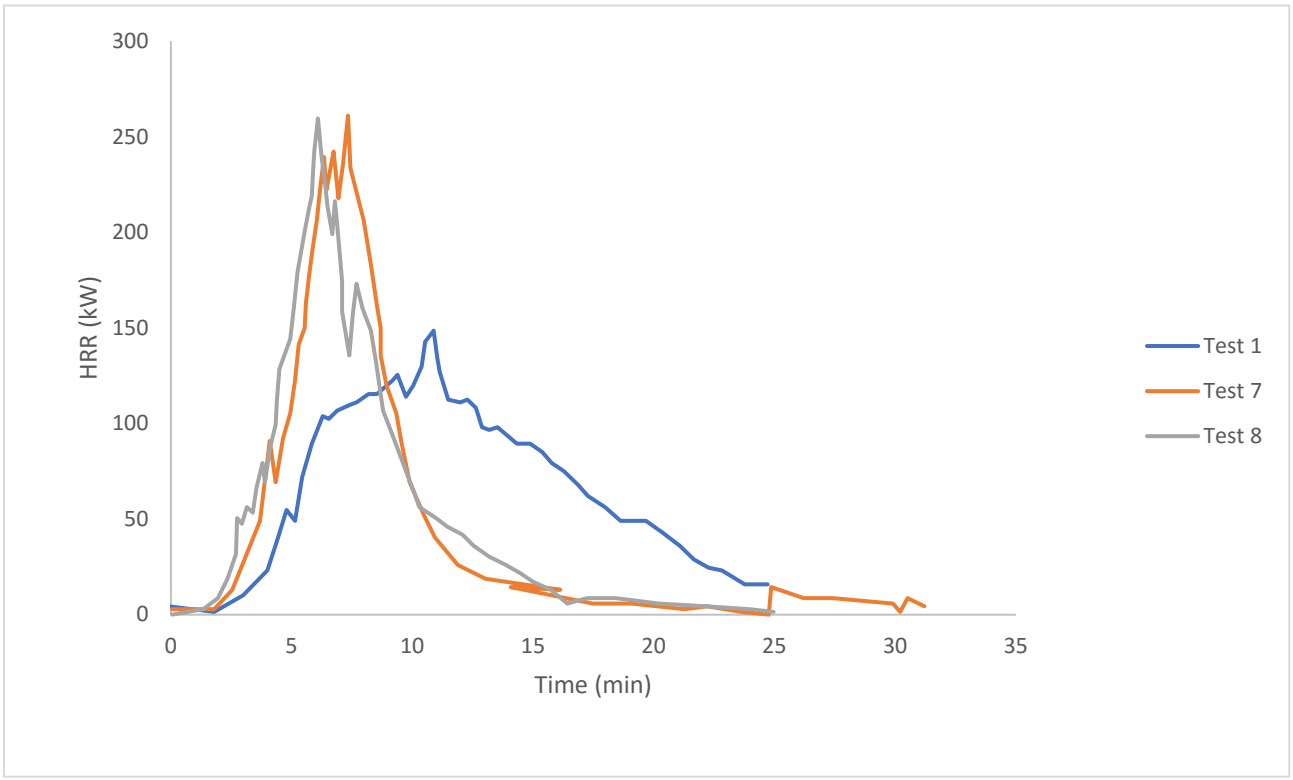
"The maximum rates of heat release for the burning TV sets were 250–300 kW, in accordance with the other studies done with modern TV sets (Simonson et al.11)."

It should be noted that the work by Hietaniemi, Mangs and Hakkarainen[9] and other associated work on television set fires, was carried out approximately 20 years ago, so is dated. The reported fire development of these appliances may not be representative of modern dwelling electrical items in the UK. It is desirable that further experimental work is carried out to characterise the fire development of modern domestic appliances.

The most recent experimental data for the fire behaviour of television sets is described by Blais and Carpenter[14] in 2015 for flat screen televisions, and the effect of the use of fire retardant in the screen casing. However, these experiments involved television sets from the Brazilian, Mexican and USA market. The various HRR fire curves from these experiments are shown in Figure 4 (a) to (c).

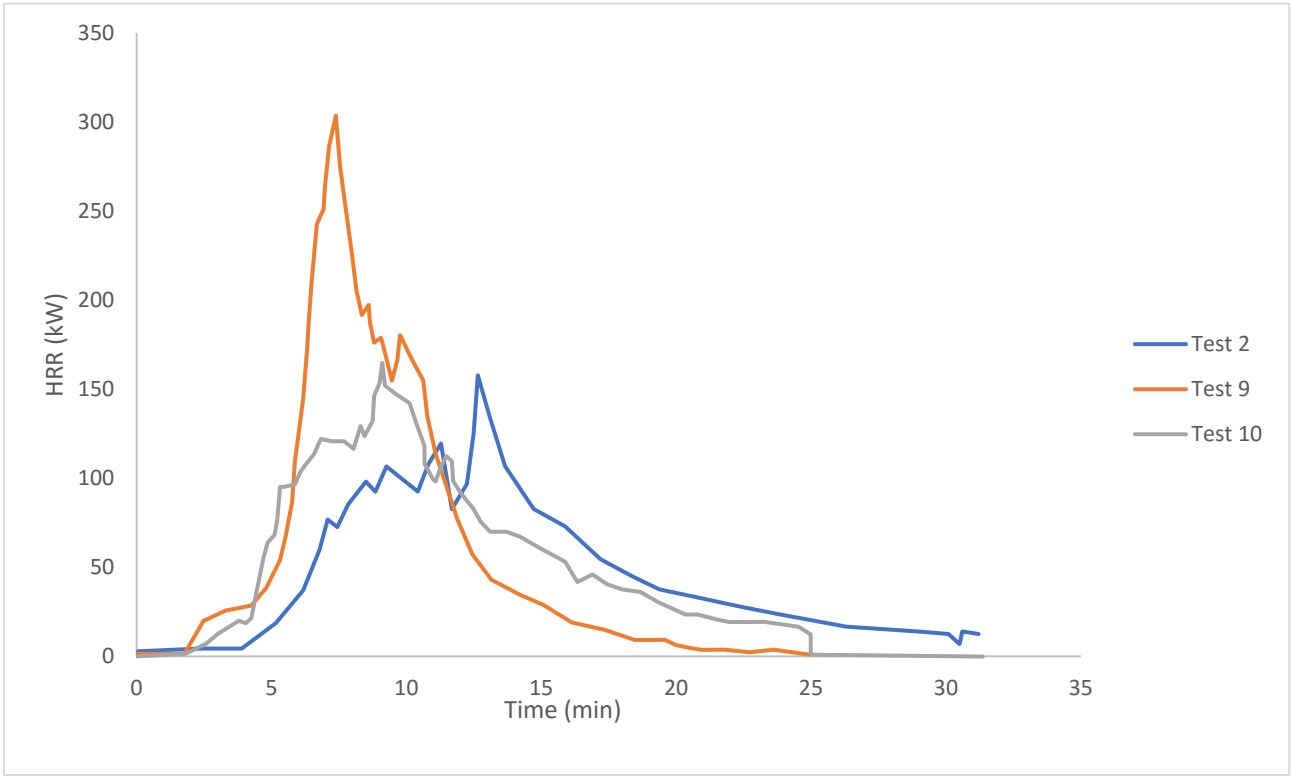
Figure 4: Heat Release Rates for television sets[14]

(a) Three Brazilian market television sets

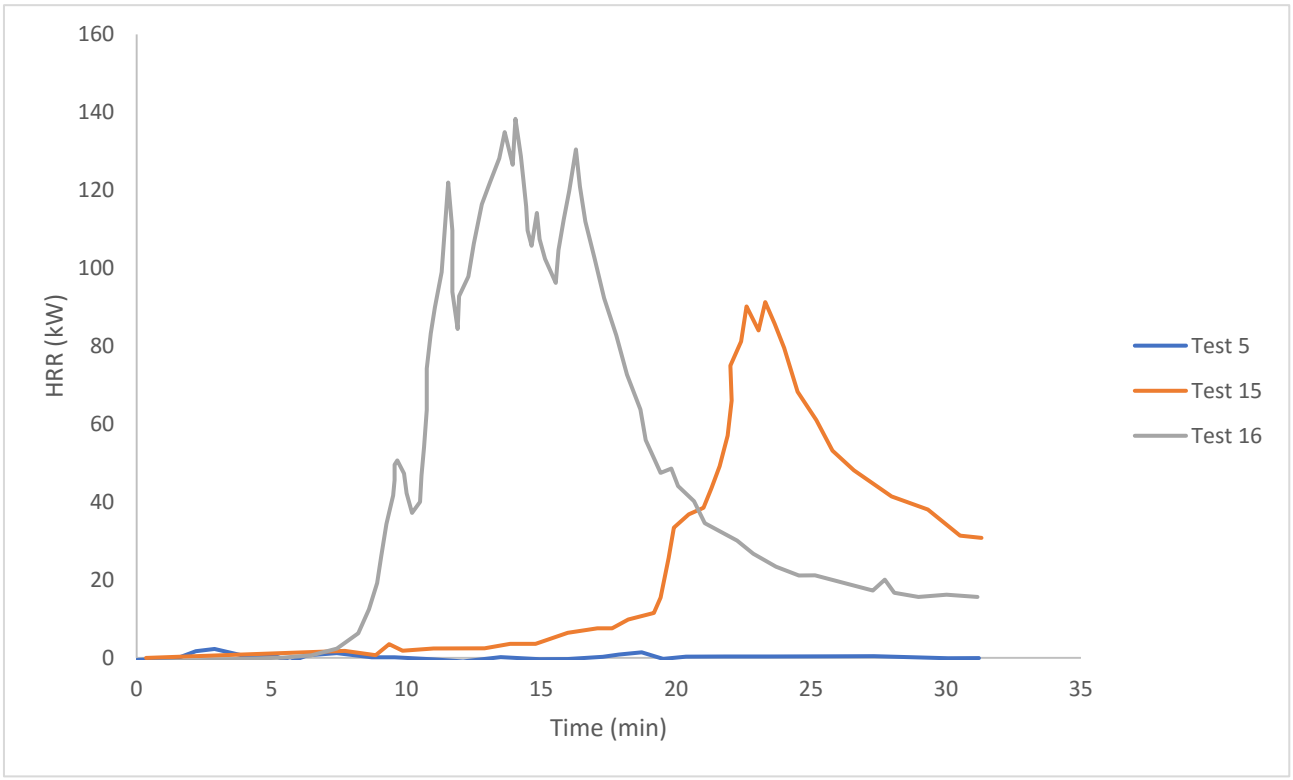


[14] Blais M and Carpenter K. Combustion characteristics of flat panel televisions with and without fire retardants in the casing. Fire Technology 51, 2015, 19-40.

(b) Three Mexican market television sets



(c) Three USA market television sets



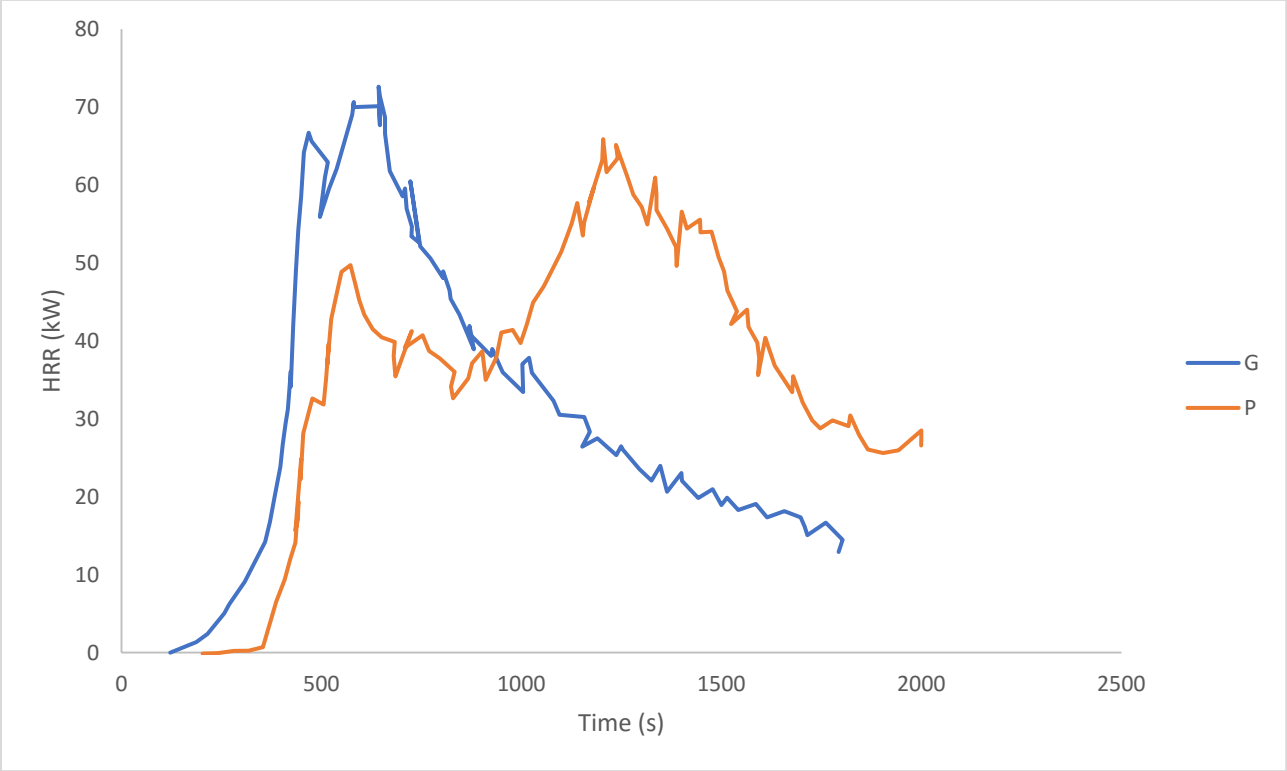
The highest measured HRR from these experiments was of a similar order of magnitude to those from the European market televisions by Hietaniemi, Mangs and Hakkaraineni[9]. Care should be taken on the interpretation of overseas literature to represent modern domestic fires in the UK. However, these are presented as the most recent data apparently available.

Other consumer products

Babrauskas[15] describes a compilation of product HRR curves determined by experiment. A summary of papers from this compilation is given in this section, describing HRR curves for consumer products, this is often based on overseas data, but presented in the absence of any relevant data to the UK. Again, care should be taken on the representation of overseas data to domestic fires in the UK.

Babrauskas[15] describes work by Beard and Goebeldecker[16], of the European Fire Retardants Association on fire testing of two bookshelf size micro-stereo systems, each comprising a receiver and a pair of stereo speakers. **Figure 5** shows the HRR curves for the two experiments.

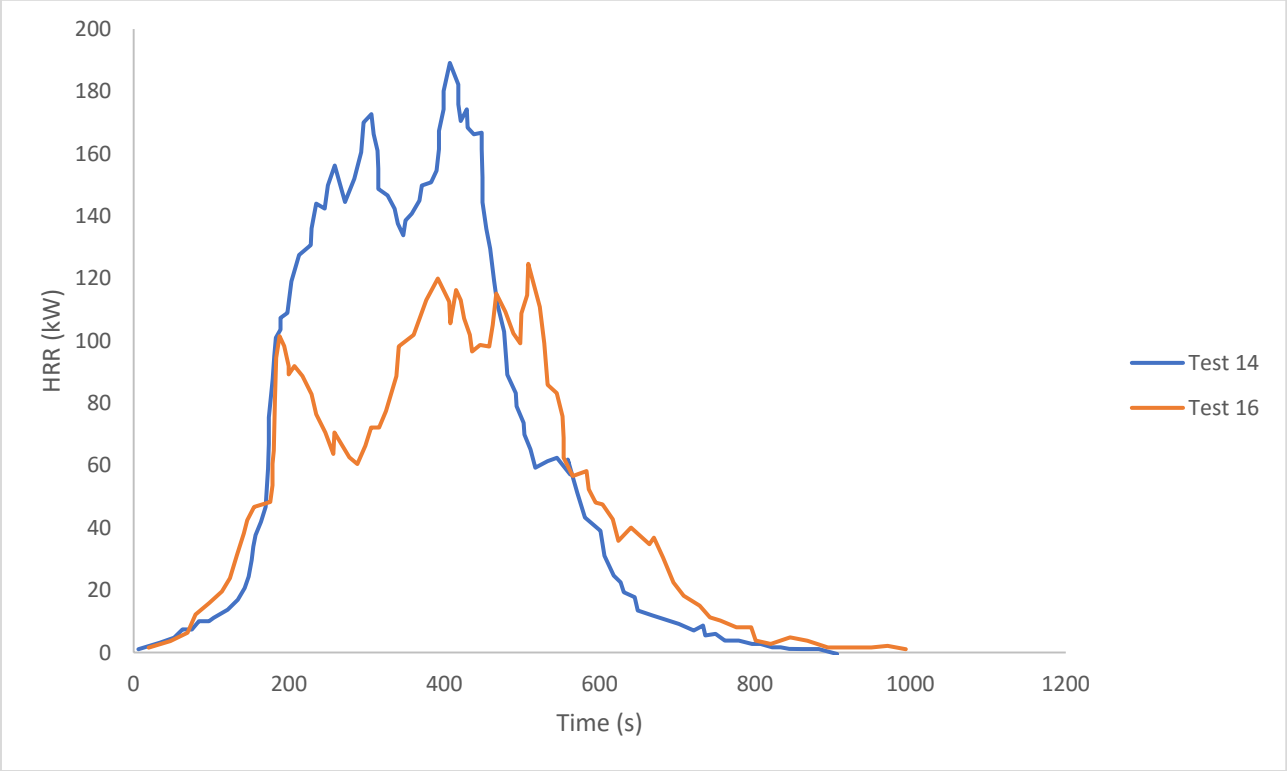
Figure 5: Heat Release Rate for micro-stereo systems[15]



Ohlemiller et al[17] tested inert twin-size beds with 12 different bedding combinations with the peak HRR values ranging from 38 kW to 200 kW. HRR curves for one bedding combination are given in Figure 6. This combination involved two polyester/cotton sheets, a mattress pad, a pillow, an acrylic blanket and a medium weight comforter from the USA market (Test 14 in Figure 6). The latter (Test 16 in Figure 6) involved two polyester/cotton sheets, a mattress pad, a pillow, a polyester blanket and a medium weight comforter from the USA market. The pillows were filled with polyester for both combinations and were covered with a polyester/cotton pillowcase.

[15] Babrauskas V. Heat Release Rates. Society of Fire Protection Engineers Handbook, Fifth edition, 2016, 799-904.
[16] Beard A and Goebeldecker S. Fire Behaviour of Household Appliances towards External Ignition. European Fire Retardants Association, 2007.
[17] Ohlemiller T J, Shields J R, McLane R A and Gann R G. Flammability Assessment Methodology for Mattresses. National Institute of Standards and Technology, NISTIR 6497, 2000.

Figure 6: Heat Release Rate for bedding sets[15]



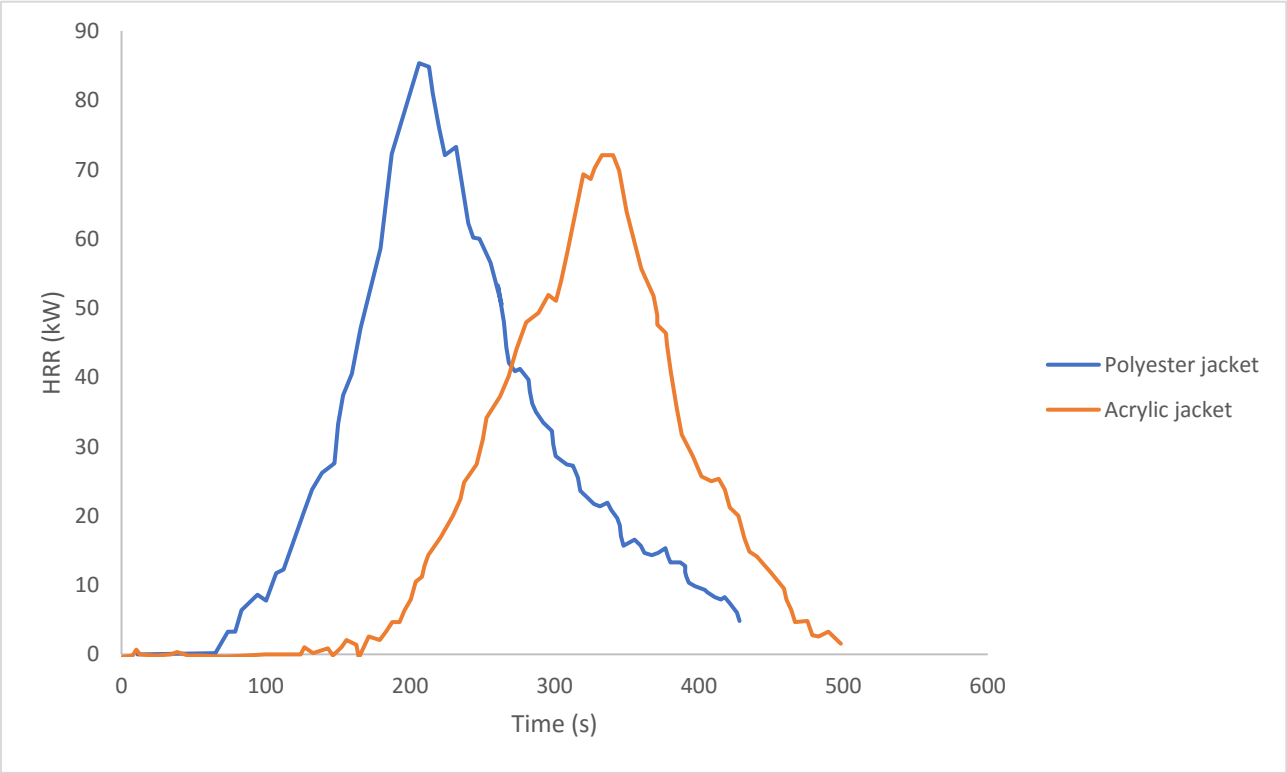
Bwalya[18] of the National Research Council Canada (NRCC) conducted four tests on bedding and measured a peak HRR up to 388 kW.

In terms of clothing items, Sundstrom[19] tested two men's jackets (anoraks) as potential ignition sources, one was a 'polyester' jacket with an outer fabric 65/35% cotton/polyester, an inner fabric of polyamide and a filling of polyester wadding. The second 'acrylic' jacket had a nylon fabric and a filling of acrylic wadding. Figure 7 shows the HRR for these experiments.

[18] Bwalya A C. Characterization of Fires in Multi-Suite Residential Dwellings: Phase 1 – Room Fire Experiments with Individual Furnishings, IRC-RR-302, National Research Council Canada, 2010.

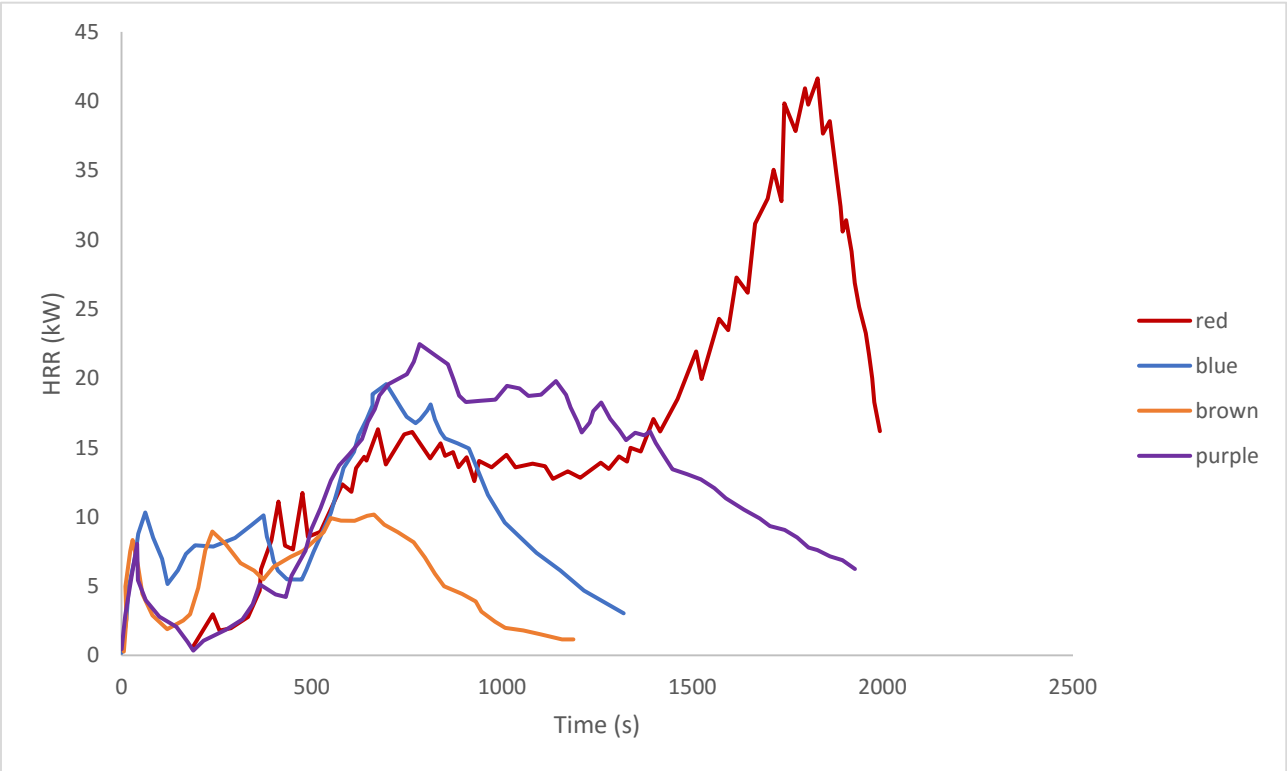
[19] Sundstrom B. Fires Safety of Upholstered Furniture. The Final Report on the CBUF Research Programme (Report EUR 16477 EN), 1995.

Figure 7: Heat Release Rate for men's jackets[15]



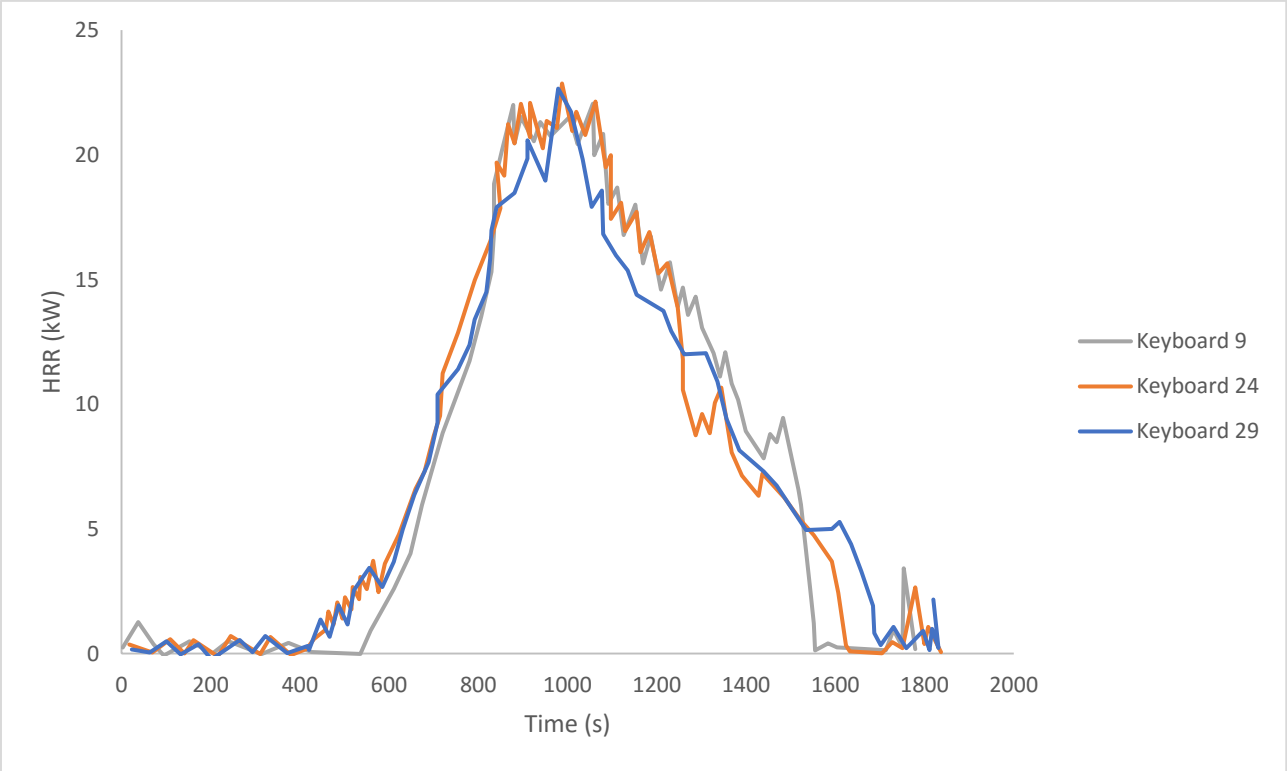
Beard and Goebeldecker[16] give HRR curves for a range of coffee makers shown in Figure 8. The material of the coffee maker with the highest HRR was polypropylene, with the materials for others unknown.

Figure 8: Heat Release Rate for coffee makers[15]



Babrauskas[15] describes HRR testing of computer products and electronic equipment. Bundy and Ohlemiller[20] tested three polystyrene computer keyboards from the USA market with HRR curves shown in Figure 9.

Figure 9: Heat Release Rate for polystyrene computer keyboards[15]



Edenburn[21] tested two brands of computer mice with a measured HRR ranging between 3.6 kW and 6.1 kW.

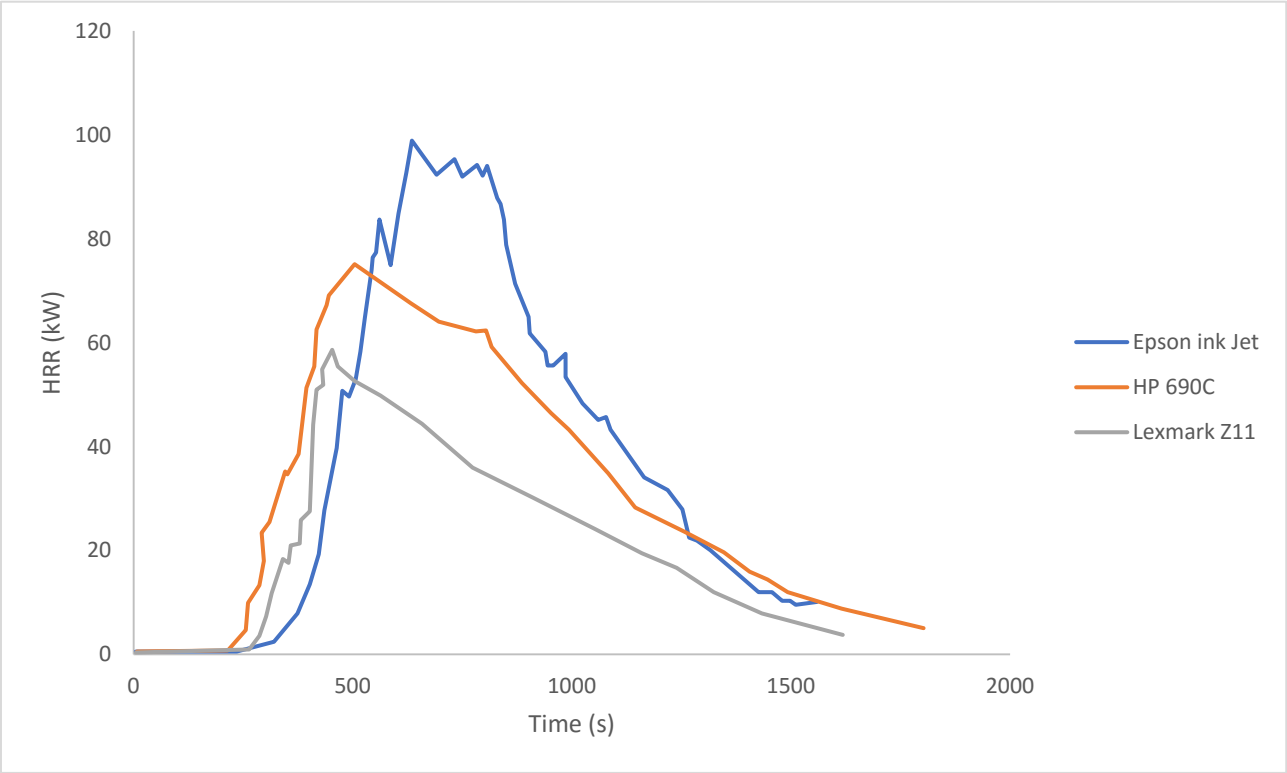
Three PC printers were tested by Bliss and Simonson[22] with no paper or toner. Figure 10 shows the measured HRR curves.

[20] Bundy and Ohlemiller. Full-Scale Flammability Measures for Electronic Equipment, Technical Note 1461, National Institute for Standards and Technology, 2004.

[21] Edenburn D. Burning Mouse, Albemarle Corporation, 2003.

[22] Bliss D and Simonson M. Fire Performance of IT Equipment Studied in the Furniture Calorimeter. Interflam 2001, proceedings from the ninth International Conference, 2001, 171-179.

Figure 10: Heat Release Rate for PC printers[15]



Moore[23] describes an extensive study of curtains and drapes, with specimens ignited by a match along the bottom. Moore's tabulated results have been reordered in order to show the primary effect of curtain weight for a variety of curtain materials. Lightweight fabrics can show HRR peaks almost as high as heavy fabrics, but their potential to ignite surrounding objects is much smaller. These conclusions appear to hold for thermoplastic and cellulosic materials, see Table 1. However, due to the very dated nature of this work (1978) these data should be used with caution for modern domestic fires in the UK.

[23] Moore L D. Full- Scale Burning Behavior of Curtains and Drapes. NBSIR 78-1448, 1978.

Table 1: Heat Release Rate data for curtains[15], two curtains each 2.13 m long by 1.25 m wide

Type of fiber	Weight (g/m^2)	Configuration	Peak HRR (kW)	Number of wall and ceiling panels ignited*
Rayon/polyester	53	Closed	219	0
Acrylic	99	Open	360	0
Acrylic	99	Closed	231	0
Polyester	108	Closed	202	0
Acetate	116	Closed	155	0
Cotton/polyester	117	Open	303	0
Cotton/polyester	117	Closed	267	1
Cotton	124	Open	157	0
Cotton	124	Closed	188	1
Rayon/cotton	126	Open	176	0
Rayon/cotton	126	Closed	214	0
Cotton	260	Open	152	7
Cotton	260	Closed	130	7
Rayon/polyester	268	Closed	329	7
Rayon/polyester/foam	284	Closed	326	0
Rayon/cotton	288	Open	191	2
Rayon/cotton	288	Closed	133	6
Rayon/acetate	296	Closed	105	4
Cotton/polyester/foam	305	Closed	385	1
Rayon/cotton	310	Closed	177	8
Cotton	313	Closed	600	3
Cotton/polyester	328	Open	236	7
Cotton/polyester	328	Closed	338	5
Acrylic	354	Open	NA	7
Acrylic	354	Closed	1177	8
Rayon/polyester	367	Closed	658	2
Rayon/fiberglass	371	Closed	129	5
Rayon/fiberglass	371	Closed	106	5

*Maximum possible number of panels to ignite = 10

Babrauskas and Krasny[24] describe HRR for mattresses from the USA market, with a complete set of bedding, with ignition achieved using a waste basket. Table 2 shows peak full-scale HRR values for common material combinations.

[24] Babrauskas V and Krasny J F. Fire Behavior of Upholstered Furniture (NBS Monograph 173), 1985.

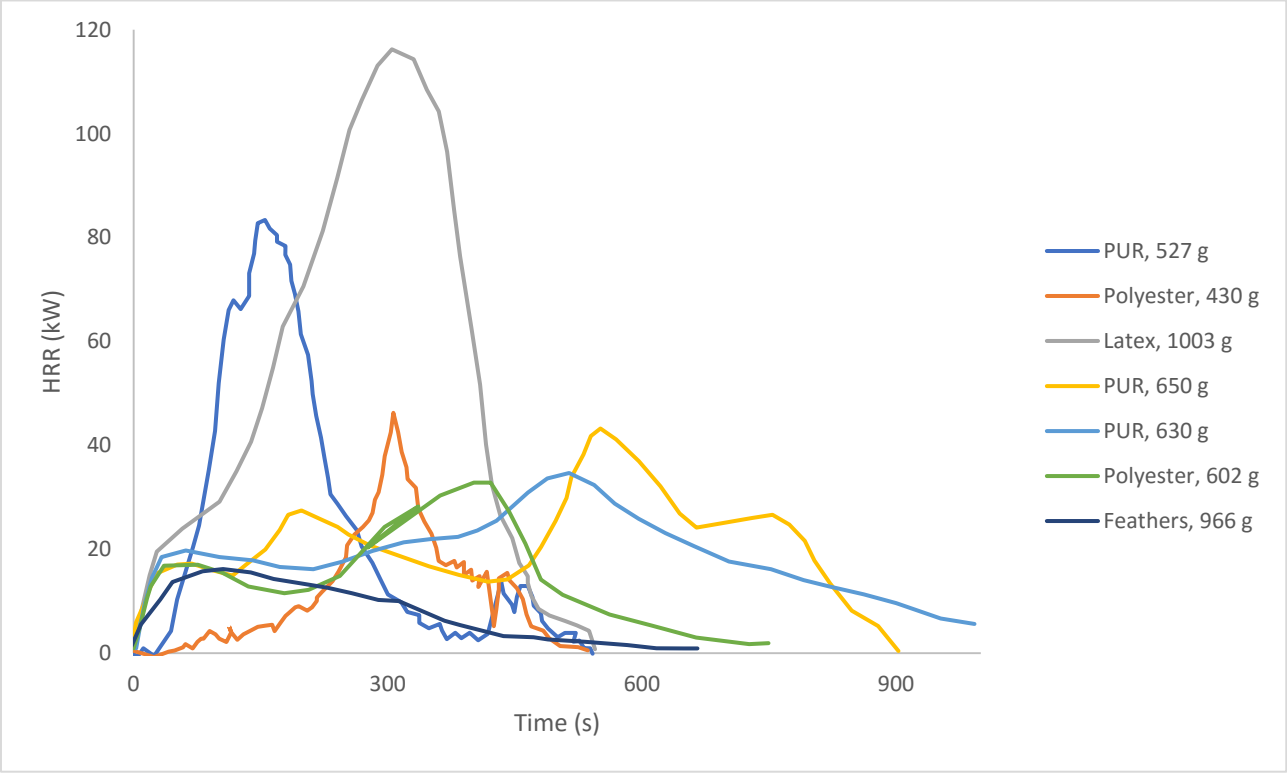
Table 2: Heat Release Rate for mattresses with bedding[15]

Padding material	Ticking* material	Combustible mass (kg)	Peak HRR, full scale (kW)
Latex foam	PVC	19	2720
Polyurethane foam	PVC	14	2630
Polyurethane foam	PVC	6	1620
Polyurethane foam	Rayon	6	1580
Polyurethane foam	Rayon	4	760
Neoprene	FR cotton	18	70
Cotton/jute	FR cotton	13	40

*USA term.

Babrauskas[25] reported tests on pillows with measured HRR curves shown in Figure 11.

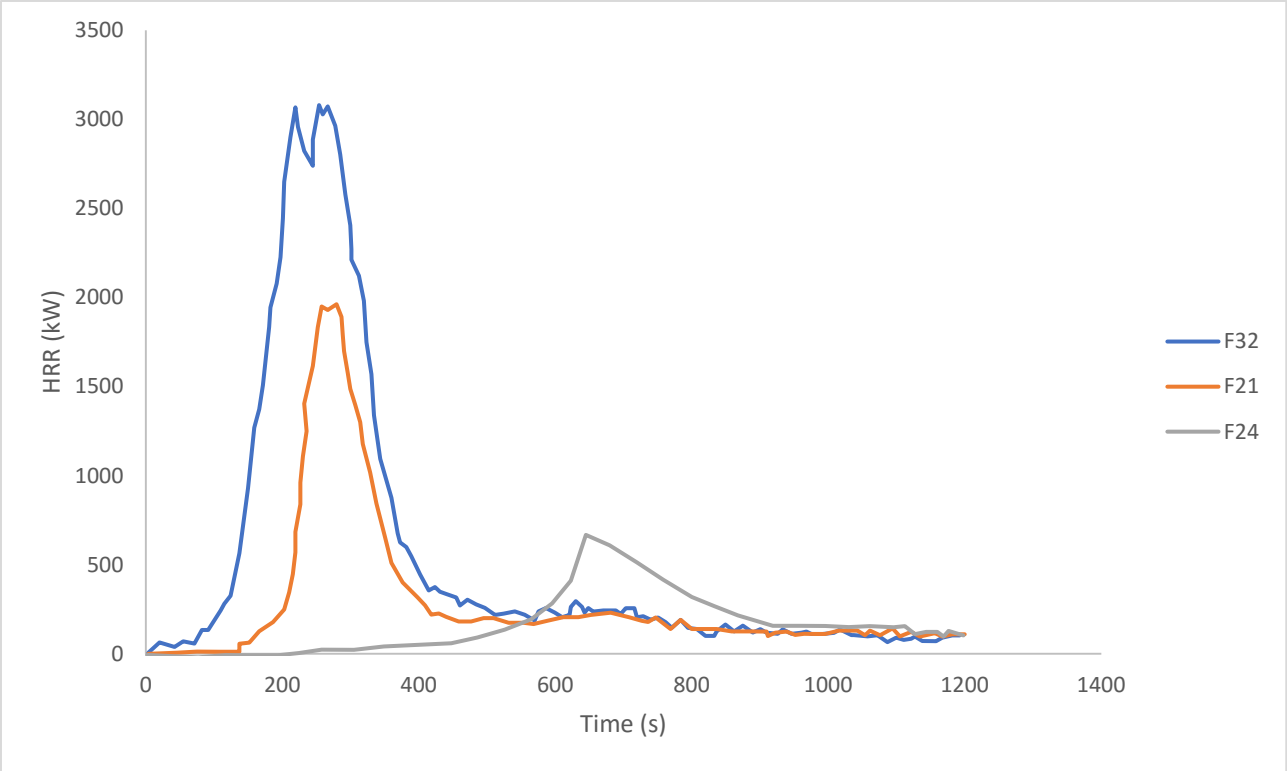
Figure 11: Heat Release Rate for pillows[15]



Babrauskas et al[26] tested several furniture items in the USA with HRR curves shown in Figure 12. 'Chair F21' was polyurethane foam with 3% to 5% fire retardant chemicals. 'Specimen F32' was a sofa made from the same materials. 'Chair F24' illustrates the large improvement in HRR when cotton fabric is substituted for polyolefin fabric. The peak HRR decreases from approximately 2 MW to 700 kW. Again, care should be taken in using overseas data to represent modern fires in the UK due to the variation in material controls (in terms of fire retardancy) between countries.

[25] Babrauskas V. Pillow Burning Rates. Fire Safety Journal, 8, 1984/85, 199-200.
[26] Babrauskas V, Lawson J R, Walton W D and Twilley W H. Upholstered Furniture Heat Release Rates Measured with a Furniture Calorimeter, NBSIR82-2604, 1982.

Figure 12: Heat Release Rate for upholstered furniture[15]



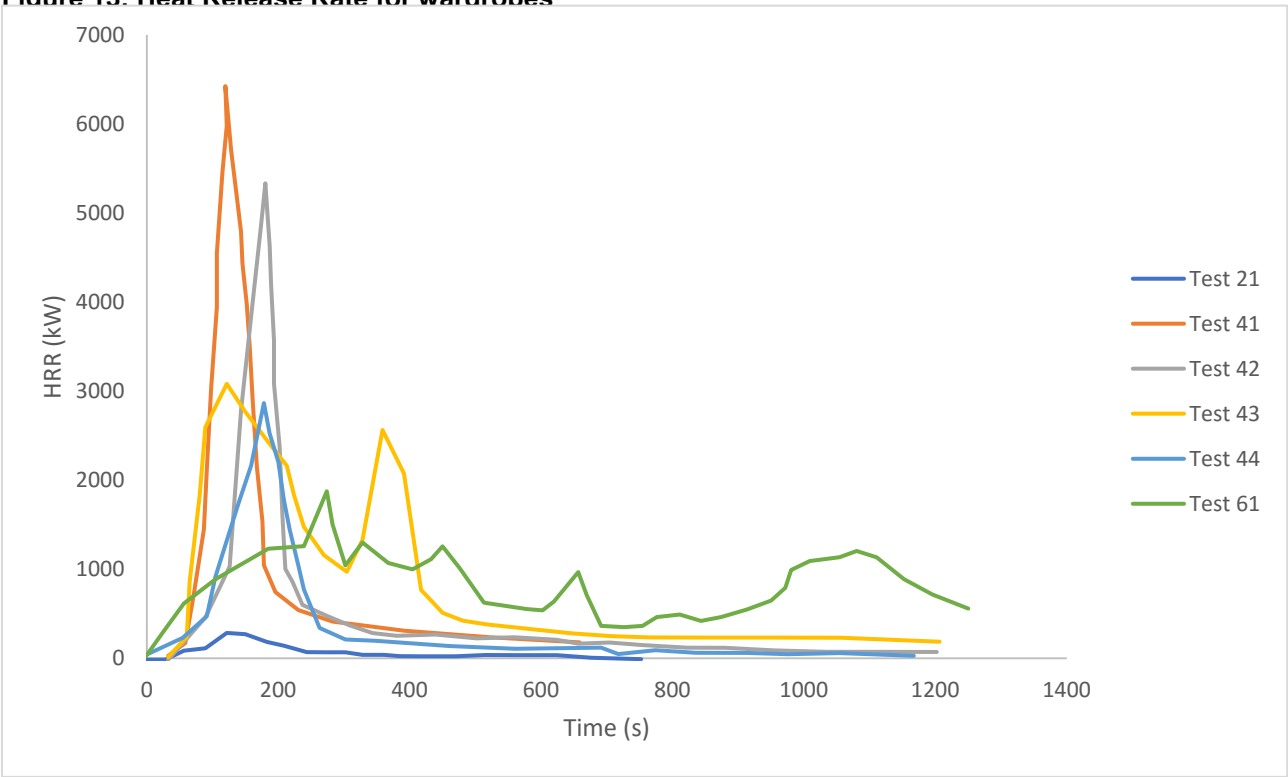
Lawson, Walton and Twilley[27] examined the HRR of wardrobes. The tested wardrobes are detailed in Table 3, with the measured HRR curves in Figure 13.

Table 3: Heat Release Rate for wardrobes[15]

Test No.	Construction	Wardrobe combustible mass (kg)	Clothing and paper (kg)	Peak HRR (kW)	Total heat released (MJ)	Average heat of combustion (MJ kg^{-1})
21	Steel	0	1.93	270	52	18.8
43	Plywood, 12.7mm thick	68.3	1.93	3100	1068	14.9
41	Plywood, 3.2mm thick, unpainted	36.0	1.93	6400	590	16.9
42	Plywood, 3.2mm thick, 1 coat FR paint	37.3	1.93	5300	486	15.9
44	Plywood, 3.2mm thick, 2 coats FR paint	37.3	1.93	2900	408	14.2
61	Particleboard, 19mm thick	120.3	0.81	1900	1349	17.5

[27] Lawson J R, Walton W D and Twilley W H. Fire Performance of Furnishings as Measured in the NBS Furniture Calorimeter Part 1. NBSIR 83-2787, 1983.

Figure 13: Heat Release Rate for wardrobes[15]



Lithium-ion battery products

Modern consumer products such as mobile phones, laptops, e-cigarettes, hover boards and e-bikes are not yet specifically recognised on the statistical reporting forms of fire. Consequently, these products may be listed under an unspecified class when considering item first ignited or responsible for the development of a fire. Therefore, a literature search was conducted to see whether cases are known of fire hazard concerning such modern consumer products.

The US Fire Administration released a report[28] listing 195 cases involving fires and/or explosions from e-cigarettes from 2009 to 2016. This is broadly consistent with the 100 cases found in the analysis by BRE Global of the Home Office Fire Statistics for England 2010/2011 to 2017/2018, as described in the Fire Statistics section, Analysis of 'other' ignition sources: example of e-cigarettes.

A safety alert in the USA, from the Consumer Product Safety Commission (CPSC)[29] states that:

> *"Since 2015 there were more than 300 self-balancing scooter/hoverboard incidents related to fires or overheating."*

This was somewhat driven by counterfeit products entering the market, not provided with third-party certification to UL 2272[30].

Furthermore, weeks after the launch of a particular model of smartphone in September 2017, an initial recall of 2.5 million devices was issued after several phones experienced overheating

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28 US Fire Administration. Electronic Cigarette Fires and Explosions in the United States 2009-2016. Available from https://www.usfa.fema.gov/downloads/pdf/publications/electronic_cigarettes.pdf. Last accessed 27 February 2019.

29 CPSC. Hoverboard Safety Alert, 2017. Available from https://www.cpsc.gov/s3fs-public/CPSC-Hoverboard-Safety-Alert.pdf?NaDiKrW4fd88yJaKh1o90Q.nNHrgLMnv. Last accessed 27 February 2019.

30 UL 2272. Standard for Electrical Systems for Personal E-Mobility Devices, 2016.

issues. By the time the CPSC issued a formal nationwide recall two weeks later, nearly 100 dangerous battery incidents had been reported in the USA[31].

London Fire Brigade[32] expressed concerns over the safety of e-cigarettes, and in particular the dangers of using an incompatible charger, after a serious fire incident in April 2014. This was the first e-cigarette fire attended by the London Fire Brigade Fire Investigation team.

Kong et al[33] identified that incidents of this type are generally related to a 'thermal runaway' reaction of the lithium-ion (Li-ion) battery powering these types of consumer products.

One of the most high-profile cases involving a Li-ion battery runaway reaction, is the one where, after numerous incidents, the US Federal Aviation Administration ordered the full grounding of an airliner fleet in 2013[34].

The use of Li-ion batteries in modern products is recognised as a fire risk due to thermal runaway, such that an extensive amount of research has been published in peer-reviewed journals[35] [36] [37] [38] [39] [40] [41] [42]. This is a specific area of research that is expected to have continued support.

Li-ion batteries have become favourable as they have high specific capacity, energy density, efficiency, cycle life and power density, and despite fire risk concerns, Li-ion battery technology is dominating the market today.

Sanden and Pontus[43] state that the risk associated with Li-ion batteries as follows:

> *"The risks involved with the use of lithium-ion batteries are closely related to the chemistries used, the design of cell and system, the handling of the battery when in use and the quality of the production."*

Sanden and Pontus[43] also describe failure mechanisms for Li-ion batteries as shown in Figure 14 which can lead to a battery temperature of 120°C to 150°C. Above these temperatures, exothermal reactions start to occur, increasing the temperature even further and therefore triggering additional exothermal reactions. Once a rapid temperature increase occurs a, so-called, thermal runaway reaction is propagated, which usually results in one of the following phenomena: rapid gas release, electrolyte leakage, fire or explosion.

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31 Moynihan T. Samsung Finally Reveals Why the Galaxy Note 7 Kept Exploding. Available from https://www.wired.com/2017/01/why-the-samsung-galaxy-note-7-kept-exploding/. Last accessed 28 February 2019.

32 London Fire Brigade. 'Exploding' e-cig leads to safety warning from Brigade, 2014. Available from https://www.london-fire.gov.uk/news/2014-news/exploding-e-cig-leads-to-safety-warning-from-brigade/. Last accessed 28 February 2019.

33 Kong L Li, C, Jiang J and Pecht M G. Li-ion battery fire hazards and safety strategies. Energies, 11(9), 2018, 1-11.

34 BBC. Dreamliner: Boeing 787 planes grounded on safety fears, January 17, 2013. Available from https://www.bbc.co.uk/news/business-21054089. Last accessed 27 February 2019.

35 Balakrishnan P G, Ramesh R and Prem Kumar T. Safety mechanisms in lithium-ion batteries. Journal of Power Sources, 155, 2006, 401-414.

36 Chen M, Liu J, He Y, Yuen R and Wang J. Study of the fire hazards of lithium-ion batteries at different pressures. Applied Thermal Engineering, 125, 2017, 1061-1074.

37 Chen M, Yuen R and Wang J. An experimental study about the effect of arrangement on the fire behaviors of lithium-ion batteries. Journal of Thermal Analysis and Calorimetry, 129, 2017, 181-188.

38 Eshetu G G, Grugeon S, Laruelle S, Boyanov S, Lecocq A, Bertrand J P and Marlair G. In-depth safety-focused analysis of solvents used in electrolytes for large scale lithium ion batteries. Physical Chemistry Chemical Physics, 15, 2013, 9145-9155.

39 Liu X, Stoliarov S I, Delinger M, Masias A and Snyder K. Heat release during thermally-induced failure of a lithium ion battery: Impact of cathode composition. Fire Safety Journal, 85, 2006, 10-22.

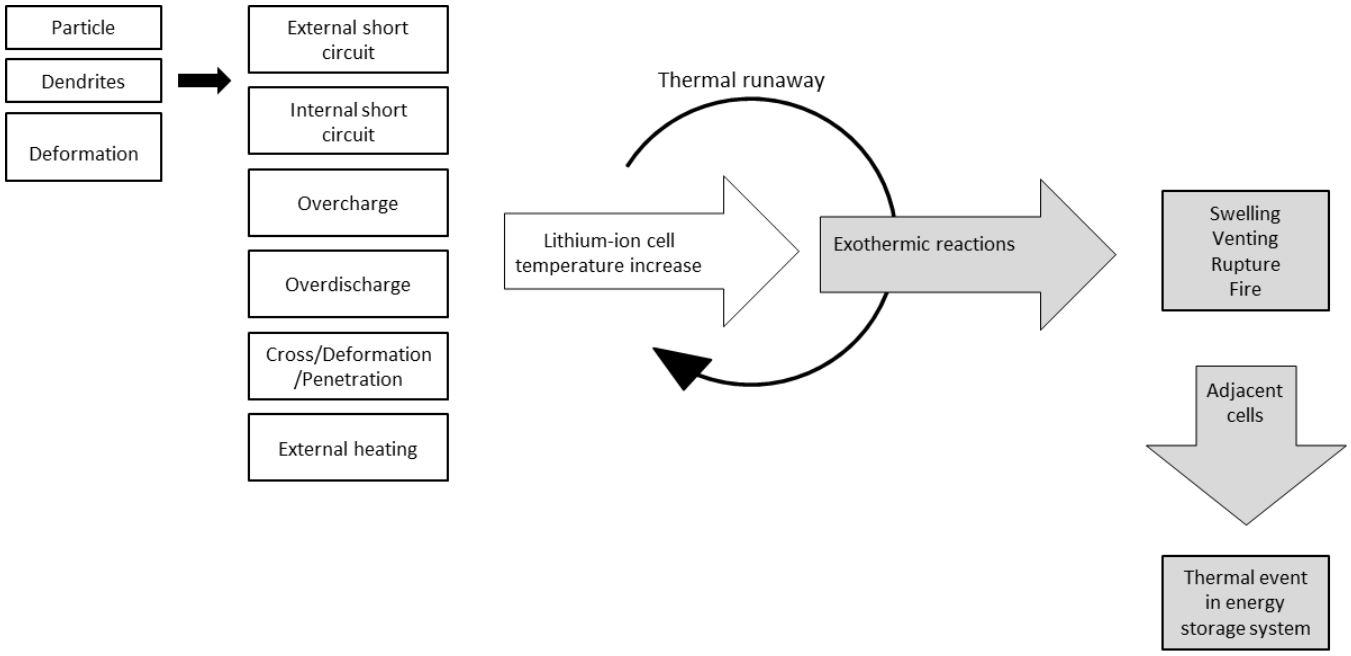
40 Kvasha H, Guitierrez C, Osa U, De Meatza I, Blazquez A, Macicior H and Urdampilleta I. A comparative study of thermal runaway of commercial lithium ion cells. Energy, 159, 2018, 547-557.

41 Lisbona D and Snee T. A review of hazards associated with primary lithium and lithium-ion batteries. Process Safety and Environmental Protection, 89, 2011, 434-442.

42 Mikolajczak C, Kahn M, White K and Thomas Long R. Lithium-Ion Batteries Hazard and Use Assessment. The Fire Protection Research Foundation, 2011. ISBN 978-1-4614-3486-3.

43 Sandén B and Pontus W. System perspectives on electromobility, 2014. Chalmers University of Technology. Available from http://www.chalmers.se/en/areas-of-advance/energy/cei/. Last accessed 28 February 2019.

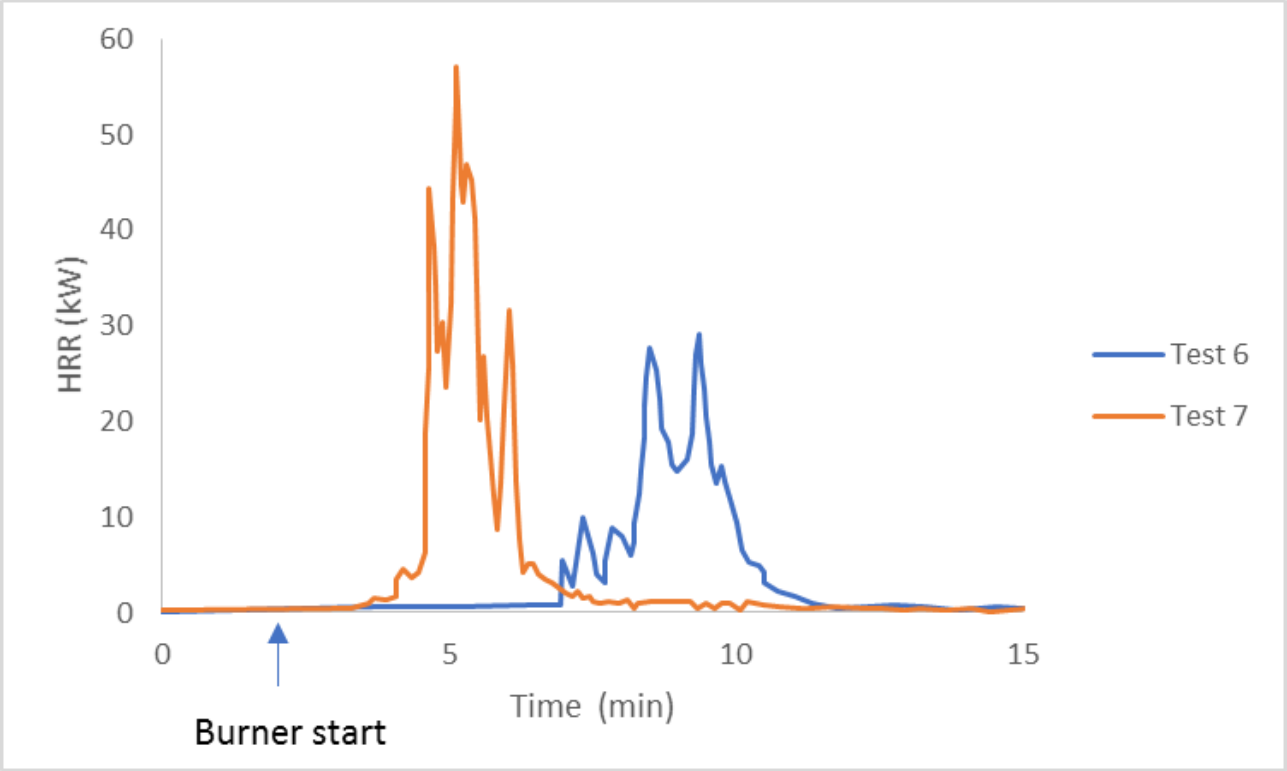
Figure 14: Failure mechanisms of Li-ion batteries[43]



Larsson et al[44] describe seven experiments on a variety of commercially available battery types. The tests used a 15 kW propane gas burner as an ignition source. The measured variables were the HRR, cell voltage, surface temperature and toxic gas emissions. One of these tests involved two laptop computer batteries (33 Ah capacity), with the measured HRR curve shown in Figure 15.

[44] Larsson F, Anderson P, Lor A and Mellander B E. Characteristics of lithium-ion batteries during fire tests. Journal of Power Sources, 271, 2014, 414-420.

Figure 15: Heat Release Rate curve for two laptop computer batteries (Test 7), by Larsson et al[44]



Larsson and Mellander[45] describe potential mitigation to improve fire safety of Li-ion batteries, including: use of fire retardants as additives to the electrolytes; replacing cobalt-based electrode by lithium ion phosphate to improve thermal stability, battery life, to give high power but with a lower energy density; and provide a temperature coefficient to generate cell resistance to increased temperature, reducing current going through the cell. Research in fire risk mitigation for Li-ion batteries continues.

Consumer product design

In general, there was a lack of relevant literature on consumer product design and fire risks. However, Beasley et al[8] describe causes and possible prevention of fridge/freezer fires in residential dwellings. This work identified various failure modes leading to ignition, namely, failure of starter relays, Positive Temperature Coefficient (PTC) starter switches, mechanical defrost switches, capacitors, solenoid valves and cut-out switch failures in integrated appliances. The work identified that these potential ignition sources were located in close proximity to combustible plastics and insulation material used in the appliance housing. It was recommended that potential ignition sources should be isolated from combustible foam insulation materials by locating them behind fire resisting barriers (such as a metal plate) and containing ignition sources in metal boxes to mitigate fire spread to the insulation.

Beasley et al[8] also identified specific fire growth and spread mechanisms once ignition had occurred, due to the use of plastic drip trays, and ‘twin-wall’ backing materials and polyurethane foam insulation panels.

The work identified that UK and European fridge/freezer appliances tend to contain plastic housings and the use of substantial quantities of polyurethane foam insulation. It recommended that the use of combustible plastics in appliance housings and drip trays should

[45] Larsson F and Mellander B-E. Abuse by External Heating, Overcharge and Short Circuiting of Commercial Lithium-Ion Battery Cells. Journal of the Electrochemical Society, 161(10), 2014, A1611–A1617.

be avoided, with the use of alternative non-combustible materials, such as steel. The work also recommended the use of more fault tolerant components that are less likely to fail and act as sources of ignition, in addition to limiting the flammability and combustibility of foam insulation materials used.

Hietaniemi, Mangs and Hakkarainen[9] also state from their experiments that:

> *"The origin of the very high RHR levels of the refrigerator-freezers lies mainly in two factors. First, there are considerable amounts of plastics in these apparatuses (polyurethane as insulating material, polypropylene or polystyrene in the freezer boxes, etc.) and secondly, during a fire the construction of the apparatus provides chimney-like flue enhancing the burning considerably."*

Again, this suggests the avoidance of plastics, combustible insulation, and design creating chimney-flue conditions, would be beneficial in the product design of fridge/freezers.

Modern home design

In recent years, new houses (and flats) have generally been smaller than those built previously. The trend in dwelling size showed an increase from the 1930's to 1970's, followed by a decline in size thereafter. The average floor space is now under 80 m² [46]. With smaller room sizes, fires may be more likely to grow if combustible materials are in closer proximity; also, with smaller rooms it is more likely that flashover could occur.

A consequence of diminishing house sizes is a greater tendency for living areas to be open plan, in order to maximise the feeling of space. Without dividing walls, it is easier for smoke to spread throughout the dwelling (or at least the living space); however, the larger volume of the living space makes flashover less likely.

In a 'traditional' flat, the rooms are accessed by a hallway which contains the front door to the common parts (or the outside in some cases). Fires in the hallway are less likely than in other types of room. Although the recommendation for self-closing doors was removed from Approved Document B in the 2006 edition (for England and Wales) (recognising the tendency of occupants to wedge such doors open, or remove them entirely), the hallway should still be of 30 minute fire-resisting construction and the doors should have a similar period of fire resistance. In principle, occupants could close the door to the room of fire origin (once any people inside it had left) in order to maintain reasonably tenable conditions in the hallway to permit escape from the flat. The protected hallway also provides an obstacle to fire breaking out of the flat and into the common parts.

In open plan flats, there is no protected hallway; the living area contains the front door. In order to reduce the risk of occupants being unable to escape from a fire in an open plan flat, guidance recommends that a residential sprinkler system would be provided (see NF19[47], BS 9991[48]; BS 9251[49]). The sprinklers are intended to prevent a fire growing further once operation has occurred; however, they may often succeed in effectively extinguishing the fire if it is not shielded from the spray. In most cases, only a single sprinkler head would need to operate to suppress the fire.

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[46] LABC. Are Britain's house getting smaller? (new data), 2019. Available from www.labcwarranty.co.uk/blog/are-britain-s-houses-getting-smaller-new-data/ Last accessed 24 July 2019.

[47] Fraser-Mitchell J and Williams C. Open plan flat layouts – assessing life safety in the event of a fire. NHBC Foundation report NF19, 2006.

[48] BS 9991:2015 Fire safety in the design, management and use of residential buildings. Code of practice, British Standards Institution, 2015.

[49] BS 9251:2014 Fire sprinkler systems for domestic and residential occupancies. Code of practice, British Standards Institution, 2014.

One of the drivers for decreasing house size is the high cost of land, which is also a driver for building town houses of greater than two storeys in order to increase the floor space to footprint ratio. However, if a dwelling has a storey height more than 4.5 m above the ground, Approved Document B recommends additional provisions of means of escape (a second stairway) to compensate for the fact that upper storey windows cannot be used as escape routes without assistance from the Fire and Rescue Service.

Modern Methods of Construction (MMC)[50] [51] [52] are often broadly defined as methods of construction that vary from traditional brick and block construction. However, there is no universally agreed definition and MMC is a collective term used to describe a wide range of construction methods aimed at improving efficiency and performance.

Types of MMC include:

- Thermal insulation
- Combustible frames (of which timber frames are most common)
- Lightweight roofs
- Sandwich panels

The use of combustible materials is a common factor in a range of types of MMC. In order to achieve satisfactory performance in fire, the combustible materials need to be lined or encapsulated by a non-combustible outer surface. Problems can arise if this protective lining is breached (e.g. service penetrations created during refurbishment works) or simply absent (e.g. as may be the case during stages of the construction process).

[50] Ross, K, Cartwright, P and Novakovic, O, A guide to modern methods of construction, NHBC Foundation, 2006, ISBN 10: 1-86081-937-0.

[51] Ross, K, Modern methods of house construction, A surveyor's guide, FB11, IHS BRE Press, 2005. ISBN 1 86081 755 6.

[52] Charters D and Fraser-Mitchell J. The potential role and contribution of fire safety to sustainable buildings, Proceedings, Interflam, 2007, 1231-1242.

Fire hazards of MMC include:

- External fire spread, either due to cladding systems, or external fires that somehow find a way into the structure through a weak point.
- Concealed fire spread (cavities); the fire may either start in the cavity or break into it. Such fires are difficult to locate and fight, and if cavity barriers are insufficient, the spread of fire can be extensive
- Disproportionate collapse (lightweight roof/Structural Insulated Panels [SIPs]) can occur if the fire involves such systems and robs them of their structural strength. If the fire is in a concealed location (e.g. a roof space, or the combustible core of a sandwich panel) then its progress is difficult to monitor and collapse can occur unexpectedly.
- With greater levels of insulation and air tightness, there is a potential for fires to generate higher temperatures because the heat cannot easily escape, either via conduction through the structure, or venting of hot smoke to the outside. This may then expose elements of the building to a more severe fire than represented by current fire resistance tests.

There are opportunities to manage the risk throughout the building life cycle, starting with design and construction, then while the building is occupied, and also during refurbishment (if applicable).

Due to the potential for disproportionate property losses, the fire risks in MMC need to be carefully managed. However, if best practice and appropriate guidance are followed, e.g. see Figure 16 the fire risk should not be significantly greater than in more traditional methods of construction.

Figure 16: BRE Global photograph showing the benefits of correctly-installed fire barriers Note that the far end of roof is intact and the roof was formed from lightweight construction.

Kerber[53] describes full-scale experimental work to compare fire dynamics between a modern and a legacy (1970's) dwelling fire in the USA. The modern home was furnished with contents mainly consisting of synthetic materials such as a polyurethane foam filled sofa with polyester fabric covering, polyester curtains, flat screen television, etc. The legacy home was furnished with items such as a cotton covered and cotton filled sofa, cotton curtains, cathode-ray tube (CRT) television and hard furnishings constructed from wood and metal materials. Figure 17 shows photographs of the modern and legacy rooms in one of the

[53] Kerber S. Analysis of Changing Residential Fire Dynamics and its Implications on Firefighter Operational Timeframes. Fire Technology, 48, 2012, 865-891.

comparative experiments.

Figure 17: Photographs of modern room (left) and legacy room (right) in experiments by Kerber[53]

Table 4 shows a comparison of the time to room flashover between the modern and legacy room fires, with flashover typically occurring in around 3 minutes to 4 minutes from ignition for the modern rooms and up to around 30 minutes to 35 minutes (if at all) for the legacy room.

Table 4: Comparison of time to flashover in experiments by Kerber[53]

Experiments	Modern	Legacy
1, 2	3:40	29:30
3, 4	4:45	34:15
5, 6	3:20	Not achieved

Care should be taken on the interpretation of data from these experiments for application to the UK, as modern contents in the UK are likely to have more strict flammability controls than those used in these experiments.

Fire load density in dwellings

The literature relating to fire load energy density in dwellings is very limited. This is likely to be due to privacy concerns and issues relating to physically entering dwellings.

The current fire load energy density values assumed for dwelling fires in the UK are given by Thomas[54]. This work generally defines differences in permanent (i.e. physical structure) and variable (i.e. contents) fire load energy densities. It should be noted that this work is very dated and may not be representative of modern dwelling fires in the UK. However, this remains to be the most relevant data available.

Table 5 shows variable fire load energy densities in dwellings in Europe, Switzerland and the USA as given by Thomas[54]. Thomas[54] states that the differences in values between countries are likely to be due to national differences of the effect of the various different methodologies used. The European data in Table 5 is used to represent UK dwelling fires in fire safety design.

[54] Thomas P H. Design guide: Structure fire safety CIB W14 Workshop report. Fire Safety Journal, 10 (2), 1986, 77-137.

Table 5: Variable fire load energy densities (MJ/m²) in dwellings given by Thomas[54]

	Average	Standard deviation	Fractile			Remarks
			80%	90%	95%	
Swedish data 3 rooms 2 rooms	 720 780	 104 128	 770 870			qf = qt x 5.2 Characteristic value (0.8 fr.) - Bedroom 630 - Living room 510
European data 6 rooms 5 rooms 3 rooms 2 rooms 1 room	 500 540 670 780 720	 180 125 133 129 104	 760 870 760	 780 1020 780	 830 950 890	qf = qt x 5.2 5.2 = cubic measure 3.2 x 4.3 x 2.9
Swiss risk evaluation Flat	 330					
USA data Living room Family room Bedroom Dining room Kitchen All rooms	 350 250 390 330 290 320	 104 58 104 92 71 88				
USA data Residence Max. for linen closet Range of maximum values for single occupied room	 750* 4440* 730-1270*					*Total fire load including permanent fire load

BS EN 1991-1-2[55] and PD 6696-2[56] recommend an average fire load density of 780 MJ/m² using the European data (for six rooms) from Thomas[54] shown in Table 5, when applied to structural fire design in the UK.

Other UK-specific fire load density data for residential occupancies is given by Juster[57] for student accommodation, who examined floorplans/designs from architectural practices for eighteen planned and newly opened student halls of residence, incorporating 75 different room

[55] BS EN 1991-1-2 Eurocode 1. Action on structures. General actions. Actions on structures exposed to fire. British Standards Institution, 2002.

[56] PD 6696-2 Background paper to BS EN 1994-2 and the UK National Annex to BS EN 1994-2. British Standards Institution, 2007.

[57] Juster A. Fuel Load and Design Fires for Student Accommodation. MEng Thesis. The University of Edinburgh, 2017.

designs. This analysis gave an average fire load energy density for a student room to be 310 MJ/m^2 to 340 MJ/m^2.

Due to the lack of data on fire load energy density in the UK, a search was carried out for relevant overseas data. Ocran[58] reports a fire load study carried out in the USA by the National Bureau of Standards (now National Institute of Standards and Technology) in 1942, so is particularly dated. This work recommended a fire load density for an entire apartment or residence of 799 MJ/m^2 and appears to be a combination of permanent and variable loads.

Bwalya, Sultan and Benichou[59] in Canada used an internet questionnaire which generated a response from 598 people. However, all participants were working at the National Research Council of Canada, so may not be representative of the general population. The study focused on combustible items found in living rooms, family rooms and recreation rooms. Although not explicitly stated by Bwalya, Sultan and Benichou[59] the data listed in Table 6 are assumed to be inclusive of the permanent fire load as the questionnaire included questions about the floor and ceiling finishes.

Table 6: Mean values (standard deviation in brackets) of fire load and fire load density for home in Canada by Bwalya, Sultan and Benichou[59]

House category	Mean fire load (MJ)	Mean fire load density (MJ/m^2)	Number of samples
2 storey detached	7800	390 (160)	231
Bungalow	7790	410 (270)	118
Apartment	7920	440 (272)	64
2 storey town home	8300	490 (240)	58
2 storey semi-detached	7920	440 (300)	29
3 storey detached	8190	390 (240)	28
3 storey town home	6290	370 (240)	14
Duplex	8360	440 (190)	12

The rather low values listed in Table 6 compared to those in Table 5 could be due to the fact that areas such as storage rooms, bedrooms and kitchens were not part of the questionnaire.

A fire load study in Canada by Bwalya et al[60] for 515 multi-family dwellings, including semi-detached houses, town houses and low-rise apartments, was conducted by the novel method of studying photographs from estate agents' websites. Similarly, as with the previous study it can be concluded that fire loads listed in are inclusive of the permanent fire loads. Bwalya et al[60] concluded that although kitchens had the highest fire load density (MJ/m²), it was bedrooms which had the highest fire load (MJ) due to the presence of carpeting, clothing and mattresses. See Table 7.

Table 7: Fire load densities for various rooms by Bwalya et al[60]

Room	Mean FLD (MJ/m^2)	Standard deviation (MJ/m^2)	95th percentile	Sample size	Mean FL (MJ)

[58] Ocran N. Fire Loads and Design Fires for Mid-Rise Buildings. Master of Applied Science in Civil Engineering Thesis. Carleton University, 2012.

[59] Bwalya A, Sultan M and Benichou N. A pilot survey of fire loads in Canadian homes. NRC Research Report No 159, 2004.

[60] Bwalya A, Lougheed G, Kashef, A and Saber H. Survey Results of Combustible Contents and Floor Areas in Canadian Multi-Family Dwellings. Fire Technology, 47(4), 2009, 1121–1140.

Kitchen	807	123	940	515	7908 (2)[a]
Secondary bedroom	594	146	846	129	6237 (5)
Primary bedroom	534	125	753	347	8864 (1)
Living room	412	127	610	397	7251 (3)
Dining room	393	132	576	292	3812 (6)
Basement living room	288	96	450	130	6682 (4)

FLD = fire load density, FL = total fire load, [a]() = FL ranking

In general, variation in the methodologies used to determine fire load density between different countries, makes comparison between them very difficult, if not impossible.

Due to the scarcity and very dated nature of the available data on fire load energy density in the UK, further study of fire load in modern dwellings is needed.

Fire statistics

Introduction

A review and analysis of Fire Statistics for England was conducted. BRE Global examined the Home Office IRS fire statistics for England on domestic fires covering the period 2010/2011 to 2017/2018 (eight years). The Incident Recording System (IRS) collects detailed information on every incident (not just fires) attended by Fire and Rescue Services. There are nearly 200 questions within the IRS; in general, the more serious the incident, the more questions that are asked. The system is maintained by the Home Office and information is entered by Fire and Rescue Services, using information collected by automatic systems and those present at the time of the incident. Fire and Rescue Services add incidents on a daily basis.

The Home Office currently publishes a set of annual reports, and supporting data tables, based on IRS data. Whilst these publications provide a good overview of the main trends in incidents and related outcomes, it is not feasible to publish in this way the huge volume of information captured by the Home Office through the IRS. To address this, and as part of the Government's transparency agenda, the Home Office considered ways to publish more detailed IRS data. It is not possible to make everything in the IRS publicly available due to privacy considerations. Nevertheless, the Home Office fire statistics website does contain some incident-level datasets, suitably anonymised.

However, in order to detect emerging trends, it was necessary to work with even more detailed data than is currently in the public domain, i.e. the spreadsheets downloadable from the Home Office website. For example, an unusual ignition source (e.g. e-cigarettes) would probably be classed as 'other', with a further text field being available to define this in more detail. If the item ignited is an appliance (e.g. washing machine, fridge freezer, television, etc.) there would be information regarding make and model, assuming this could be determined during the fire investigation.

In order to access this more detailed data it was necessary to request it from the Home Office Fire Statistics team. This data was provided for England only, and dwelling fires only.

As well as examining sources of ignition, item ignited, and material involved, the statistics survey also covered the consequences of fire, e.g. fatalities, injuries, and extent of fire and smoke damage. In fact, the only consequences examined were the area of fire damage for each fire. Previous studies[61] have shown that, particularly for residential fires, the life safety risks were strongly correlated with the area of damage. It was decided not to investigate fatalities and injuries explicitly, for two reasons. First, the number of fatalities per year is relatively small, and could lead to spurious conclusions. Second, citing concerns with GDPR (General Data Protection Regulation), the Home Office are very reluctant to release casualty data associated with individual fire records. It would have been necessary to devise an aggregated form of data before the casualty information could be included.

[61] Williams, C, Fraser-Mitchell, J, Campbell, S and Harrison, R. Effectiveness of sprinklers in residential premises, BRE Project report number 204505 for the Office of the Deputy Prime Minister, 2004. Available from www.bre.co.uk/page.jsp?id=422. Last accessed 24 July 2019.

The review of the fire statistics assisted in meeting project objectives 1 and 2.

1. To review the impact on fire characteristics of the changes in the content of the home, and in the design of homes
2. To review the impact on product flammability fire testing of new sources of ignition, such as e-cigarettes batteries and space heaters.

English House Condition Survey

A Stakeholder Group member suggested that the English House Condition Survey (EHCS) might also contain information on domestic fires, which could supplement data supplied by the Home Office. Before embarking on a detailed examination of the Home Office data, the EHCS results will firstly be discussed.

From the published results of the English House Condition Survey in 2016 to 2017[62], the following conclusions were noted.

Based on a sample size of 393 responders, it was estimated that 332,000 households in England (about 1% of the total) had experienced a fire at home in the last two years. In the majority of these fires, the fire was put out by someone in the household, or the fire went out by itself. 25% of fires were extinguished by the Fire and Rescue Service. From this, it can be estimated that there were approximately 40,000 fires per year attended by the Fire and Rescue Service. This value should be compared against the number estimated from the Home Office fire statistics, which would be about 30,000 per year. Note that the Home Office fire statistics should have recorded all fires attended, whereas the EHCS value was an estimate based on a small sample.

According to the EHCS, most fires (86%) started inside the house or flat; 14% started outside (e.g. in the garden or communal area).

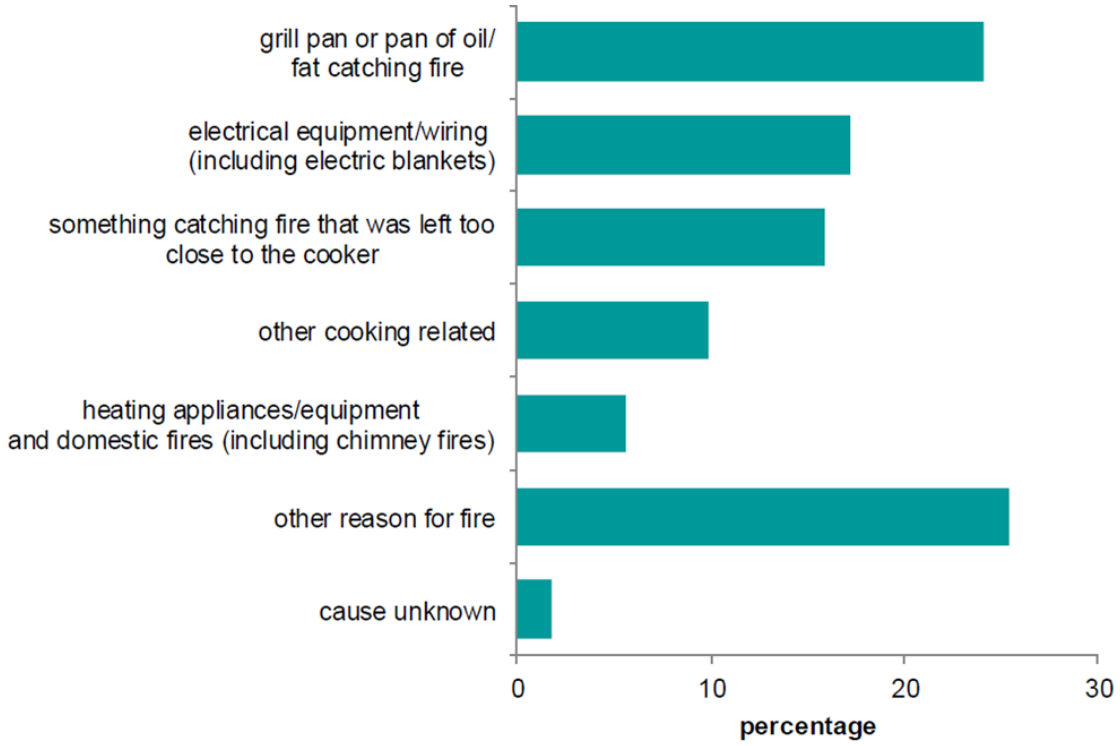
Of the fires that started inside the house or flat, two-thirds started in the kitchen. It is therefore not surprising that fires in the home were most commonly recorded as cooking-related activities, such as a grill or chip pan fire.

Figure 18 shows the causes of fire, as recorded by the EHCS. Approximately 35% of fires were caused by a grill or chip pan catching fire, or other cooking-related activity. In addition, approximately 15% of fires were caused by something catching fire that was left too close to the cooker.

The English Housing Condition Survey did not contain any further information, other than that presented in this graph. It is therefore not possible to analyse data to the extent that it is possible to analyse the Home Office fire statistics.

[62] Ministry of Housing, Communities and Local Government. English Housing Survey, Fire and fire safety, 2016-17, July 2018.

Figure 18: Causes of fire, as recorded by the English House Condition Survey[62]

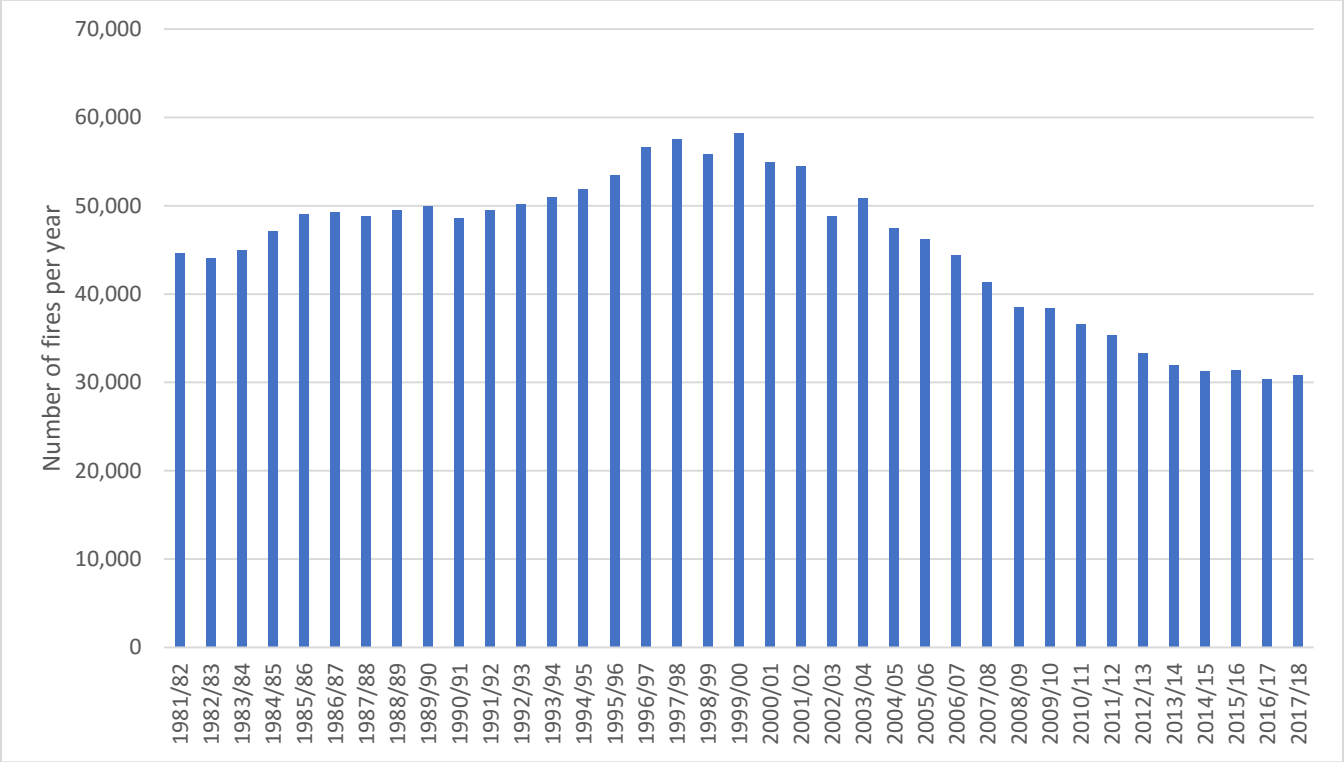


Total numbers of fires

The Home Office fire statistics show that the total number of fires per year in England recorded in the IRS rose to a peak value of 58,280 in 1999/2000, and then declined[63], as shown in Figure 19.

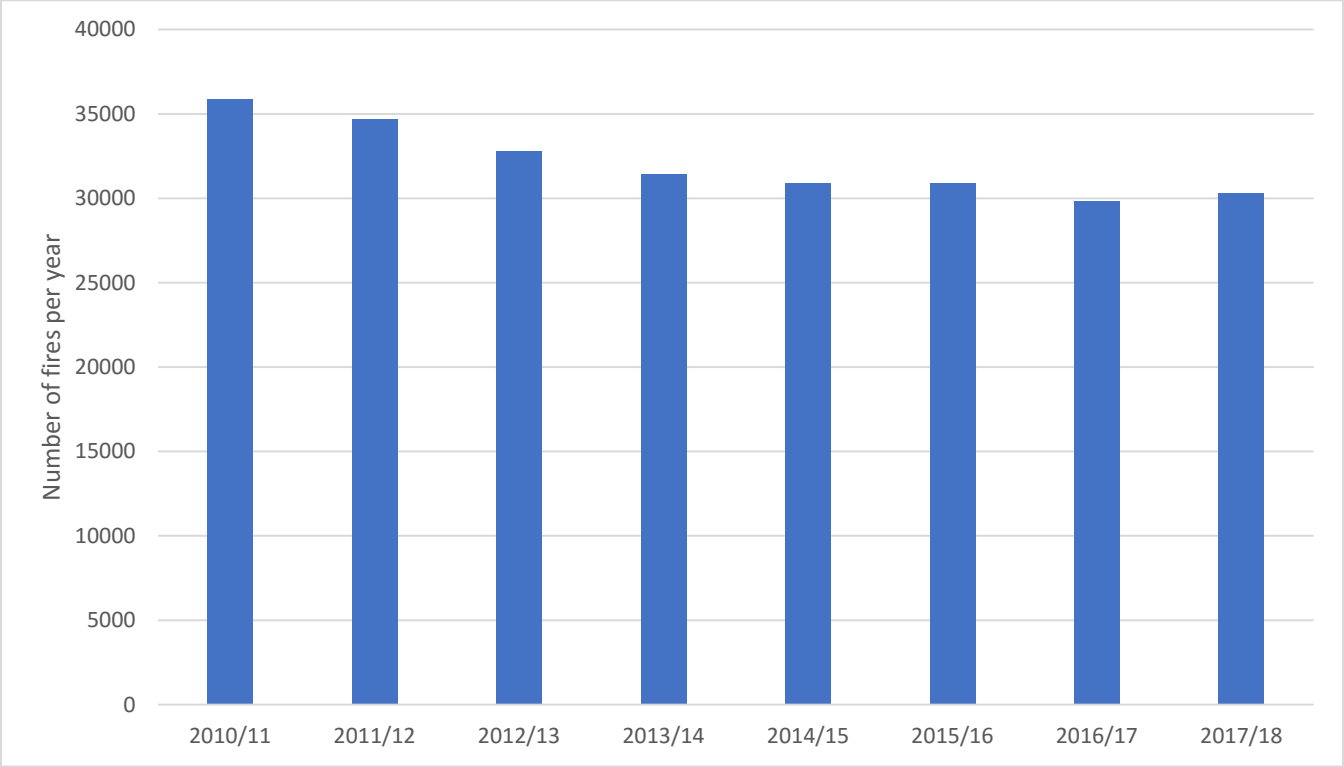
[63] Home Office Fire Statistics Table 0201. Available from https://www.gov.uk/government/statistical-data-sets/fire-statistics-data-tables. Last accessed 17 June 2019.

Figure 19: Total number of fires per year recorded in the Home Office fire statistics in England



The detailed data supplied by the Home Office covered the period 2010/2011 to 2017/2018. The annual trend in the total number of domestic fires shows they declined starting from about 35,000 fires per year to 30,000 fires per year at the end of the period. In the second half of the period, the number of fires per year stayed approximately constant, as shown in Figure 20.

Figure 20: Number of UK domestic fires per year in England



Accidental and non-accidental fires

The fire statistics differentiate between accidental and non-accidental fires and, as shown in Figure 21, the vast majority of domestic fires are accidental. Those that are classified as deliberate can be subdivided as other's property, owned property, or an unknown owner. There is also a small proportion of fires where it is not known whether they were accidental or not.

Figure 21: Accidental and deliberate domestic fires (England 2010 to 2018, total fires 256,716)

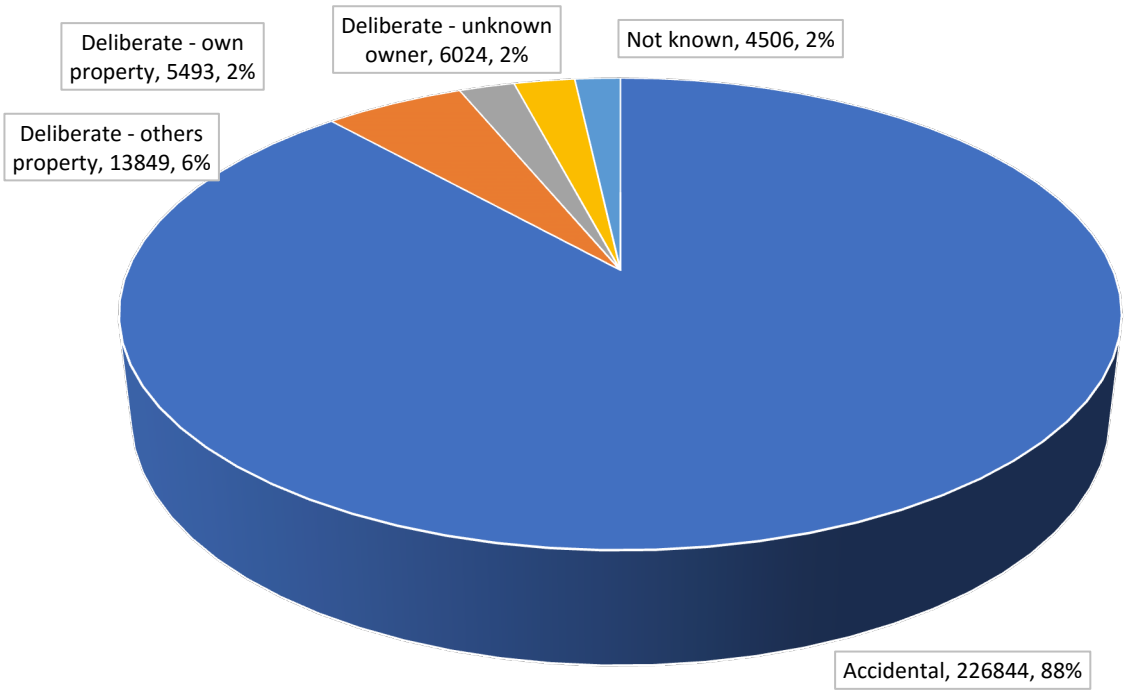
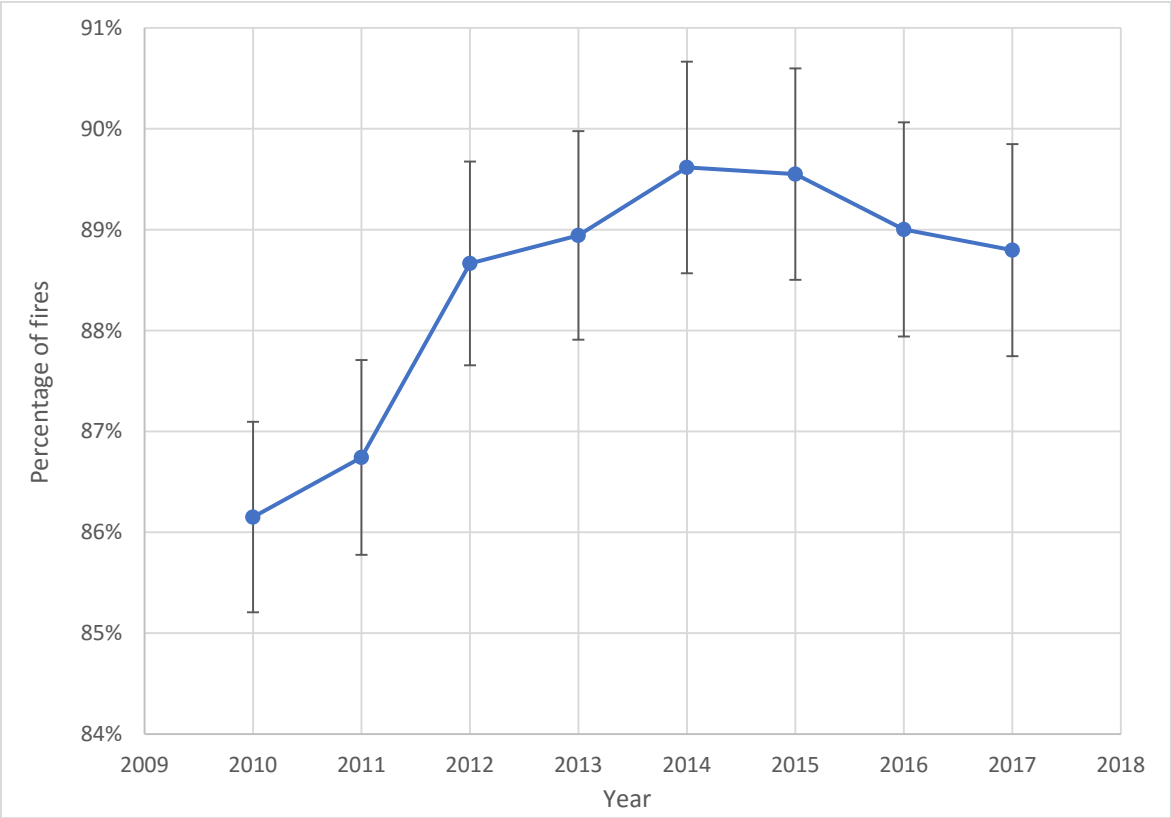


Figure 22 shows the trend in the number of accidental and deliberate fires with a slight increase in the proportion that are accidental. This is from about 86% at the start of period to around about 88% at the end of the period. By inference, the proportion of non-accidental fires, i.e. the remainder, has declined slightly.

Figure 22: Fraction of all domestic fires that are accidental in England



Error bars are 1 standard deviation.

Room of fire origin

The fire statistics record the room of fire origin. Figure 23 shows the most common locations that account for roughly 90% of fires, with the remainder amalgamated under a new category 'All other locations'. (Note that there is also an existing category 'Other' in the fire statistics, which here accounts for 3% of all fires). It can be seen that over half of all fires started in the kitchen. The next commonest locations are bedrooms or the living room with approximately 10% of all fires each.

Figure 23: Room of fire origin (England 2010 to 2018, total fires 256,716)

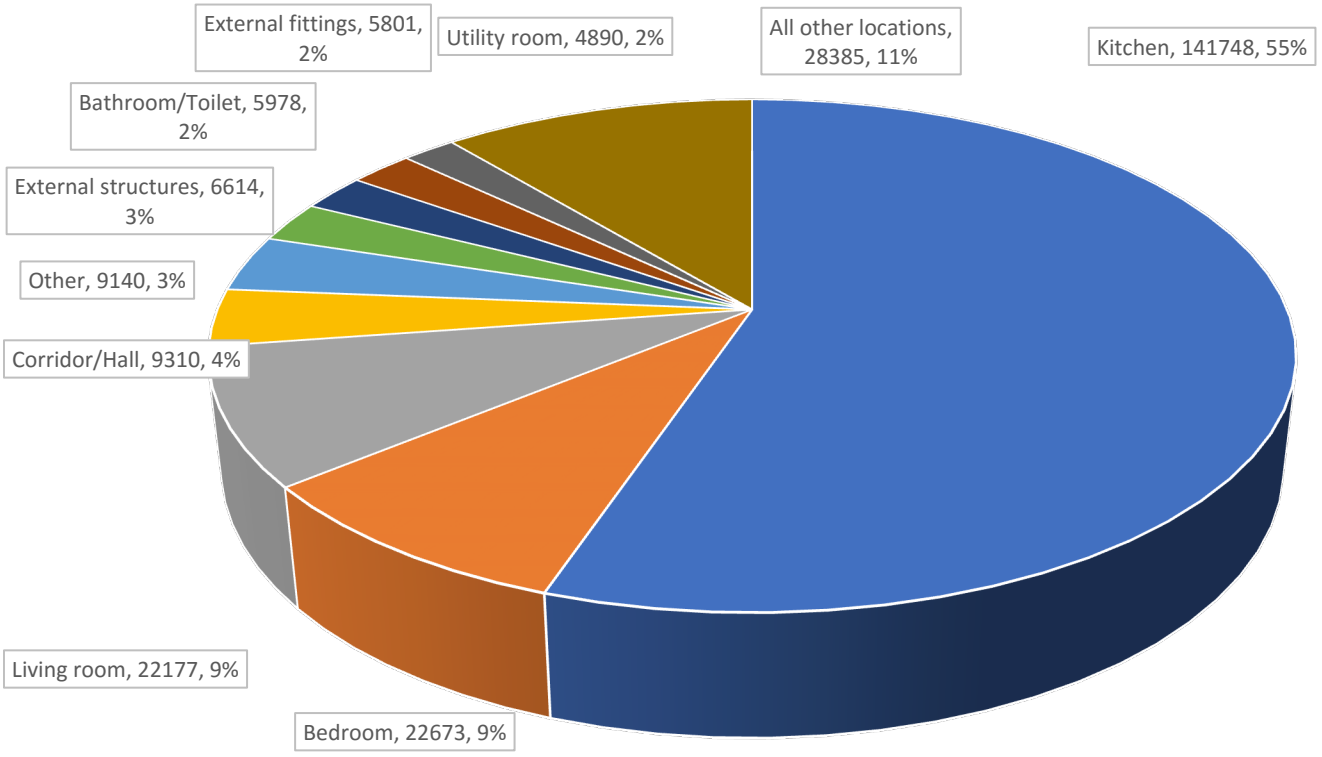
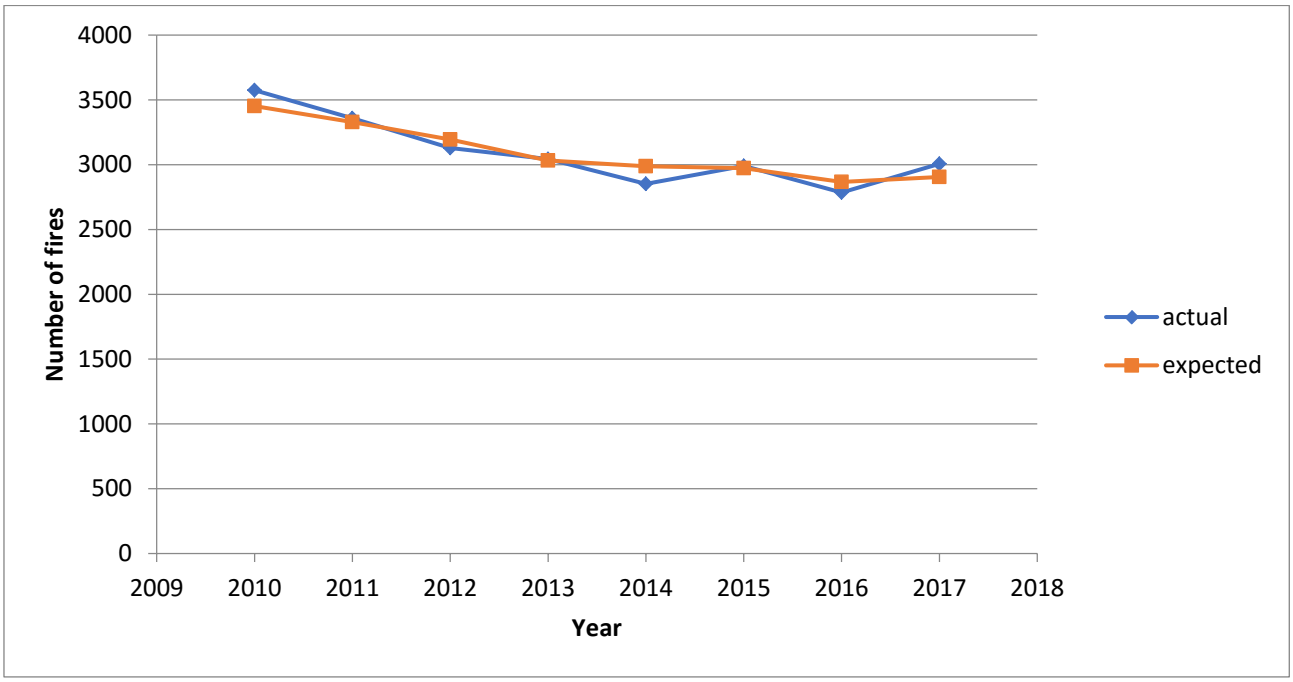


Figure 24 (a) to (c) shows the annual trend in the number of fires in the three commonest locations, namely kitchen fires, bedroom fires and living area fires. In all cases, the actual number of fires per year closely follows the expected trend.

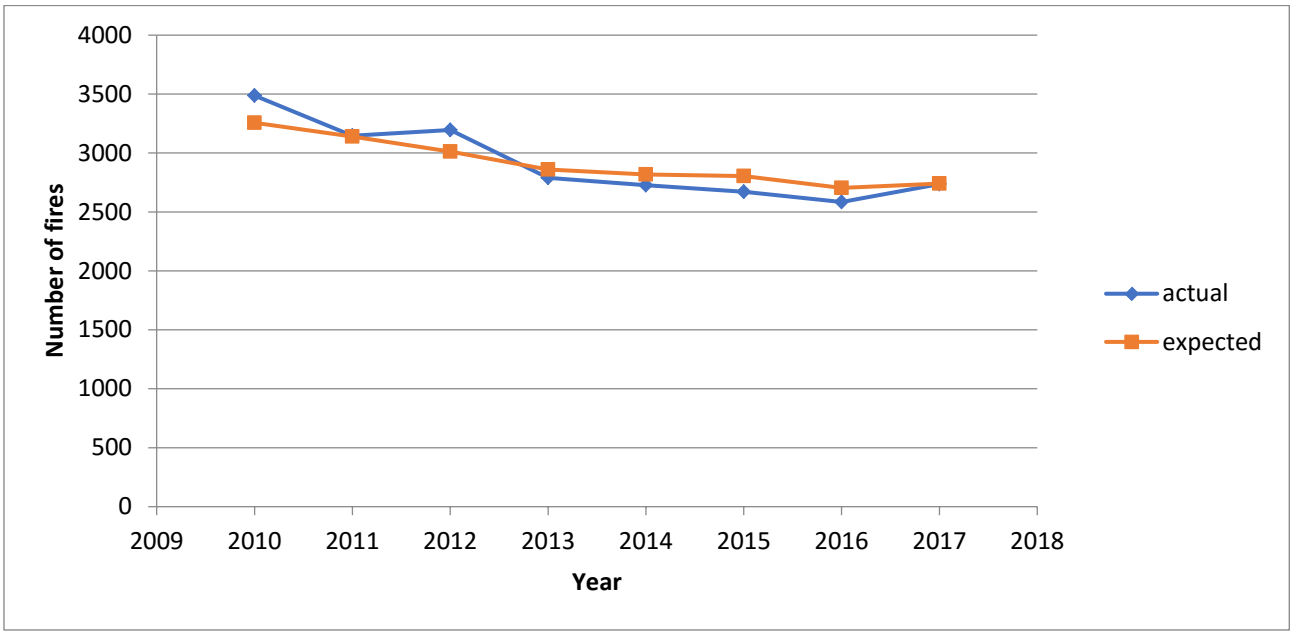
The expected trend is derived from the assumption that the proportion of fires in different locations remains constant. Hence the expected number of fires is given by the total number of fires shown in Figure 20, scaled by the average annual proportion of fires starting a particular room type (Figure 23). Therefore, bedroom fires, which constitute approximately 10% of the total number, have an expected trend that starts at about 35,000 x 0.1 = 3,500 fires in 2010/2011, declining to about 30,000 x 0.1 = 3,000 fires from 2014/2015 to 2017/2018.

Figure 24: Annual trends in the number of fires in the three commonest locations (England 2010 to 2018)

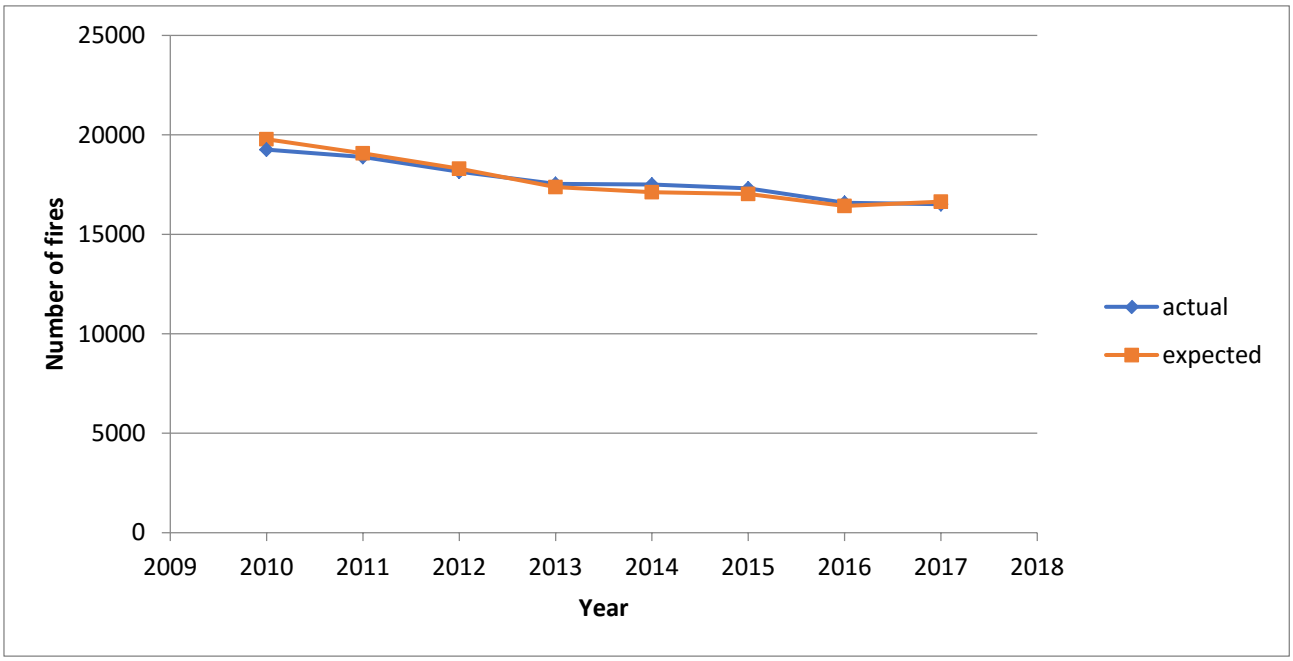
(a) Bedroom fires



(b) Living area fires



(c) Kitchen fires



Fire types

The fire statistics have a number of ways of describing the type of fire. These are:

- The main cause of fire (which generally speaking is related to the actions and of the occupants of the dwelling).
- The source of ignition (which in some cases may define the item first ignited).
- The material first ignited (which may define the item first ignited if it is not itself the cause of ignition).
- The material mainly responsible for fire spreading (which may be 'none' if the fire does not spread).

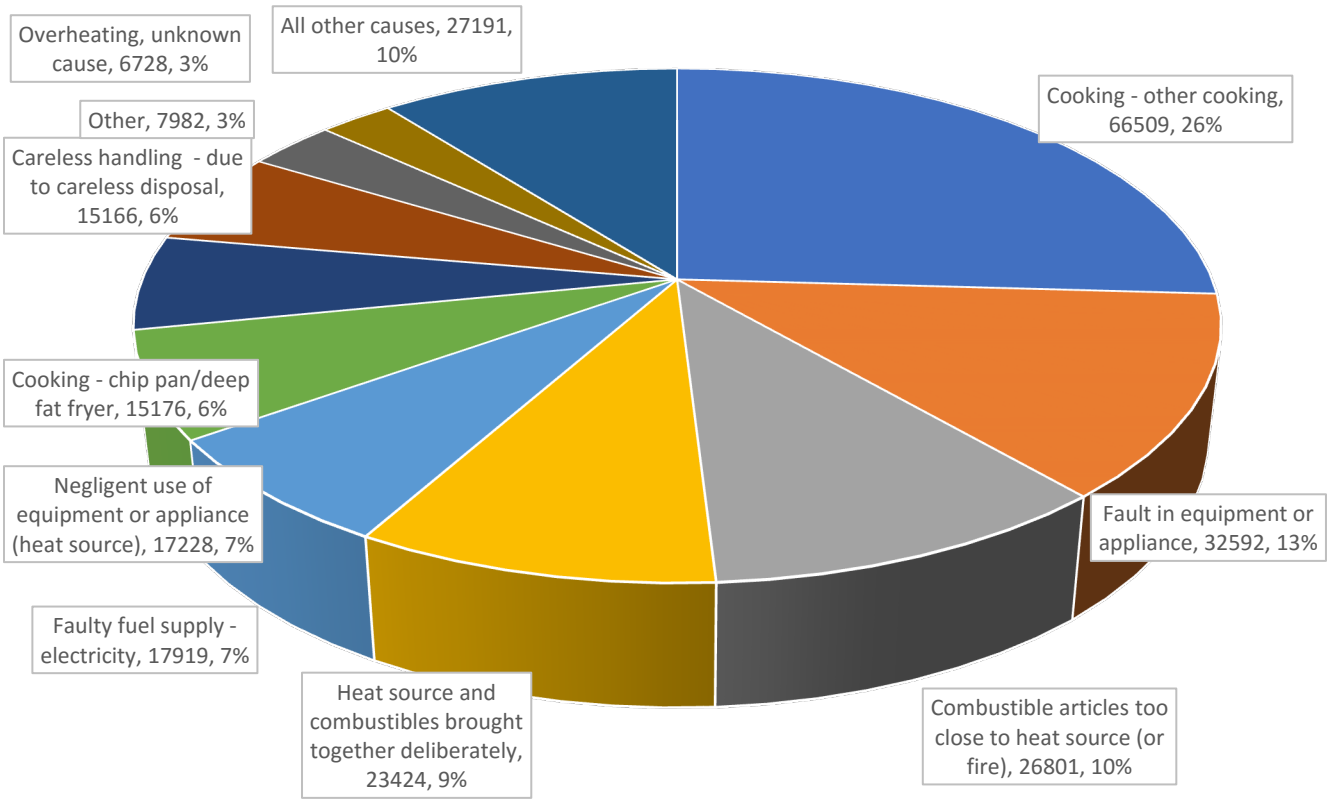
The next series of charts show the commonest categories accounting for roughly 90% of all fires for each of the above bullet points, with the remaining 10% amalgamated into a new category 'All other …'.

Main cause of fire

Figure 25 shows the main cause of fire is ‘other cooking’; note that cooking involving a chip pan or deep fat fryer is explicitly recorded and comprises a further 6% of fires in the sample. Faults in the equipment or appliance (13%) or its power supply (7%), normally electrical, comprise approximately one-fifth of all fires. Combustible items and heat sources brought together, either accidentally by negligence or misuse, or deliberately, comprise a further fifth of the sample.

Note that ‘other’ causes (3%) are those specified in the fire statistics, and do not include the 10% of fires with various less common causes that have been amalgamated under the new ‘All other causes’ category.

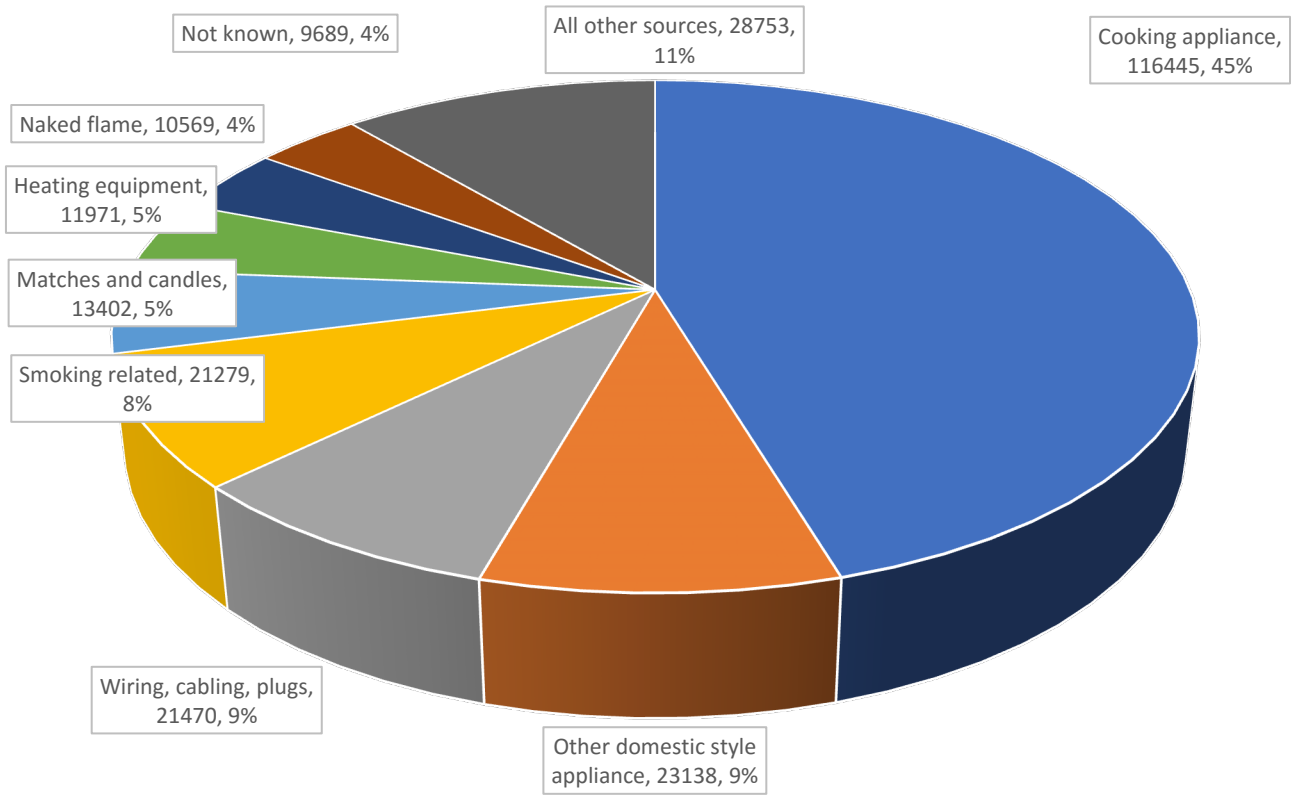
Figure 25: Main causes of domestic fires (England 2010 to 2018, total fires 256,716)



Source of ignition

Another way to describe the type of fire is in terms of the source of ignition, see Figure 26. Cooking appliances account for nearly half of the sources of ignition; these fires not only include those where the activity was cooking, but also others where combustibles were placed e.g. on a still-hot hob once cooking was completed. Other significant sources of ignition include domestic style appliances, and wiring, cabling and plugs. Smoking-related sources of ignition account for under 10% of all fires, a very significant decrease in from earlier years (e.g. over 25% of all fires in 1987[64]).

Figure 26: Source of ignition (England 2010 to 2018, total fires 256,716)

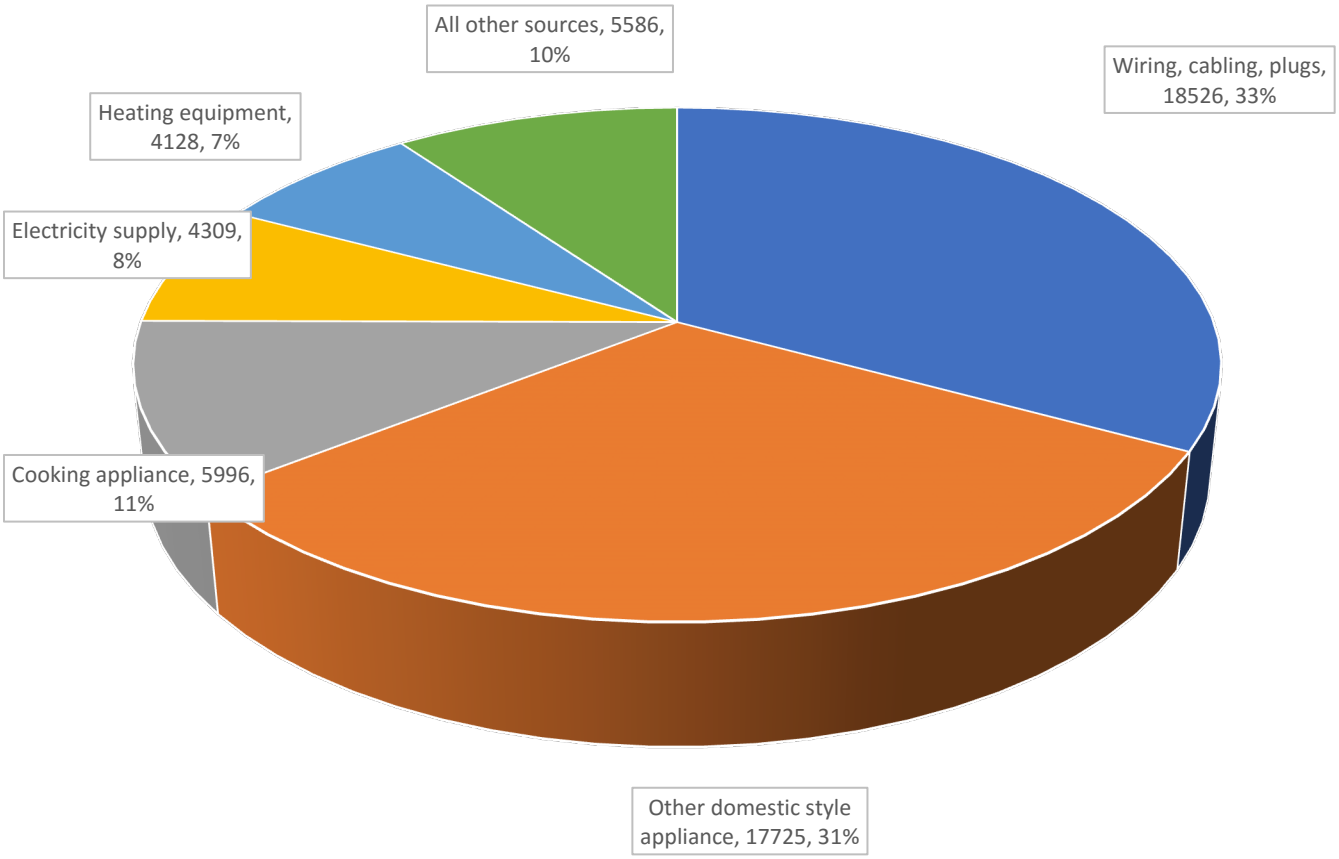


64 Chandler S. Private communication, 1992.

Source of ignition (when caused by fault)

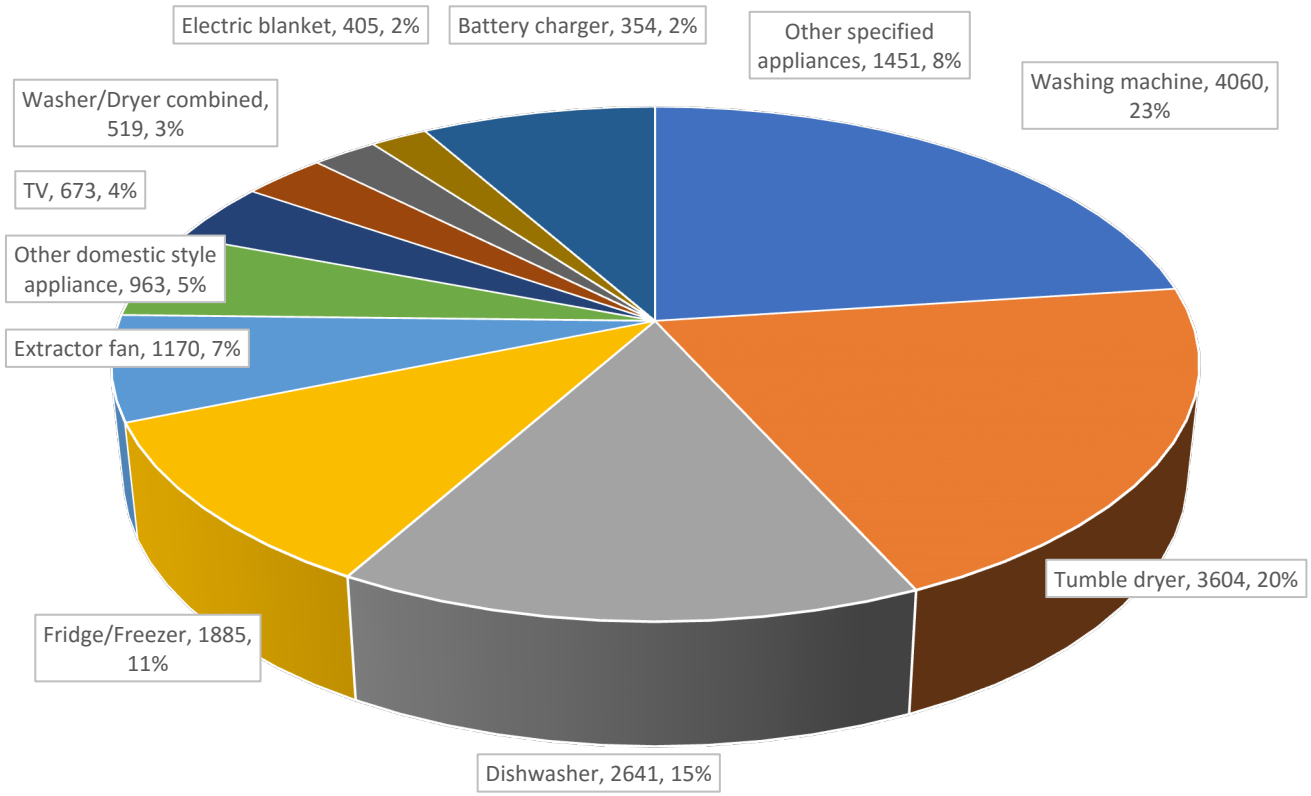
It is possible to examine the source of ignition, in the subset of fires where the cause of fire is described as a fault. In these cases, approximately two-thirds of the fires are due to the faults in wires, cabling or plugs, or ‘other domestic style appliances’, as shown in Figure 27.

Figure 27: Source of ignition, when caused by a fault (England 2010 to 2018, total fires 56,270)



It is possible to break down the large category of other domestic style appliances, in order to look at more specific items. This is shown in Figure 28. The 17,725 fires generally classed as ‘other domestic appliance’ have been subdivided to show the commonest types accounting for 90% of these fires explicitly, with the remaining less common types amalgamated within the new category 'Other specified appliances’. Most of the fires caused by faulty appliances are ‘white goods’ such as washing machines, tumble dryers, dishwasher, fridge/freezer, or combined washer/dryers. Consumer items such as televisions account for about 4% of fires, but other consumers items such as audio-visual equipment, PC equipment, gadgets etc. are included in the ‘Other specified appliances’ category.

Figure 28: 'Other domestic style appliances' broken down into categories (England 2010 to 2018, total fires 17,725)



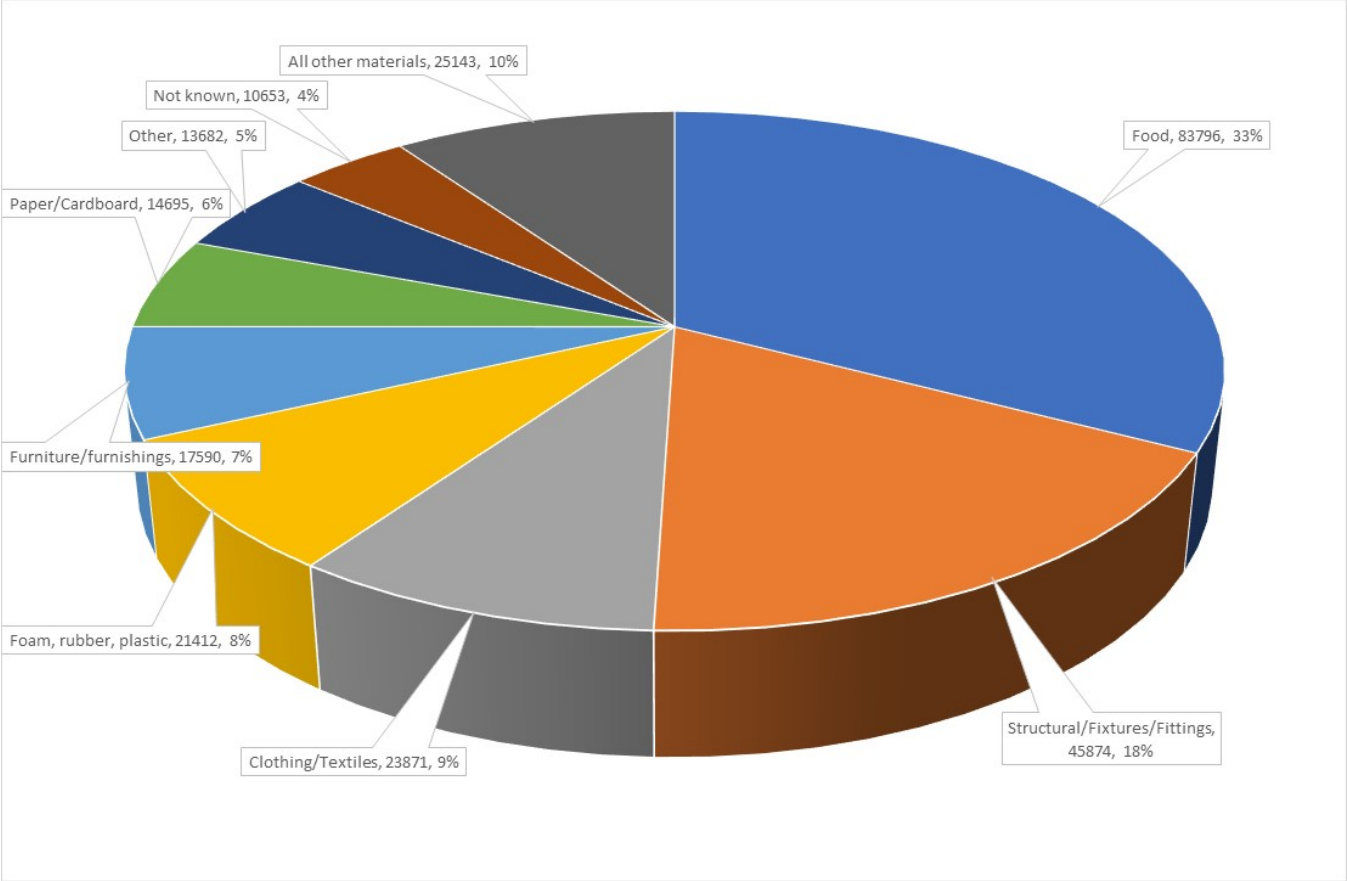
Material first ignited

Consistent with the large number of cooking fires, food is the commonest material first ignited, as shown in Figure 29. This is followed by structural fixtures and fittings, then clothing and textiles. The category of “Foam, rubber and plastic” includes materials that items are made from, for example plastic casings, or foam insulation. Furniture or furnishings comprise a relatively small proportion of the total number of fires in the sample, at 8%.

Note that ‘other’ causes (5%) are those specified in the fire statistics, and do not include the 10% of fires with various less common causes that have been amalgamated under the new ‘All other materials’ category.

Bedding is a separate category, which by itself does not make it into the 90% of commonest materials so is included in the amalgamated “All other materials” category, and bedclothes are included in the clothing and textiles category. The category for paper and cardboard includes waste materials and packaging.

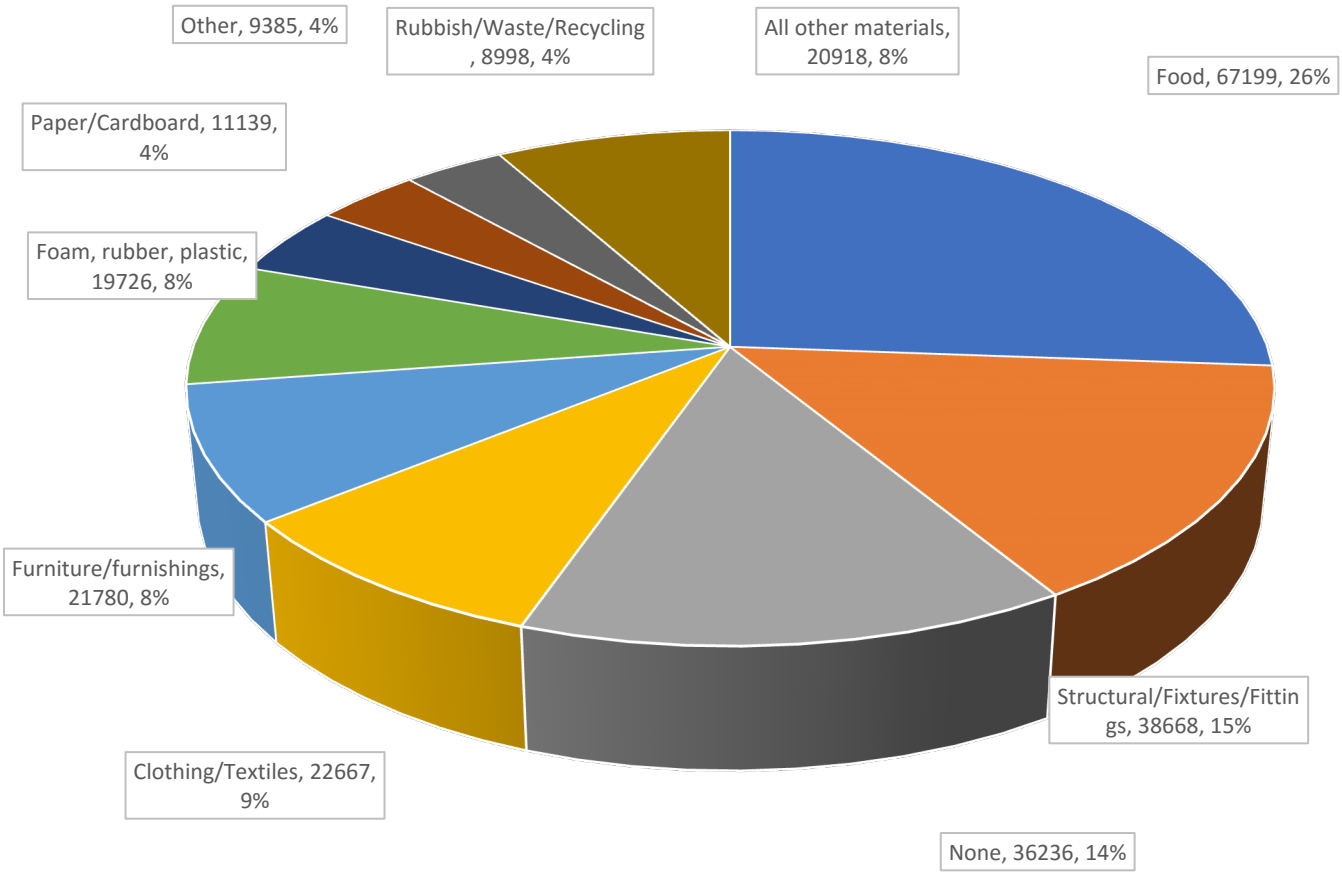
Figure 29: Material first ignited (England 2010 to 2018, total fires 256,716)



Material mainly responsible for fire spread

The material mainly responsible for fire spread can be the item or material first ignited, or some other material. If the fire did not spread beyond the first item, then a material type of 'none' may be recorded. As was the case in Figure 29, food, then structural fixtures and fittings are the materials most commonly responsible for fire spread, as shown in Figure 30.

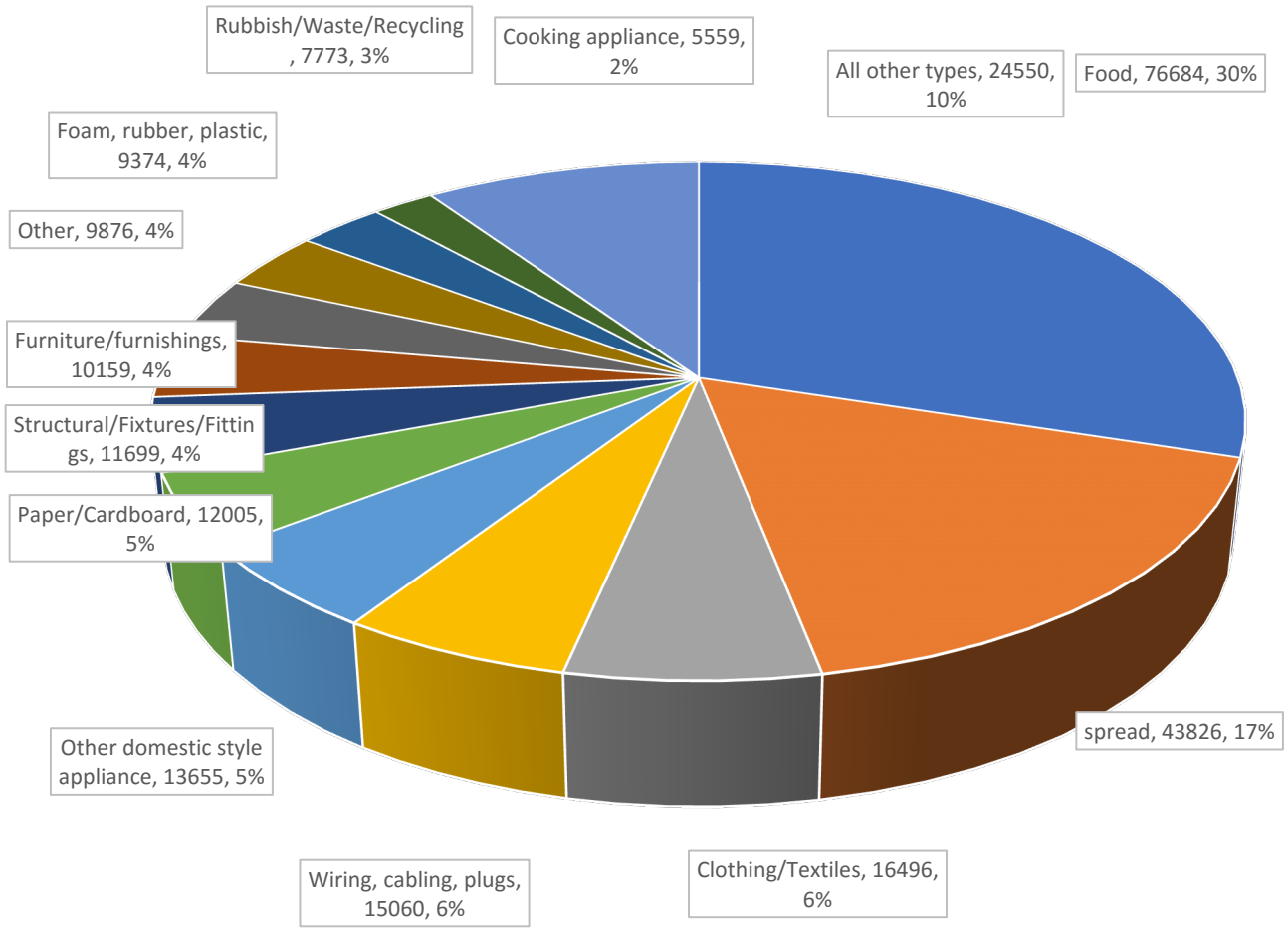
Figure 30: Material mainly responsible for fire spread (England 2010 to 2018, total fires 256,716)



Definition of overall fire type

In order to better understand ‘what is burning’, it possible to combine these four categories that describe the fire into a single definition of the overall fire type. The definition that it has been chosen to use is as follows. If the area of fire damage is greater than 5 m² (the smallest area category recorded in the fire statistics), then the fire is principally defined by the material responsible for spread. Alternatively, if the fire area is less than 5 m², then there is a further breakdown. If the main cause was due to a fault, then the fire type is defined by the source of ignition (which will generally either be wiring cabling or plugs, or a specific appliance or item). For other main causes, the fire type is defined by the material first ignited. Figure 31 shows the overall fire types, using this definition. As with similar charts, the commonest categories accounting for roughly 90% of all fires are shown explicitly, with the less common categories merged into a new category ‘All other types’.

Figure 31: Overall fire type (using definition above) (England 2010 to 2018, total fires 256,716)



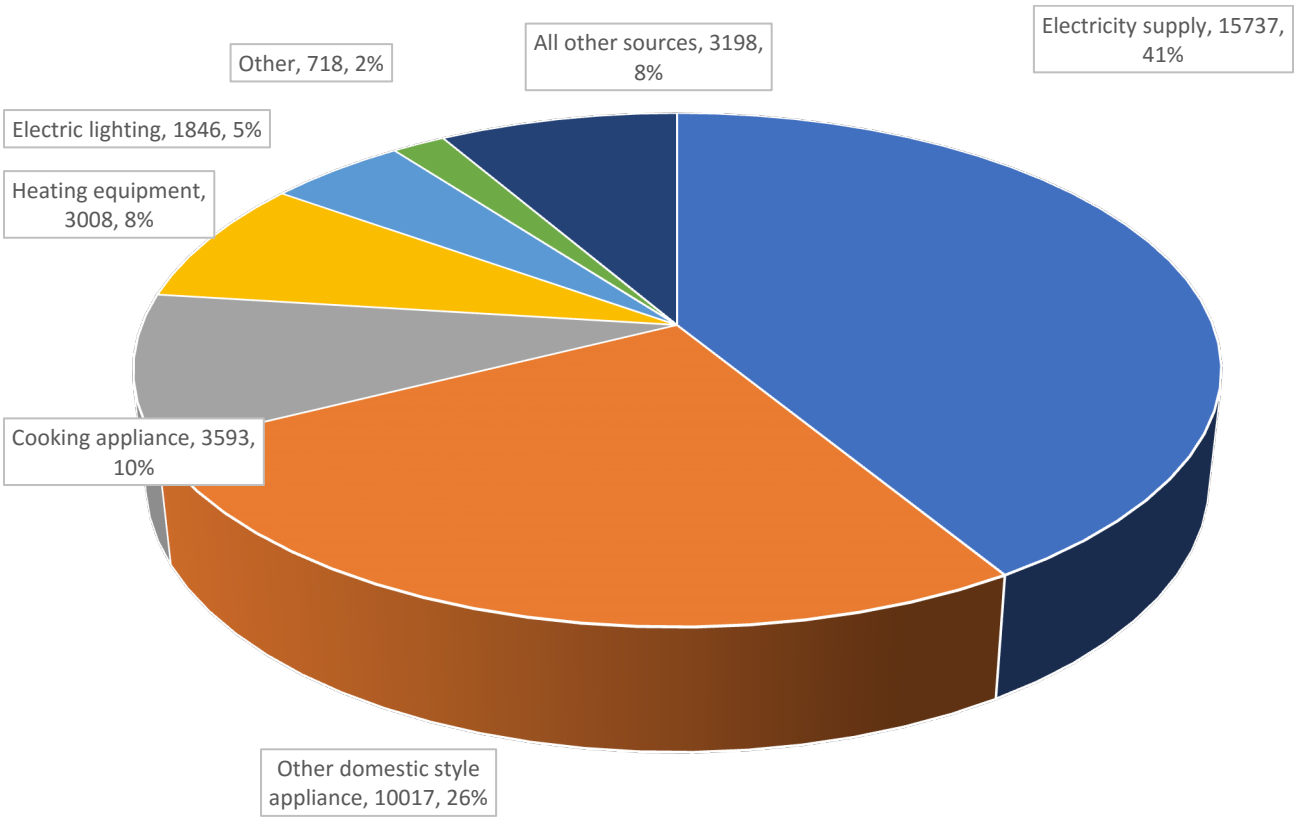
Ignition sources causing different materials to be ignited

Figure 32, Figure 33, Figure 34 and Figure 35 show the ignition sources, when different materials are ignited first. This information is valuable when considering what fire tests should be defined in different fire safety standards.

Ignition sources, when structure, fixtures etc ignited first (Internal structure etc only)

Figure 32 shows the ignition sources when structural fixtures and fittings are ignited first. This applies to internal structures only. As before, the chart explicitly shows the commonest types of ignition sources accounting for roughly 90% of all fires. The remaining 10% are merged into the new category ‘All other sources’. In approximately two-thirds of fires when structural fixtures or fittings are first ignited, the source is either the electricity supply, or other domestic style appliances. This pattern is the same as the source of ignition, irrespective of the material ignited.

Figure 32: Ignition sources where ‘structure’ is first ignited (England 2010 to 2018, total fires 38,117)



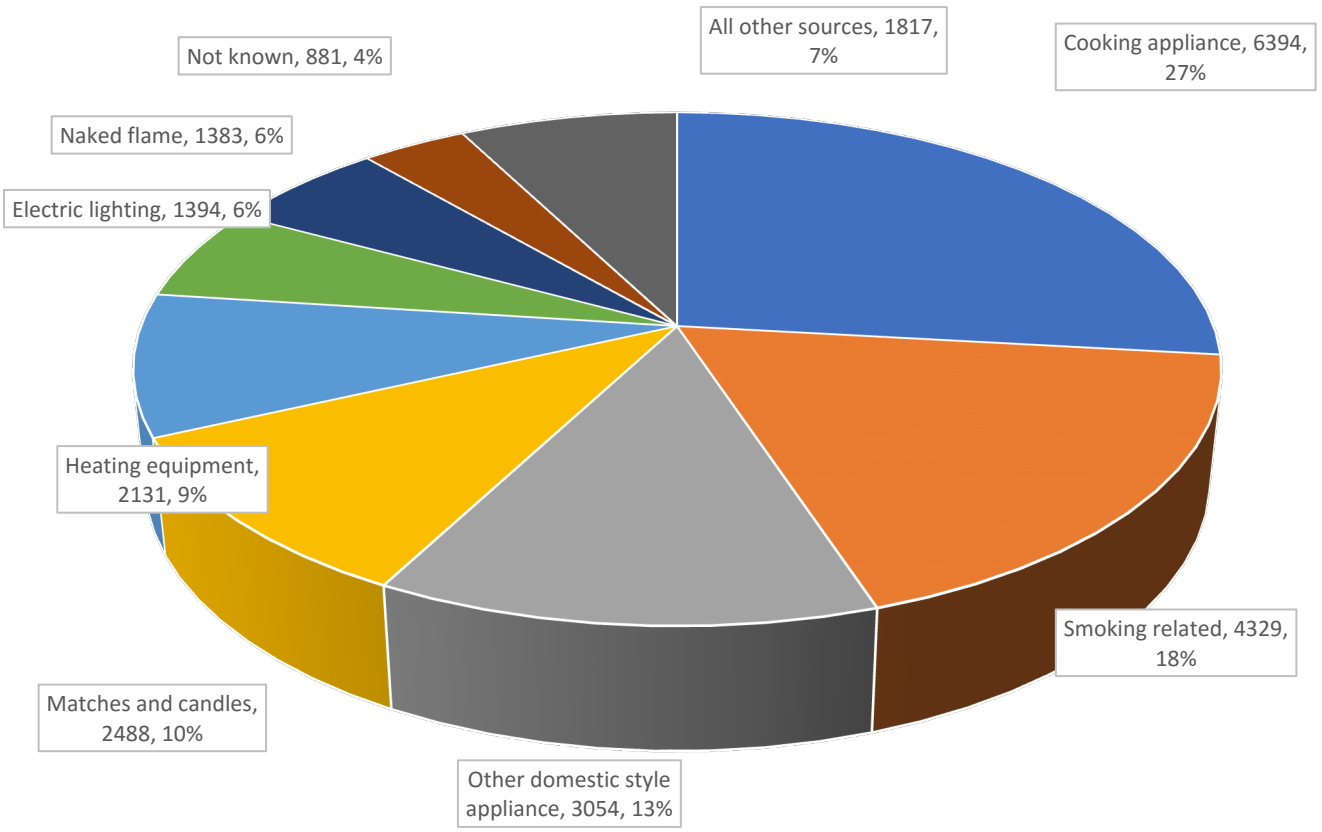
Ignition sources, when clothing or textiles ignited first

If clothing or textiles are ignited first, the most common ignition sources are cooking appliances, followed by smoking-related causes, then the generic category ‘other domestic style appliances’. Matches and candles, or heating equipment are also significant causes. In the case of cooking appliances, the scenario is most likely to be the case where clothing materials are left on something such as a hot cooker hob, see Figure 33.

The generic category ‘other domestic style appliances’ has not been examined in greater detail, but it would be reasonable to assume that washing machines, tumble dryers or combined washer/dryers would be the main sources of ignition.

Smoking-related items, matches, candles and other naked flames are all relatively small ignition sources, yet combined account for 34% of clothing and textiles fires.

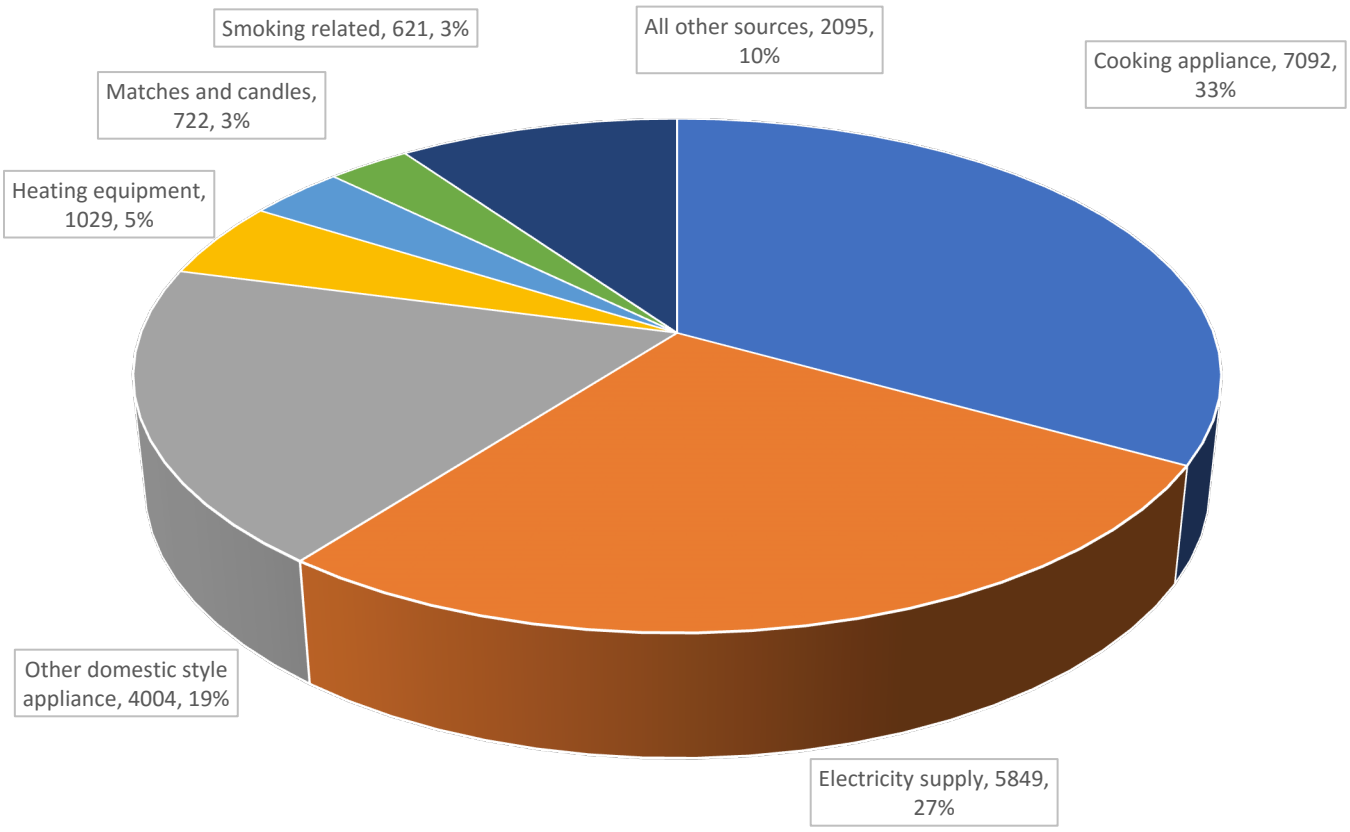
Figure 33: Ignition sources where ‘clothing/textiles’ is first ignited (England 2010 to 2018, total fires 23,871)



Ignition sources, when foam/rubber/plastics ignited first

When foam, rubber, or plastics are ignited first, the main ignition sources are either cooking appliances, or the electricity supply. Other domestic style appliances are also a significant source. It is quite often the case that the material ignited first is a constituent of the item ignited first, or of the ignition source itself, see Figure 34.

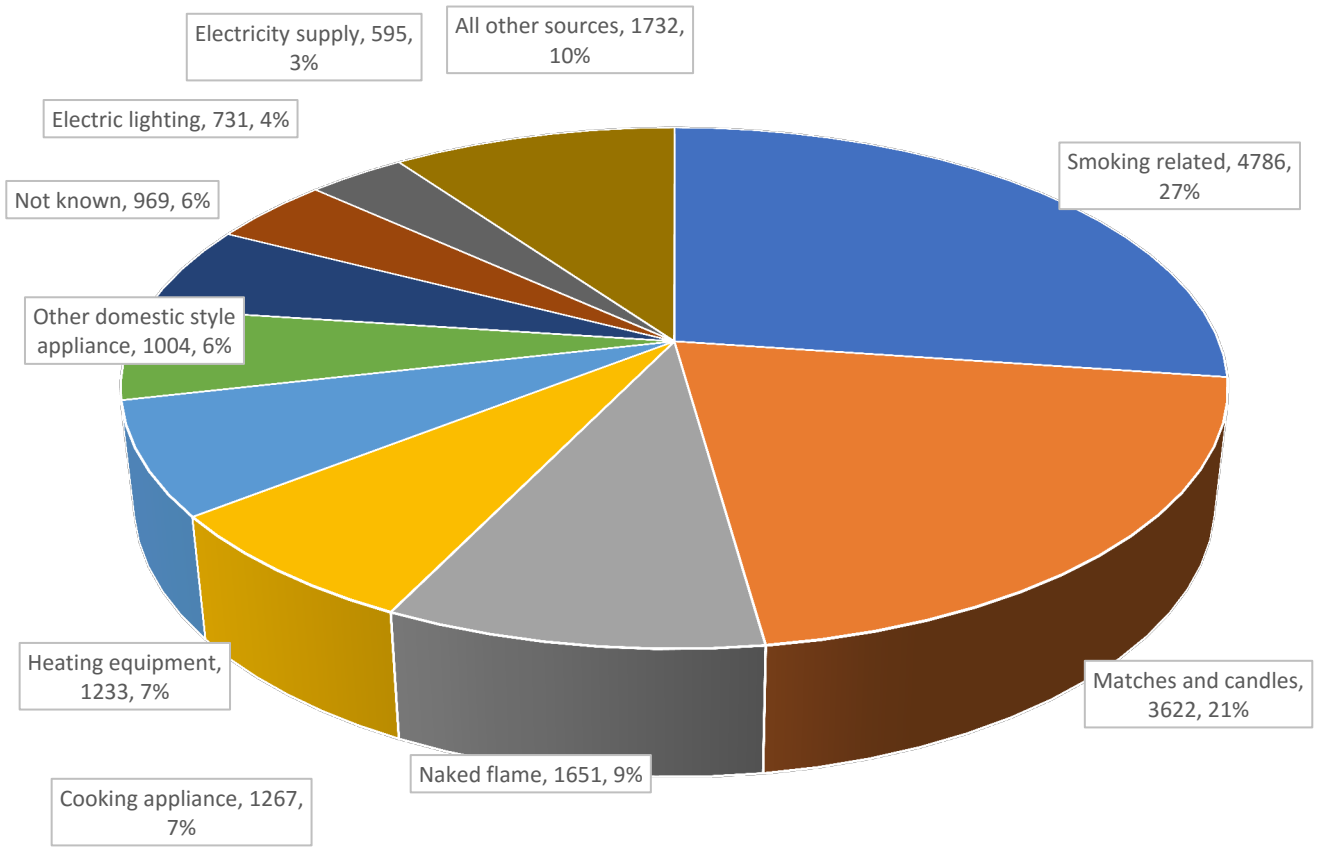
Figure 34: Ignition sources for 'foam/rubber/plastic (raw material)' ignited first (England 2010 to 2018, total fires 21,412)



Ignition sources, when furniture ignited first

Where furniture is the item first ignited, the main ignition sources are either smoking-related, matches and candles, or other naked flame. Combined, these account for over half of all furniture fires. This is a similar pattern to the ignition of clothing and textiles, except that cooking appliances are less significant sources of ignition, see Figure 35.

Figure 35: Ignition source when 'furniture' is first ignited (England 2010 to 2018, total fires 17,590)

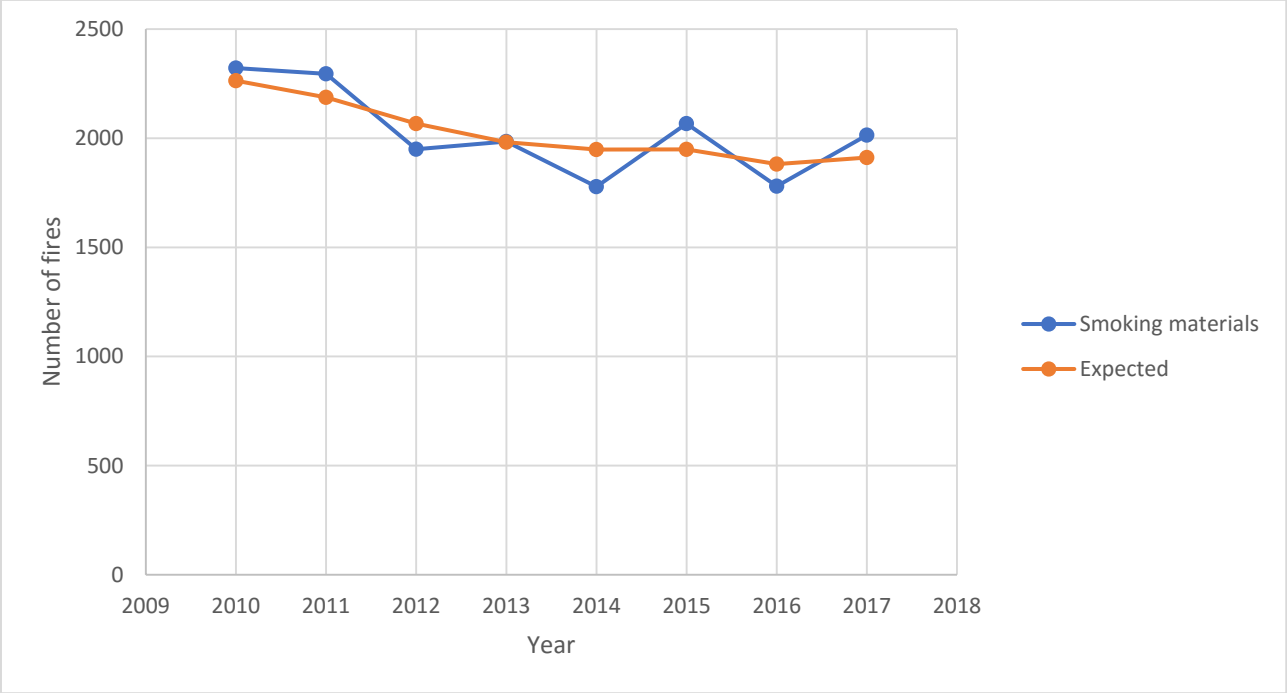


Ignition sources: annual trends

The following series of charts shows the annual trend in fires caused by different ignition sources. In each case the number of fires is compared against the expected number, if the proportion of fires caused by particular ignition source remained constant, and therefore, the number of fires follows the scaled trend for the overall annual total number of fires (Figure 20).

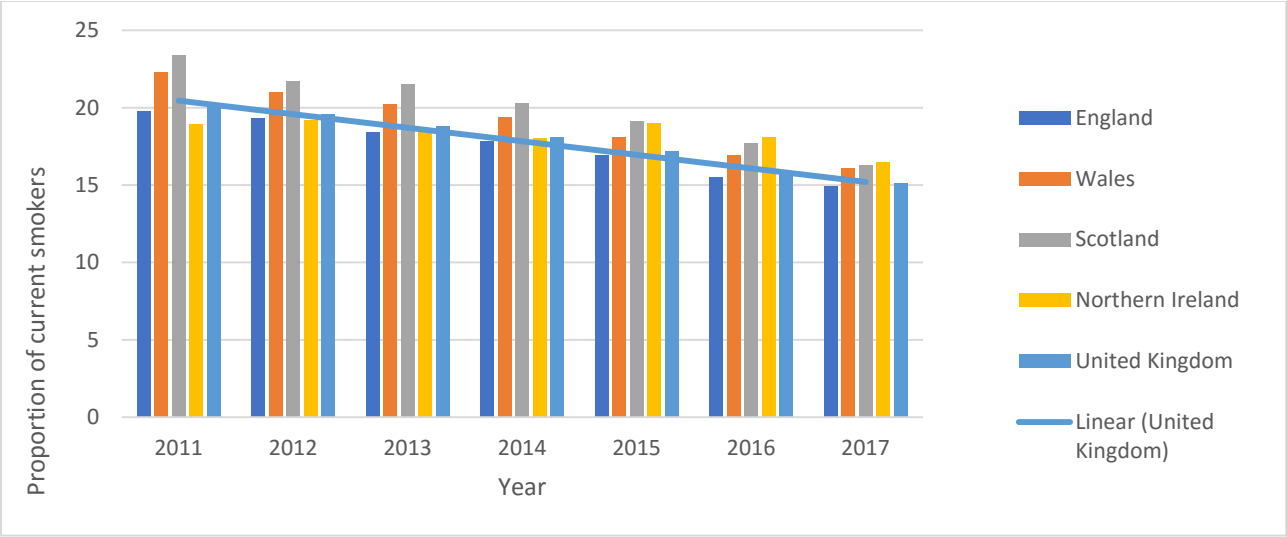
Figure 36 shows the trend for smoking materials as source of ignition. In this case the differences between the actual and the expected trend lines are not significant. Therefore, the proportion of fires caused by smoking materials has remained constant, even as the total number of fires has followed the average annual downward trend.

Figure 36: Annual trend in fires caused by smoking materials (England 2010 to 2018)



Note that the number of people who are smokers follows a similar downward trend[65], which may explain the observation above, see Figure 37 (redrawn and adapted by BRE Global from the referenced source).

Figure 37: Proportion who were current smokers, all persons aged 18 years and over in the UK 2011 to 2017[65]



[65] Office for National Statistics. Annual population survey. Available from https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/bulletins/adultsmokinghabitsingreatbritain/2017#the-proportion-who-are-current-smokers-in-the-uk-its-constituent-countries-and-local-areas-2011-to-2017

All the other charts in this sequence are considered to be statistically significant[66] in their difference between the expected trend line and the actual number of fires per year.

In general, there are three types of chart:

- The number of fires per year associated with a particular ignition source has increased in more recent years, or has remained constant, or declined more slowly than the expected trend. See Figure 38 (a) to (i).
- The number of fires per year associated with a particular ignition source has decreased more rapidly than the expected trend. See Figure 39 (a) to (h).
- The difference between the expected trend line and the actual number of fires per year is statistically significant, but there is no consistent trend unlike cases (1) and (2). In some cases of this third type, the actual trend may be U-shaped (or inverted U-shaped). See Figure 40. These trends are presented in Table 8.

Table 8: Examples of trends in numbers of fires with different ignition sources

Chart type	Ignition source
Increasing proportion of fires started by this source	Washing machine, Tumble dryer, PC equipment, Battery charger, Extractor fan, Candles, Batteries/Generator, Petrol/Oil, Barbeque
Decreasing proportion of fires started by this source	Fridge/freezer, Dishwasher, Other domestic style appliance, Grill/toaster, Naked flame, Matches, TV set, Lighting (other)
U-shaped trend in proportion of fires started by this source	Fireworks

Fires in appliances do not show a uniform trend. Fires where the ignition source was a washing machine or tumble dryer have remained constant in number (an increasing proportion) whereas the numbers of fires started by a fridge/freezer, dishwasher or other domestic appliance have been declining.

Fires in consumer electronics products show increasing trends for PC equipment and battery chargers. The latter is a strong trend even though the absolute number of fires involved is not that large. Fires started by television sets have declined strongly. This may be due to a combination of the phasing out of old cathode-ray tube sets (which have higher internal voltages) and replacing them with flat screens, or a general decline in the number of households with televisions as downloading programmes via the internet becomes more prevalent.[67]

Fires started by naked flames (other) or matches have declined, which probably reflects the decline in smoking, and also a switch from conventional to e-cigarettes. However, the number of fires started by candles has remained constant.

Fires starting by washing machines and tumble dryers are both increasing as a proportion of all fires. Note that it is not known if washing machines or tumble dryers have become inherently more dangerous, or there are simply larger numbers of these appliances in dwellings in England. A third possibility is that the number of washing machines and tumble dryer fires has remained constant while other types have declined.

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66 95% level of significance, as determined by a chi-squared test, with 7 degrees of freedom.

67 BBC. Number of UK homes with TVs falls for first time, 9 December 2014. Available from https://www.bbc.co.uk/news/entertainment-arts-30392654. Last accessed June 2019.

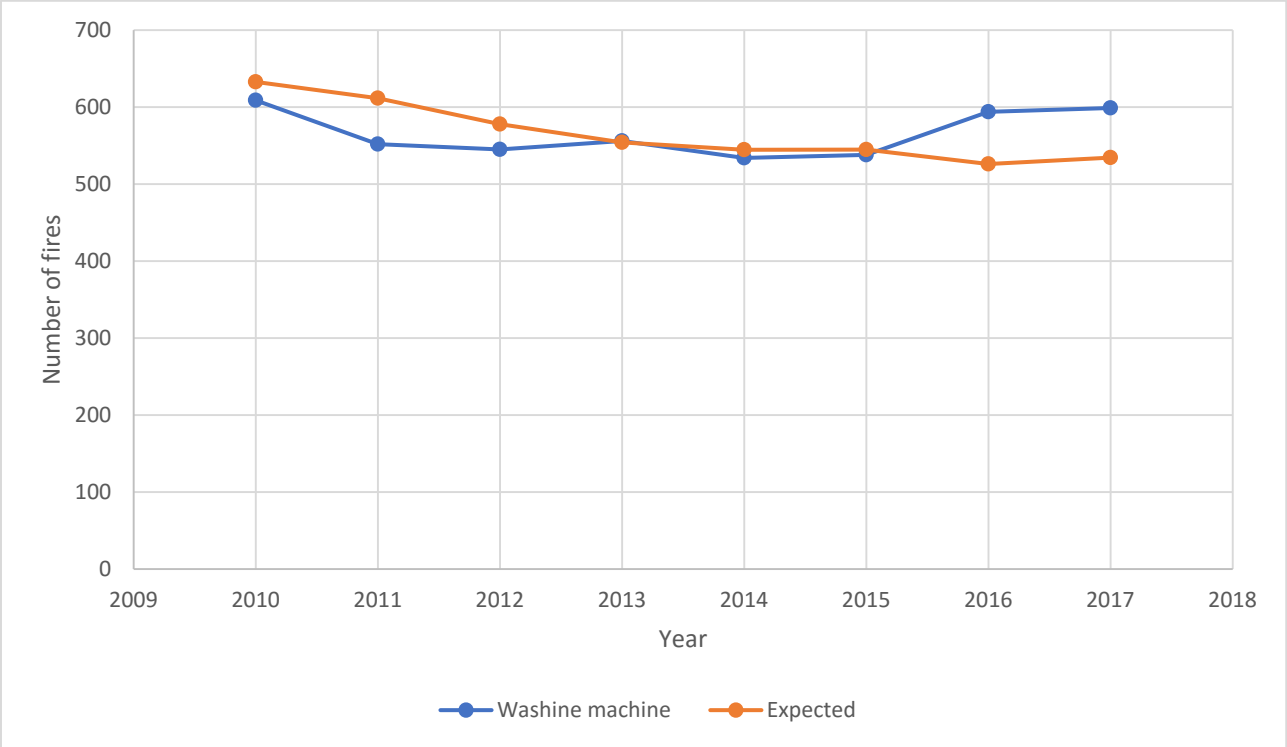
Fires started by PC equipment also shown an increasing trend line, as opposed to the expected decline with the proportion constant. Again, this may be due to increasing numbers of households having such equipment, rather than any change in the safety of individual items.

It should be noted that the statistics record many types of ignition source, and these graphs are only showing those where a statistically significant difference from the expected trend has been observed. Therefore, there are number of forms of lighting which may act as ignition sources, but only in the case of 'lighting (other)' is there a notable trend. Different forms of lighting (specified in the fire statistics) do not show any statistically significant annual trends.

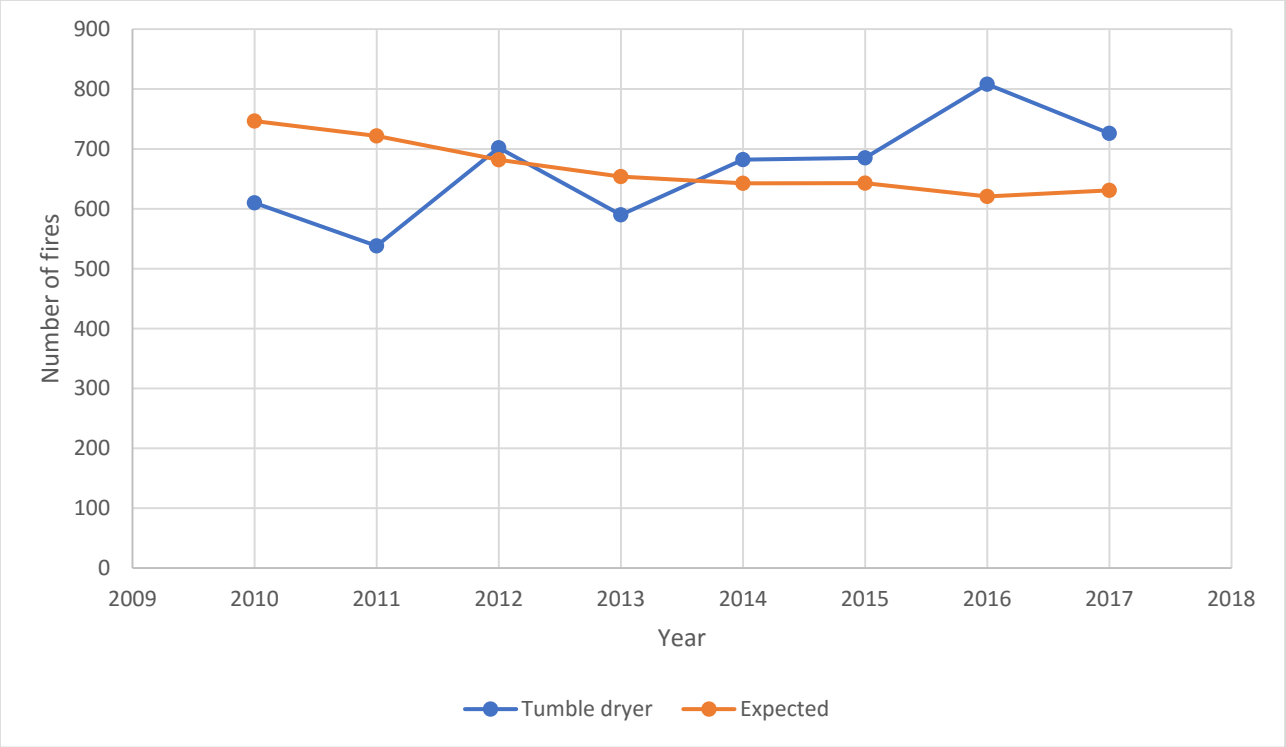
Ignition sources becoming more prevalent

Figure 38: Ignition sources becoming more prevalent (England 2010 to 2018)

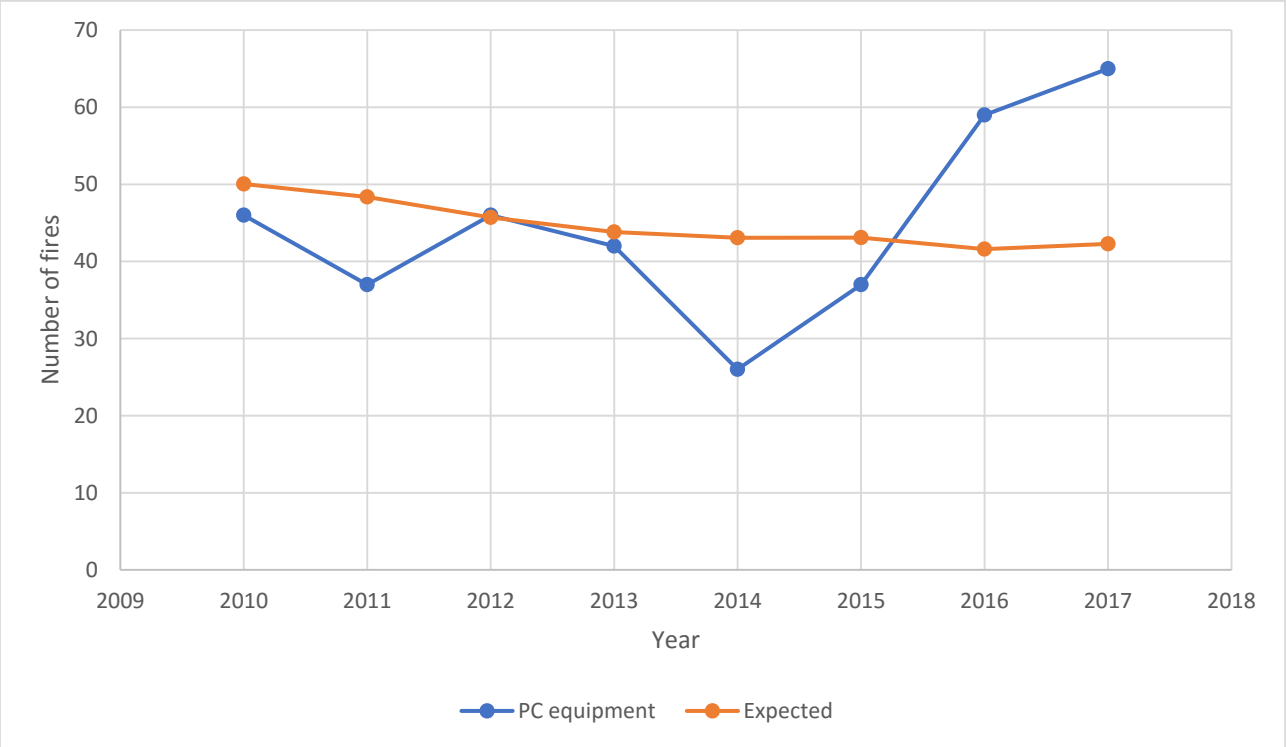
(a) Annual trend of fires caused by washing machines



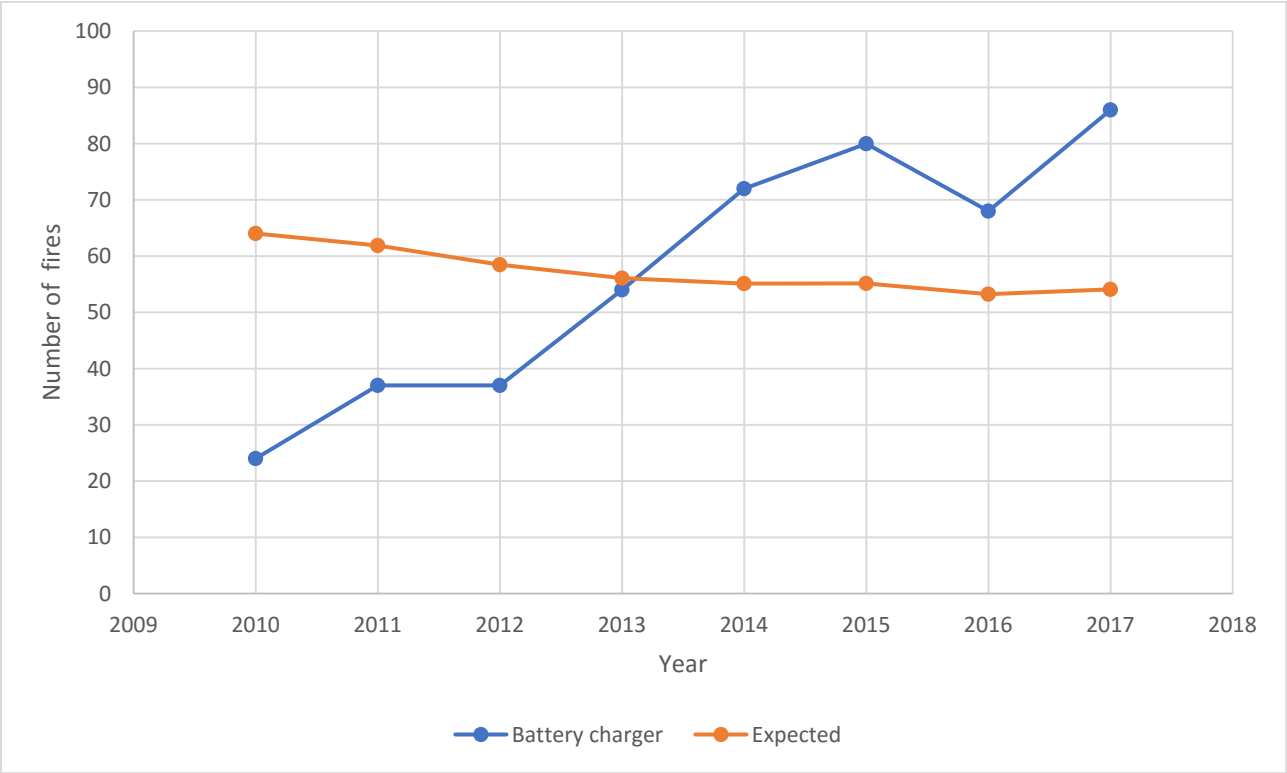
(b) Annual trend of fires caused by tumble dryers



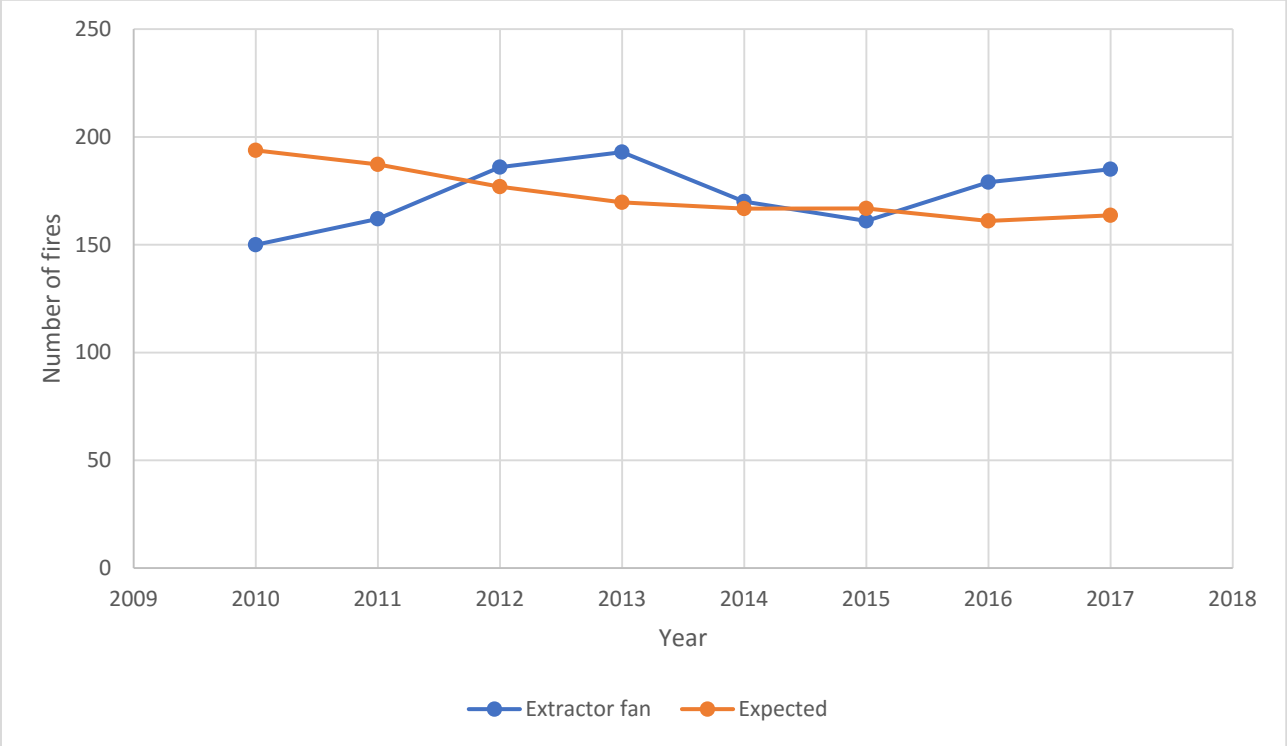
(c) Annual trend of fires caused by PC equipment



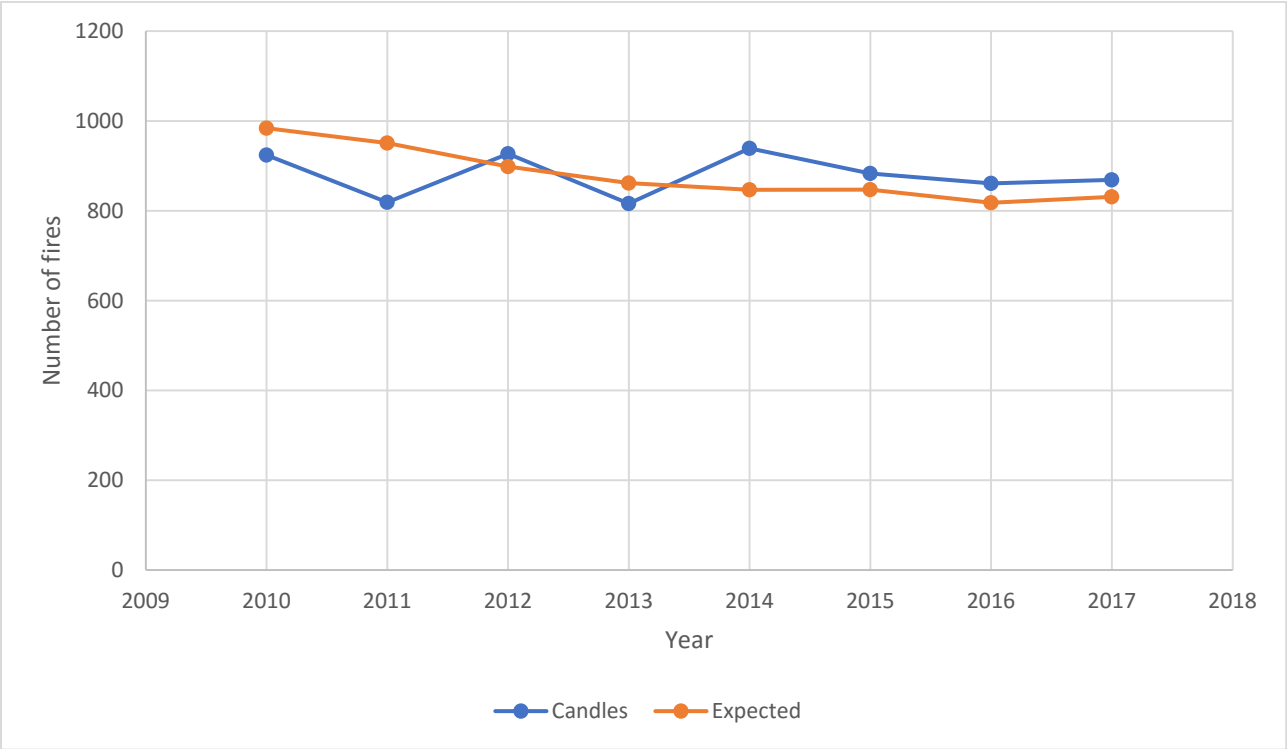
(d) Annual trend of fires caused by battery chargers



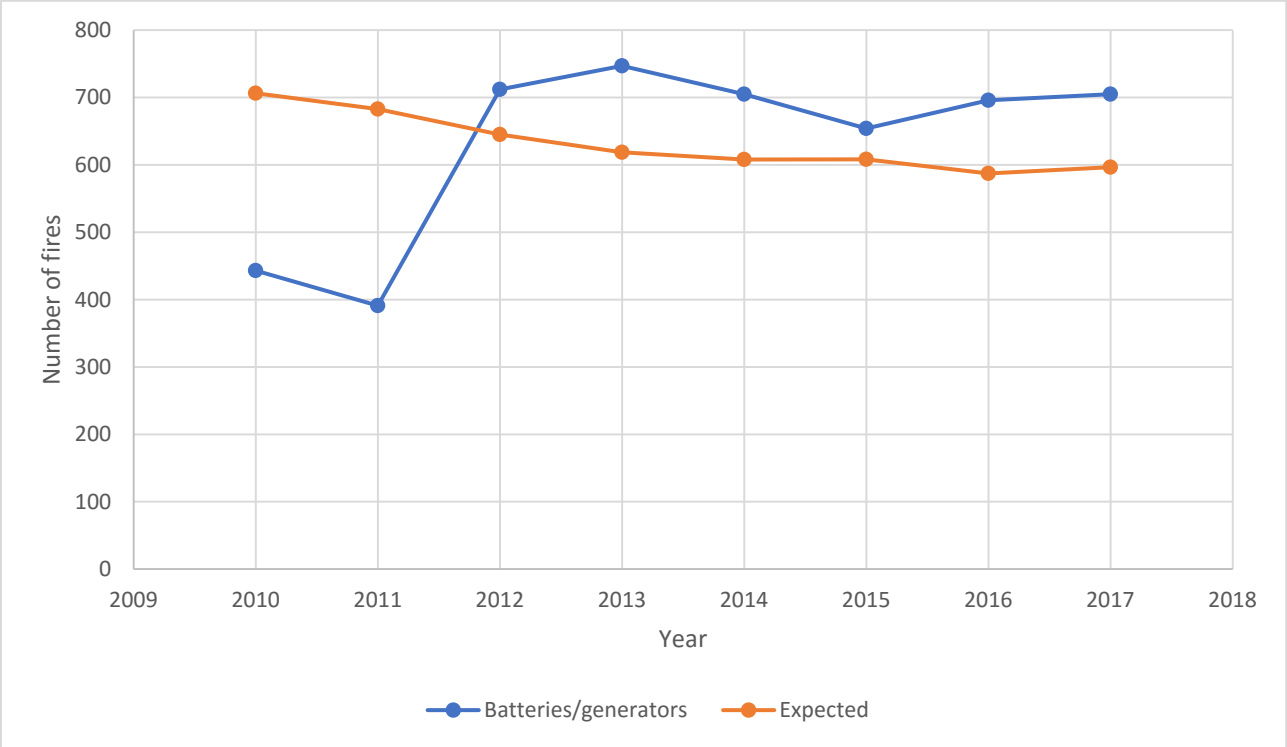
(e) Annual trend of fires caused by extractor fans



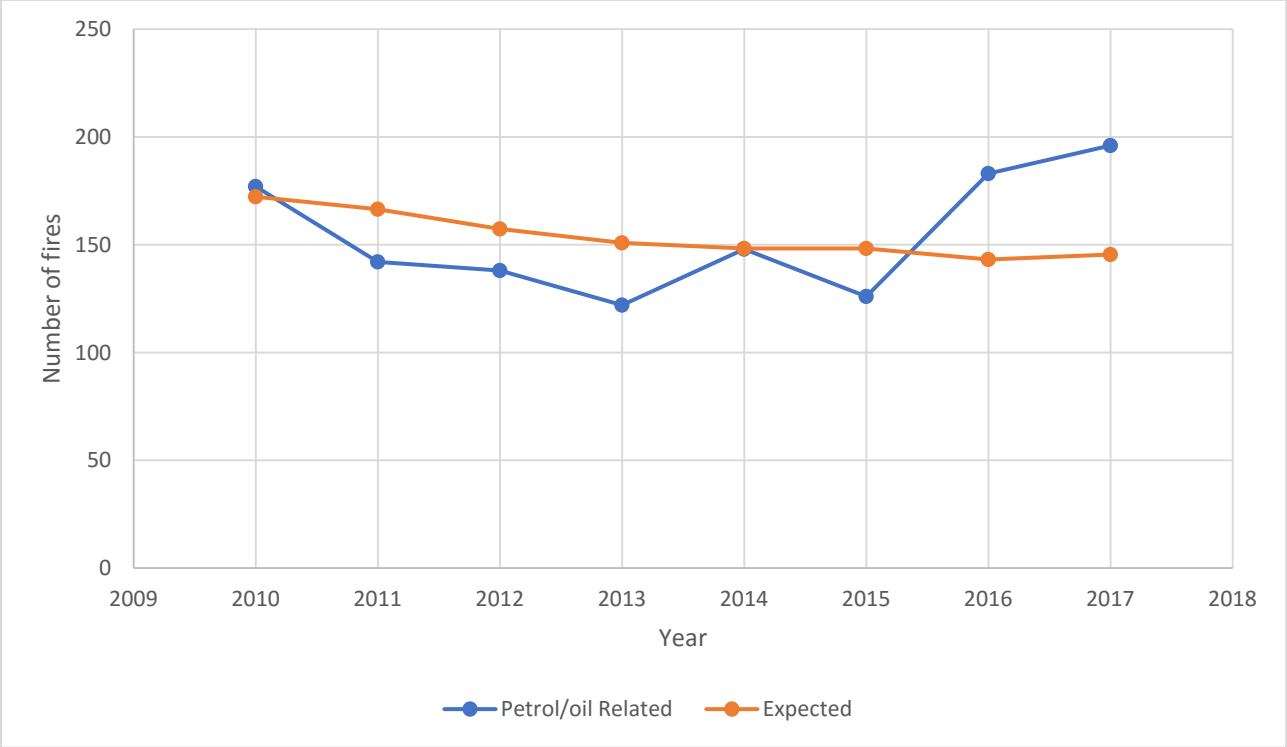
(f) Annual trend of fires caused by candles



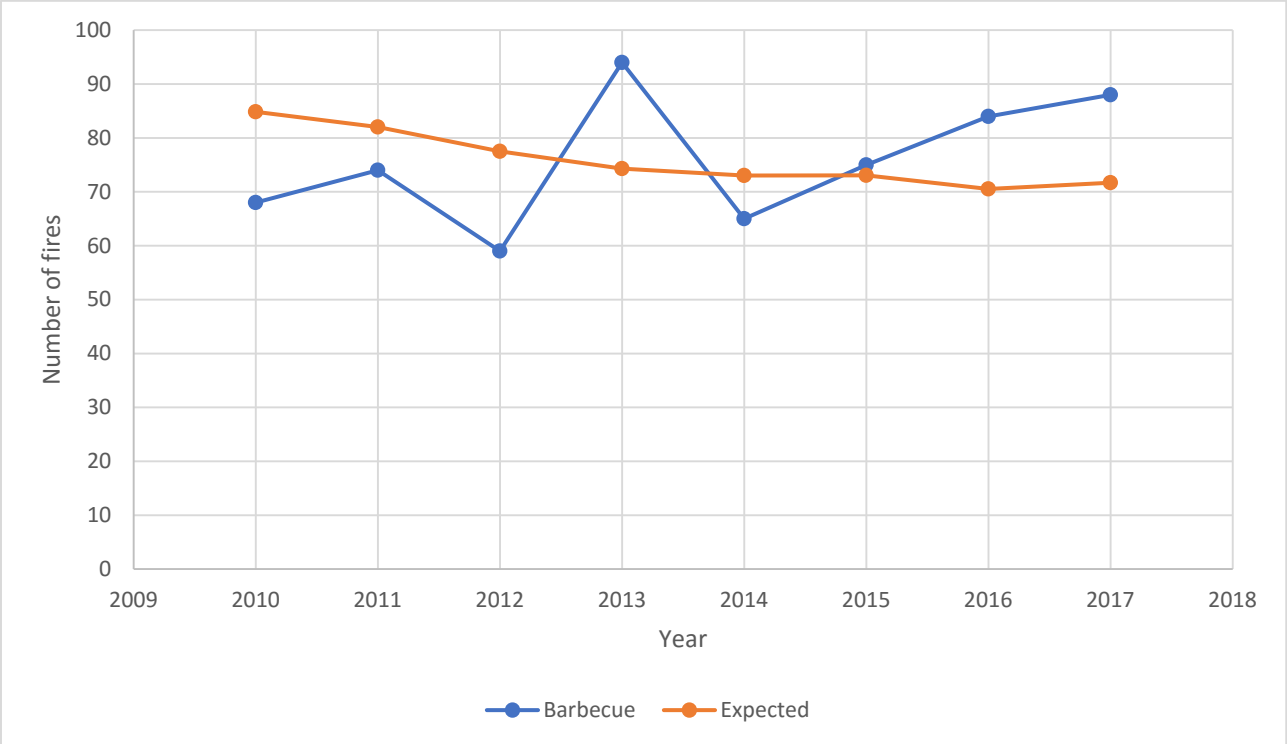
(g) Annual trend of fires caused by batteries/generators



(h) Annual trend of fires related to petrol/oil



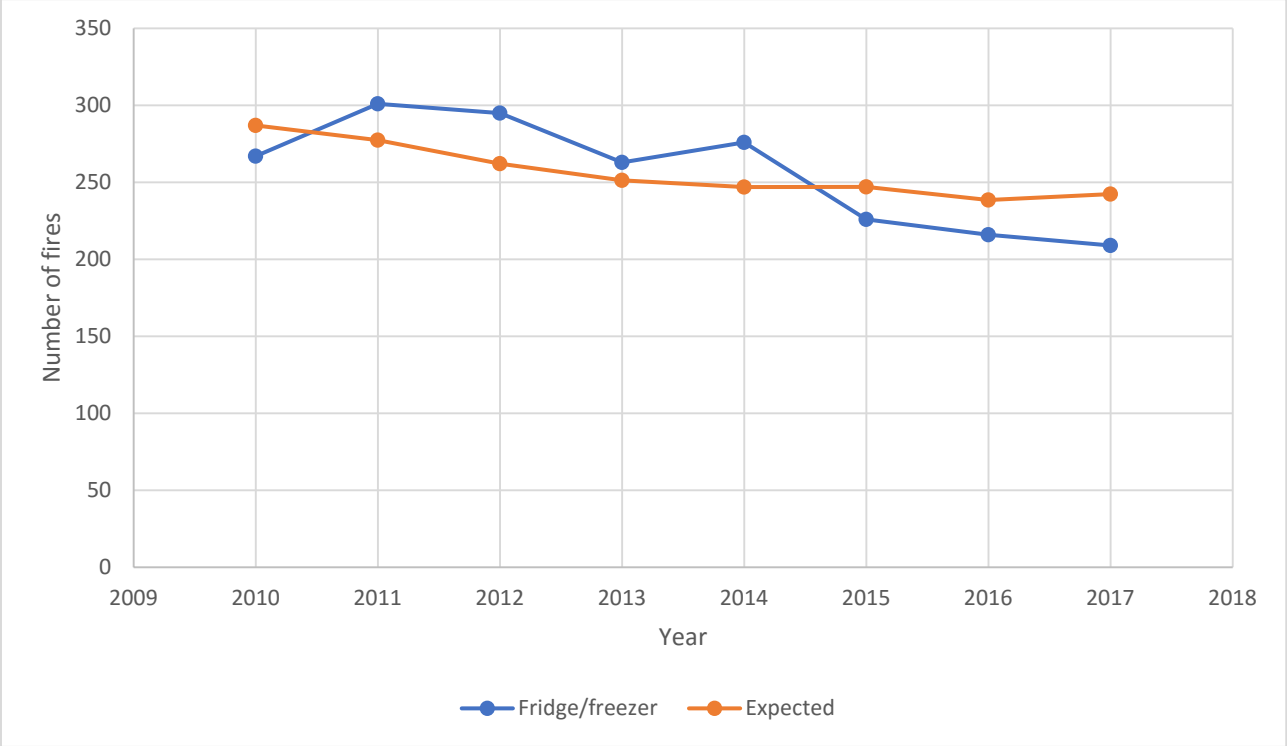
(i) Annual trend of fires caused by barbecues



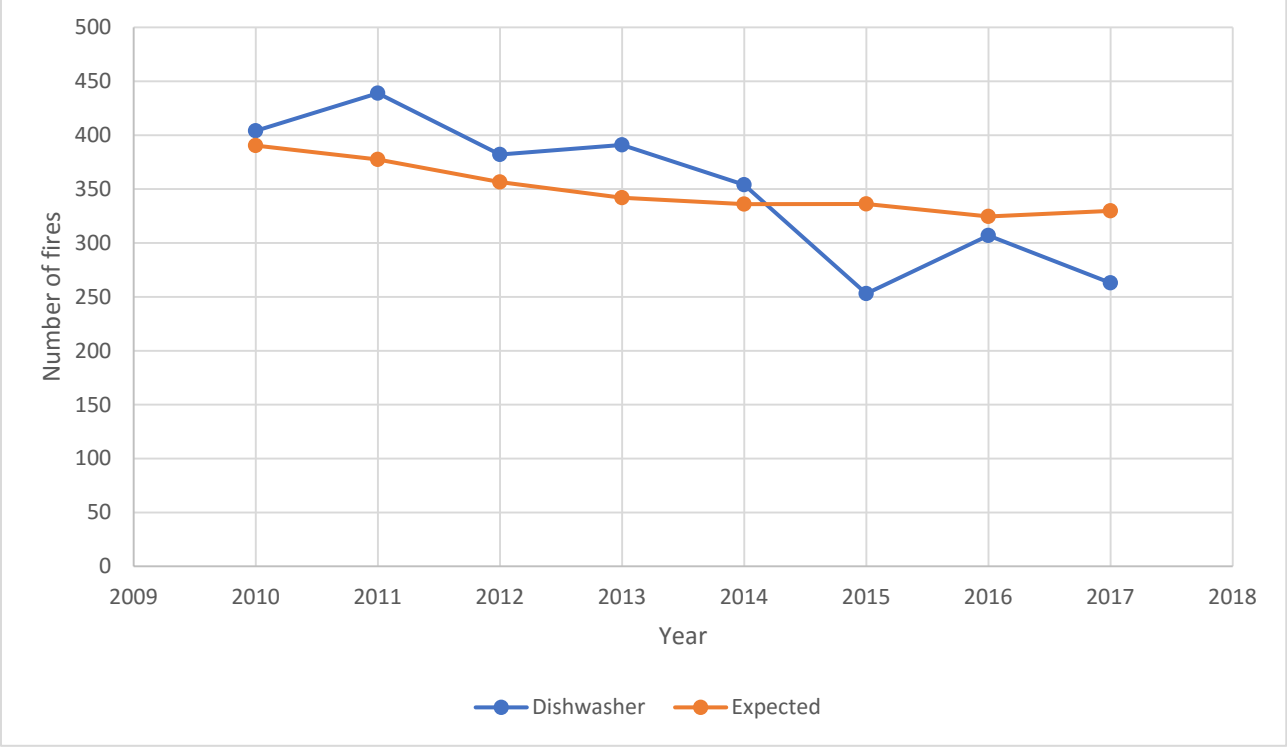
Ignition sources becoming less prevalent

Figure 39: Ignition sources becoming less prevalent (England 2010 to 2018)

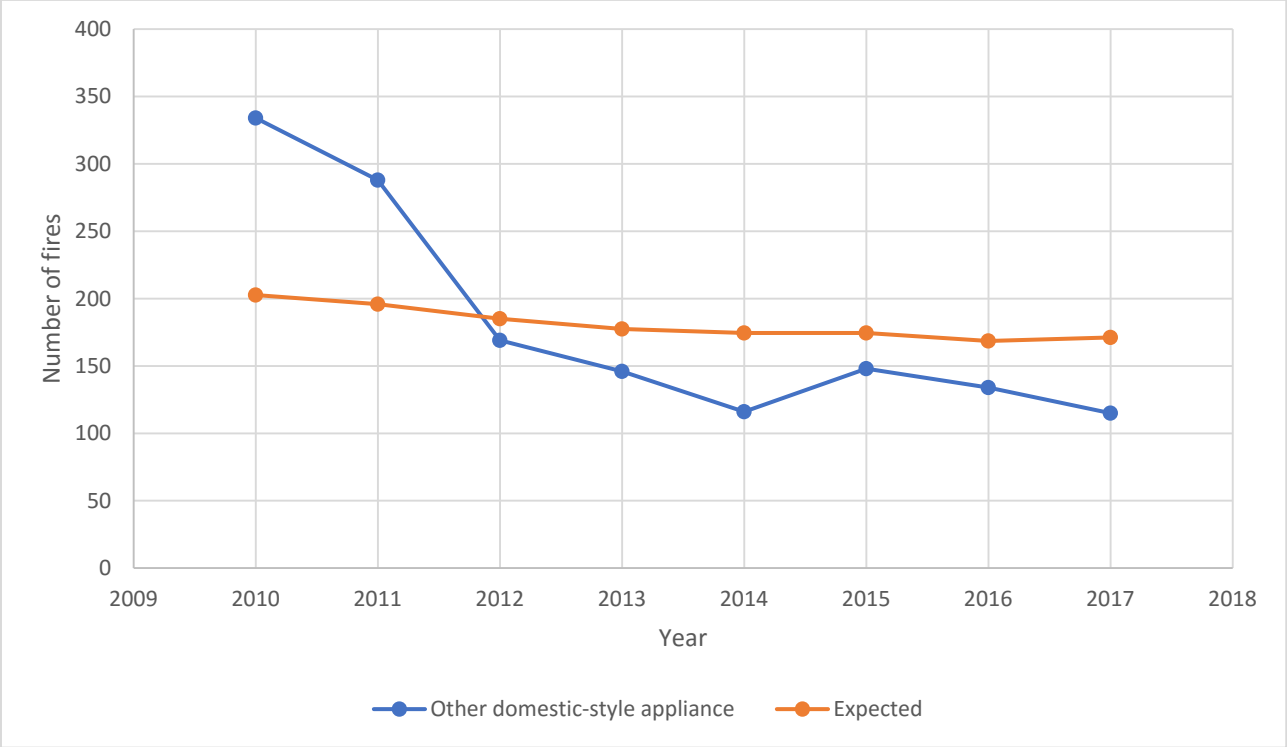
(a) Annual trend of fires caused by fridges/freezers



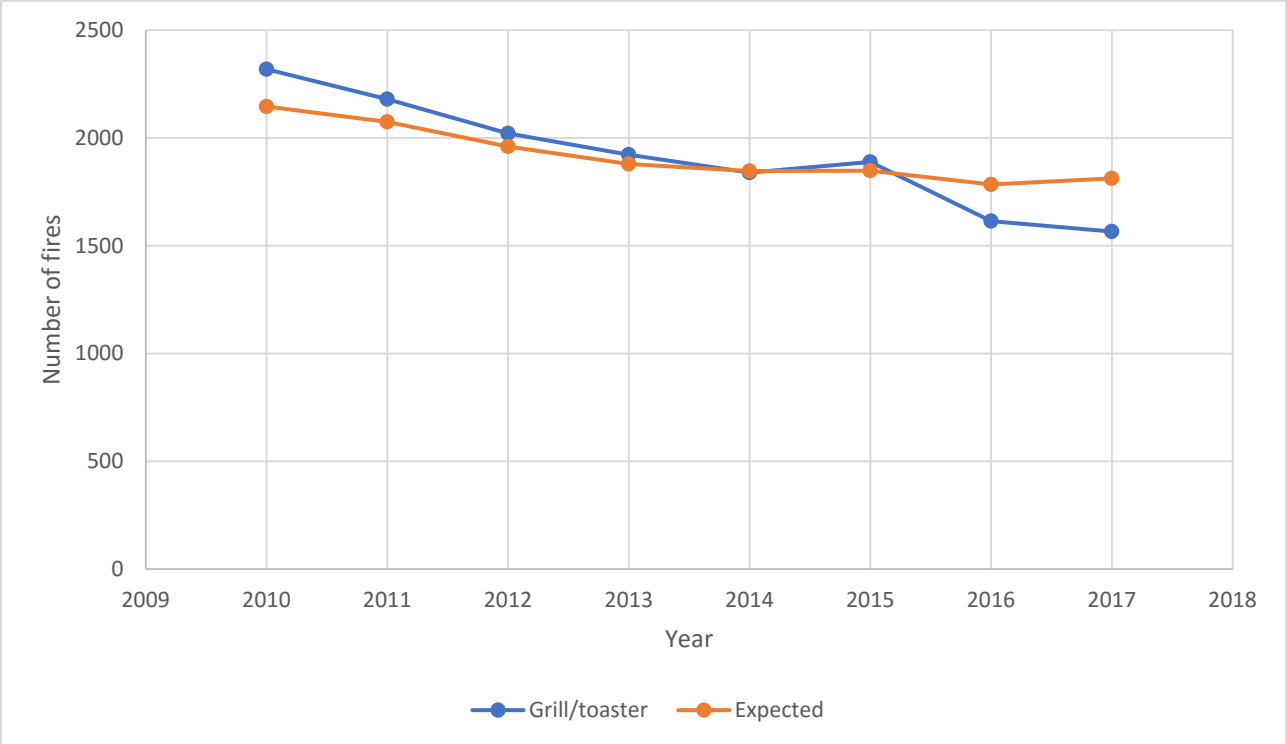
(b) Annual trend of fires caused by dishwashers



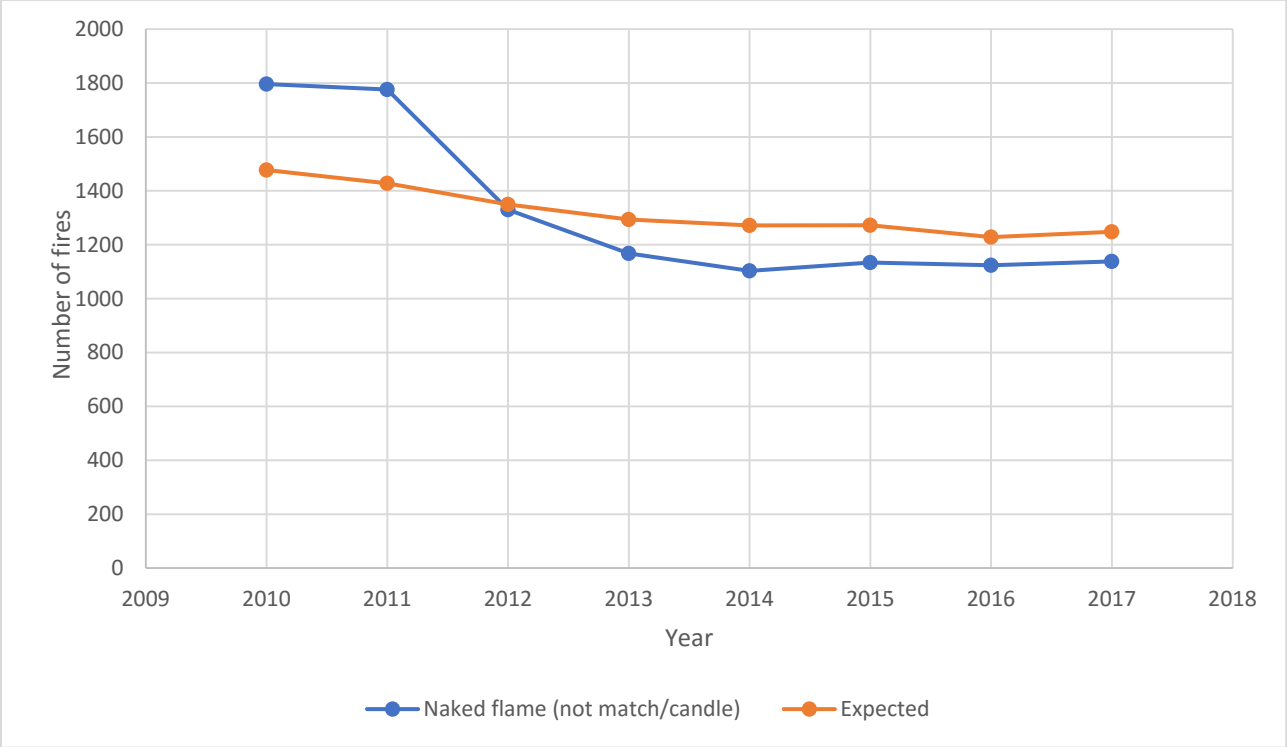
(c) Annual trend of fires caused by other domestic style appliances



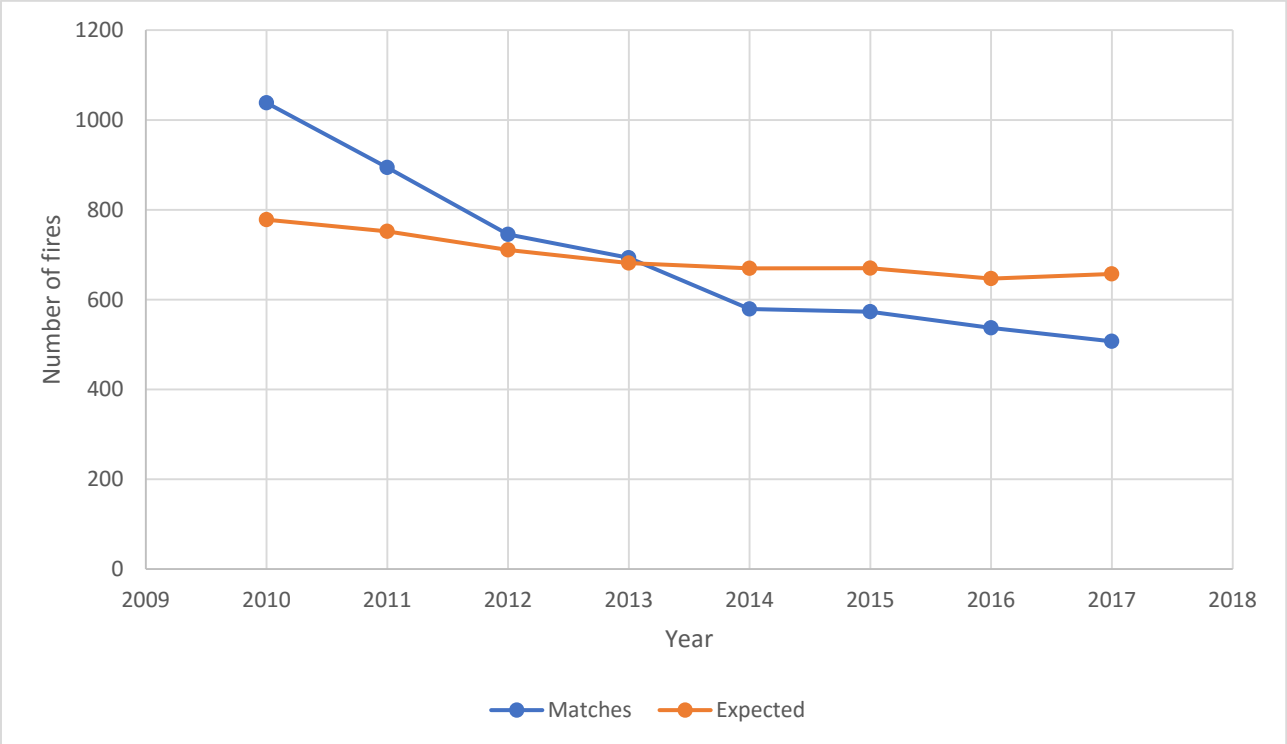
(d) Annual trend of fires caused by grills/toasters



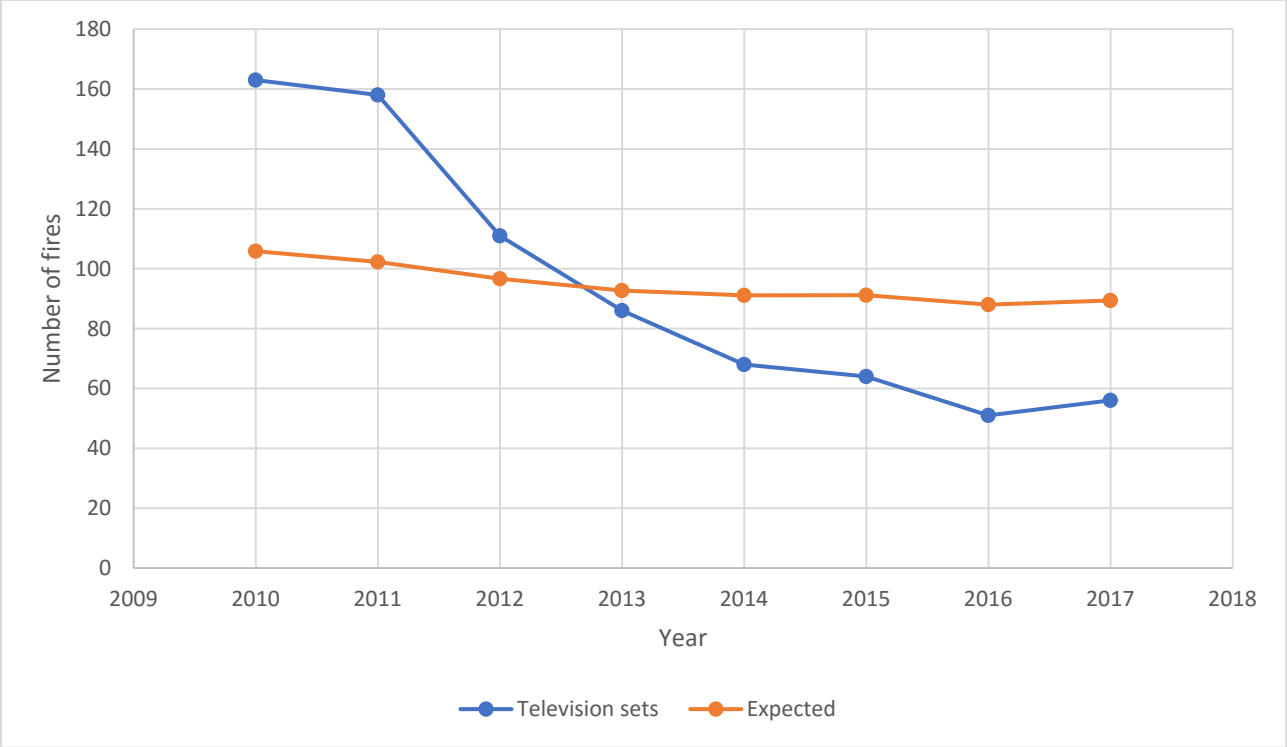
(e) Annual trend of fires caused by naked flames (not matches/candles)



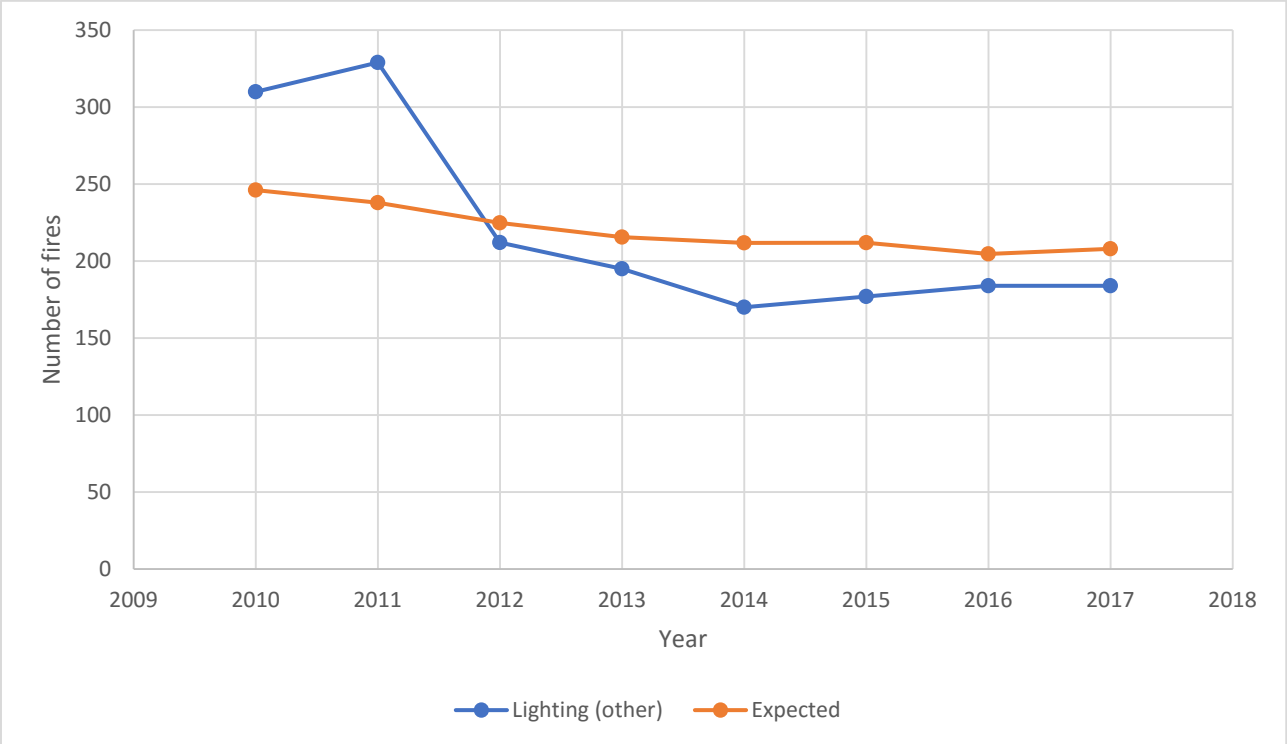
(f) Annual trend of fires caused by matches



(g) Annual trend of fires caused by television sets

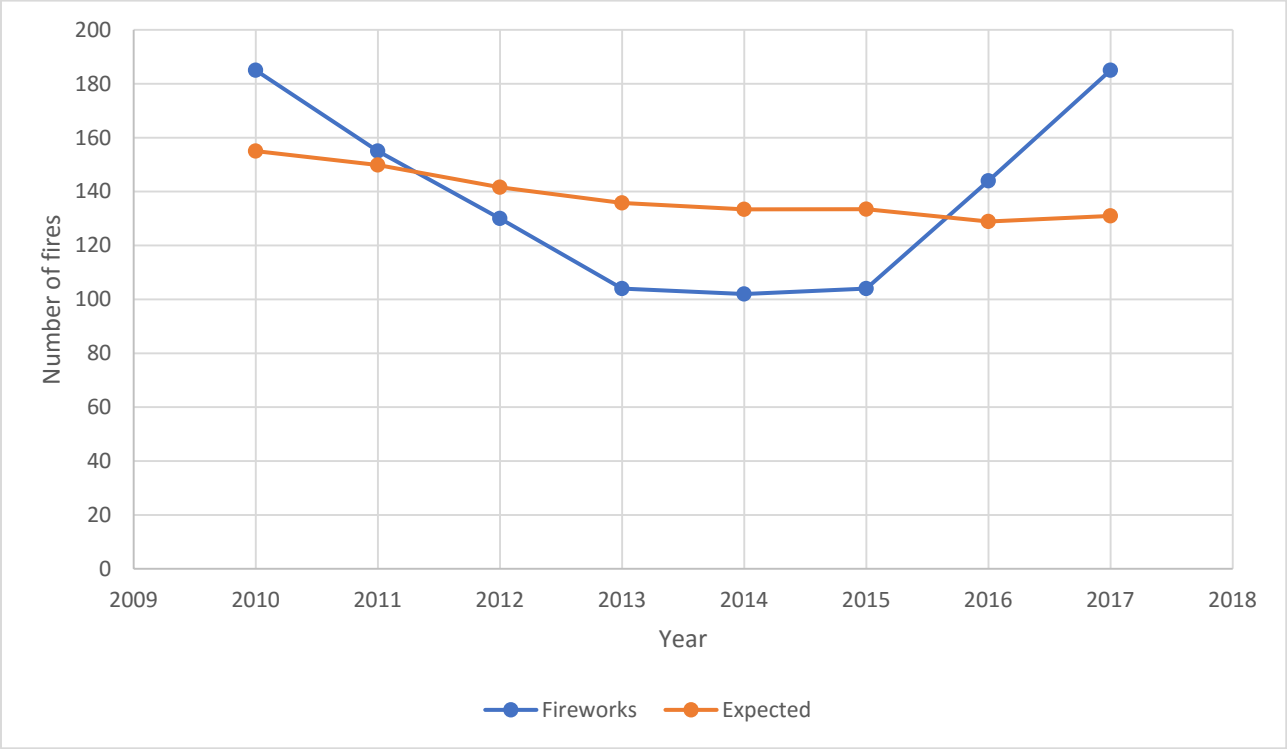


(h) Annual trend of fires caused by other lighting



Ignition sources showing other statistically significant trends

Figure 40: Annual trend of fires caused by fireworks (England 2010 to 2018)



Analysis of ‘other’ ignition sources: example of e-cigarettes

The Incident Recording System for the fire statistics has drop-down menus that enable the most common ignition sources to be selected. Less common items are all included in the ‘other’ category which represents approximately 1% of all fire incidents. In these cases, there is an associated free-text field, which can be completed if the ignition source is known but not in the drop-down menu.

As an example, the free text fields of the ‘other’ ignition sources have been looked at and those where electronic cigarettes are mentioned have been selected. This exercise highlights a number of interesting points. Firstly, it should be noted that there is a considerable range of different text fields all describing the same thing and reflecting what different individuals have chosen to record. In this case it was relatively easy to identify electronic cigarettes. This was achieved by searching a text string ‘e-cig’, see Table 9. Even so, there is still one instance where a spelling mistake (‘E-cigarette’) could have led to an incident being overlooked.

The next interesting point to note is that in the first two years (2010/2011 and 2011/2012), there were no recorded instances of fires being ignited by electronic cigarettes. In 2012/13, there were two incidents, and thereafter there were approximately 10 incidents per year. The London Fire Brigade Investigation Team first attended a fire attributed to an electronic cigarette in April 2014.

Table 9: E-cigarettes

Row Labels	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	Grand Tota
batteries in e cig							1		1
E Cig			1				1	1	3
E Cig Charger						1			1
E cigarette				1	2		3	1	7
E cigarette charger					1				1
E Cigarette in charger					1				1
E Cigarette on charge							1		1
e cigerette charging lead								1	1
e ciggarette					1				1
E-caigarette							1		1
e-cig on charge							1		1
ecigarette				1		1		1	3
E-cigarette							2		2
E-Cigarette (E Go-T)				1					1
E-cigarette battery							1		1
e-cigarette charger					1	1	1	1	4
e-cigarette used with incompatible charger				1					1
e-cigarrete				1					1
e-cigerette							1		1
E-Ciggarette vapouriz						1			1
Electric Cigarette				1					1
ELECTRICAL CIGARETTE ON CHARGE TO MAINS SOCKET				1					1
Electronic Cigarette				2			1		3
electronic cigarette charger								1	1
Electronic cigarrette					1				1
electronic cigerette					1				1
electronic vapour cigarette							1		1
Mirage E-Cig rechargable battery				1					1
other appliance or equipment - e-cigarette						2			2
Other appliance or equipment - e-cigarette charger						1			1
Other appliance or equipment - Re-chargeable E-Cigarette				1					1
Rechargeable electronic cigarette			1						1
Smoke related - ecigerette					1				1
smoking cigarettes						1			1
Smoking related - ECigarette/Vapouriser charging cable								1	1
TOTAL	**0**	**0**	**2**	**11**	**9**	**8**	**15**	**7**	**52**

What is unable to be determined purely from the fire statistics is whether electronic cigarettes are much safer than ordinary cigarettes, even though all ordinary cigarettes on sale now should be of the reduced ignition propensity type, or whether many fires involving electronic cigarettes are simply being recorded as smoking materials, and not specifically electronic cigarettes.

However, other statistics estimate that the number of people currently vaping is about one-third of the number smoking[68]. Another source presents data for the prevalence of smoking in the adult population in England, being virtually zero at mid-2011 and rising linearly to about 5% of the adult population by first quarter of 2015[69]. On the other hand, the number of fires per year ignited by 'smoking materials' is nearly 200 times those where e-cigarettes are explicitly

[68] Office for National Statistics. Adult smoking habits in the UK: 2017, July 2018. Available from https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/bulletins/adultsmokinghabitsingreatbritain/2017#the-proportion-who-are-current-smokers-in-the-uk-its-constituent-countries-and-local-areas-2011-to-2017. Last accessed June 2019.

[69] McNeill A, Brose L S, Calder R, Hitchman S C, Hajek P (Chapters 9 and 10), McRobbie H (Chapters 9 and 10), E-cigarettes: an evidence update, a report commissioned by Public Health England, published August 2015. PHE publications gateway number 2015260. Available from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/733022/Ecigarettes_an_evidence_update_A_report_commissioned_by_Public_Health_England_FINAL.pdf. Last accessed June 2019.

mentioned under the ‘other’ ignition source category, or 100 times where e-cigarettes are mentioned anywhere.

Looking at the ‘make or model’ field associated with fires ignited by smoking materials, there were 16,191 fires in all, of which 15,780 had ‘null’ recorded in the make or model field, and 27 made reference to e-cigarettes. For ‘other appliance or equipment’, e-cigarettes were mentioned in 8 out of 1,324 fires, and for ‘battery charger’, e-cigarettes were mentioned in 27 out of 458 fires (therefore, with 52 fires from the previous page, giving a total of 114 fires where e-cigarettes were mentioned anywhere).

If the number of fires due to e-cigarettes and ordinary cigarettes is simply proportional to the number of vapers or smokers, then if there are roughly 2,000 fires per year attributed to smoking materials, there should be over 600 per year due to e-cigarettes. Instead, the statistics only record about 20 per year.

It seems reasonable to conclude that e-cigarettes have a significantly reduced likelihood of starting a fire, compared to the risk from conventional cigarettes.

Overall, there were approximately 2,500 fires (about 1% of the total) where the ignition source was classed as ‘other’. It was very hard to discern any particular trends regarding ‘other’ ignition sources. In part this was due to the inconsistencies in spellings of the free text fields, as shown by the electronic cigarettes example, and in part also due to the small numbers of fires involved.

A relatively large fraction (roughly half) of fires classed as ‘other’ could have been categorised as one of the options defined by the drop-down lists in the IRS, judging from the content of the free text fields. However, as the number of ‘other’ fires is only 1% of the total number of fires, this should not introduce significant error in this analysis of defined categories.

It is not known how many of the fires classified by one of the defined categories should have used the ‘other’ category and supplied further details via the associated free text field. This may introduce significant errors when trying to analyse the ‘other’ text field to discern emerging trends. Indeed, a trend cannot emerge until the specific item starts to be recorded using the ‘other’ text field.

It should be mentioned that in drop-down categories such as ‘lighting (other)’ or ‘heating (other)’, the free text field is not used to provide further details (although there is another free text field, ‘Make or Model’, which may help in this regard). The free text is only used where the drop-down category is ‘other’.

In an ideal world, the free text fields would be used wherever the drop-down menu is not fully specific but would not be used if an appropriate drop-down menu category was available.

Fire-damaged area

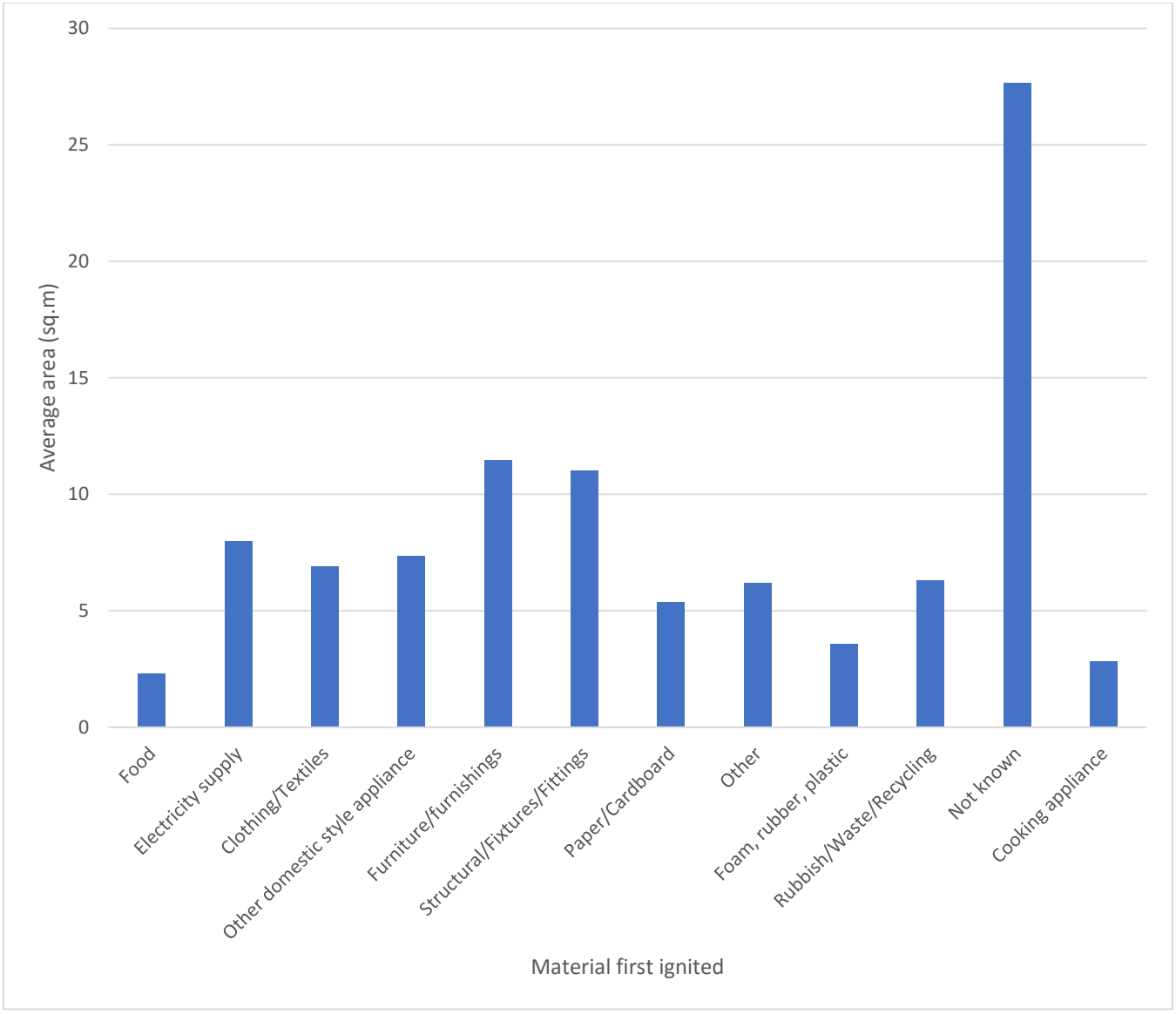
In addition to looking at the causes of fires, their consequences have also been examined. As mentioned in the introduction to this analysis of the fire statistics, the consequences have been restricted to the area of fire damage; other consequences have been shown to be strongly correlated with this value.

Average area of fire damage

Figure 41 shows the average area of fire damage for different materials first ignited. Cooking fires where food is ignited do relatively little damage. Fires where the cause is unknown, or those where furniture or furnishings are ignited first, cause the greatest area damage.

Note that, because the smallest fire area recorded in the IRS (apart from 'heat/smoke damage only') is '0-5 m^2', the actual average fire area may be overestimated.

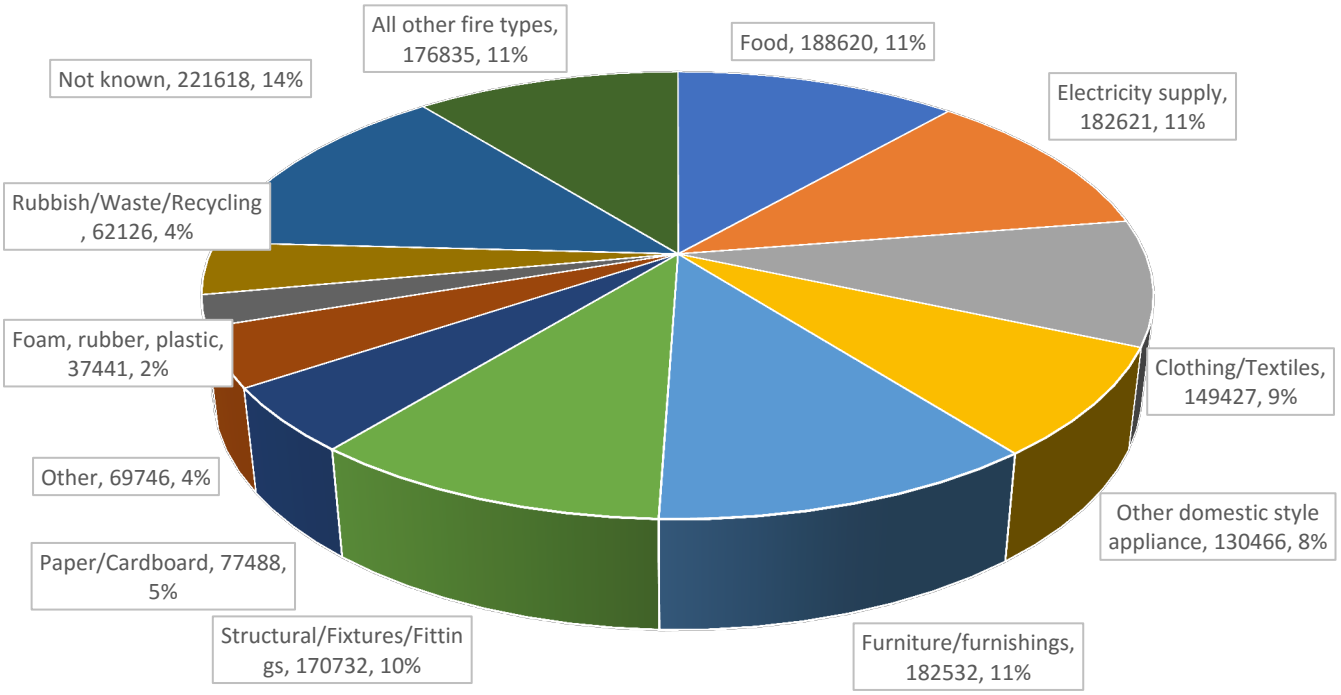
Figure 41: Average area of fire damage (England 2010 to 2018)



Contribution to overall fire damage from different fire types

Figure 42 shows the contribution to the overall total fire damage caused by different fire types. Note that, although cooking fires are the most common cause (36% of all fires, see Figure 29), they only account for about 10% of the total area of fire damage. This is because these fires tend to cause less damage the other types of fires.

Figure 42: Contribution to total area of fire damage (England 2010 to 2018, total area damage 1,649,652 m^2)



Impact of Fire and Rescue Service response time

It was suggested by a Stakeholder Group member that the average fire area might increase in line with an increase in the average Fire and Rescue Service response time. Figure 43 shows the annual trend in the average response time. Overall, there has been an increase of about 30 seconds, approximately 6%, from 2010/2011 to 2017/2018. The response time is defined as the difference between the time of arrival at the fire of first appliances, and the time of the first call alerting the Fire and Rescue Service[70].

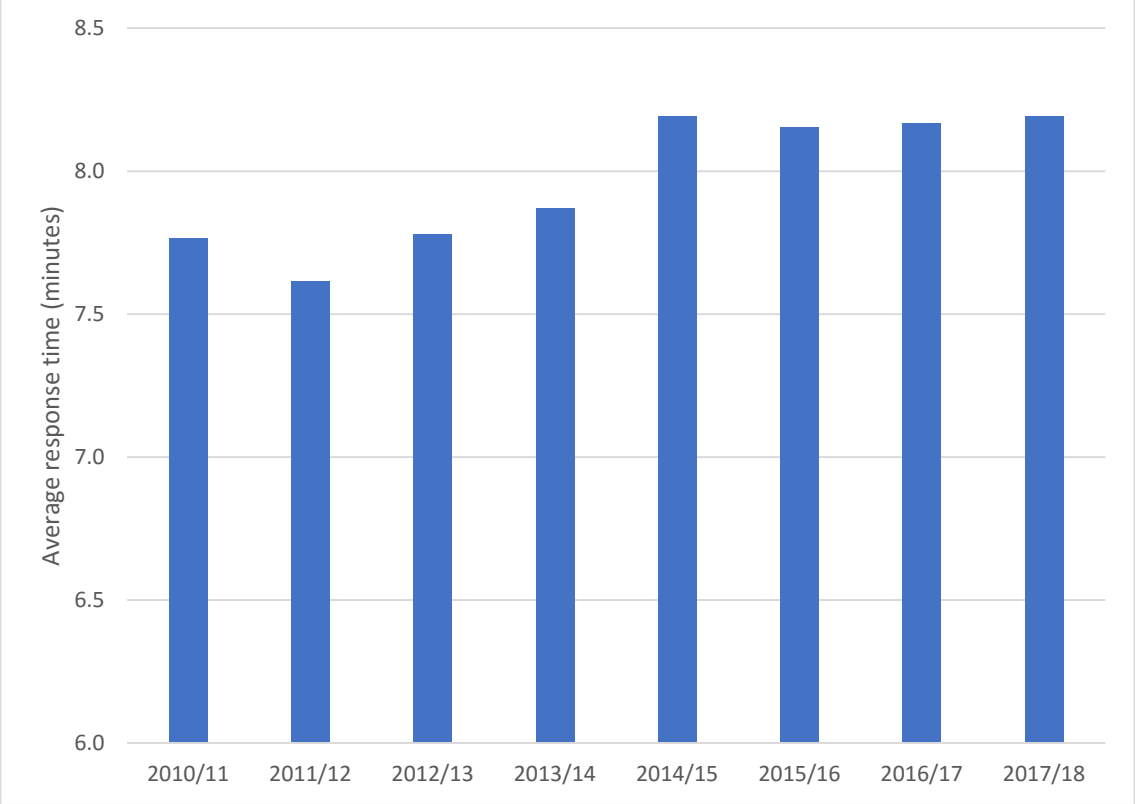
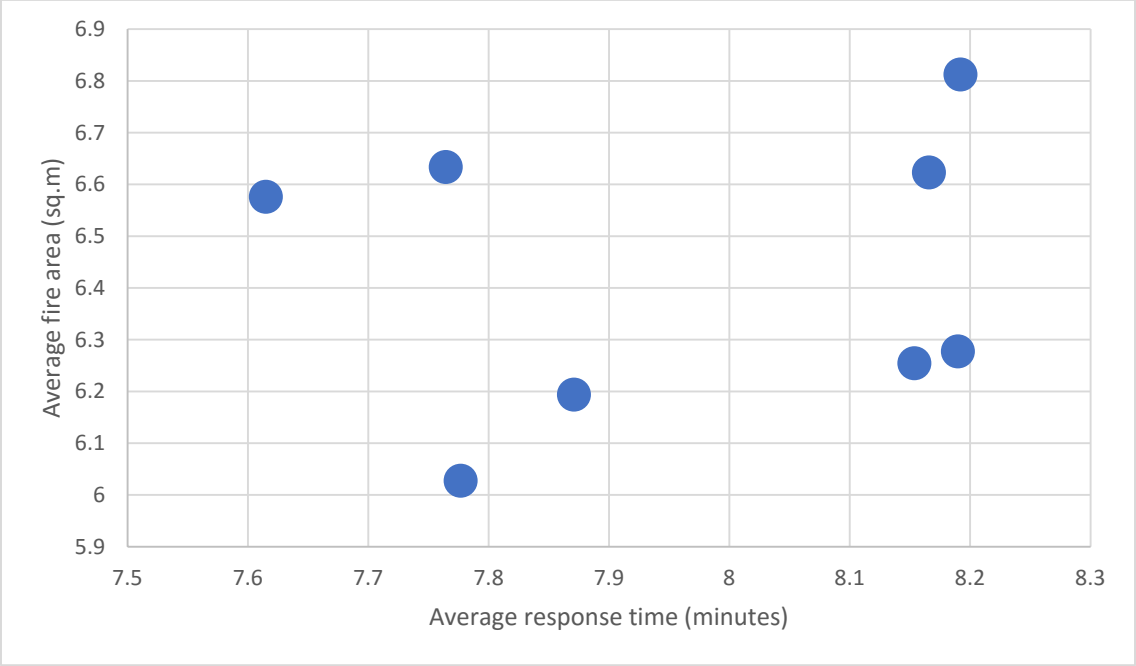


Figure 43: Average Fire and Rescue Service response times (2010/2011 to 2017/2018)

When the average fire area for all fires in a year is plotted against the average response time for that same year, there is no apparent correlation, see Figure 44.

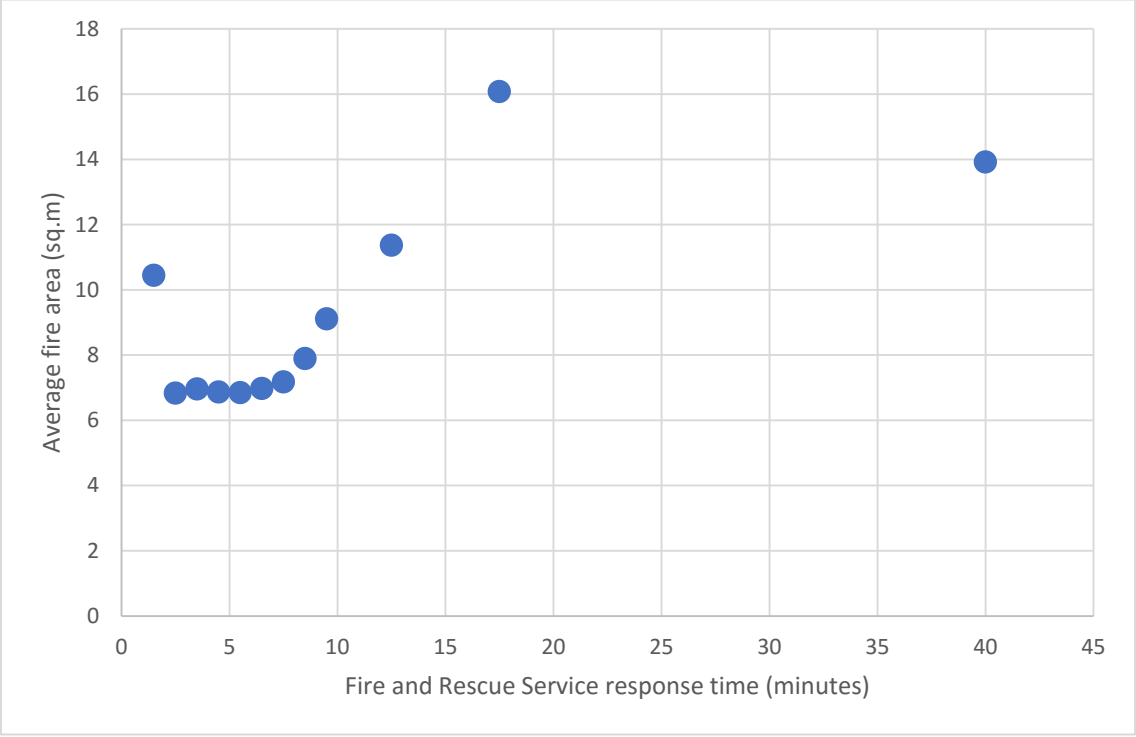
[70] Publishing Incident Recording System data on the fire and rescue service at an Incident Level: Dwelling Fires Dataset Guidance, produced by the Fire Statistics team, FireStatistics@homeoffice.gsi.gov.uk, first publication: 27 April 2017, latest update: 9 August 2018.

Figure 44: Annual average fire area versus annual average Fire and Rescue Service response time



However, when individual fires are examined, there is a correlation between the Fire and Rescue Service response time and the average area damaged for all fires with that response time, see Figure 45. The reason that there was no apparent trend in Figure 44 was because the response time averages were all in the range of around two to eight minutes, where the average fire area does not vary much with the response time. However, should the response time be longer than about 10 minutes, there is a noticeable increase in the average fire area, approximately doubling with an increase in the response time to 20 minutes.

Figure 45: Average fire area for specific Fire and Rescue Service response time



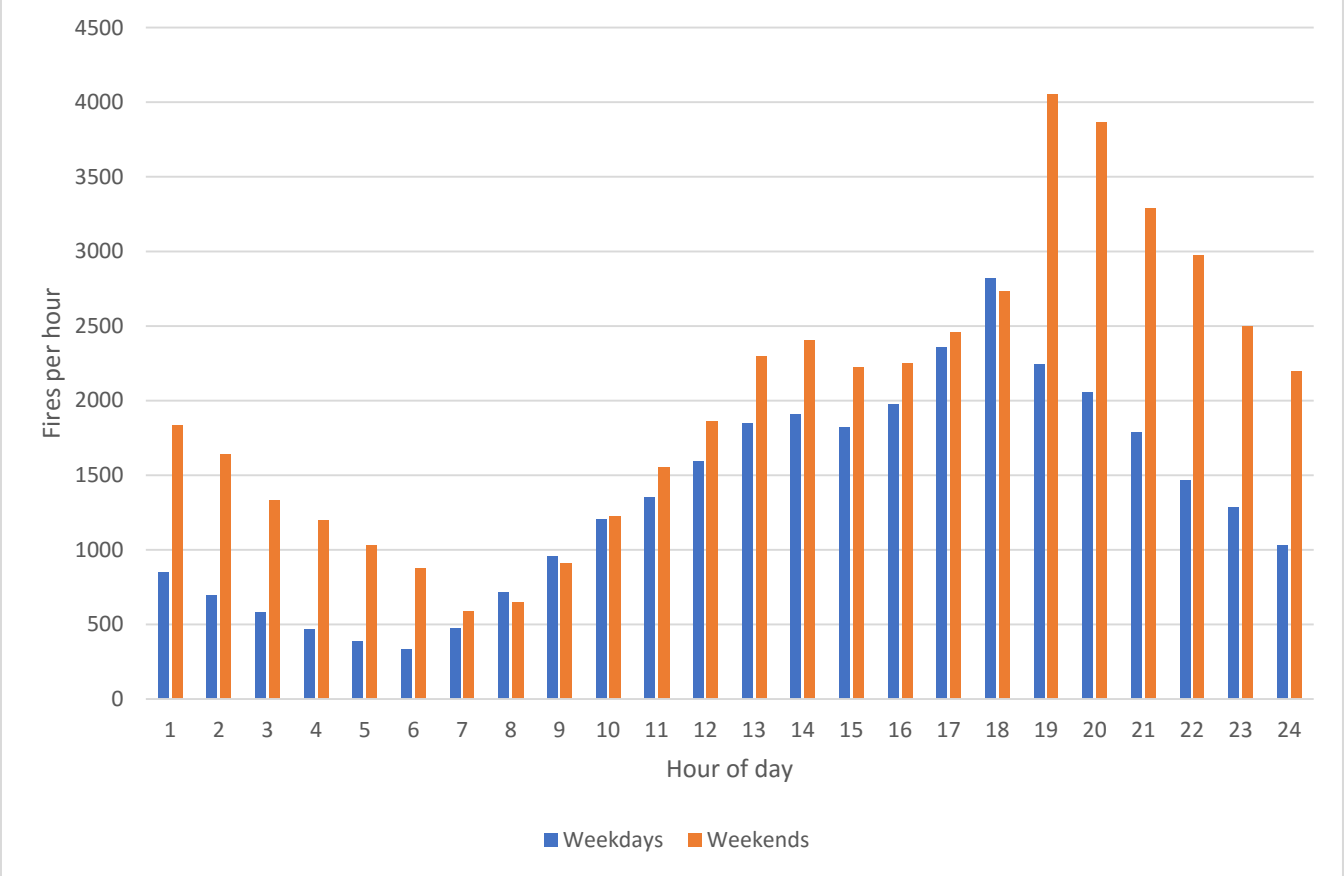
Additional analysis

Figure 46 to Figure 48 illustrate a number of miscellaneous points.

Variation in number of fires per hour during the day

Figure 46 shows the hourly variation in the number of fires. This information is of relevance when considering the impact of fire may have on occupants of the dwelling. There is an approximately sinusoidal variation in the number of fires during the day, with a minimum about 6am, a maximum around about 6pm. On weekends as opposed to week days, during the day from 7am to 6pm the number of fires per hour is very similar, but from 7pm through the night to 6am there is a much higher number of fires per hour during the weekends than weekdays. The reason for this has not been investigated further at this stage. See Appendix 4.

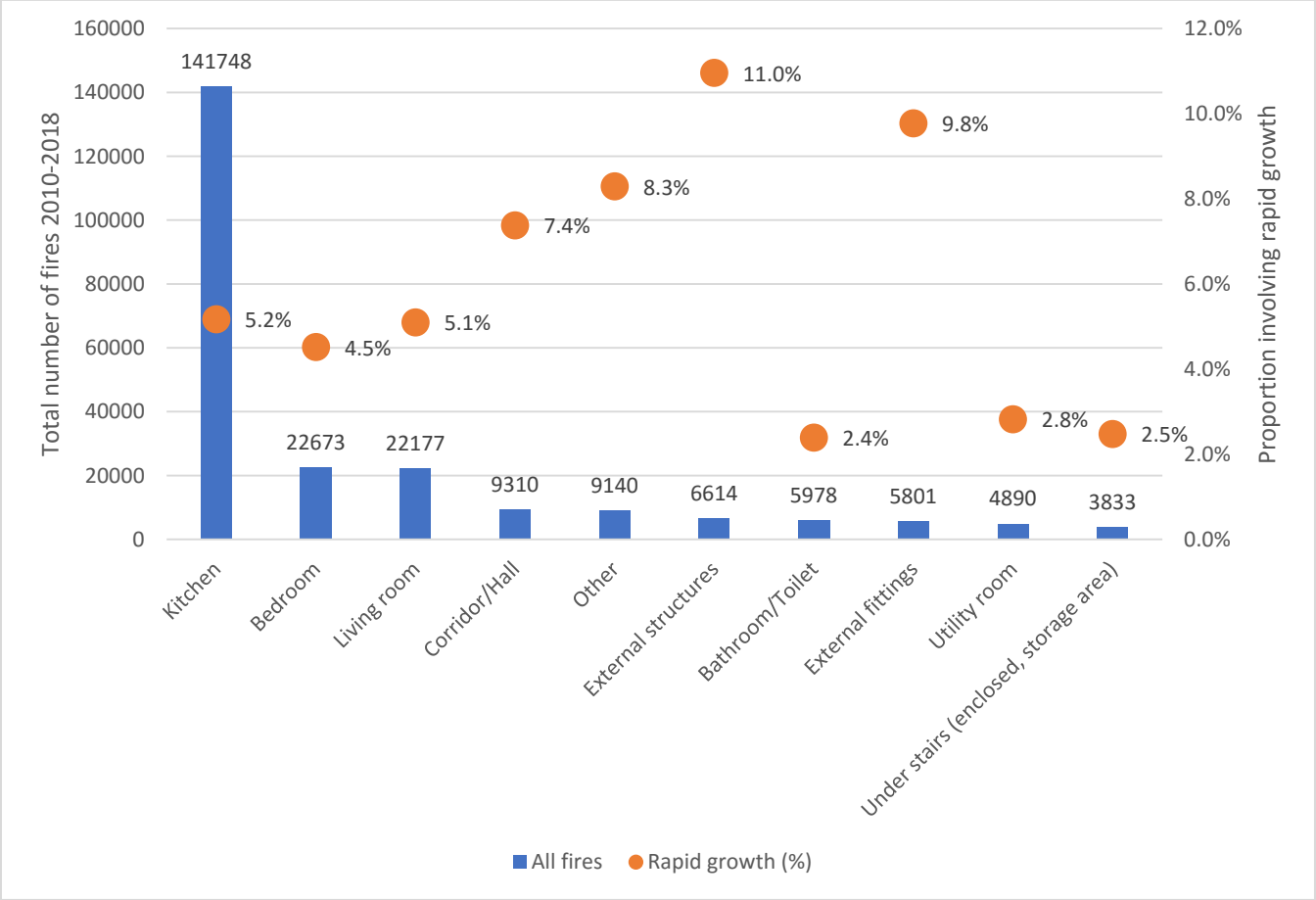
Figure 46: Numbers of fires per hour of the day



Rapid fire growth, by room of origin

The fire statistics also note if rapid fire growth has occurred, see Figure 47. This is a somewhat subjective opinion on the part of the person filling out the report form. However, with such a large sample of fires, any differences between opinions should tend to average out. In the most likely rooms of fire origin, namely the kitchen, bedroom or living area, the proportion of fires where rapid growth occurs is approximately 5%. In other areas, this proportion varies between 3% and 10%. This has not been investigated further, for example whether a rapid growth is related to particular fire types.

Figure 47: Proportion of fires where rapid growth occurs



Hoarding

The issue of hoarding is one that has concerned Fire and Rescue Services in recent years. Since the Incident Recording System was developed, in 2008, there has been category of fires defined as involving 'excessive or dangerous storage'.

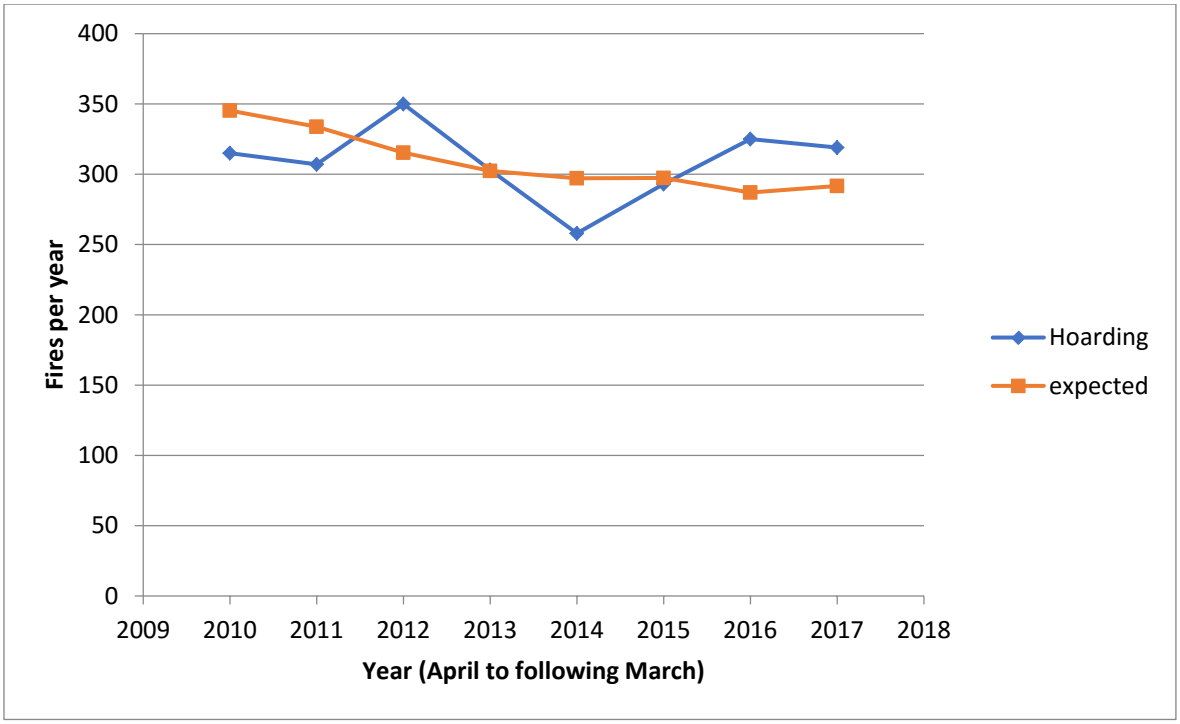
Figure 48 shows nine separate images, each reflecting a different level of fire load in a particular room, in this case the living room. There are analogous series for kitchen and bedroom as well. The clutter levels are rated on the numerical scale of one to nine. Hoarding is now recognised as a specific psychological disorder. A dwelling occupant (usually singular) would be considered to have a problem, if the clutter ratings were four or more. Estimates of the prevalence of hoarding disorder within the overall population range between about 1% and 3%[71].

[71] Steketee and Frost, International OCD Foundation Hoarding Center, Compulsive Hoarding and Acquiring Therapist Guide, NY Oxford University Press, 2007. Available from https://hoarding.iocdf.org/about-hoarding/do-i-have-hoarding-disorder/. Last accessed 24 January 2019.

Figure 48: Clutter image rating for living room[71]

Figure 49 shows the number of fires per year where hoarding ('excessive and dangerous storage') was a factor. The actual number of such fires closely follows the scaled overall trend line for the total number of fires per year. Note that the expected line is almost exactly 1% of the total number of fires per year. This is consistent with the other estimates of the prevalence of the hoarding disorder. Since the proportion of fires involving excessive or dangerous storage is the same as the prevalence of hoarding disorder within the overall population, this suggests that fires where hoarding is present are no more likely than where it is not.

Figure 49: Fires per year where hoarding was a factor



Real fire incidents

Introduction

A review and analysis of real fire incident data in the UK was conducted. For this review, the data utilised was originally collected for a Ministry of Housing, Communities and Local Government (MHCLG) project entitled 'Investigation of Real Fires'[72]. This project is carried out by BRE Global and encompasses an ongoing monitoring and reporting of fire incidents which involve potential aspects of interest in relation to the Building Regulations, consisting of both desk-based investigations and site visits to relevant fire incidents. In particular, this project focuses on aspects including, but not limited to, the extent of fire spread, external fire spread and the presence/absence of working smoke alarms; within both domestic and non-domestic dwellings.

The dataset used to conduct a review and analysis of real fire incident data in the UK does therefore not encompass all fire incidents which occurred involving consumer products in domestic dwellings, particularly if the incident has no aspects of interest relating to the Building Regulations.

Real fire incident data, collected between January 2008 and December 2018 as part of the MHCLG project, was reviewed to determine the number of fires from the period which involved consumer products. The dataset resulting from this review was interrogated to ascertain if consumer products involved in these incidents were either the ignition source or were later involved in the fire. The review focused on two areas:

- Which product was identified as the main source of ignition?
- Which product was identified as the item first ignited?

Note that the real fire incident dataset which was reviewed does not encompass the data for all real fires which occurred in the UK between January 2008 and December 2018.

The review of real fire incidents assisted in meeting project objectives 1 and 2.

1. To review the impact on fire characteristics of the changes in the content of the home, and in the design of homes.
2. To review the impact on product flammability fire testing of new sources of ignition, such as e-cigarettes batteries and space heaters.

Number of real fire incidents involving consumer products

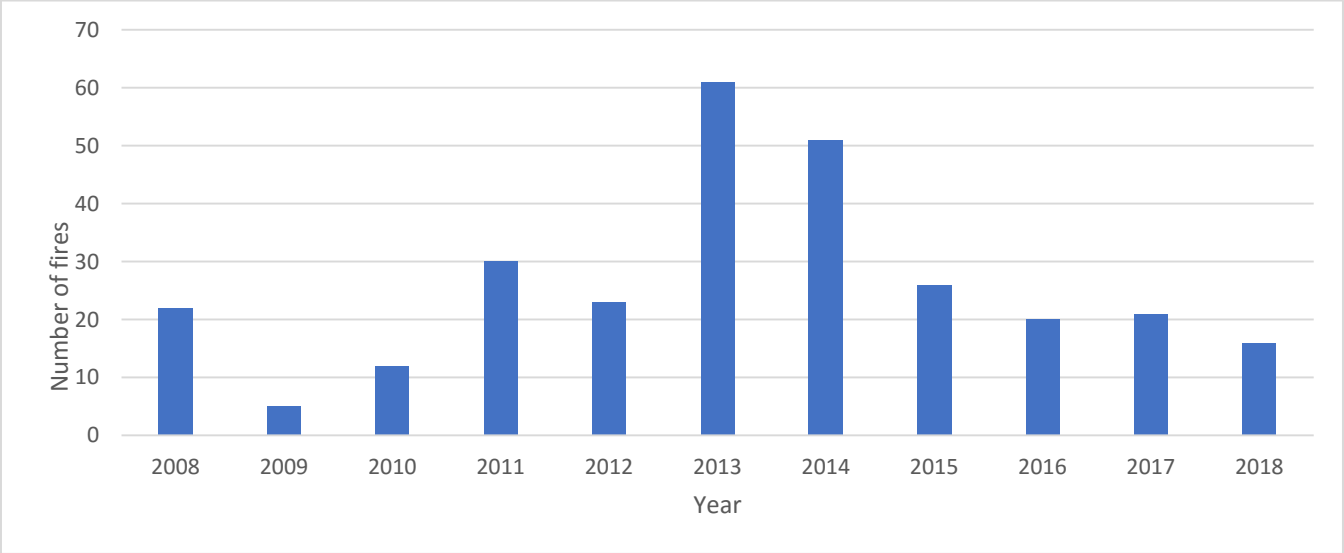
Between January 2008 and December 2018 there was a total of 4,208 real fire incidents which were reported on by BRE Global as part of the 'Investigation of Real Fires' MHCLG project. In this dataset, there was a total of 287 real fire incidents which involved one or more consumer products (a small fraction of the total numbers of fires in the IRS Home Office fire statistics for the same period).

The years 2013 and 2014 had the largest number of real fire incidents involving a consumer product, where the consumer product was either the ignition source of the fire or later involved in the fire. In 2013, there were 61 fires involving consumer products, and in 2014, there were 51 fires involving consumer products; as shown in Figure 50. It is noted that the increase seen

[72] Investigation of real fires: Final report – BD 2651, published by Department of Communities and Local Government, 2011.

in 2013/2014 may be due to a higher number of fires being reported in these years under the original project, or due to a focus on consumer product fires as a result of high profile incidents involving consumer products. Therefore, it cannot be said for certain that there was an upward trend of fires involving consumer products in the years 2013 and 2014.

Figure 50: Number of real fire incidents in domestic dwellings involving consumer product/s in the period January 2008 to December 2018



Main source of ignition

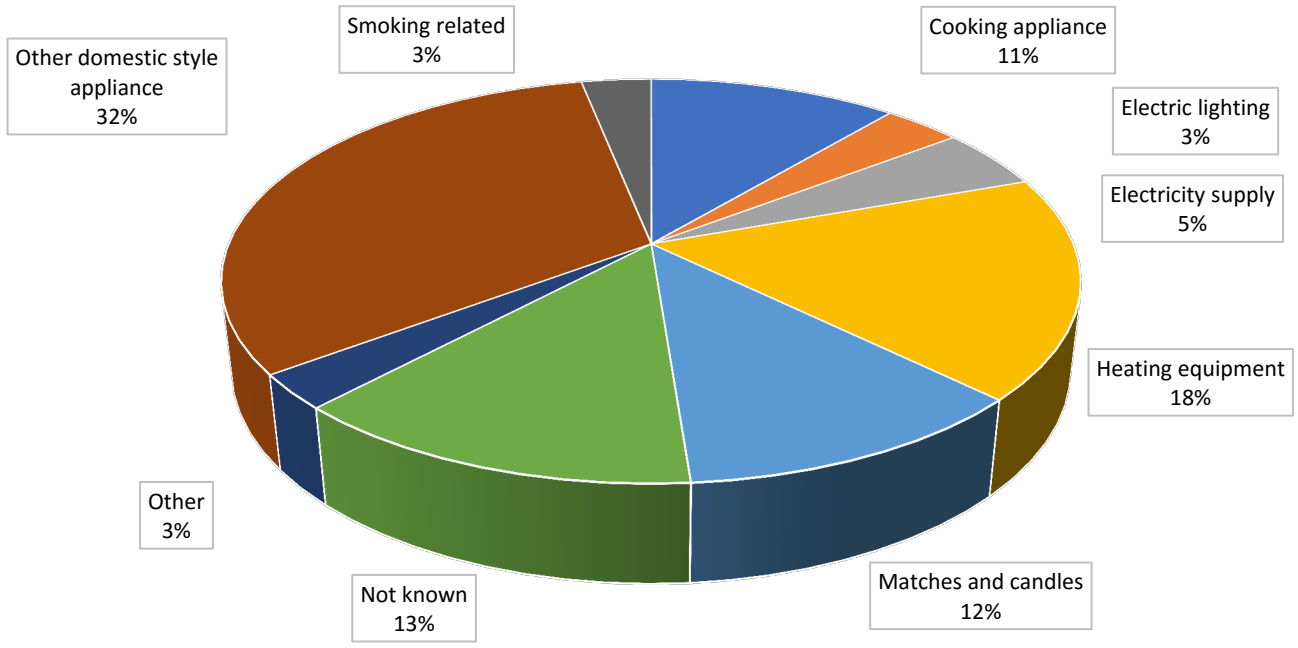
The main source of ignition for the 287 real fire incidents was categorised using subsections listed within Section 8.4 (What was the source of ignition?) of the Incident Recording System (IRS) which is used by the Home Office for recording information from fire incidents in the UK.

It should be noted that the data collected for real fires concentrates on fires which have possible implications for the Building Regulations and is therefore focussed on more severe fires and does not incorporate less significant fires, such as cooking fires.

IRS category

The main sources of ignition for the 287 real fires which occurred in domestic dwellings between January 2008 and December 2018 involving a consumer product are shown in Figure 51.

Figure 51: Main ignition source for real fire incidents involving consumer products in domestic dwellings between 2008 and 2018; specified using IRS categories (see also Figure 26)



From Figure 51, the most common sources of ignition for real fires in a domestic dwelling involving a consumer product were 'other domestic style appliances' which accounted for approximately one third (32%) of fires in the sample. Heating equipment was the main source of ignition for 18% of fires involving a consumer product, while matches and candles and cooking appliances accounted for 12% and 11% of the sample, respectively.

The main source of ignition for 13% (38 fires) of the dataset was recorded as unknown. This data was included in the analysis of the sample, as the incidents included consumer products which were later involved in the fire.

The real fire incidents dataset for main source of ignition can be compared to the Home Office IRS fire statistics for England reported in the Fire Statistics section. A comparison between a selection of categories for the main ignition source from both datasets is shown in Table 10.

Table 10: Comparison of main ignition source for real fire incidents and fire statistics

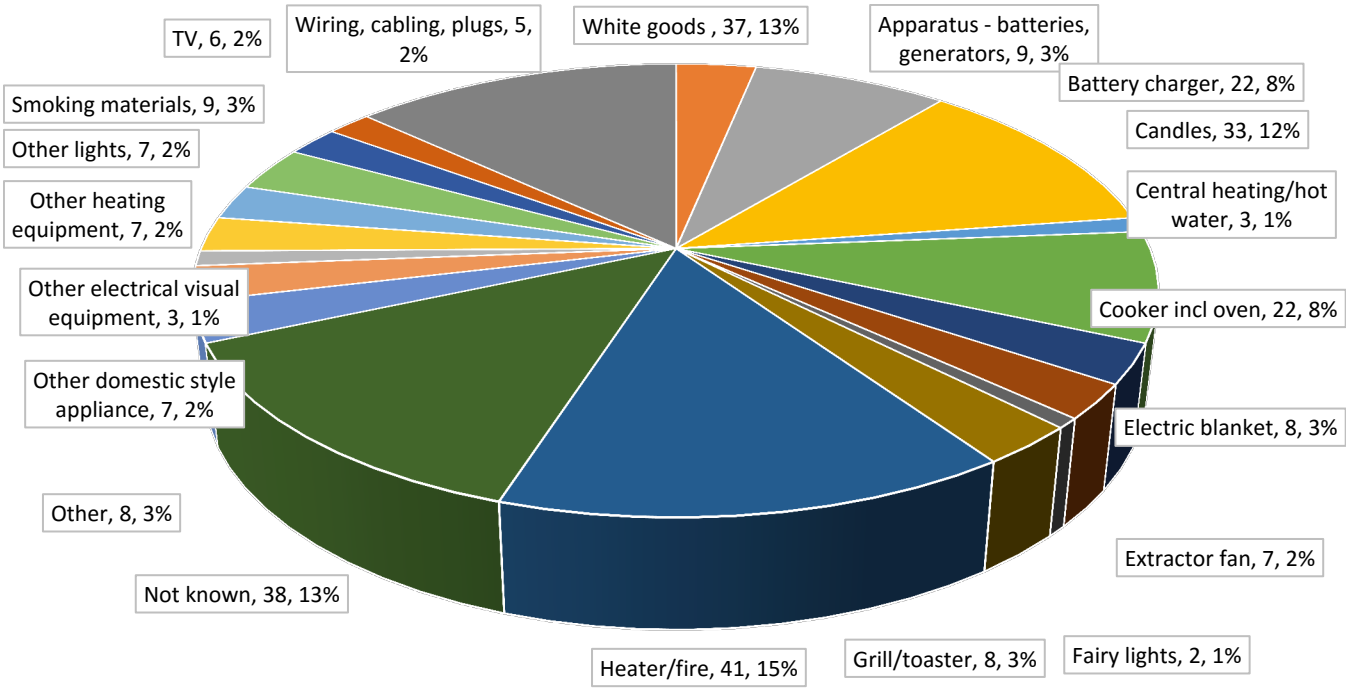
Main ignition source (IRS category)	Real fire incidents (%)	Fire statistics (%)
Cooking appliance	11	45
Electric lighting	3	2
Electricity supply	9	2
Heating equipment	18	5
Matches and candles	12	5
Other domestic style appliances	32	9
Smoking related	3	8

Main sources of ignition including smoking related sources, electricity supply and electric lighting are low percentages of the dataset for both real fire incidents and the Home Office IRS fire statistics. Differences are seen in the cooking appliance category, which accounts for 11% of the main ignition source in the real fire incidents dataset, but 50% of the main source of ignition in the fire statistics dataset. A difference is also seen in the heating equipment category, which accounts for 18% and 5% of the main ignition source for real fire incidents and fire statistics, respectively. Therefore, there is evidence of some selection bias in the real fire incidents dataset. However, this could be due to the real fire incident dataset not comprising all domestic fires which involved a consumer product in the UK in the given time period. Note that the real fires database focuses on fire of interest regarding the Building Regulations and therefore omits a large number of cooking fires which tend to be smaller and insignificant.

IRS category using specific item

Within each IRS category detailed above, there are also specific items listed as the source of ignition. When the data is categorised using the specific item listed within the IRS, the main source of ignition for the 287 real fires in domestic dwellings which involved a consumer product can be broken down further. Figure 52 represents approximately 97% of the dataset, with products types of low frequency omitted for clarity.

Figure 52: Main ignition source for real fire incidents involving consumer products in domestic dwellings between January 2008 and December 2018; specified using specific items listed in IRS categories (see also Figure 28)



From Figure 52, the most common specific source of ignition found in the review of real fires involving a consumer product was ‘heater/fires’ which accounted for 15% of the sample. This was closely followed by white goods, which accounted for the main source of ignition in 13% of the real fire incidents reviewed. Candles comprised the main source of ignition for a further 12% of the dataset. The next commonest source of ignition from the data reviewed was battery chargers and cookers including ovens, which both accounted for 8% of the sample.

Therefore Figure 52 shows that with regards to consumer products: heating appliances, white goods and battery chargers were the main sources of ignition observed in real fire incidents in domestic dwellings between January 2008 and December 2018, based on the available dataset of 287 real fires.

The real fire incidents dataset for specific sources of ignition can be compared to the Home Office IRS fire statistics reported in the Fire Statistics section. A comparison between the subdivisions of the 'other domestic style appliance' category is shown in Table 11. Some subdivisions of the real fire incidents dataset have been merged to allow comparison with the fire statistics. For example, 'cooker incl. oven' has been merged with 'grill/toaster' to compare with the fire statistics subdivision of 'cooking appliance'. For the purposes of comparison, white goods have also been amalgamated.

Table 11: Comparison of 'other domestic style appliance' category as an ignition source in real fire incidents and fire statistics

Subdivision of 'other domestic style appliance'	Real fire incidents (%)	Fire statistics (%)
Cooking appliance	11	11
Electric blanket	3	1
Extractor fan	2	2
Heating equipment (all)	19	7
Other domestic style appliance	2	5
TV	2	1
White goods	13	22
Wiring, cabling, plugs	2	33

The comparison of the real fire incident data and the fire statistics data shows some alignment in the breakdown of the 'other domestic style appliance' category as a main source of ignition. Items such as TVs, extractor fans and electric blankets comprise the ignition source for a relatively low percentage of fires in both real fire incidents and fire statistics, e.g. extractor fans are shown to account for 2% of ignition sources in both datasets. Cooking appliances as an ignition source are also comparable and are recorded as the main source of ignition for 11% of real fire incidents and also the fires recorded in the fire statistics dataset.

There are differences observed in the comparison of data for heating equipment and white goods; however, this could be as a result of the selection bias in the small dataset for real fire incidents. The largest difference between the two datasets is shown in the subsection of wiring, cabling and plugs; which represents the main source of ignition for 33% of the fire statistics dataset, but only accounts for the main ignition source for 2% of real fire incidents. Again, this difference could be due to the selection bias of the real fire incidents dataset, which does not comprise all domestic fires in the UK involving consumer products; and is specifically focused on fires which have aspects of interest with regards to the Building Regulations.

Item first ignited

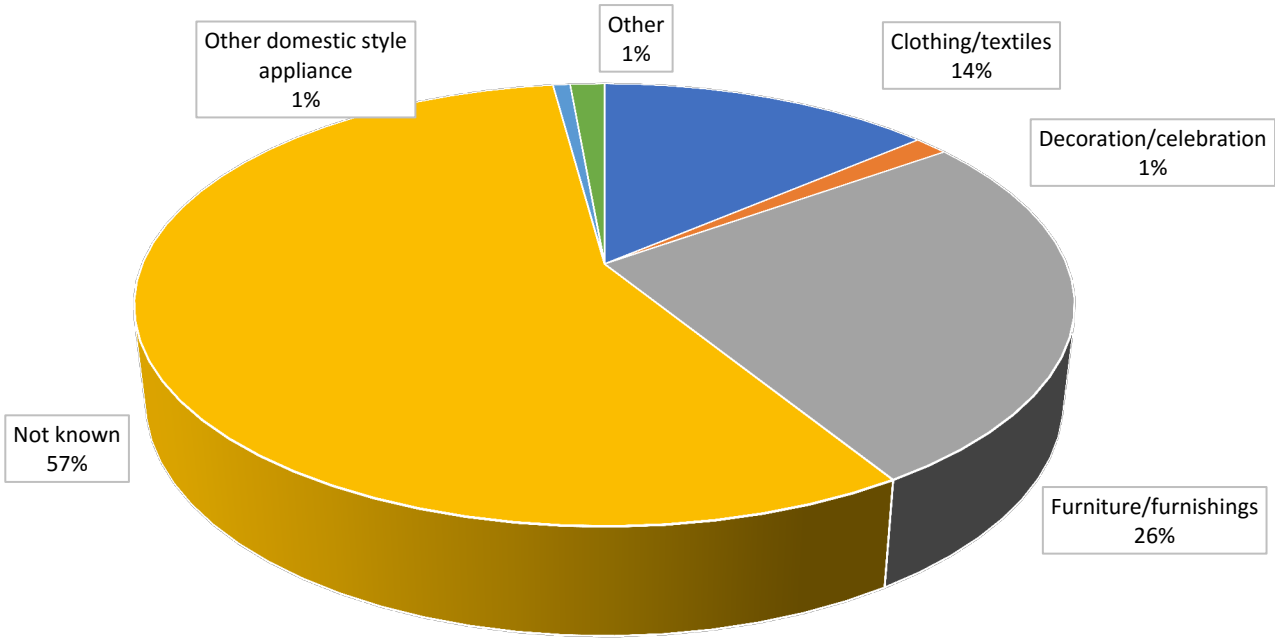
By reviewing the data collated for real fire incidents, it could be determined which consumer products were the item first ignited in the incident, or later involved in the fire.

The item first ignited for the 287 real fire incidents was categorised using subsections listed within Section 8.6 (What item/material was damaged first?) of the Incident Recording System used by the Home Office for recording information from fire incidents within the UK.

IRS category

The items first ignited for the 287 real fires which occurred in domestic dwellings between January 2008 and December 2018 involving a consumer product are shown in Figure 53.

Figure 53: Item first ignited in real fire incidents involving consumer products in domestic dwellings between January 2008 and December 2018; specified using IRS categories (see also Figure 29)



The most common items first ignited were found to be furniture and furnishings which accounted for 26% of the data, and clothing and textiles which accounted for 14% of the data. It should be noted that this information is based on 123 fires from the 287 real fires incidents and therefore does not provide a full set of results, as the item first ignited was not known or recorded for 57% of the fires in the dataset which was reviewed.

Product recalls

A review of recent product recalls has provided a snapshot of the types of consumer products and materials that are having an impact on fires in dwellings. Relevant and available cases of product recalls in the public domain were reviewed. Product recall data was collected from the following websites: Product Recall Campaign, HM Government, Electrical Safety First, White Good Safety, UK Association of Fire Investigators and UK Whitegoods.[73, 74, 75 76, 77, 78, 79, 80, 81]

This review of product recalls assisted in meeting project objectives 2 and 3:

2. To review the impact of new sources of ignition, such as e-cigarettes, batteries and space heaters on product flammability fire testing.
3. To identify any follow-on practical work for product flammability fire performance testing in order to make recommendations on the design of revised standards that are representative of modern fire scenarios.

According to a recent Which? Investigation, faulty household appliances such as washing machines, tumble dryers and fridge-freezers are causing more than 60 fires every week[82]. From the analysis of fire data obtained via Freedom of Information requests, Which? reported that the number of fires has stayed at a similar level for five years, with malfunctioning kitchen appliances causing close to 16,000 fires across the UK since 1 April 2012[83]. Freedom of Information data was gathered from the organisations responsible for collating UK fire statistics; the Home Office, the Scottish Fire and Rescue Service and the Welsh and Northern Irish governments[83]. Which? also revealed that there were 6,206 household fires caused by faulty appliances and leads between 1 April 2014 and 31 March 2016[83]. Fires caused by faulty washing machines and tumble dryers account for more than a third (35%) of this overall number, meaning these two appliances cause more than 20 fires per week on average[83].

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73 Beko Fridge Freezer Recall, UK whitegoods. Available from https://www.ukwhitegoods.co.uk/help/about-the-appliance-industry/product-recalls/3133-beko-fridge-freezer-recall. Last accessed 19 January 2019.

74 Dishwasher Safety Notice – safety notice, Hotpoint. Available from https://www.hotpointservice.co.uk/safety-notice-dishwasher. Last accessed 19 January 2019.

75 Household appliances recalled due to fire risk since 2010. Available from https://www.gov.uk/government/publications/household-appliances-recalled-due-to-fire-risk. Last accessed 19 January 2019.

76 Forums, the latest product recalls. Available from http://product-recalls.org/forum/Thread-indesit-eos-platform-dishwashers-safety-notice-risk-of-fire. Last accessed 19 January 2019.

77 Product recall make sure products are safe to use, product recall campaign. Available from https://productrecall.campaign.gov.uk/. Last accessed 19 January 2019.

78 Product recalls, electrical safety first. Available from https://www.electricalsafetyfirst.org.uk/product-recalls/. Last accessed 16 January 2019.

79 Product recalls, United Kingdom Association of Fire Investigators. Available from https://www.uk-afi.org/product-recall. Last accessed 16 January 2019.

80 Safety notice on White goods, product recalls, electrical safety first. Available from http://www.whitegoodsafety.com/product-recalls?take=32. Last accessed 18 January 2019.

81 Recalls Direct, food, drug, product and vehicle recalls, alerts and safety bulletins, LivingSafely.org. Available from https://livingsafelyrecalls.wordpress.com/2014/07/08/indesit-eos-platform-dishwasher-recall-uk/, Last accessed 19 January 2019.

82 Slater B. Revealed: the brands linked to the most appliance fires, Which? 15 February 2018. Available from https://www.which.co.uk/news/2018/02/revealed-the-brands-linked-to-the-most-appliance-fires/. Last accessed 23 January 2019.

83 FIRE0601: Primary fires in dwellings and other buildings by cause of fire, gov.uk. Available from https://www.gov.uk/government/statistical-data-sets/fire-statistics-data-tables#cause-of-fire. Last accessed 23 January 2019.

Other high-risk appliances for the same period include cookers and ovens (11%), dishwashers (10%) and fridges, freezers and fridge-freezers (8%)[83].

Table 12 data, collected from the gov.uk website, demonstrates that the number of fires in dwellings caused by faulty appliances and leads has stayed at a similar level for a number of years.

Table 12: Primary fires in dwellings, by cause of fire, England[83]

Year	Total fires	Faulty appliances and leads	Percentage of fires due to faulty appliances and leads (%)
2010/2011	36,602	5,061	13.8
2011/2012	35,403	4,933	13.9
2012/2013	33,295	4,942	14.8
2013/2014	31,908	4,654	14.6
2014/2015	31,331	4,651	14.8
2015/2016	31,371	4,330	13.8
2016/2017	30,343	4,446	14.7
2017/2018	30,744	4,345	14.1

Table 13 details the websites that were reviewed to obtain information about recalled electrical domestic appliances, the number of entries found and the period of recalled dates for those entries. It can be seen that the data was collected over a 10-year period, from January 2008 to December 2018.

Table 13: Review of product recall databases

Website	Code	Number of entries	Period
Product recall campaign	PRC	1	09/11/2018
Gov.uk	GOV	15	18/05/2011 – 05/06/2018
Electrical Safety First	ESF	137	01/02/2008 – 18/12/2018
White Good Safety	WGS	4	17/03/2008 – 06/11/2015
UK Association of Fire Investigators	UK-AFI	32	15/12/2008 – 01/11/2017
UK Whitegoods	UKWG	5*	10/07/2011 – 25/04/2016

* Duplicated data

The recalled electrical appliances were organised into the most appropriate/relevant category under question 8.4 within the IRS. 8.4 – What was the source of ignition? within the Incident Recording System (IRS).

Details of the product recall appliances which posed a risk of fire were collated and sorted by appliance type, manufacturer, models, recall date, and underlying cause of fire risk or source of ignition. Any duplicated entries were identified and deleted.

Analysis

By product type

Figure 54 shows the proportion of different product types within the collected product recall data. Due to the large number of different product types the chart explicitly shows those

responsible for approximately 90% of the data (171 recalls). Low frequency product types (17 recalls, 9%) were amalgamated in the category ‘Other appliances’.

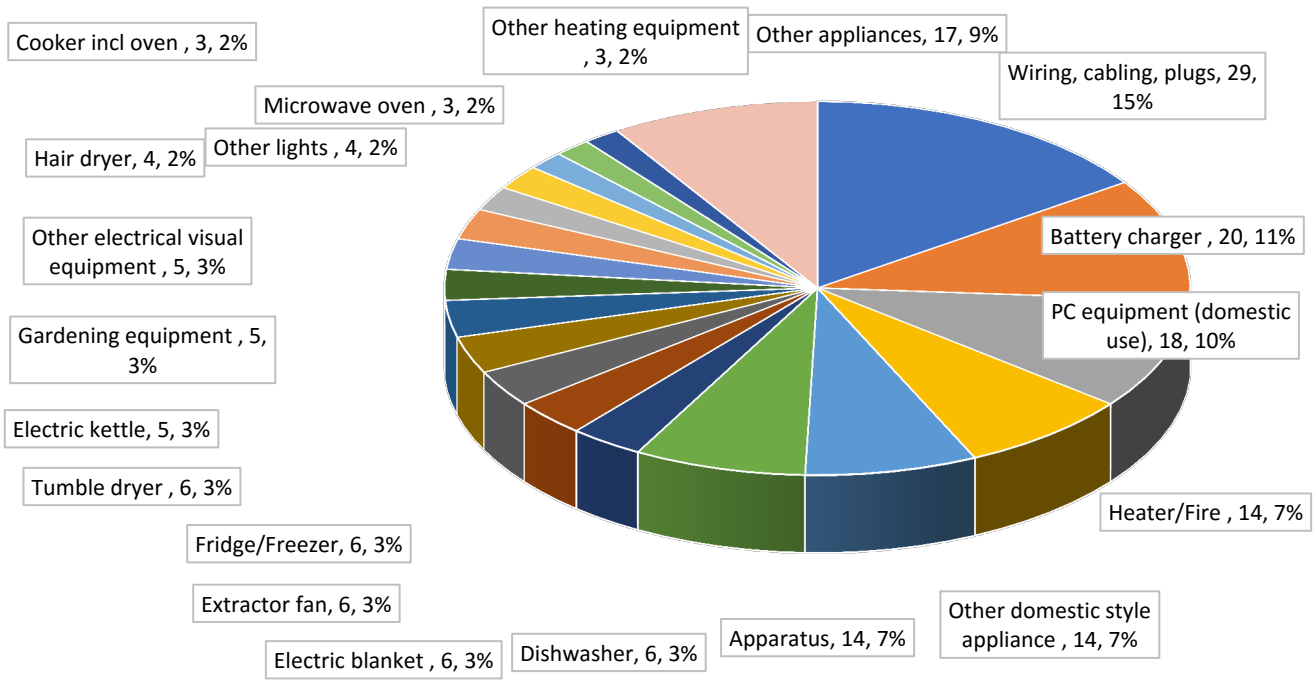

Figure 54: Proportion of each product type

Figure 54 shows that the most frequent product types which were recalled over a ten-year period, in descending order, were wiring, cablings, plugs, then battery charger and finally PC equipment. Therefore, this suggests that wiring, cabling, and plug type products are a key appliance type that have the possibility of causing a fire.

By risk

It is important that the underlying risks associated with the recalled products are identified, as these issues are what potentially cause a fire.

Figure 55 shows the underlying potential causes of fire associated with the recalled products. As with the previous chart the commonest causes, accounting for approximately 90% of the data (155 recalls in this case), are shown explicitly, with less common causes accounting for the remainder of the data being amalgamated in the ‘Other causes’ category.

Figure 55: Underlying potential causes of fire

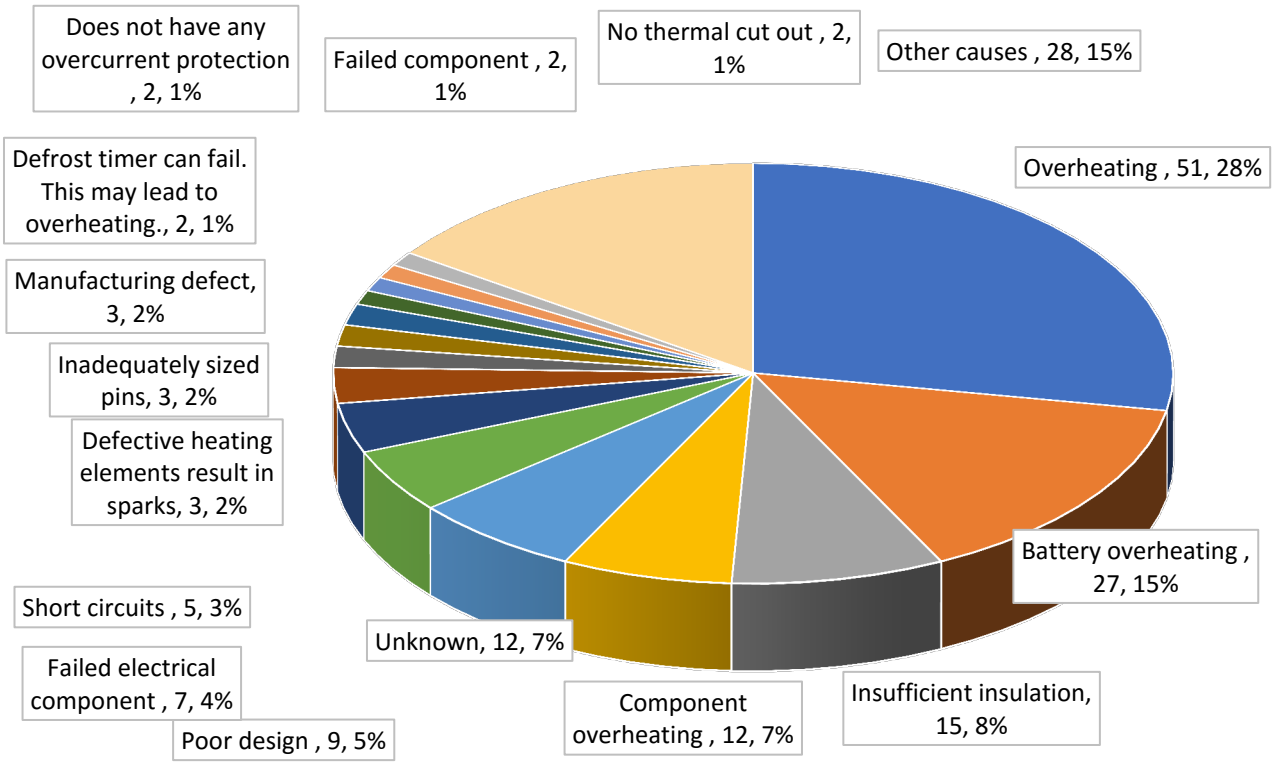

Figure 55 shows that overheating of appliances is the most frequent (28%) underlying cause of fire for the recalled products recorded, followed by battery overheating and then insufficient electrical insulation. Therefore, this suggests that domestic electrical appliances are most likely to cause a fire due to overheating.

Detailed analysis of three most frequent product type recalls

It should be noted that some of the products and underlying causes of fire detailed below are too few in number for robust conclusions to be drawn. However, they are included to complete the data set.

Wiring, cabling, plugs

As previously stated, wiring, cabling and plug type products were the most frequent type of product recalled according to the reviewed product recall databases. The specific products organised into this category and the underlying causes of fire for these types of products were further investigated.

The two most frequent products categorised under wiring, cabling, plugs which included a total of 29 individual products were plug adaptor (12 recalls) and extension lead (5 recalls). The products referred to as plug adaptors were voltage transformers enabling devices to run off mains power e.g. laptop. The other products, which were low in frequency, categorised under wiring, cabling, plugs were remote control socket set, travel plug adaptor, miniature circuit breakers, fuse wire, mixed fuses, wiring kits and ‘Sentry’ switches and consumer units. The frequency of these products in this category were low.

The three most frequent underlying causing of fire within the wiring, cabling and plugs category were insufficient insulation (5 recalls), overheating (5 recalls) and unknown (5 recalls). The other underlying causes of fire for this category were very low in frequency.

Battery charger

Battery chargers were the second most frequent type of product recalled.

The most frequent product, representing half of the products categorised under battery charger was phone charger (10 recalls). The other products categorised under battery charger, which have a low frequency, were power banks, AC power cords, battery chargers and hands free.

Several different products were organised under the category of battery charger. The most frequent underlying cause of fire for the products categorised under battery charger was insufficient insulation (5 recalls). The other underlying causes of fire for the products for this category were very low in frequency.

PC equipment (domestic use)

PC equipment (domestic use) was the third most frequent type of product recalled.

The most frequent product which was categorised under PC equipment (domestic use) was notebook batteries (9 recalls). The other products which were categorised under PC equipment (domestic use), which had a low frequency, were: tablets, laptop battery packs, hard disk drives, external cases, notebooks and laptops.

The most frequent underlying cause of fire for this category was battery overheating (10 recalls). The other underlying causes of fire for the products categorised under PC equipment (domestic use), which were low in frequency, were: overheating, insufficient insulation and short circuits.

Comparison of product recalls with Home Office fire statistics

Product recall data was compared with the Home Office fire statistics data.

Table 14 shows the comparison of the proportion of each product type recalled due to a fire risk (from Figure 54) with the source of ignition when caused by fault according to the Home Office fire statistics data (from Figure 28). The cells in bold represent the product types displayed in both charts. The cells not in bold represent the product types which are only displayed in one of the charts.

Table 14: Comparison of Home Office data with product recall data

Category	Data source	
	Product recalls	**Home Office fire statistics (ignition caused by fault)**
Wiring, cabling, plugs	**15% (29)**	**33% (18,526)**
Heating equipment	**9% (17)**	**7% (4,128)**
Tumble dryer	**3% (6)**	**6% (3,604)**
Other domestic style appliance	**7% (14)**	**5% (2,768)**
Electric blanket	**3% (6)**	**<1% (405)**
Extractor fan	**3% (6)**	**2% (1,170)**
Dishwasher	**3% (6)**	**5% (2,641)**
Cooking appliance	**2% (3)**	**11% (5,996)**
Battery charger	**11% (20)**	**< 1% (354)**
PC equipment (domestic use)	10% (18)	< 1% (270)
Electricity supply	-	8% (4,309)
Washing machine	-	7% (4,060)

Figure 56: Comparison of number of product recalls to number of fires due to faults

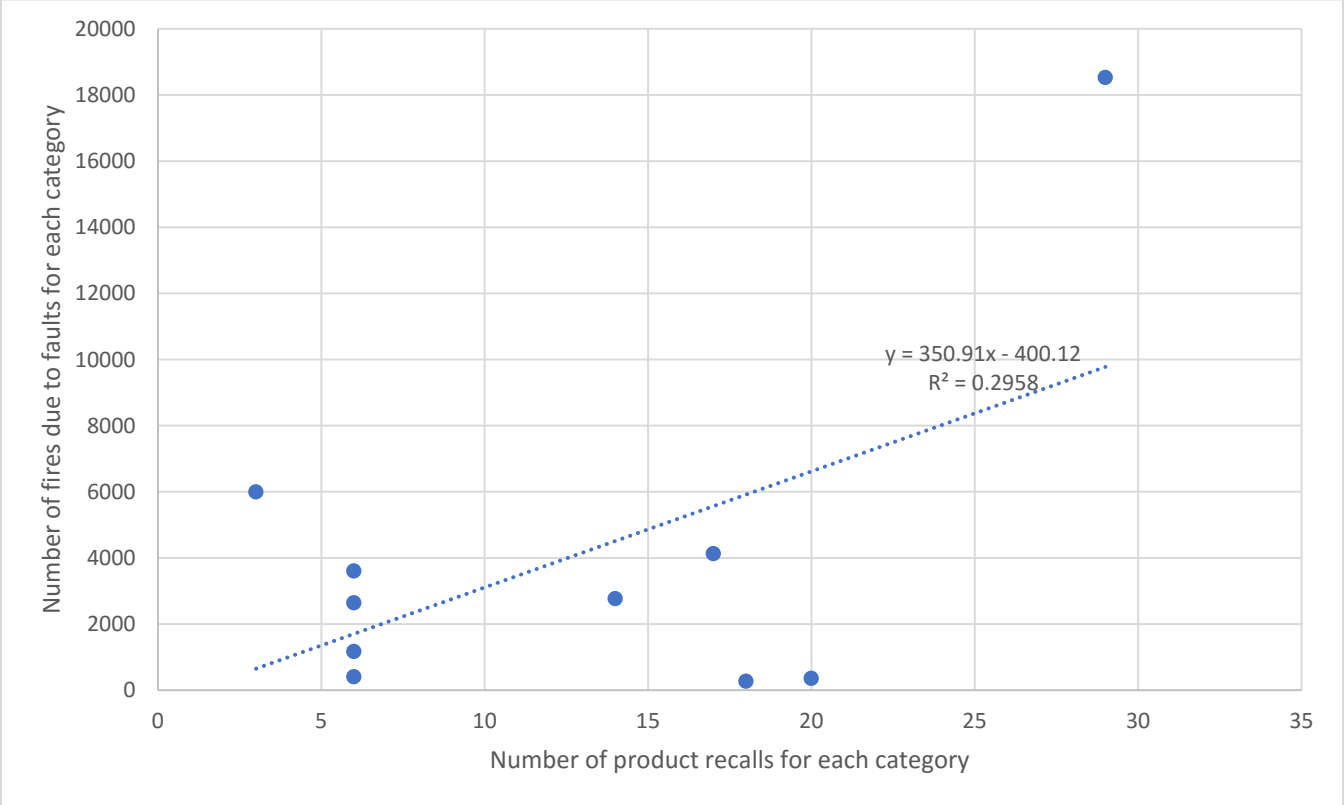

Figure 56 shows that there is almost no correlation between the data collected from product recall websites and the Home Office fire statistics. Therefore, no conclusions can be drawn from this comparison.

It has not been possible to determine the number of items affected by a given product recall.

Review of Flammability Standards

A review of the flammability fire tests, which are in place for consumer products, was carried out. This review has comprised a literature review, web search, information received from consultations with stakeholders and input from the British Standards Institution.

This review has focused on two main areas: furniture and furnishings (including beds and mattresses) and electrical appliances. Other consumer products are also discussed.

This review of flammability standards assisted in meeting project objectives 2 and 3:

2. To review the impact of new sources of ignition, such as e-cigarettes, batteries and space heaters on product flammability fire testing.
3. To identify any follow-on practical work for product flammability fire performance testing in order to make recommendations on the design of revised standards that are representative of modern fire scenarios.

Furniture and furnishings

Domestic upholstered furniture

Domestic upholstered furniture in the UK must adhere to the Furniture and Furnishings (Fire Safety) Regulations 1988 (as amended).[84] The Furniture and Furnishings Regulations were introduced in 1988 following an increasing trend in the number of fire-related deaths in domestic dwellings in the 1960s to 1980s. The Furniture and Furnishings Regulations are specifically for use in domestic dwellings to ensure that all components of furniture upholstery are compliant with specified ignition resistance levels. The regulations do not apply to furniture which is intended for export from the UK or furniture manufactured prior to 1950.[85] Furniture and furnishings used in a non-domestic environment are covered by the Regulatory Reform (Fire Safety) Order 2005[86] in England and Wales and equivalent legislation in Scotland and Northern Ireland.

Assessment of ignitability

The ignitability of domestic upholstered furniture can be assessed using two groups of static ignition sources: smouldering ignition sources or flaming ignition sources, as described in BS 5852: Part 1.[87] Smouldering ignition sources involve the use of a single cigarette, whereas flaming ignition sources involve a series of butane flames and burning cribs which have a range of thermal outputs starting from a small match-flame equivalent, to approximately four double sheets of a newspaper.[87]

84 Furniture and Furnishings Regulations 1988 (as amended).
85 Fire safety of furniture and furnishings in the home – A Guide to the UK Regulations, FIRA, 2009 and updated 2011.
86 The Regulatory Reform (Fire Safety) Order 2005.
87 BS 5852-1:1979 Fire tests for furniture. Methods of test for the ignitability by smokers' materials of upholstered composites for seating, British Standards Institution, 1979.

In the ignitability testing of domestic upholstered furniture, the sources of ignition used are a cigarette and match flame equivalent. The exception to this is the use of a 'source 5 crib' which regulates the risk from higher ignition sources in polyurethane foam slab materials and interliner fabrics.[88]

Testing requirements

Upholstered furniture for use in domestic dwellings must meet ignition resistance testing requirements as detailed in the Furniture and Furnishings Regulations[84]. Fillings, covers and upholstery composites must adhere to the testing requirements which are defined in the appropriate Schedule of the Furniture and Furnishings Regulations[84].

Table 15 outlines the test requirements for fillings of domestic upholstered furniture and Table 16 shows the requirements for upholstery composites and covers of domestic upholstered furniture.

Table 15: Ignitability tests and ignition sources for fillings

Filling material	Material composition	Ignitability test	Test method	Ignition source	Pass criteria
Foam	Polyurethane – Slab or cushion	Schedule 1, Part 1	BS 5852: Part 2	Source 5 crib	BS 5852: Part 2, Clause 4
Foam	Polyurethane crumb	Schedule 1, Part 2	BS 5852: Part 2	Source 2 butane flame	BS 5852: Part 2, Clause 4
Foam	Latex rubber	Schedule 1, Part 3	BS 5852: Part 2	Source 2 butane flame	BS 5852: Part 2, Clause 4
Non-foam	Single filling	Schedule 2, Part 1	BS 5852: Part 2	Source 2 butane flame	BS 5852: Part 2, Clause 4
Composite	Furniture	Schedule 2, Part 2	BS 5852: Part 2	Source 2 butane flame	BS 5852: Part 2, Clause 4
Composite	Pillows/scatter cushions	Schedule 2, Part 3	BS 5852: Part 2	Source 2 butane flame	BS 5852: Part 2, Clause 4
Composite	Mattresses	Schedule 2, Part 4	BS 6807	Source 2 butane flame	BS 5852: Part 2, Clause 4
Composite	Futons	Schedule 2, Part 4	BS 6807	Source 2 butane flame	BS 5852: Part 2, Clause 4

[88] Department for Environment, Food and Rural Affairs study: Fire retardant technologies: safe products with optimised environmental hazard and risk performance (Annex 1, legislative landscape), 2010.

Table 16: Ignitability tests and ignition sources for upholstery composites and covers

Material	Material category	Ignitability test	Water soak required	Test method	Ignition source	Pass criteria
Upholstery composites	Visible: FR treated	Schedule 4, Part 1	Yes	Cigarette test (BS 5852)	Untipped standard cigarette	BS 5852: Part 1, Clause 4
Upholstery composites	Visible: Non-FR treated	Schedule 4, Part 1	No	Cigarette test (BS 5852)	Untipped standard cigarette	BS 5852: Part 1, Clause 4
Covers	Visible/ permanent : FR treated	Schedule 5, Part 1	Yes	Match flame test equivalent (BS 5852)	Source 1 butane flame	BS 5852: Part 1, Clause 4
Covers	Visible/ permanent : Non-FR treated	Schedule 5, Part 1	No	Match flame test equivalent (BS 5852)	Source 1 butane flame	BS 5852: Part 1, Clause 4
Covers	Loose: FR Treated	Schedule 5, Part 1	Yes	Match flame test equivalent (BS 5852)	Source 1 butane flame	BS 5852: Part 1, Clause 4
Covers	Loose: Non-FR treated	Schedule 5, Part 1	No	Match flame test equivalent (BS 5852)	Source 1 butane flame	BS 5852: Part 1, Clause 4
Covers	Stretch	Schedule 5, Part 2	No	Match flame test equivalent (BS 5852)	Source 1 butane flame	BS 5852: Part 1, Clause 4
Fire barriers/ interliners	FR treated	Schedule 3	Yes	BS 5852	Source 5 crib	BS 5852: Part 2, Clause 4
Fire barriers/ interliners	Non-FR treated	Schedule 3	No	BS 5852	Source 5 crib	BS 5852: Part 2, Clause 4

Fillings in domestic upholstered furniture

Filling materials present in upholstered domestic furniture are divided into three categories: foam, non-foam and composite. All filling materials should be assessed against the criteria for smouldering or flaming ignition as detailed in Clause 4 of BS 5852: Part 2[89] to determine if they meet the required standard for resistance to ignitability. All filling materials must meet the test requirements detailed in the relevant Schedule of the Furniture and Furnishings Regulations[84] before the filling can be included for use in a final furniture product.

Foam fillings

Foam fillings must always be tested individually from other filling materials. Schedule 1 of the Furniture and Furnishings Regulations details the requirements for foam fillings.[84]

[89] BS 5852-2:1982 Fire tests for furniture. Methods of test for the ignitability of upholstered composites for seating by flaming sources, British Standards Institution, 1982.

Where polyurethane foam is used in slab or cushion form, it must be tested using the method detailed in BS 5852: Part 2[89], using a 'source 5 crib' as the ignition source. The sample must self-extinguish within ten minutes and cease smouldering within one hour. The test rig should be weighed pre- and post-test; and the weight loss must be no greater than 60 g. The damage observed must not penetrate the full thickness of the test specimen or reach the extremities of the test rig.[90]

If polyurethane foam is used in crumb form, the filling must meet the criteria for two tests. The foam from which the crumb is formed must meet the requirements in Schedule 1, Part 1 of the Regulations; while the foam in crumb form must meet the requirements in Schedule 1, Part 2 and be tested to BS 5852: Part 2[89], using a 'source 2 butane flame' as the ignition source. The flame is applied for 40 seconds, and the test specimen must be observed to self-extinguish in 120 seconds after removal of the flame.[89,90]

Where foam is present in latex rubber form, it should be tested following Schedule 1, Part 3 of the Regulations[84]; using the test method detailed in BS 5852: Part 26 using a 'source 2 butane flame' as the ignition source. [89] The ignition source should be applied for 40 seconds, and the test specimen must be observed to self-extinguish in 120 seconds after removal of the flame. The weight loss of the test rig must be no greater than 60 g and the damage must not reach the extremities of the test rig.[89,90]

Non-foam fillings

Non-foam single fillings must adhere to Schedule 2, Part 2 of the Furniture and Furnishing Regulations[84], and should be tested using the method detailed in BS 5852: Part 2[89], using a 'source 2 butane flame' as the ignition source. The flame is applied to the sample for 40 seconds, and the test specimen must be observed to self-extinguish within 120 seconds after removal of the ignition source.[89, 90] For non-foam fillings in pillows, scatter cushions or mattresses, the flaming should not penetrate the full thickness of the test specimen or reach the extremities of the test rig.[90]

Composite fillings

If any composite fillings contain foam, then the foam must also be tested in accordance with Schedule 1, Part 1 of the Furniture and Furnishings Regulations.[84] Composite fillings used in domestic furniture (excluding mattresses, bed-bases, cushions and pillows) should be tested in accordance with Schedule 2, Part 2 of the Furniture and Furnishings Regulations, using the method detailed in BS 5852: Part 2[89], with a source 2 butane flame as the ignition source. [89,90] Testing requirements for composite fillings in pillows and scatter cushions are detailed in Schedule 3 of the Regulations, and requirements for composite fillings present in mattresses are detailed in Schedule 2, Part 4 of the Regulations. [90]

Covers

Cover materials of furniture for use in domestic dwellings must meet the cigarette and match resistance requirements as defined in BS 5852: Part 1[87], before the cover can be included in the final product. If a fabric cover material is non-resistant to matches, compliance with the Regulations may still be achieved if the specimen is cigarette resistant and a fire resistant

[90] The Furniture Retail Quality Group – Best Practice Guide – Flammability testing – Best Practice Guide for ignition testing regarding the UK Furniture and Furnishings (Fire Safety) Regulations 1988 amended 1989, 1993 and 2010, FIRA, 2011.

interliner is present.[90] The cover material must fulfil these requirements before it can be included in the final product.

The cigarette test

The cigarette test is described in Schedule 4 of the Furniture and Furnishings Regulations, with the procedure outlined in BS 5852: Part 1.[87, 90] It should be noted that the cigarette ignition source must comply with requirements of mass, length, diameter and smoulder rate. Currently, only reduced ignition propensity cigarettes are available in the UK and EU; which do not meet the requirements of the Regulations.[90]

Upholstery composites

The regulations require that all upholstery composites are cigarette resistant, therefore, complying with the cigarette test as described above. In order to fulfil this requirement, a ‘worst case’ cigarette test can be carried out. This is where a cover is tested over a ‘worst case’ filling; i.e. a filling which would make the material most likely to ignite.[87, 90] Non-combustion modified foam is a common choice as a worst case filling used to test cover materials. A satisfactory result for the cigarette test with the worst case filling indicates that the cover would be cigarette resistant with other fillings which were less likely to smoulder.[90]

The match test

The match test is described in Schedule 5 of the Furniture and Furnishings Regulations, with the procedure outlined in BS 5852: Part 2.[89] The parameters of the test are detailed to specify how the correct calorific output for a ‘source 1 match flame ignition source’ can be achieved. The ignition source is applied for 20 seconds. The sample must self-extinguish within two minutes of removal of the ignition source.[89,90]

Mattresses

Mattresses, bed-bases and divans should meet the ignition resistance standards which are specified in BS 7177[91]; however, this is not enforceable under the Furniture and Furnishings Regulations.[84]

Mattresses for use in a domestic dwelling are classified as 'low hazard', and should be both cigarette and match resistant.[91] Criteria specified in BS 597-1[92] when tested for resistance to ignition using a smouldering cigarette; and the criteria in BS 597-2[93] when tested for resistance to ignition with a match flame equivalent using a 'source 1 butane flame', should be met. It is recommended that resistance to ignition for mattresses should be tested every 2,400 units, or once per month.[85]

The filling material (foam or non-foam) within a mattress is controlled under the Furniture and Furnishings Regulations.[84] Filling materials in a mattress can be tested as a composite filling. However, if more than one type of foam is included in the filling material; each foam material present must pass the relevant test specified in Schedule 1 of the Furniture and Furnishings Regulations.[84]

Upholstered headboards must also comply with Schedule 4 of the Furniture and Furnishings Regulations.[84]

Bedding

Bedding, including bedsheets, blankets and pillow cases; should be tested for resistance to ignitability following the test methods described in BS 7175[94]; however, this is not enforceable under the Furniture and Furnishings Regulations.[84]

Bedding should be tested for resistance to cigarettes using a smouldering ignition source, and for resistance to matches using a match flame equivalent ignition source; which are described in BS 5852 Part 1[87] and Part 2.[89] The test should be conducted following BS 7175[94], with the test specimen placed on a mineral wool fibre pad with the ignition source placed either on top or below the test specimen. The test specimen is monitored for evidence of sustained combustion after a specified time[92], which can be shown through extensive combustion, flaming combustion, progressive smouldering or concealed smouldering.

Pillowcases should be tested under BS 7175[94], as described above; however, fillings within pillowcases must adhere to the Furniture and Furnishings Regulations.[84] Foam fillings must pass the ignition resistance test detailed in Schedule 1, Part 1; while non-foam fillings must either individually pass the test outlined in Schedule 2; or be tested as a composite if a primary cover is present.

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91 BS 7177:2008+A1:2011 Specification for resistance to ignition of mattresses, mattress pads, divans and bed bases, British Standards Institution, 2008.

92 BS 597-1 BS EN 597-1:2015 Furniture. Assessment of the ignitability of mattresses and upholstered bed bases. Ignition source smouldering cigarette, British Standards Institution, 2016.

93 BS EN 597-2:2015 Furniture. Assessment of the ignitability of mattresses and upholstered bed bases. Ignition source: match flame equivalent, British Standards Institution, 2016.

94 BS 7175:1989 Methods of test for the ignitability of bedcovers and pillows by smouldering and flaming ignition sources, British Standards Institution, 1989.

Electrical appliances

Fires involving electrical appliances can be initiated from several scenarios, including from external non electrical sources, component failure in an appliance including overheating metal parts; and the resultant spread of flame from failed components to surrounding combustible materials.

BS EN 60335[95] is the specification for safety of household and similar electrical appliances. Part 1[96] of this standard covers the general requirements for all products which fall under the standard. Part 2 of this standard comprises individual products; including dishwashers[97], tumble dryers[98] and cookers.[99] An extended list of the BS EN 60335 Part 2 standards is included in Appendix 1.

BS EN 60335 clause 30[96] details the requirements for resistance to heat and fire of electrical appliances; and discusses the glow wire test and needle flame test.

The glow wire test

BS EN 60695-1-10[100] and BS EN 60695-1-11[101] were developed to reduce the potential risks of fire during the normal operating conditions of electrical products. The aim of these standards is to provide guidance on how to prevent ignition caused by an electrically energised component part of a product; and in the event of a fire to confine the fire within the bounds of the enclosure of the product; or minimise fire spread beyond the product enclosure.

Overheated metal parts can act as an ignition source in an electrical appliance product. The glow wire test which is outlined in BS EN 60695-1-10[100] and BS EN 60695-1-11[101], uses a glowing wire to mimic an overheated metal component in an electrical product. This test ultimately mimics a fault which could occur in a product, therefore, assessing how the end electrical consumer product would react to the thermal stress caused by component fault, overload or poor electrical connections.

The glow wire test method is used to determine whether an electrical product which is "exposed to an electrically heated source has either a limited ability to ignite or, if it ignites, a limited ability to propagate flame."[95]

The preferred test specimen for a glow wire test is a complete end product. However, if testing on a complete end product is not possible, testing on a piece of the end product containing the part which is under examination, or the cutting of an aperture into the complete end product to allow access of the glow wire, is acceptable.[100,101]

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95 BS EN 60335 Household and similar electrical appliances. Safety. Series of parts, British Standards Institution.

96 BS EN 60335-1:2012+A13:2017 Household and similar electrical appliances. Safety. General requirements, British Standards Institution, 2012.

97 BS EN 60335-2-5:2015 Household and similar electrical appliances. Safety. Particular requirements for dishwashers, British Standards Institution, 2015.

98 BS EN 60335-2-11:2010+A2:2018 Household and similar electrical appliances. Safety. Particular requirements for tumble dryers, British Standards Institution, 2010.

99 BS EN 60335-2-6:2015 Household and similar electrical appliances. Safety. Particular requirements for stationary cooking ranges, hobs, ovens and similar appliances, British Standards Institution, 2015.

100 BS EN 60695-1-10:2017 Fire hazard testing. Guidance for assessing the fire hazard of electrotechnical products. General guidelines, British Standards Institution, 2017.

101 BS EN 60695-1-11:2015 Fire hazard testing. Guidance for assessing the fire hazard of electrotechnical products. Fire hazard assessment, British Standards Institution, 2015.

The test is carried out by inserting a heated glow wire into the test specimen alongside a thermocouple at a depth of 7 mm and a pressing force of 1 N, for a period of 30 seconds. The temperature of the glow wire is determined using the glow wire flammability index.[102]

The criteria for passing the glow wire test are that the specimen must not be considered to be an ignition risk to the environment, and that any flames or glowing which is observed on the test specimen during the test must be observed to extinguish within 30 seconds after removal of the ignition source.[100,101]

The needle flame test

BS EN 60695-11-5[103] focuses on the response of a product material to heat and flames under laboratory conditions, in a scenario where flames from a component fault impinge on other materials within an electrical product.

The needle flame test is described in BS EN 60695-11-5.[103] This test simulates a small flame which may arise from a component fault in an electrical product and looks at the effect of the flame on the end product. The areas observed include if the flame causes ignition, and if so if the combustible parts of the product burn for a limited time, or if the spread of flame occurs.

The ignition source for this test is a butane gas flame which is produced by a needle burner. The flame is applied to the edge or surface of the test specimen for 5, 10[103], 30, 60 or 120 seconds.[102] The burning length and time are noted.

For a product to withstand the needle flame test, there must either be no ignition of the specified layer, and after removal of the needle flame, no flame or glowing of the specimen is observed; or flames and glowing of the specimen must extinguish within 30 seconds of removal of the ignition source, with no ignition of the specified layer.[103]

Toys

BS EN 71-2[104] specifies the requirements for flammability of toys when they are exposed to a small ignition source. Clause 5 of this standard details the test methods which are used to determine the flammability of certain toys under test conditions, including soft filled toys and toys which are designed to be worn or entered by a child. The ignition source used is a flame from a burner, which is operated with butane or propane gas.[104]

For testing soft filled toys, the flame height should be 20 mm and the burner should be positioned at a 45° angle. For testing for toys which are comprised of hair or pile material, the flame height should be 20 mm and the burner should be positioned vertically. For testing of toys designed to be worn by a child as a costume, the flame height should be 30 mm and the burner should be positioned vertically.[104]

[102] BS EN 60695-2-12:2010+A1:2014 Fire hazard testing. Glowing/hot-wire based test methods. Glow-wire flammability index (GWFI) test method for materials, British Standards Institution, 2011.
[103] BS EN 60695-11-5:2017 Fire hazard testing. Test flames. Needle-flame test method. Apparatus, confirmatory test arrangement and guidance, British Standards Institution, 2017.
[104] BS EN 71-2:2011+A1:2014 Safety of toys. Flammability, British Standards Institution, 2011.

Baby products also have separate standards which define any flammability requirements, including BS EN 12227[105] for playpens and BS EN 14988 for high chairs.[106] An extended list of standards for baby products can be found in Appendix 2. Some baby products are required to meet the Furniture and Furnishings Regulations[84], while some baby products standards refer to BS EN 71-2.[104].

Nightwear

In the UK, nightwear should comply with the Nightwear (Safety) Regulations 1985 (as amended).[107] These regulations refer to BS 5722[108] and BS 5438[109]; which detail the flammability requirements for nightwear. Children's nightwear must meet flammability criteria, while all other nightwear must carry a label to indicate whether or not it meets the flammability criteria. Testing of nightwear uses a butane flame ignition source of 45 mm in height which is applied for 10 seconds. The performance of the test specimen is assessed according to the rate of flame spread which is observed.

Nightwear which meets the flammability requirements should have a label saying, "low flammability to BS 5722." Nightwear which may or may not comply with the requirements should have a label saying "keep away from fire".

For children's nightwear, any fabric which consists of cellulosic fibres must be treated with a flame retardant agent. Children's nightwear must meet the flammability performance requirements and do not need to carry a label.

[105] BS EN 12227:2010 Playpens for domestic use. Safety requirements and test methods, British Standards Institution, 2011.
[106] BS EN 14988:2017 Children's high chairs. Requirements and test methods, British Standards Institution, 2017.
[107] The Nightwear (Safety) Regulations 1985 (as amended).
[108] BS 5722:1984 Specification for flammability performance of fabrics and fabric assemblies used in sleepwear and dressing gowns, British Standards Institution, 1984.
[109] BS 5438:1976 Methods of test for flammability of vertically oriented textile fabrics and fabric assemblies subjected to a small igniting flame, British Standards Institution, 1976.

One to one consultations

Introduction

One to one consultations were undertaken with participants from the furniture and furnishings industry, the bed industry and the electrical appliance industry to gain specialist views in these areas. The consultations were carried out by telephone with selected participants. A total of ten interviews were carried out, with eleven consultees involved.

The one to one consultations assisted in meeting project objectives 3 and 4:

3. To identify any follow-on practical work for product flammability fire performance testing in order to make recommendations on the design of revised standards that are representative of modern fire scenarios.
4. To make suggestions as to how modern designs of consumer products can be amended to improve their safety in a modern domestic fire. To identify any practical follow-on work required in order to verify these suggestions.

Questions asked

Each participant was asked a series of questions which were split into three categories: introductory questions, questions about standards and questions about changes to product design. These questions gave a general structure to the interview; with participants expanding on topics where desired. The questions asked in each interview are given as follows and in Appendix 3.

Question 1. Do you think that changes in the composition of products in the modern home have changed the characteristics of modern domestic fires?

Question 2. Do you think that new sources of ignition in the modern home have changed the characteristics of modern domestic fires?

Question 3. What are the new fire safety risks associated with products in the modern home e.g. counterfeit goods, new types of goods?

Question 3a. How do these new risks affect the overall characteristics of modern domestic fires?

Question 3b. Are these risks being addressed or how could they be addressed?

Question 4. Are there any fire safety and flammability standards for the specific consumer products/risks described in Question 3?

Question 4a. If yes, what are the associated fire tests?

Question 4b. If no, is there any consumer guidance on good practice, or industry best practice to mitigate fire risks for this type of consumer product?

Question 5. If yes to question 4, which of these fire and flammability standards and associated fire tests need updating to reflect modern domestic fires and new sources of ignition?

Question 5a. Name of each standard and relevant part of the standard.

Question 5b. If yes, why do these need updating? Are they too onerous, about right, not onerous enough?

Question 5c. If yes, have you any suggestions for practical work to assist the development of product flammability testing representative of modern fire scenarios?

Question 6. Can you suggest what changes to the design of this type of consumer product might be possible to improve its safety in a modern domestic fire scenario?

Question 6a. Can you identify any practical follow-on work required in order to verify these suggestions?

Question 7. Are there any additional comments you would like to make?

Responses

The responses from the one to one consultations were collated and divided into two categories:

1. Furniture and furnishings (including beds and mattresses) and
2. Electrical appliances.

Note that the responses and findings in this section of the report are the opinions of the individual participants and are not necessarily the opinion of BRE Global. It should also be noted that in some cases participants have made a statement which they have not expanded upon. These statements are included in the feedback for completeness.

Furniture and furnishings (including beds and mattresses)

The collated responses are presented in each category for each question, as follows.

Changes in the composition of products in the modern home: changing the characteristics of modern domestic fires

Whilst it was recognised that fillings within domestic upholstered furniture have not changed (with polyurethane foam still being the main filling used), there was consensus by participants that covering materials which are used in furniture have become more customisable by the consumer, and are changing more frequently in the modern home due to changes in fashion trends and products becoming more fashion orientated. For example, materials such as velvet which have recently come into fashion are more prevalent in the modern domestic home than previously. The increase in the use of modern materials in furniture could have an impact on the flammability of the product and also increase the fuel load within the home. It was also noted that materials used in the construction of furniture, such as timber and plastics, have also changed over the years.

A change in the buying process (for both furniture and beds) was raised as changing the composition of the modern home, as consumers are looking for cheaper, short-term products rather than more expensive long-term products. Therefore, the cost of materials is having an impact on the composition of the modern home as the consumer is attracted to less expensive products which may be inherently less flame retardant.

The introduction of electrical accessories in furniture in the modern home was discussed; as there is now the possibility to include accessories such as mobile phone charging ports in sofas and armchairs as technology evolves.

For the bed industry, it was noted that there are more foam only mattresses in the modern home than previously.

New sources of ignition in the modern home: changing the characteristics of modern domestic fires

It was stated that smouldering and open flame sources of ignition in the modern home still remain; however, the cause of these ignition sources is changing, particularly in regards to smouldering ignition sources.

All participants from the furniture and furnishings (including beds and mattresses) industry agreed that there has been an increase in both the number of electrical items in the modern home and the number of counterfeit goods in the modern home, which in turn leads to an increase in the number of potential ignition sources present in the home.

In relation to furniture and furnishings, a lack of consumer awareness was highlighted in relation to ignition sources in the home. Multiple participants discussed the issues surrounding human behaviour: leaving electrical products (including mobile phones and e-cigarettes) to charge unattended in unsuitable locations such as on the arm of a sofa, or on top of a bed.

New fire safety risks associated with products in the modern home

The main fire safety risk in the modern home with regards to furniture and furnishings was agreed by participants to be imported furniture. Furniture originating from outside the UK which is then imported can incorporate the use of unknown materials into the final product. Imported furniture has an unknown level of fire safety; as imported products are potentially non-compliant with the Furniture and Furnishings Regulations 1988 (as amended).

It was also raised that the composition of modern materials may lead to increased smoke production in the event of involvement in a fire; which could lead to an onset of untenable conditions more rapidly than seen with natural materials. This can make it increasingly difficult for residents to use the means of escape in their home, and also for Fire and Rescue Services who attend incidents.

The variability of the flame-retardant coating process was discussed; as the same process each time cannot be ensured, which could introduce variation in the level of flame retardancy achieved by products in the home. The use of flame-retardant chemicals, in itself, causes concern among consumers; particularly in items such as bedding.

For beds and mattresses, one of the main fire safety risks is that, aside from fillings, these items are not required to comply with standards as requirements are not detailed in the Regulations. Therefore, items such as bedding may not have been tested for flammability. When combined with misuse of consumer products, such as leaving mobile phones to charge on top of bedding, this leads to fire safety risks in the home.

Addressing the new fire safety risks in the modern home

It was raised by several participants that although there is good enforcement of the current regulations within the furniture industry, there is always potential to improve due-diligence and self-regulation.

In order to address the new fire safety risks which are present in the modern home, participants suggested that routine testing could be carried out on furniture and furnishings which are imported into the UK to identify any products which are non-compliant with the Furniture and Furnishings Regulations 1988 (as amended).

It was also suggested that a review and update of the Furniture and Furnishings Regulations and associated standards could take place to include items including potential new sources of ignition in the modern home and unintentional misuse of consumer products.

Participants from the furniture and furnishings industry stated that it would be useful for industry to receive information regarding the types of ignition sources which are causing fires in the UK, as this would give industry insight into these risks, and would give potential for them to be addressed, particularly as products are evolving at a faster rate than legislation.

Fire safety and flammability standards for furniture and furnishings

A brief summary of the feedback in relation to the fire safety and flammability standards for furniture and furnishings is given as follows. The detailed feedback from participants has been included in the Review of Flammability Standards section.

Domestic upholstered furniture

All domestic upholstered furniture in the UK must adhere to the Furniture and Furnishings Regulations 1988 (as amended). Fillings, covers and upholstery composites must adhere to requirements which are detailed in the relevant Schedule of the Furniture and Furnishings Regulations. Each Schedule of the Regulations refers to standards which define the flammability tests required for different products. BS 5852-1 (1979) and BS 5852-2 (1982) detail the cigarette test and the match test.

Beds/mattresses

Mattresses, bed-bases and divans should meet the ignition resistance standards which are specified in BS 7177 and the final product should be both cigarette and match resistant, however, this is not enforceable under the Furniture and Furnishings Regulations. Fillings (foam or non-foam) within mattresses must comply with the Furniture and Furnishings Regulations. Upholstered headboards must also comply with the Regulations.

Bedding (including pillowcases) should be tested for ignition to resistance following BS 7175; however, this is not enforceable under the Furniture and Furnishings Regulations. Fillings within pillowcases must adhere to the Furniture and Furnishings Regulations.

Best practice guides

Best practice guides for the flammability testing of furniture and furnishings are available. These are:

- Fire safety of furniture and furnishings in the home – A Guide to the UK Regulations[110]
- The Furniture Retail Quality Group Best Practice Guide – Flammability Testing[111]

[110] Fire safety of furniture and furnishings in the home – A Guide to the UK Regulations, FIRA, 2009 and updated 2011.
[111] The Furniture Retail Quality Group – Best Practice Guide – Flammability testing – Best Practice Guide for ignition testing regarding the UK Furniture and Furnishings (Fire Safety) Regulations 1988 amended 1989, 1993 and 2010, FIRA, 2011.

It was noted by participants that despite the best practice guides, the Regulations and guidance around flammability testing for furniture is still greatly misunderstood.

Do flammability standards for furniture need to be updated?

All the participants from the furniture and furnishings industry agreed that the Furniture and Furnishings Regulations need to be updated; with one opinion being that a change in the environment of the modern home warrants a review of the Regulations.

It was discussed that consultations in regards to updating the Furniture and Furnishings Regulations had previously taken place; with the last consultation occurring in 2016. However, the outcome of the consultations was unknown by participants from the industry.

The main subject raised by participants in regards to updating the Regulations was the topic of a smouldering ignition source. The Furniture and Furnishings Regulations 1988 (as amended) require the smouldering ignition source used in testing is a non reduced ignition propensity cigarette. However, non reduced ignition propensity cigarettes are no longer commercially available in the UK, with only reduced ignition propensity cigarettes available to purchase. Therefore, the requirements of the cigarette test described in the Furniture and Furnishings Regulations cannot be met without deviation from the prescribed ignition source. It was also raised that there was currently no alternative smouldering ignition source to a cigarette detailed in the Regulations, and that there are potentially new smouldering ignition sources other than cigarettes which are present in the modern home. In this topic, the increase in use of e-cigarettes was also noted.

The Furniture and Furnishings Regulations require that all upholstery composites are cigarette resistant. Currently, in the testing of upholstery composites, a ‘worst case’ filling is often used. This is where a cover is tested over a filling which would make the material most likely to ignite. The common choice used for a ‘worst case’ filling is non-combustion modified foam; however, there are a number of fillings which can be used and there is no standardisation of the ‘worst case’ filling.

Participants in the one to one consultations felt that the Furniture and Furnishings Regulations could be updated to include a standardisation of the ‘worst case’ filling, to ensure consistency across the furniture industry.

Concern around the use of fire retardants was also raised, as they are classified as high concern substances.

Note that in July 2019, BEIS OPSS provided a response to the 2016 consultation on updating the Furniture and Furnishings Regulations[112], announcing the development of a new approach which will focus on safety outcomes such as reduced risk of ignition, reduced risk of fire spread and will be underpinned by a set of essential safety requirements which all upholstered furniture placed on the market must meet.

Suggestions for practical work to assist the development of product flammability testing

All the suggestions for practical work to assist the development of product flammability (in relation to the furniture and furnishing industry) involved undertaking research.

Several participants suggested that research into modern sources of smouldering ignition would be greatly beneficial and could lead to the potential development of an alternative smouldering ignition source to that of the current non reduced ignition propensity cigarette.

[112] Department for Business, Energy & Industrial Strategy, Office for Product Safety & Standards, Updating The Furniture and Furnishings (Fire) (Safety) Regulations 1988, Government response to consultation, July 2019. Available from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/822072/furniture-fire-regulations-2016-consultation-government-response-july-2019.pdf. Last accessed 28 February 2020.

There were also suggestions for research into how to maintain fire safety while reducing the quantity of fire retardant present in furniture coverings, as many consumers are uncomfortable with the presence of fire retardant in the modern home.

Research to determine the contribution of individual furniture components (for example, covers/fillings/frame) to a modern domestic fire was also suggested.

Finally, research into the types of hazards in modern homes was suggested, and research into the modern materials present in domestic dwellings was recommended.

Changes to product design that could be made to improve product safety in a modern domestic fire

Whilst it was felt by the participants that the essential design of furniture could not particularly be changed, it was agreed that there could be a greater focus on the selection of materials used for furniture products; such as coverings; as this could have an impact on the safety of furniture in a modern domestic fire. It was acknowledged, however, that this could be challenging as materials used in furniture are essentially fashion items, which are designed to look good. In relation to this topic, it was suggested that the use of inherently/naturally flame retardant materials could be increased; however, this could be difficult as these materials are not widely manufactured and are also expensive, in a climate where consumers are gravitating towards cheaper products. It was suggested that it would be beneficial to look at other industries, such as the transport industry, for use of durable, inherently flame retardant material, to identify any common learning in this area.

It was also acknowledged that consideration needs to be given to electrical furniture, as previously the Furniture and Furnishings Regulations applied. However, electric furniture is now classified under the Machinery Directive and is CE marked. It was raised by participants that national legislation cannot be applied to products which are under CE marking and therefore, there is a question around whether electrical furniture must still adhere to the Furniture and Furnishings Regulations. It was noted that as technology in the modern home continues to advance, this topic should be clarified. OPSS has confirmed that both Furniture and Furnishings Regulations and the Machinery Directive apply to electric furniture.

Suggestions for practical work for changes to product design

There was a focus on suggestions to undertake use and misuse testing of electrical consumer products alongside furniture products, as many consumers are of the opinion that all products are safe in all scenarios. For instance, participants felt that misuse testing, such as leaving a mobile phone to charge unattended on a sofa, would be beneficial for practical work in relation to material selection for furniture. Testing of furniture products in close proximity to electrical appliances such as heaters was also suggested as being a beneficial piece of practical work to undertake, as an example of testing overheating of products through misuse.

Electrical products

The collated responses are grouped under headings to aid understanding of the opinions of the consultees. Note that additional BRE Global comments are indicated in italics.

Changes in the composition of products in the modern home: changing the characteristics of modern domestic fires

Increased quantity of electrical products

Over the last few years there has been a significant increase in the number and types of electrical products that are present in domestic premises. Not only are there significantly more types of products now than in the past but products that have been around (such as

dishwashers, dryers, etc.) are more commonplace and in greater use. For example, in the past families had one, perhaps two, televisions and now it is normal for there to be multiple smart televisions in the kitchen, lounge and bedrooms.

There has also been a rapid rise in the use of battery (lithium ion) powered electrical items that require periodic charging (e.g. electrical toothbrushes, smartphones, tablets, laptops). Rechargeable devices utilising lithium ion batteries are designed to store a lot of energy and therefore inherently have the capacity to cause fires. The Home Office fire statistics for England show that chargers are attributed as the cause for 60 fires/year and batteries and generators for 760 fires/year. The risk increases as poor quality and counterfeit batteries are more likely to cause fires than batteries from reputable manufacturers.

The increase in electrical items has also led to an increase in the number of support equipment required to provide power to these devices e.g. extension cables, multiple mains sockets, USB sockets. There is also an increase in the presence of gadgets which fall in and out of fashion (e.g. hoverboards) as well as small-scale specialised gadgets (e.g. coffee makers) and also cordless appliances (e.g. cordless vacuums).

Whilst there has been a decline in the number of smokers and fire risks associated with smoking, there has been an increase in the use of e-cigarettes that have been known to cause fires both during operation and during charging (currently 10 to 20 fires involving e-cigarettes recorded per year). See the Fire Statistics section, Analysis of 'other' ignition sources, example of e-cigarettes.

New sources of ignition in the modern home: changing the characteristics of modern domestic fires

Variable quality of electrical products

As well as an increase in the number of products in domestic homes, there is also increasing variability in terms of the quality of the products, their components and the associated support provided before and after purchase.

The evolution of the online marketplace allows the consumer accessibility to cheaper products from sources that cannot be easily determined. The same type of product can be very different in terms of quality (depending on manufacturer, where they were manufactured, etc.). Also, there is less available technical support from a product specialist at the pre-purchasing stage to assist consumers in choosing the most appropriate item. Poor quality and counterfeit items are difficult to identify, and these are more likely to cause fires than items from reputable manufacturers. It has been claimed that a significant proportion of products that have been recalled are often rechargeable items from lesser known brands.

It has been reported during the consultations that white goods appear to contribute to fires in a lot of high-profile cases. Table 17 details those items responsible, the associated frequency and trends of incidents from the Home Office Fire Statistics analysis.

Table 17: Fire incidents and trends for white goods

Electrical Item	Fire Incidents/year	Trend
Tumble dryers	~750	Increasing
Washing machines	~600	Increasing
Dishwashers	~300	Decreasing
Fridge/Freezers	~250	Decreasing
Others	~100	Decreasing
Total	~2000	

Whilst there are many reasons for this, including the greater number of white goods in premises, other factors such as the desire for noise dampening (e.g. washing machines), leading to more polyurethane foam being present which increases the chances of a fire developing (see also Figure 35 detailing the eight year totals of faults). Appliances such as fridge freezers have a large fire load (see the Literature Review section, Heat release and fire risk of consumer products) and also produce more toxic chemicals when burning. The flame retardants within them are increasingly coming off the market as some of their combustion products released during a fire are considered to be carcinogenic and have led to a number of restrictions and bans under EU legislation (see Literature Review section).

Other domestic style appliances account for around 10% of fires (~3,000 per year) but not all are white goods and it is difficult to distinguish faults and misuse from the other causes of fire.

New fire safety risks associated with electrical products in the modern home

Human behaviour

Human behavioural aspects, such as choice of products and how they are used, contribute to increasing the fire risk in the modern home. Generally, consumers purchasing electrical items and chargers for devices are driven towards those that are generally cheaper (but potentially of lower quality). These cheaper goods can be counterfeit or can contain counterfeit components. These products are readily available for convenience. For example, a consumer purchasing a replacement charger online will typically not consider the consequences and risks of buying cheaper goods. Safety is considered 'dull and boring' and people are not aware of the consequences of their choices or of the associated risks.

There is also evidence to suggest that consumers are unaware of the misuse of products, such as attempting to draw power (e.g. for charging) from USB slots in televisions (this causes overheating) when the purpose of the slot is for serving only (e.g. transferring data), but this is not labelled. People tend to leave chargers unattended or on charge overnight and they are not aware of how to deal with lithium fires should they occur which are generally made worse by applying water to them. The introduction of smart meters has led to increased usage of appliances at night and also people run items such as tumble dryers whilst they are out.

Some product manufacturers aim to make their products more repairable; therefore, there are potentially more untrained people opening up appliances in an effort to repair them; which presents a risk. Increasingly with the 'right to repair'[113] gathering momentum, it can only be expected that, in the future, this may lead to faults or fires unless manufacturers are on board to make this simple and safe for consumers to perform.

It is difficult for consumers, using online suppliers, to identify products that are counterfeit or that contain counterfeit components.

Other examples of fires caused by human behaviour are when items are placed too close to heat sources.

Addressing the new fire safety risks associated with electrical products in the modern home

Some support is available for consumers to help them reduce fire safety risks such as:

- Registering appliance schemes
- Availability of PAS 7100[114] (Code of practice on consumer product safety related recalls and other corrective actions)
- Product safety yougov survey.

[113] Consumer Rights Act 2015. Available from http://www.legislation.gov.uk/ukpga/2015/15/section/23/enacted. Last accessed 9 August 2019.

[114] PAS 7100:2018 Code of practice on consumer product safety related recalls and other corrective actions: Part I: Business Part 2: Regulators, British Standards Institution, 2018

However, more could be done to help consumers by:

- Raising awareness around the correct use of products.
- Promoting purchasing “good” [reputable] brands from “good” [reputable] retailers.
- Introduction of legislation around online marketplaces to outline who is responsible for checking the safety of products before their release into the UK market.

It has been claimed that fires could start from localised small sources (such as chargers) and this may not trigger smoke alarms in the early stages but only later when the fire develops.

Considering the fact that there are more electrical items in more areas of the home, it is possible that fires could be starting in areas far from circulation spaces which is the typical location of smoke alarms in most people’s homes. It may now be time to recommend consumers extending the number of smoke alarms in homes to include areas of high risk such as lofts containing photovoltaic cells on the roof and utility spaces that contain a number of white goods appliances.

Fire safety and flammability standards for electrical products

Standards

Product test standards provide a baseline of requirements for products to ensure that they are fit for use in expected service environments. Technical experts are involved in the drafting of standards to ensure that they include a comprehensive set of tests so that the products will perform under anticipated conditions in the field throughout their lifetime.

With value engineering, modern products are less over-engineered by design to meet the minimum requirements of standards and whilst compliant may lead to a small number of fires. Manufacturers will not voluntarily use better and more reliable quality components until standards require them even though it would be expected that doing this would lead to a reduction in the number of fires they cause.

New technologies are emerging faster than standards and the process for producing standards is time consuming. Additionally, timescales for testing of products to new or revised standards often takes a few years so there is a delay before approved products enter the market and any benefit is observed.

The standardisation process needs to be streamlined so that it can address the rapid emergence of new technology.

Do flammability standards for electrical products need to be updated?

With electrical product technologies emerging at such a rapid rate it was reported that:

- Products evolve at a faster rate than regulations.
- When products evolve before standards, old standards are applied to new technologies.
- Directives are being produced without standards in place.
- Standards do not reflect modern risks.
- Some standards such as BS EN 60335:1 and 2 series could be simplified.
- The needle flame test could be used more commonly as it is a more onerous test.
- The development of one robust standard flammability test for all products would be simple.

Suggestions for practical work to assist the development of electrical product flammability testing

The next stage would be to perform research work from which tests can be developed that are more realistic and reflect the risks in the modern home (for example, ignition with a sustained flame). However, there appears to be issues regarding the availability of test facilities to perform research that would support the development of product flammability testing.

Currently, small scale tests involving components of a product are used and it would be beneficial to research how components interact in the final product compared with individual component-led testing. If this was pursued, then tests of the final product could include more realistic scenarios of the types of fires that are likely to occur in the modern home.

Changes to electrical product design that could be made to improve product safety in a modern domestic fire

It was claimed that if risks could be mitigated by being taken away from consumers and instead incorporated into the design of products, then this would take out some of the associated risks with consumer misuse. It was stated that products should always be built to the correct design.

The standard for fire alarms and detection systems (BS 5839-6[115]) should consider detection in other areas where fires are known to develop or are more likely such as areas with multiple electrical items e.g. in utility rooms.

There is a place for innovative solutions such as the use of smoke and heat detection or other product monitoring within appliances.

The standardization process needs to be streamlined so that it can address the rapid emergence of new technology.

Suggestions for practical work for changes to electrical product design

It was proposed that it could be mutually beneficial to work with other countries to determine if the same trends and issues with electrical items are observed elsewhere. It was also proposed that the UK works more closely with market surveillance organisations who screen the market for issues around electrical items.

Currently, there is a lack of visibility for consumers about the safety of a product. If some form of rating could be incorporated in standards, such that products with more safety considerations in the design would get a higher grade, this would drive manufacturers to make better products. Such a rating could be displayed with the product (such as energy ratings) that would inform consumers.

Whilst the consultees did not state how such a safety rating could be determined, it would be expected that this would incorporate a number of factors taken together. These could include criteria such as the power rating, quality of materials used (being greater than minimum performance requirements), additional electrical safety features e.g. fuses, quality of cables used and other design features intended to additionally increase the safety of the device. An approach of groups of criteria and points under each criteria could be used to determine the overall safety rating.

[115] BS 5839-6: 2019 Fire detection and fire alarm systems for buildings. Code of practice for the design, installation, commissioning and maintenance of fire detection and fire alarm systems in domestic premises, British Standards Institution, 2019.

Main findings

Fire characteristics and changes in the contents/design of the home

Literature review

Although a review of published literature of general fire statistics for UK dwellings is available for recent years, relevant literature on the heat release rate and fire risk of consumer products is dated, generally of the order of 20 years old. This is unlikely to represent the fire risk of modern consumer products. Relevant published literature on this issue is also mostly based on overseas data. Therefore, care should be taken with the interpretation of existing literature, as this is unlikely to fully represent modern dwelling fires in the UK.

The literature review has identified ongoing research on the fire risk of lithium-ion battery consumer products (i.e. laptops, mobile phones, e-cigarettes). This is a recognised fire risk relating to modern consumer product design and the need for mitigation measures to reduce this risk. The review has identified the processes leading to fire incidents attributed to an exothermic reaction to ‘thermal runaway’ of this type of consumer product, and potential changes to lithium-ion battery design to mitigate the fire risk. This is an area of research that is ongoing internationally and expected to continue, such that review, and consideration of future research output, would be of benefit to improve lithium-ion consumer product design.

The review has identified changes in the characteristics of modern home design compared to legacy home design, with a trend for living areas to be more open plan and the increased use of Modern Methods of Construction involving the use of combustible materials. Literature on changes in the expected fire dynamics between a modern and legacy dwelling fire is very limited and based on overseas data which may not represent changes to modern dwelling fires in the UK, as modern contents in the UK are likely to have more strict flammability controls.

There is a lack of relevant data on fire load energy density/fire behaviour for modern dwellings in the UK. The current fire load energy density values assumed for dwelling fires in the UK are based on work carried out in the mid-1980’s and may not be representative of modern dwelling fires in the UK. However, this remains to be the most relevant data available. Although more recent data is available overseas, variation in the methodologies used to determine fire load density between different countries, makes comparison between them very difficult, if not impossible. Due to the scarcity and very dated nature of the available data on fire load energy density in the UK, further study of fire load in modern dwellings is needed.

Fire statistics

The IRS Home Office Fire Statistics for England has shown that the number of dwelling fires has fallen from a maximum of 58,280 in 1999/2000, to about 30,000 fires attended by the Fire and Rescue Services in each of the last five years. Roughly 90% of these fires are accidental. Over 50% of fires start in the kitchen, followed by bedroom and living room (approximately 10% each). These proportions have remained constant since 2010/2011.

Fire statistics give a number of different fields describing the fire: cause of fire; source of ignition; material first ignited; material mainly responsible for fire spread and area of fire damage. Depending on the circumstances, different fields may be more appropriate than others to describe the type of fire. If the cause was a fault, the source of ignition is usually the same as the item first ignited. However, for other causes, the material first ignited is more useful. For example, laundry accidentally placed on a hot cooker hob would have ignition source as ‘cooker hob’ and material first ignited as ‘clothing or textiles’; this is a clothing fire,

not a cooking fire. If the fire spreads beyond the first item to cause significant further damage (greater than 5 m^2) then it has been assumed that the material mainly responsible for spread is the best descriptor of the fire.

Food fires were almost all (98.8%) ignited by cooking. Other different types of material ignited may be associated with different types of ignition sources:

- Structure, etc. by electrical supply, appliances.
- Clothing/textiles by cooking, smoking, appliances.
- Foam/plastics etc. by cooking, electrical supply, appliances.
- Furniture by smoking, matches, candles and naked flames.

Annual trends for specific ignition sources are discussed under the next heading.

Different fire types result in different areas of damage. Of the commonest types, furniture fires have the largest average area of damage (after those of type ‘not known’). Cooking fires are much smaller in extent, on average.

Fire area is correlated with Fire and Rescue Service response time. The response time has increased by about 6% (30 seconds) over the period 2010 to 2018; however, the corresponding slight increase in average area is masked by random variation. Looking at the relationship between the average fire area and specific response time shows a much clearer picture, in which the average fire area does not vary much for response times under 10 minutes but increases significantly for longer times.

Real fire incidents

Throughout the ten year period of data collation of real fire incidents (January 2008 to December 2018), there were a number of fires each year attributed to electrical items. Heaters, white goods and battery chargers were among the most common sources of ignition recorded for real fire incidents which occurred in domestic dwellings and involved consumer products.

There was insufficient data recorded in many of the real fire reports to determine the most common items which were first ignited in incidents involving consumer products in domestic dwellings.

Note that the data collected for real fires concentrates on fires which have possible implications for the Building Regulations and therefore is focussed on more severe fires and does not include less significant fires, such as cooking fires.

Product recalls

Wiring, cabling and plugs were the most frequent product type recalled and the most frequent source of ignition when caused by faults, according to reviewed product recall databases. The reasons for this may include: there are a significant amount of counterfeit products of this type, and this product type is most likely to be misused by consumers.

Overheating of appliances was the most frequent underlying cause of fire for the recalled products recorded, followed by battery overheating and then insufficient electrical insulation. Therefore, this suggests that domestic electrical appliances are most likely to cause a fire due to overheating.

Changes in furniture and furnishings including beds from consultations

It was reported that fillings within domestic upholstered furniture have not changed (with polyurethane foam still being the main filling used); however, furniture has become more fashion orientated and covering materials which are used in furniture have become more

customisable by the consumer, and are changed more frequently in the modern home. The increase in the use of modern materials in furniture could have an impact on the flammability of the product and also increase the fuel load within the home. It was also noted that materials used in the construction of furniture, such as timber and plastics, have also changed over the years. There are also more foam only mattresses for beds in the modern home than previously.

A change in the buying process was also raised as changing the composition of furniture and beds in the modern home, as consumers are now seeking to buy cheaper, short-term products rather than, as previously, more expensive long-term products. These less expensive products may be inherently/naturally less flame retardant.

The introduction of electrical accessories in furniture in the modern home was discussed; as there is now the possibility to include accessories such as mobile phone charging ports in sofas and armchairs as technology evolves.

Changes in electrical products from consultations

Over the last few decades there has been an increase in the number and types of electrical products inside the home as well a rapid rise in the use of lithium ion battery powered electrical items that require periodic charging. Electrical items are readily obtainable but the consumer is not well informed to identify poor quality and counterfeit appliances, which are more likely to cause fires than appliances from reputable manufacturers.

Human behaviour increases the risk of fire in other ways such as leaving flammable items too close to heat sources or the unintentional misuse of appliances such as USB ports, intended for information transfer, but being used as a means to charge appliances. Increasingly consumers are using appliances either at night (to utilise cheaper energy tariffs) or whilst they are not present.

Trends in ignition sources

Fire statistics

Annual trends for common ignition sources show that:

- Washing machines, tumble dryers, personal computers and battery chargers account for an increasing proportion of fires.
- Television sets, ‘other’ appliance, matches, and naked flame account for a decreasing proportion of fires.
- The proportion of fires caused by smoking materials has remained unchanged during the period 2010 to 2018.

Note that these are changing trends; the ignition sources where the trend is an increasing proportion are not necessarily those sources that are currently the commonest. Also note that the commonest ignition sources vary depending on the material ignited.

In the Home Office Fire Statistics, data on the source of ignition is generally entered by means of a drop-down list. Although this list contains over 50 categories, these are still restricted to common items. For more unusual circumstances there is a category ‘other’, and an associated text field which can provide more details.

Unfortunately, it is very hard to derive any meaningful conclusions from analysis of the text fields associated with ‘other’ categories. There are a number of reasons for this, including the fact that the sample size is quite small, for example ‘other’ ignition sources account for approximately 1% of all fires; and inconsistent descriptions (and spellings) from different people completing the IRS forms.

The largest obstacle is probably that the different people completing the IRS forms do not recognise that an item is ‘new’ and therefore worthy of special mention under the ‘other’ category text field, rather than using an existing standard category. As an example, e-cigarettes could be classed as ‘smoking materials’ or ‘battery charger’ rather than explicitly mentioned.

Examining the text fields in the statistics, e-cigarettes are mentioned in 10 to 20 fires per year. To put this in context, there are 2,000 fires per year caused by ‘smoking materials’. Whilst the true number of e-cigarette fires is unknown (since some may be classified more generally), it seems reasonable to conclude that e-cigarettes have a significantly reduced likelihood of starting a fire, compared to the risk from conventional cigarettes.

Real fire incidents

There has also been a noticeable rise in the number of fires in domestic dwellings caused by battery chargers since 2014; including faulty electronic cigarettes and counterfeit charging devices.

There has also been a rise in the number of fires involving white goods in domestic dwellings since 2015, which triggered campaigns for a product recall database to record the number of real fire incidents attributed to white goods. As a result, the British Standards Institution published a code of practice for the procedure regarding product recalls (PAS 7100).

However, it should be noted that the rise in number of fires involving battery chargers and white goods seen in the dataset from real fires incidents, may not be representative of a trend for all domestic fires in the UK which involve consumer products, as this dataset has a bias towards fires with aspects of interest to the Building Regulations.

Product recalls

The correlation between the numbers of items recalled, of a given type, and the number of fires started by items of the same type, is not particularly good. However, it was still worth examining product recall databases as these may show some potentially new sources of ignition.

Some examples of items subject to product recalls, which are not explicitly mentioned in the fire statistics categories, are plug adaptors e.g. mains power supplies for laptops, overseas to UK mains plug adaptors (may not be rated for 240 V UK electricity supply), phone chargers, notebooks and laptop battery packs, laptops, tablets and external hard drives.

Furniture and furnishings consultations

Feedback from the consultees from the furniture industry indicated that causes of ignition sources in the home, particularly smouldering ignition sources are changing. Electrical furniture needs to be considered as a new source of ignition in the modern home, including the evolving technology of accessories in furniture such as charging ports. As technology continues to advance, the position of electrical furniture needs to be clarified, as electric furniture is classified under the Machinery Directive and is CE marked. During the one to one consultations it was raised that national legislation cannot be applied to products that are under CE marking, therefore there is a question around whether electrical furniture must still adhere to the Furniture and Furnishings Regulations.

Electrical appliances consultations

It has been reported during the consultations that white goods appear to contribute to fires in a lot of high-profile cases. The increasing number of white good in premises is one factor but others include consumer desires, for example for quieter white goods appliances. These lead to the implementation of noise dampening (e.g. washing machines) that contain more polyurethane foam which increases the chances of a fire developing. Flame retardants present within foams are increasingly coming off the market as the combustion products released during a fire are carcinogenic.

Flammability testing

A review of the flammability standards for consumer products, principally furniture and furnishings (including beds and mattresses) and electrical appliances, was carried out. Other consumer products were also discussed.

Whilst there are many standards for the multitude of different products, there is only a limited number of fire tests referenced by these standards. These include:

- Cigarette test (furniture)
- Match test (furniture)
- Glow wire test (electrical products)
- Needle flame test (electrical products)

The cigarette test is described in Schedule 4 of the Furniture and Furnishings Regulations, with the procedure outlined in BS 5852: Part 1. It should be noted that the cigarette ignition source must comply with requirements of mass, length, diameter and smoulder rate. Currently, only reduced ignition propensity cigarettes are available in the UK and EU; which do not meet the requirements of the Regulations.

The Regulations require that all upholstery composites are cigarette resistant, therefore complying with the cigarette test as described above. In order to fulfil this requirement, a ‘worst case’ cigarette test can be carried out. A satisfactory result for the cigarette test with the worst case filling (typically non-combustion modified foam) indicates that the cover would be cigarette resistant with other fillings which were less likely to smoulder.

The match test is described in Schedule 5 of the Furniture and Furnishings Regulations, with the procedure outlined in BS 5852: Part 2. The parameters of the test are detailed to specify how the correct calorific output for a ‘source 1 match flame ignition source’ can be achieved. The ignition source is applied for 20 seconds. The sample must self-extinguish within two minutes of removal of the ignition source.

The glow wire test, outlined in BS EN 60695-1-10[100] and BS EN 60695-1-11, is used to determine whether an electrical product which is “exposed to an electrically heated source has either a limited ability to ignite or, if it ignites, a limited ability to propagate flame”. The preferred test specimen for a glow wire test is a complete end product. However, if testing on a complete end product is not possible, testing on a piece of the end product containing the part which is under examination, or the cutting of an aperture into the complete end product to allow access of the glow wire, is acceptable.

The needle flame test is described in BS EN 60695-11-5. This test simulates a small flame which may arise from a component fault in an electrical product and looks at the effect of the flame on the end product. The areas observed include if the flame causes ignition, and if so if the combustible parts of the product burn for a limited time, or if the spread of flame occurs.

Suggestions for further practical work to support product flammability tests

Fire statistics

The review of the Home Office fire statistics for England includes a number of pie charts which show the ignition sources, when different materials are ignited first. This information may be valuable when considering what fire tests should be defined in different fire safety standards.

Additionally the fire statistics show trends for ignition sources accounting for an increasing (or decreasing) proportion of fires, which may be valuable when anticipating the future, but should not be confused with the ignition sources that are currently the commonest causes of fire.

Furniture and furnishings

The general consensus among the participants of the one to one consultations was that the Furniture and Furnishings (Fire Safety) Regulations 1988 (as amended) need to be updated to reflect the change in the environment seen in the modern home.

One of the main topics that participants aired as requiring review was the consideration of alternative smouldering sources of ignition in the modern home. The cigarette test was raised by multiple participants as a flammability fire test which needed review due to the required use of a non-reduced ignition propensity cigarette as an ignition source, an item which is no longer commercially available therefore, creating a deviation from the prescribed test. It was suggested that research into modern sources of smouldering ignition would be beneficial, possibly leading to the development of an alternative smouldering ignition source to a non-reduced ignition propensity cigarette.

Another suggestion for changes to flammability standards and the associated fire tests was the review of the ‘worst-case’ filling which can be used in the testing of upholstery composites if the filling to be used is unknown. Currently, there is no prescribed standard for material to be used, and it was suggested that the ‘worst-case’ filling could be standardised to ensure alignment across the furniture industry.

The main fire safety risk in the modern home with regards to furniture and furnishings was agreed by consultees to be imported products which have an unknown level of fire safety. It was suggested that imported products should undergo routine testing to identify products which are non-compliant.

Feedback from the consultations also highlighted a lack of consumer awareness around the use of electrical consumer products alongside furniture. This included leaving electrical products such as mobile phones to charge unattended in unsuitable locations, such as on a sofa. It was suggested that use and misuse testing of electrical products with furniture could be incorporated into flammability tests and the relevant standards.

Electrical appliances

Electrical product technologies are emerging at a faster rate than regulations so that old standards are being applied to new technologies. Some of the series of standards for electrical products could be simplified and a more consistent and more onerous test could be applied across the range of products covered. The standardisation process could be simplified to ensure that the products are tested more effectively and are available in the market sooner.

Research work could be conducted from which product flammability tests could be developed that are more realistic and reflect the risks in the modern home (e.g. ignition with sustained flame). However, it was reported that there were issues with the availability of test facilities to perform this research.

It has been proposed that instead of fire testing individual components from an electrical product, the complete product should be tested which would be more representative and give greater assurance.

Product design changes to improve product safety, including suggestions for further practical work

In general, there was a lack of relevant literature on consumer product design and fire risks.

From the ongoing research on the fire risk of lithium-ion battery consumer products (i.e. laptops, mobile phones, e-cigarettes) identified in the literature review, the potential changes to lithium-ion battery design to mitigate the fire risk include: the use of fire retardants as additives to the electrolytes; replacing cobalt-based electrode by lithium ion phosphate to improve thermal stability, battery life, to give high power but with a lower energy density; and provide a temperature coefficient to generate cell resistance to increased temperature, reducing current going through the cell.

The available literature on proposed changes to other consumer products design was mainly related to fridge-freezer fires. The review identified potential ignition sources located in close proximity to combustible plastics and insulation material used in the appliance housing. The review also identified specific fire growth and spread mechanisms once ignition had occurred due to the use of plastic drip trays, and 'twin-wall' backing materials and polyurethane foam insulation panels. Proposed changes to design include the avoidance of plastics in housings with the use of metal coverings and the use of limited combustibility foam insulation materials. In addition to limiting the flammability and combustibility of foam insulation materials used, the use of more fault tolerant components that are less likely to fail and act as sources of ignition was identified.

The product recall databases do not contain a large enough sample for robust conclusions to be drawn. However, a common failing in wiring, cabling and plugs and battery chargers was insufficient insulation. For wiring, cabling and plugs, a second common problem was overheating. In PC equipment, the most common problem was battery overheating.

Feedback from consultations with the furniture industry highlighted that there could be a greater focus on the selection of materials used for coverings of furniture, and to increase the use of inherently/naturally flame retardant materials, as this could have an impact on product safety. It was noted that use and misuse testing of electrical products could also be beneficial in the selection of materials for furniture coverings.

Concern around the use of fire retardants in furniture in the modern home was also highlighted during consultations, and it was suggested that research into how to maintain the fire safety of products while reducing the quantity of fire retardant in furniture would be beneficial to product safety.

Fire alarms could be recommended to be used in areas where fires are known to develop or are more likely such as areas containing multiple electrical items. There is a place for innovative solutions such as the use of smoke and heat detection or other product monitoring within appliances. The standardisation process needs to be streamlined so that it can address the rapid emergence of new technology.

Currently, there is a lack of visibility for consumers about the safety of a product. If some form of rating could be incorporated in standards, such that products with more safety considerations in the design would get a higher rating, this would drive manufacturers to make better products. Such a rating could be displayed with the product (similar to energy ratings) and that would better inform consumers.

It would be beneficial to identify how many of the product recalls anticipate fire problems and how many product recalls are in response to fires that have already occurred. This information is not currently included on product recall websites.

There is no single product recall website that contains all recalled products. It would be of great benefit for consumers to only have to refer to one website to identify if any product in their home has been recalled. If it was easier for the consumers to identify recalled products, they could ensure they deal with them appropriately.

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Appendix 1: Extended list of BS EN 60335 Part 1 and Part 2 standards

BS EN 60335 Household and similar electrical appliances. Safety. Part 1 and Part 2 (series):

- Part 1 Safety of household and similar electrical appliances. General requirements
- Part 2-2 Safety of household and similar electrical appliances. Particular requirements for vacuum cleaners and water suction cleaning appliances
- Part 2-3 Specification for safety of household and similar electrical appliances. Particular requirements. Electric irons
- Part 2-4 Specification for safety of household and similar electrical appliances. Particular requirements. Spin extractors
- Part 2-5 Safety of household and similar electrical appliances. Particular requirements for dishwashers
- Part 2-6 Specification for safety of household and similar electrical appliances. Particular requirements. Cooking ranges, cooking tables, ovens and similar appliances for household use
- Part 2-7 Specification for safety of household and similar electrical appliances. Particular requirements. Washing machines
- Part 2-8 Specification for safety of household and similar electrical appliances. Particular requirements. Electric shavers, hair clippers and similar appliances
- Part 2-9 Specification for safety of household and similar electrical appliances. Particular requirements. Toasters, grills, roasters and similar appliances
- Part 2-10 Specification for safety of household and similar electrical appliances. Particular requirements. Floor treatment machines and wet scrubbing machines
- Part 2-11 Specification for safety of household and similar electrical appliances. Particular requirements. Tumbler dryers
- Part 2-12 Specification for safety of household and similar electrical appliances. Particular requirements. Warming plates and similar appliances
- Part 2-13 Specification for safety of household and similar electrical appliances. Particular requirements. Frying pans, deep fat fryers and similar appliances
- Part 2-14 Specification for safety of household and similar electrical appliances. Particular requirements for kitchen machines
- Part 2-15 Specification for safety of household and similar electrical appliances. Particular requirements. Appliances for heating liquids
- Part 2-16 Specification for safety of household and similar electrical appliances. Particular requirements. Food waste disposers
- Part 2-17 Specification for safety of household and similar electrical appliances. Particular requirements for blankets, pads and similar flexible heating appliances

- Part 2-21 Specification for safety of household and similar electrical appliances. Particular requirements. Storage water heaters
- Part 2-23 Specification for safety of household and similar electrical appliances. Particular requirements. Appliances for skin or hair care
- Part 2-24 Specification for safety of household and similar electrical appliances. Particular requirements. Refrigerators, food-freezers and ice-makers
- Part 2-25 Specification for safety of household and similar electrical appliances. Particular requirements. Microwave ovens
- Part 2-26 Specification for safety of household and similar electrical appliances. Particular requirements. Clocks
- Part 2-27 Specification for safety of household and similar electrical appliances. Particular requirements. Ultra-violet and infra-red radiation skin treatment appliances for household and similar use
- Part 2-28 Specification for safety of household and similar electrical appliances. Particular requirements. Sewing machines
- Part 2-29 Specification for safety of household and similar electrical appliances. Particular requirements. Battery chargers
- Part 2-30 Specification for safety of household and similar electrical appliances. Particular requirements. Room heaters
- Part 2-31 Specification for safety of household and similar electrical appliances. Particular requirements. Range hoods
- Part 2-32 Specification for safety of household and similar electrical appliances. Particular requirements. Massage appliances
- Part 2-33 Specification for safety of household and similar electrical appliances. Particular requirements. Coffee mills and coffee grinders
- Part 2-34 Specification for safety of household and similar electrical appliances. Particular requirements. Motor-compressors
- Part 2-35 Specification for safety of household and similar electrical appliances. Particular requirements. Instantaneous water heaters
- Part 2-36 Specification for safety of household and similar electrical appliances. Particular requirements. Commercial electric cooking ranges, ovens, hobs and hob elements
- Part 2-37 Specification for safety of household and similar electrical appliances. Particular requirements. Commercial electric deep fat fryers
- Part 2-38 Specification for safety of household and similar electrical appliances. Particular requirements for commercial electric griddles and griddle grills
- Part 2-39 Specification for safety of household and similar electrical appliances. Particular requirements. Commercial electric multi-purpose cooking pans
- Part 2-40 Specification for safety of household and similar electrical appliances. Particular requirements. Electric heat pumps, air conditioners and dehumidifiers
- Part 2-41 Specification for safety of household and similar electrical appliances. Particular requirements. Pumps for liquids having a temperature not exceeding 35°C

- Part 2-42 Specification for safety of household and similar electrical appliances. Particular requirements. Commercial electric forced convection ovens, steam cookers and steam-convection ovens
- Part 2-43 Specification for safety of household and similar electrical appliances. Particular requirements. Clothes dryers and towel rails
- Part 2-44 Specification for safety of household and similar electrical appliances. Particular requirements. Electric ironers
- Part 2-45 Specification for safety of household and similar electrical appliances. Particular requirements. Portable electric heating tools and similar appliances
- Part 2-47 Specification for safety of household and similar electrical appliances. Particular requirements. Commercial electric boiling pans
- Part 2-48 Specification for safety of household and similar electrical appliances. Particular requirements. Commercial electric grillers and toasters
- Part 2-49 Specification for safety of household and similar electrical appliances. Particular requirements. Commercial catering electric hot cupboards
- Part 2-50 Specification for safety of household and similar electrical appliances. Particular requirements. Commercial electric bains-marie
- Part 2-51 Specification for safety of household and similar electrical appliances. Particular requirements. Stationary circulation pumps for heating and service water installations
- Part 2-52 Specification for safety of household and similar electrical appliances. Particular requirements. Oral hygiene appliances connected to the mains supply through a safety isolating transformer
- Part 2-53 Specification for safety of household and similar electrical appliances. Particular requirements. Electric sauna heating appliances
- Part 2-54 Specification for safety of household and similar electrical appliances. Particular requirements. General purpose cleaning appliances
- Part 2-55 Specification for safety of household and similar electrical appliances. Particular requirements. Electrical appliances for use with aquariums and garden ponds
- Part 2-56 Specification for safety of household and similar electrical appliances. Particular requirements. Projectors and similar appliances
- Part 2-57 Specification for safety of household and similar electrical appliances. Particular requirements. Ice-cream appliances with incorporated motor-compressors
- Part 2-58 Specification for safety of household and similar electrical appliances. Particular requirements. Commercial electric dishwashing machines
- Part 2-59 Specification for safety of household and similar electrical appliances. Particular requirements. Insect killers
- Part 2-60 Specification for safety of household and similar electrical appliances. Particular requirements. Whirlpool baths and similar equipment
- Part 2-61 Specification for safety of household and similar electrical appliances. Particular requirements. Thermal storage room heaters
- Part 2-62 Specification for safety of household and similar electrical appliances. Particular requirements. Commercial electric rinsing sinks

- Part 2-63 Specification for safety of household and similar electrical appliances. Particular requirements. Commercial electric water boilers and liquid heaters
- Part 2-64 Specification for safety of household and similar electrical appliances. Particular requirements. Commercial electric kitchen machines
- Part 2-65 Specification for safety of household and similar electrical appliances. Particular requirements. Air-cleaning appliances
- Part 2-66 Specification for safety of household and similar electrical appliances. Particular requirements. Water-bed heaters
- Part 2-67 Specification for safety of household and similar electrical appliances. Particular requirements. Floor treatment and floor cleaning machines, for industrial and commercial use
- Part 2-68 Specification for safety of household and similar electrical appliances. Particular requirements. Spray extraction appliances, for industrial and commercial use
- Part 2-69 Specification for safety of household and similar electrical appliances. Particular requirements. Wet and dry vacuum cleaners, including power brush, for industrial and commercial use
- Part 2-70 Specification for safety of household and similar electrical appliances. Particular requirements for milking machines
- Part 2-71 Specification for safety of household and similar electrical appliances. Particular requirements. Electrical heating appliances for breeding and rearing animals
- Part 2-72 Specification for safety of household and similar electrical appliances. Particular requirements. Automatic machines for floor treatment for commercial and industrial use
- Part 2-73 Specification for safety of household and similar electrical appliances. Particular requirements. Fixed immersion heaters
- Part 2-74 Specification for safety of household and similar electrical appliances. Particular requirements. Portable immersion heaters
- Part 2-75 Specification for safety of household and similar electrical appliances. Particular requirements. Particular requirements for commercial dispensing appliances and vending machines (electric or gas-heated)
- Part 2-76 Specification for safety of household and similar electrical appliances. Particular requirements. Particular requirements for electric fence energizers
- Part 2-77 Specification for safety of household and similar electrical appliances. Particular requirements for pedestrian controlled mains-operated lawn-mowers
- Part 2-78 Specification for safety of household and similar electrical appliances. Particular requirements. Outdoor barbecues
- Part 2-79 Specification for safety of household and similar electrical appliances. Particular requirements. Particular requirements for high pressure cleaners and steam cleaners for industrial and commercial use
- Part 2-80 Specification for safety of household and similar electrical appliances. Particular requirements. Fans
- Part 2-81 Specification for safety of household and similar electrical appliances. Particular requirements. Foot warmers and heating mats

- Part 2-82 Specification for safety of household and similar electrical appliances. Particular requirements for service machines and amusement machines
- Part 2-83 Household and similar electrical appliances. Safety. Particular requirements for heated gullies for roof drainage
- Part 2-84 Specification for safety of household and similar electrical appliances. Particular requirements for toilets
- Part 2-85 Specification for safety of household and similar electrical appliances. Particular requirements for fabric steamers
- Part 2-86 Specification for safety of household and similar electrical appliances. Particular requirements for electric fishing machines. Particular requirements for electric fishing machines
- Part 2-87 Specification for safety of household and similar electrical appliances. Particular requirements. Particular requirements for electric animal-stunning equipment
- Part 2-88 Specification for safety of household and similar electrical appliances. Particular requirements. Humidifiers intended for use with heating, ventilation, or air-conditioning systems
- Part 2-89 Household and similar electrical appliances. Safety. Particular requirements for commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor
- Part 2-90 Specification for safety of household and similar electrical appliances. Particular requirements. Commercial microwave ovens
- Part 2-91 Specification for safety of household and similar electrical appliances. Particular requirements for walk-behind and hand-held lawn trimmers and lawn edge trimmers
- Part 2-92 Household and similar electrical appliances. Safety. Particular requirements for pedestrian-controlled mains-operated lawn scarifiers and aerators
- Part 2-95 Specification for safety of household and similar electrical appliances. Particular requirements. Particular requirements for drives for vertically moving garage doors for residential use
- Part 2-96 Household and similar electrical appliances. Safety. Particular requirements for flexible sheet heating elements for room heating
- Part 2-97 Safety of household and similar electrical appliances. Particular requirements for drives for rolling shutters, awnings, blinds and similar equipment
- Part 2-98 Specification for safety of household and similar electrical appliances. Particular requirements. Humidifiers
- Part 2-99 Specification for safety of household and similar electrical appliances. Particular requirements for commercial electric hoods
- Part 2-101 Household and similar electrical appliances. Safety. Particular requirements for vaporizers
- Part 2-102 Household and similar electrical appliances. Safety. Particular requirements for gas, oil and solid-fuel burning appliances having electrical connections
- Part 2-103 Household and similar electrical appliances. Safety. Particular requirements for drives for gates, doors and windows

- Part 2-105 Household and similar electrical appliances. Safety. Particular requirements for multifunctional shower cabinets
- Part 2-106 Household and similar electrical appliances. Safety. Particular requirements for heated carpets and for heating units for room heating installed under removable floor coverings
- Part 2-108 Household and similar electrical appliances. Safety. Particular requirements for electrolysers
- Part 2-109 Household and similar electrical appliances. Safety. Particular requirements for UV radiation water treatment appliances

Lithium Cells:

- IEC 62281:2019. Safety of primary and secondary lithium cells and batteries during transport
- IEC 60086-4:2019 RLV. Primary batteries - Part 4: Safety of lithium batteries

Appendix 2: Extended list of baby products standards

Number	Title
BS 1877-10:2011+A1:2012	Domestic bedding. Specification for mattresses and bumpers for children's cots, perambulators and similar domestic articles
BS 7972:2001+A1:2009	Safety requirements and test methods for children's bedguards for domestic use
BS 8509-2008 + A1:2011	Children's beds domestic use. Safety requirements and test methods
BS 8510:2008	Child use and care articles. Safety of children's sleep bags. Safety requirements and test methods
BS EN 1130-1:1997	Furniture. Cribs and cradles for domestic use. Safety requirements
BS EN 12221-1:2008+A1:2013	Child use and care articles. Changing units for domestic use. Safety requirements
BS EN 12227:2010	Playpens for domestic use. Safety requirements and test methods
BS EN 1272:2017	Child care articles. Table mounted chairs. Safety requirements and test methods
BS EN 1273:2005	Child use and care articles. Baby walking frames. Safety requirements and test methods
BS EN 12790:2009	Child use and care articles. Reclined cradles
BS EN 13209-1:2004	Child use and care articles. Baby carriers. Safety requirements and test methods. Framed back carriers
BS EN 13209-2:2015	Child use and care articles. Baby carriers. Safety requirements and test methods. Soft carrier
BS EN 14036:2003	Child use and care articles. Baby bouncers. Safety requirements and test methods
BS EN 1466:2014	Child use and care articles. Carry cots and stands. Safety requirements and test methods
BS EN 14988:2017	Children's high chairs. Requirements and test methods
BS EN 16120:2012+A2:2016	Child use and care articles. Chair mounted seat
BS EN 16232:2013+A1:2018	Child use and care articles. Infant swings
BS EN 16780:2018	Textile child care articles. Safety requirements and test methods for children's cot bumpers
BS EN 16890:2017	Children's furniture. Mattresses for cots and cribs. Safety requirements and test methods
BS EN 1888-1:2018	Child use and care articles. Wheeled child conveyances. Pushchairs and prams
BS EN 1888-2:2018	Child care articles. Wheeled child conveyances. Pushchairs for children above 15 kg up to 22 kg
BS EN 1930:2011	Child use and care articles. Safety barriers. Safety requirements and test methods

BS EN 716-1:2017	Furniture. Children's cots and folding cots for domestic use. Safety requirements
PD CEN/TR 13387-4:2015	Child use and care articles. General safety guidelines. Thermal hazards
PD CEN/TR 16512:2015	Child use and care articles. Guidelines for the safety of children's slings
Industry specifications	
FIRA/FRQG C001:2016	Furniture Industry Quality Group (FRQG) Children's Domestic Furniture - Part 1 General Safety requirements

Appendix 3: List of questions for the one to one consultations

Introductory information
Name
Organisation
Manufacturer/Consumer group/Consumer products fire testing organisation/Other (all that apply)
Types of consumer products (all that apply and add details): Furniture and furnishings Electrical consumer products • Gadgets or appliances • Battery or mains powered Other (not covered by the above)

Questions Note. The following will relate to each type of consumer product
Introductory questions
1. Do you think that changes in the composition of products* in the modern home have changed the characteristics of modern domestic fires?
2. Do you think that new sources of ignition in the modern home have changed the characteristics of modern domestic fires?
3. What are the new fire safety risks associated with products in the modern home e.g. counterfeit goods, new types of goods? • How do these new risks affect the overall characteristics of modern domestic fires? • Are these risks being addressed or how could they be addressed?

4. Are there any fire safety and flammability standards for the specific consumer products/risks described in Question 3? • If yes, what are the associated fire tests? • If no, is there any consumer guidance on good practice, or industry best practice to mitigate fire risks for this type of consumer product?
5. If yes to earlier question, which of these fire and flammability standards and associated fire tests need updating to reflect modern domestic fires and new sources of ignition? • Name of each standard and relevant part of the standard. • If yes, why do these need updating? Are they too onerous, about right, not onerous enough? • If yes, have you any suggestions for practical work to assist the development of product flammability testing representative of modern fire scenarios?
Question on changes to consumer product design
6. Can you suggest what changes to the design of this type of consumer product might be possible to improve its safety in a modern domestic fire scenario? • Can you identify any practical follow-on work required in order to verify these suggestions?
Final question
7. Are there an additional comments you would like to make?

*Products: furniture/furnishings or electrical appliances as applicable to each interview.

Appendix 4: Dwelling fire scenarios

This appendix presents the complete IRS fire statistics for England data set, for the period 2010 to 2018 for dwelling fires, categorised by:

- Type of the room of fire origin
- Type of item or material on fire
- Time of day
- Weekday or weekend

This information may be useful for the stochastic modelling of dwelling fires or to gain an understanding of the different frequencies of various fire scenarios.

Data from the English Housing Survey[116] has been used to estimate the number of rooms of different types. This then allows estimates of the likelihood of a particular fire scenario, should a room or rooms be present in a particular dwelling. It is assumed that the number of fires in a particular room type in a given dwelling is proportional to the number of rooms of that type that are present in the dwelling.

The frequency of fires in different room types

Table A4.1 shows the IRS fire statistics 2010 to 2018 for England provided by the Home Office for this project, categorised according to the type of the room of fire origin. Some types (e.g. external structures, roof space, garage, etc.) have been included for completeness although they are not of direct relevance to this report.

The estimated number of rooms is also included in Table A4.1, with the derivation of these estimates given in the notes, from which the frequency of fire has been derived for different room types.

[116] Communities and Local Government. English Housing Survey, HOMES 2010, Annual report on England's housing stock, 2010, July 2012.

Table A4.1: The frequency of fire in different room types, per room per year

Room type	Number of fires 2010-2018	Number of rooms (/million)	Fire frequency (/million-room.years)
Airing/drying cupboard	2409	11.4 {a}	26.4
Bathroom/toilet	5978	37.8 {b}	19.8
Bedroom	22673	63.3 {c}	44.7 (or 48.8 {k})
Bedsitting room	2068		
Chimney	1071		
Conservatory	1166	4.2 {d}	34.9
Corridor/hall	9310	23.2 {e}	50.2
Dining room	1624		
External fittings	5801		
External structures	6614		
Garage	2944		
Indoor swimming pool	61		
Kitchen	141748	23.2 {f}	763.7
Lift/lift shaft/motor room	305		
Living room	22177	23.2 {g}	119.5 (or 134.5 {l})
Not known	1019		
Open plan area	1160		
Other	9140		
Refuse store	3792		
Roof	2157		
Roof space	3133		
Sauna	59		
Stairs	1584	16.5 {h}	12.0
Under stairs (enclosed, storage)	3833	16.5 {i}	29.1
Utility room	4890	3.0 {j}	202.7
GRAND TOTAL	256716		

Notes

Entries in italics included for completeness but not of direct interest.

a) Source: Energy and Utilities Alliance website[117].

b) According to the EHCS there were 22.4 million dwellings in 2010[118] and 23.9 million in 2017[119], average 23.2 million. 41% of homes had an extra WC, and 22% had an extra bath or shower[11], thus assumed to be 1.63 bathroom/toilet per dwelling.

c) The proportions of dwellings with different numbers of bedrooms[118] was: 1 – 10%; 2 – 27%; 3 – 43%, 4+ - 20%, from which the average number of bedrooms per dwelling is 2.73.

[117] Energy and Utilities Alliance. UK Homeowners love their airing cupboards, article dated 1 October 2015, Available from https://www.eua.org.uk/uk-homeowners-love-their-airing-cupboards/ Last accessed July 2019.

[118] Communities and Local Government. English Housing Survey, HOMES 2010, Annual report on England's housing stock, 2010, July 2012.

[119] Ministry of Housing, Communities and Local Government. English Housing Survey, Stock profile and condition, 2017, July 2019.

d) 18% of dwellings have a conservatory[120].

e) Assumed to be 1 room per dwelling. Note that the fire statistics may include fires in common parts of blocks of flats under this room type.

f) Assumed to be 1 room per dwelling.

g) Assumed to be 1 room per dwelling.

h) Assumed to be 1 room per dwelling, excluding flats (20% of dwellings) and bungalows (9% of dwellings)[118].

i) Assumed to be the same as the number of stair spaces – see {h}

j) 13% of dwellings have a utility room[118]

k) It is not clear whether a fire in a studio flat would be considered to be a 'bedsit' or 'open plan area'. If all 'bedsit' fires are combined with 'bedroom' fires, without altering the estimated number of bedrooms, the frequency is 48.8 fires per million rooms per year.

l) If all 'dining room' and 'open plan area' fires are combined with 'living room' fires, without increasing the estimated number of rooms, the frequency is 134.5 fires per million rooms per year.

When the fire frequencies are expressed as in Table A1, it is interesting to note that 'utility room' has the second highest frequency, after 'kitchen' but ahead of 'living room' and 'bedroom'.

Room type, item/material type and time of day

Tables A4.2 to A4.14 present the number of fires for different combinations of room type, item or material type, and time of day (four-hour bands). Some room and item types were omitted as being unknown or undefined, of less relevance (e.g. external fires) or of such low frequency as to be insignificant.

The omitted room types were:

- Other (9140)
- External structures (6614)
- External fittings (5801)
- Refuse store (3792)
- Roof space (3133)
- Garage (2944)
- Roof (2157)
- Chimney (1071)
- Not known (1019)
- Lift/Lift shaft/Motor room (305)
- Indoor swimming pool (61)
- Sauna (59)

The omitted item/material types were:

- Other (9876)
- Not known (4216)

[120] Department of Energy and Climate Change. Energy Follow-up Survey 2011, Report 6: Conservatories, BRE report 287473, December 2013.

- None (1862)
- Animal products (1068)
- Vegetation (873)
- Other appliance or equipment (570)
- Decoration/celebration (265)
- Battery charger (230)
- Fuel/chemical (206)
- Industrial equipment (104)
- Office equipment (84)
- Smoking related (71)
- Garden shed (60)
- Matches and candles (43)
- Naked flame (43)
- Vehicles only (41)
- Spread from secondary fire (20)
- Chimney (18)
- Blow lamp/paint remover (11)
- Gardening equipment (8)
- Natural occurrence (3)

The effect of fire occurring at the weekend, rather than during a weekday, was to increase the likelihood of fire during the night time (see Analysis of fire statistics section in the report). However, there were no obvious trends in terms of particular room types or item types being responsible for the increased numbers of fires per day on the weekend. Hence, in the tables that follow, weekend and weekday fires are not distinguished.

Table A4.2: Number of fires 2010-2018, by item type and time of day, in Airing/drying cupboard

Item/material type	00-04h	04-08h	08-12h	12-16h	16-20h	20-24h	Total
Wiring, cabling, plugs	72	58	83	99	127	114	553
Heating equipment	61	62	81	74	104	97	479
Fullroom	72	55	68	94	102	67	458
Clothing/textiles	26	31	42	62	77	61	299
Structural/fixtures/fittings – Internal	11	15	12	23	29	28	118
Batteries, generators	19	12	17	18	21	16	103
White goods	2	2	9	21	17	13	64
Foam, rubber, plastic	12	4	17	6	13	7	59
Paper/cardboard	4	3	5	8	8	5	33
Domestic appliance		3	2	2	3	7	17
Furniture/furnishings	2	1	1	3	4	3	14
Explosives, gas, chemicals	1		2	3	2	2	10
Food				2	6	1	9
Wood	1		1	3	3		8
Electric lighting		2	1	1	1	3	8
Rubbish/waste/recycling	1	1		2	2	2	8
Cooking appliance					2		2
Home entertainment	1						1
TOTAL	285	249	341	421	521	426	2243

Table A4.3: Number of fires 2010-2018, by item type and time of day, in Bathroom/toilet

Item/material type	00-04h	04-08h	08-12h	12-16h	16-20h	20-24h	Total
Wiring, cabling, plugs	78	90	203	145	189	195	900
Fullroom	103	86	166	141	159	155	810
Domestic appliance	79	79	150	128	130	145	711
Clothing/textiles	46	42	73	89	124	134	508
Paper/cardboard	45	37	75	102	100	98	457
Heating equipment	37	49	104	81	88	95	454
Structural/fixtures/fittings – Internal	45	40	75	73	91	86	410
Furniture/furnishings	35	27	35	50	53	57	257
Foam, rubber, plastic	27	14	32	48	48	56	225
Rubbish/waste/recycling	19	15	21	32	34	26	147
Electric lighting	15	5	24	15	32	33	124
Batteries, generators	16	9	20	10	13	22	90
Wood	1	6	7	19	23	12	68
White goods	1	2	16	9	19	16	63
Explosives, gas, chemicals	7	1	11	19	5	12	55
Home entertainment			2		2	3	7
Food	1			1	3	1	6
Cooking appliance					1		1
TOTAL	555	502	1014	962	1114	1146	5293

Table A4.4: Number of fires 2010-2018, by item type and time of day, in Bedroom

Item/material type	00-04h	04-08h	08-12h	12-16h	16-20h	20-24h	Total
Fullroom	973	764	1224	1647	1828	1688	8124
Clothing/textiles	491	350	563	660	850	870	3784
Furniture/furnishings	392	283	449	657	746	695	3222
Paper/cardboard	135	107	200	235	334	288	1299
Wiring, cabling, plugs	128	80	150	189	210	269	1026
Structural/fixtures/fittings – Internal	52	43	78	123	151	111	558
Domestic appliance	64	45	89	81	98	101	478
Foam, rubber, plastic	52	39	65	74	130	107	467
Rubbish/waste/recycling	47	36	92	82	100	83	440
Heating equipment	45	40	63	44	71	85	348
Home entertainment	39	25	39	48	49	62	262
Electric lighting	18	14	32	25	57	56	202
Batteries, generators	22	12	23	32	49	57	195
Wood	14	7	24	32	35	40	152
Explosives, gas, chemicals	8	6	16	21	30	27	108
White goods	4	2	18	22	28	12	86
Food	5	3	6	4	14	14	46
Cooking appliance			1	2	2		5
TOTAL	2489	1856	3132	3978	4782	4565	20802

Table A4.5: Number of fires 2010-2018, by item type and time of day, in Bedsitting room

Item/material type	00-04h	04-08h	08-12h	12-16h	16-20h	20-24h	Total
Fullroom	82	62	53	98	108	124	527
Food	58	27	26	44	79	67	301
Clothing/textiles	42	45	44	43	55	62	291
Furniture/furnishings	41	25	38	48	55	57	264
Paper/cardboard	24	16	18	29	40	42	169
Rubbish/waste/recycling	10	8	14	14	14	10	70
Foam, rubber, plastic	12	6	6	9	16	20	69
Wiring, cabling, plugs	8	10	4	8	9	16	55
Structural/fixtures/fittings – Internal	5	3	4	3	6	7	28
Heating equipment	3	4	3	5	3	6	24
Explosives, gas, chemicals	5		1	2	3	4	15
Domestic appliance	1		2	3	3	5	14
White goods	4	1	3	4		2	14
Wood	1	1	1	4	1	6	14
Home entertainment	2	2	2	1	2	4	13
Batteries, generators	4		2	2	3	2	13
Electric lighting	1			4	1	3	9
Cooking appliance	1	2		2	2	2	9
TOTAL	304	212	221	323	400	439	1899

Table A4.6: Number of fires 2010-2018, by item type and time of day, in Conservatory

Item/material type	00-04h	04-08h	08-12h	12-16h	16-20h	20-24h	Total
Fullroom	45	29	53	75	63	50	315
White goods	7	3	23	21	20	18	92
Clothing/textiles	9	5	15	18	19	19	85
Wiring, cabling, plugs	4	6	23	12	16	19	80
Furniture/furnishings	4	6	8	15	17	14	64
Heating equipment	7	4	10	9	8	4	42
Paper/cardboard	3	4	7	6	7	13	40
Foam, rubber, plastic	3	5	6	9	9	7	39
Structural/fixtures/fittings – Internal	4		6	9	14	5	38
Rubbish/waste/recycling	1	4	7	6	14	3	35
Wood	1	2	7	10	6	3	29
Domestic appliance	1	3	1	6	1	2	14
Food			1	4	8		13
Batteries, generators	2	1			7	3	13
Explosives, gas, chemicals				5	5	2	12
Home entertainment		1	2	2	3	1	9
Electric lighting	1	1		2	1	2	7
Cooking appliance		2	2		1		5
TOTAL	92	76	171	209	219	165	932

Table A4.7: Number of fires 2010-2018, by item type and time of day, in Corridor/Hall

Item/material type	00-04h	04-08h	08-12h	12-16h	16-20h	20-24h	Total
Wiring, cabling, plugs	232	160	263	304	424	417	1800
Paper/cardboard	229	82	98	128	230	295	1062
Fullroom	284	123	100	120	183	242	1052
Batteries, generators	90	51	113	117	182	171	724
Clothing/textiles	115	49	72	98	133	172	639
Structural/fixtures/fittings – Internal	94	47	59	102	140	151	593
Furniture/furnishings	106	48	59	64	150	161	588
Explosives, gas, chemicals	105	35	33	30	73	142	418
Rubbish/waste/recycling	74	36	24	54	88	90	366
Electric lighting	31	28	49	51	80	84	323
Foam, rubber, plastic	37	26	37	49	72	59	280
Heating equipment	17	25	16	21	36	28	143
Wood	9	3	13	18	18	23	84
White goods	6	7	11	14	25	21	84
Domestic appliance	4	7	16	26	12	10	75
Food	3	1	2	7	10	3	26
Home entertainment	1			1	1	1	4
TOTAL	1437	728	965	1204	1857	2070	8261

Table A4.8: Number of fires 2010-2018, by item type and time of day, in Dining room

Item/material type	00-04h	04-08h	08-12h	12-16h	16-20h	20-24h	Total
Fullroom	49	30	45	51	62	70	307
Furniture/furnishings	33	15	27	21	41	28	165
Wiring, cabling, plugs	14	13	28	24	43	37	159
Clothing/textiles	13	13	20	26	39	25	136
Paper/cardboard	13	8	19	27	22	27	116
Wood	6	5	12	24	23	19	89
Structural/fixtures/fittings – Internal	7	4	10	12	33	20	86
Electric lighting	5	1	7	8	11	17	49
Foam, rubber, plastic	6	1	8	7	12	13	47
Rubbish/waste/recycling	4	2	3	8	20	7	44
Batteries, generators	3	3	8	5	15	4	38
Heating equipment	3	4	2	7	12	7	35
Home entertainment	1	3	3	7	6	6	26
Food	3		2	6	10	5	26
Explosives, gas, chemicals	5		4	4	5	4	22
White goods	2	4	4	2	4	6	22
Domestic appliance	2	1	4	4	6	4	21
Cooking appliance		1	2	1	1		5
TOTAL	169	108	208	244	365	299	1393

Table A4.9: Number of fires 2010-2018, by item type and time of day, in Kitchen

Item/material type	00-04h	04-08h	08-12h	12-16h	16-20h	20-24h	Total
Food	5078	2652	9558	18811	26527	13170	75796
Fullroom	1082	653	1505	2438	3049	1776	10503
White goods	508	344	1857	1952	1692	1463	7816
Clothing/textiles	429	355	1218	1779	2136	1138	7055
Foam, rubber, plastic	316	254	1044	1700	2200	956	6470
Cooking appliance	213	202	777	1224	2121	888	5425
Wiring, cabling, plugs	263	186	764	875	1145	891	4124
Paper/cardboard	255	208	643	999	1225	714	4044
Structural/fixtures/fittings – Internal	134	92	348	530	673	435	2212
Rubbish/waste/recycling	147	80	262	329	394	305	1517
Furniture/furnishings	90	74	248	311	397	224	1344
Wood	55	53	171	241	277	157	954
Domestic appliance	60	64	136	158	217	144	779
Heating equipment	46	62	91	115	164	107	585
Explosives, gas, chemicals	22	13	92	139	197	92	555
Batteries, generators	50	42	104	88	144	103	531
Electric lighting	19	22	40	35	83	91	290
Home entertainment	9	2	7	9	9	10	46
TOTAL	8776	5358	18865	31733	42650	22664	130046

Table A4.10: Number of fires 2010-2018, by item type and time of day, in Living room

Item/material type	00-04h	04-08h	08-12h	12-16h	16-20h	20-24h	Total
Fullroom	911	575	696	871	1102	1136	5291
Furniture/furnishings	442	276	412	558	706	736	3130
Paper/cardboard	222	171	279	363	533	413	1981
Clothing/textiles	258	208	294	317	433	381	1891
Wiring, cabling, plugs	158	107	205	236	357	366	1429
Wood	73	66	116	234	384	290	1163
Structural/fixtures/fittings – Internal	103	97	131	162	267	233	993
Rubbish/waste/recycling	99	69	109	154	176	166	773
Heating equipment	57	69	132	122	190	150	720
Foam, rubber, plastic	63	36	85	115	143	106	548
Home entertainment	44	26	48	59	89	98	364
Explosives, gas, chemicals	42	16	31	47	91	94	321
Batteries, generators	20	19	40	54	76	63	272
Electric lighting	18	13	21	30	59	64	205
Domestic appliance	14	10	22	43	35	35	159
Food	11	8	9	25	24	15	92
White goods	3	2	8	12	10	9	44
Cooking appliance		2	3	2	4	3	14
TOTAL	2538	1770	2641	3404	4679	4358	19390

Table A4.11: Number of fires 2010-2018, by item type and time of day, in Open plan area

Item/material type	00-04h	04-08h	08-12h	12-16h	16-20h	20-24h	Total
Fullroom	43	35	28	45	54	72	277
Food	23	11	9	26	48	31	148
Paper/cardboard	19	8	11	18	16	17	89
Clothing/textiles	5	5	7	16	14	22	69
Furniture/furnishings	7	9	8	9	20	15	68
Rubbish/waste/recycling	12	4	6	13	16	9	60
Wiring, cabling, plugs	8	7	6	10	15	9	55
Structural/fixtures/fittings – Internal	7	6	8	11	8	12	52
Foam, rubber, plastic	2	1	7	7	11	12	40
Wood	4	2	9	4	15	2	36
White goods	4	1	3	8	7	2	25
Electric lighting	3	1	1	5	6	2	18
Cooking appliance			1	3	6	4	14
Explosives, gas, chemicals	3	1		1	1	5	11
Batteries, generators			1	5	3		9
Heating equipment		1	2	3		2	8
Domestic appliance	2			1	2	1	6
Home entertainment						1	1
TOTAL	142	92	107	185	242	218	986

Table A4.12: Number of fires 2010-2018, by item type and time of day, in Stairs

Item/material type	00-04h	04-08h	08-12h	12-16h	16-20h	20-24h	Total
Paper/cardboard	43	13	20	49	74	73	272
Fullroom	62	19	18	29	48	78	254
Rubbish/waste/recycling	30	17	9	25	39	48	168
Clothing/textiles	15	18	15	19	32	37	136
Wiring, cabling, plugs	9	11	30	26	26	31	133
Furniture/furnishings	21	10	9	17	33	29	119
Structural/fixtures/fittings – Internal	4	3	13	14	27	22	83
Foam, rubber, plastic	8	4	8	6	23	18	67
Batteries, generators	4	9	5	6	19	12	55
Electric lighting	4	6	5	5	9	19	48
Explosives, gas, chemicals	6	5	4	5	4	3	27
Wood	2	2	2	4	3	4	17
Domestic appliance			3	2	4	2	11
Heating equipment			1	1		2	4
Home entertainment				2	1		3
Food						1	1
White goods					1		1
TOTAL	208	117	142	210	343	379	1399

Table A4.13: Number of fires 2010-2018, by item type and time of day, in Under stairs (enclosed, storage area)

Item/material type	00-04h	04-08h	08-12h	12-16h	16-20h	20-24h	Total
Wiring, cabling, plugs	145	116	254	263	378	327	1483
Batteries, generators	55	56	109	142	205	178	745
Fullroom	62	53	63	88	90	82	438
Structural/fixtures/fittings – Internal	21	11	30	32	49	32	175
Clothing/textiles	21	10	22	25	38	31	147
Paper/cardboard	19	10	20	19	33	27	128
White goods	7	6	13	26	32	24	108
Foam, rubber, plastic	11	5	13	22	27	18	96
Rubbish/waste/recycling	14	5	6	16	19	23	83
Heating equipment	5	9	9	12	11	16	62
Furniture/furnishings	7		3	9	10	4	33
Explosives, gas, chemicals	3	1	5	4	5	2	20
Wood	2	2	1	3	5	6	19
Domestic appliance			2	4	4		10
Electric lighting		1	1	2	4	2	10
Home entertainment			1	1		2	4
Food				2	1		3
Cooking appliance		1			1		2
TOTAL	372	286	552	670	912	774	3566

Table A4.14: Number of fires 2010-2018, by item type and time of day, in Utility room

Item/material type	00-04h	04-08h	08-12h	12-16h	16-20h	20-24h	Total
White goods	64	52	312	353	313	197	1291
Fullroom	108	76	184	226	171	151	916
Wiring, cabling, plugs	63	49	135	135	130	104	616
Clothing/textiles	26	23	71	96	111	73	400
Batteries, generators	18	15	41	34	44	53	205
Heating equipment	14	28	36	34	50	33	195
Structural/fixtures/fittings – Internal	11	2	35	54	55	36	193
Foam, rubber, plastic	5	3	24	37	30	18	117
Paper/cardboard	12	8	19	22	37	13	111
Rubbish/waste/recycling	10	5	10	14	17	15	71
Food	1		9	13	14	7	44
Domestic appliance		4	11	14	9	4	42
Furniture/furnishings	3	1	12	5	7	10	38
Explosives, gas, chemicals	3	2	6	8	5	9	33
Wood	3	1	4	8	7	4	27
Electric lighting	2	3	5	7	6	2	25
Cooking appliance			2	6	10		18
Home entertainment			2		1	1	4
TOTAL	343	272	918	1066	1017	730	4346

Tables A4.2 to A4.14 can be used to derive the probability that the fire occurs at a particular time and involves a particular item, given that the fire starts in a particular room type. The frequency of fires in particular room types is given in Table A4.1.

In most cases the probability of fire involving a particular item in a particular room would not be affected by the presence or absence of other room types or items. One exception might be made for White Goods in either the Utility Room or Kitchen. A household would presumably only have one example of specific types of white goods (e.g. fridge, freezer, washing machine, dishwasher, etc) which would normally either be in the utility room (if present) or kitchen. Utility rooms are present in 13% of dwellings, therefore in 87% of dwellings there would be a kitchen without an accompanying utility room. The number of fires in 2010-2018 involving white goods was 1291 in utility rooms, and 7816 in kitchens – not quite a ratio of 13:87, but close.

Further details for item/material types

The item/material type categories in Table A4.2 to Table A4.14 may in some cases be an amalgamation of various sub-items defined in the fire statistics (the amalgamation being introduced by BRE Global for convenience/conciseness). The following tables provide further details where these are available. It is assumed that the proportion of fires due to particular sub-items is not dependent on the room type where the item is located. Obviously, there will be some exceptions to this; bedding/mattress being most likely in a bedroom, for example.

For completeness, these tables include all item/material types, including those being unknown or undefined, of less relevance (e.g. external fires) or of such low frequency as to be insignificant.

The fire statistics description in these tables may either be the description of the item ignited first, if caused by a fault, or the material ignited first.

Table A4.15: Further details for fires defined as Clothing/textiles

Fire statistics description	All fires 2010-2018
Clothing/textiles - Other textiles	8216
Clothing/textiles – Clothing	5858
Clothing/textiles – Bedding	2422
TOTAL	16496

Table A4.16: Further details for fires defined as Cooking appliance

Fire statistics description	All fires 2010-2018
Cooking appliance - Cooker incl. oven	3004
Cooking appliance - Grill/toaster	971
Cooking appliance - Microwave oven	819
Cooking appliance - Ring/hot plate (separate appliance)	335
Cooking appliance - Other cooking appliance	266
Cooking appliance - Deep fat fryer	71
Cooking appliance - Barbecue	48
Cooking appliance - Camping stove	45
TOTAL	5559

Table A4.17: Further details for fires defined as Decoration/celebration

Fire statistics description	All fires 2010-2018
Decoration/celebration - Decorations/cards	229
Decoration/celebration - Christmas trees	36
TOTAL	265

Table A4.18: Further details for fires defined as Domestic appliance

Fire statistics description	All fires 2010-2018
Other domestic style appliance - Extractor fan	921
Other domestic style appliance - Other domestic style appliance	737
Other domestic style appliance - Electric blanket	269
Other domestic style appliance - Iron	171
Other domestic style appliance - Electric kettle	141
Other domestic style appliance - Vacuum cleaner	118
Other domestic style appliance - Hair dryer	70
Other domestic style appliance - Trouser press	2
TOTAL	2429

Table A4.19: Further details for fires defined as Electric lighting

Fire statistics description	All fires 2010-2018
Electric lighting - Other lights	496
Electric lighting - Fluorescent lights	478
Electric lighting - Spot lights	438
Electric lighting - Other incandescent light bulbs	248
Electric lighting - Fairy lights	36
TOTAL	1696

Table A4.20: Further details for fires defined as Explosives, gas, chemicals

Fire statistics description	All fires 2010-2018
Explosives, gas, chemicals - Petrol/oil products	1066
Explosives, gas, chemicals - Gases	650
Explosives, gas, chemicals - Fireworks	318
Explosives, gas, chemicals - Paint, varnish, resins, creosote	179
Explosives, gas, chemicals - Chemicals in raw state	53
Explosives, gas, chemicals - Explosives/ammunition	12
TOTAL	2278

Table A4.21: Further details for fires defined as Foam, rubber, plastic

Fire statistics description	All fires 2010-2018
Foam, rubber, plastic - Plastic - raw material only	8160
Foam, rubber, plastic - Foam - raw material only	659
Foam, rubber, plastic - Rubber - raw material only	555
TOTAL	9374

Table A4.22: Further details for fires defined as Food

Fire statistics description	All fires 2010-2018
Food - Other	39934
Food - Cooking oil or fat	36750
TOTAL	76684

Note. 11,066 “Food – cooking oil or fat” and 412 “Food – other” fires had a main cause of “Cooking – chip pan/deep fat fryer”. (Chip pans were also a main cause for other types of fires as well, though less frequent than “Food” fires)

Table A4.23: Further details for fires defined as Fuel/chemical

Fire statistics description	All fires 2010-2018
Fuel/chemical - Gases	101
Fuel/chemical - Liquids; petrol/oil related	75
Fuel/chemical - Solids; coal, coke, wood, card	23
Fuel/chemical - Flammable chemicals	7
TOTAL	206

Table A4.24: Further details for fires defined as Furniture/furnishings

Fire statistics description	All fires 2010-2018
Furniture/furnishings - Floor coverings	1983
Furniture/furnishings - Window coverings	1957
Furniture/furnishings - Upholstered furniture	1623
Furniture/furnishings - Bed/mattress	1580
Furniture/furnishings - Other furniture	1448
Furniture/furnishings - Other/unspecified furnishings	1397
Furniture/furnishings - Lampshades	171
TOTAL	10159

Table A4.25: Further details for fires defined as Heating equipment

Fire statistics description	All fires 2010-2018
Heating equipment - Central heating/hot water	1274
Heating equipment - Heating/Fire	1078
Heating equipment - Other heating equipment	454
Heating equipment - Separate water heating	339
Heating equipment - Power source	194
Heating equipment - Food warming equipment (not cooking)	18
Heating equipment - Patio equipment	6
TOTAL	3363

Table A4.26: Further details for fires defined as Home entertainment

Fire statistics description	All fires 2010-2018
Other domestic style appliance - TV	409
Other domestic style appliance - PC equipment (domestic use)	163
Other domestic style appliance - Audio equipment	89
Other domestic style appliance - Other electrical visual equipment	82
Other domestic style appliance - Video/DVD	17
TOTAL	760

Table A4.27: Further details for fires defined as Industrial equipment

Fire statistics description	All fires 2010-2018
Industrial equipment - Lift	49
Industrial equipment - Dryer	22
Industrial equipment - Other	21
Industrial equipment - Welding/cutting equipment	10
Industrial equipment - Kiln, oven, furnace	1
Industrial equipment - Manufacturing equipment	1
TOTAL	104

Table A4.28: Further details for fires defined as Matches and candles

Fire statistics description	All fires 2010-2018
Matches and candles - Matches	27
Matches and candles - Candles	12
Matches and candles - Oil/incense burners	4
TOTAL	43

Table A4.29: Further details for fires defined as Office equipment

Fire statistics description	All fires 2010-2018
Office equipment - PC	43
Office equipment - Other computer equipment	19
Office equipment - Telephone/answering machine/fax machine	15
Office equipment - Copiers/printers	7
TOTAL	84

Table A4.30: Further details for fires defined as Paper/Cardboard

Fire statistics description	All fires 2010-2018
Paper/cardboard - Household paper/cardboard	9401
Paper/cardboard - Other	2604
TOTAL	12005

Table A4.31: Further details for fires defined as Rubbish/waste/recycling

Fire statistics description	All fires 2010-2018
Rubbish/waste/recycling - Rubbish/waste material	5940
Rubbish/waste/recycling - Recycling - paper, cardboard	1444
Rubbish/waste/recycling - Recycling - other	389
TOTAL	7773

Table A4.32: Further details for fires defined as Smoking related

Fire statistics description	All fires 2010-2018
Smoking related - Cigarette lighter	39
Smoking related - Smoking materials	32
TOTAL	71

Table A4.33: Further details for fires defined as Structural/Fixtures/Fittings - External

Fire statistics description	All fires 2010-2018
Structural/fixtures/fittings - External - External fittings	3409
Structural/fixtures/fittings - External - Roof	985
Structural/fixtures/fittings - External - Other	699
TOTAL	5093

Table A4.34: Further details for fires defined as Structural/fixtures/fittings - Internal

Fire statistics description	All fires 2010-2018
Structural/fixtures/fittings - Internal - Internal fittings	2808
Structural/fixtures/fittings - Internal - Wiring insulation	2600
Structural/fixtures/fittings - Internal - Other	1198
TOTAL	6606

Table A4.35: Further details for fires defined as Vegetation

Fire statistics description	All fires 2010-2018
Vegetation - Other	388
Vegetation - Leaves	203
Vegetation - Trees	105
Vegetation - Straw/stubble	71
Vegetation – Hedge	63
Vegetation - Grassland/heath/scrub	29
Vegetation - Crops	14
TOTAL	873

Table A4.36: Further details for fires defined as Vehicles only

Fire statistics description	All fires 2010-2018
Vehicles only - Electrical fault	27
Vehicles only - Engine, fuel line or pump	9
Vehicles only - Unknown	3
Vehicles only - Other non-electrical	2
TOTAL	41

Table A4.37: Further details for fires defined as White goods

Fire statistics description	All fires 2010-2018
Other domestic style appliance - Washing machine	3770
Other domestic style appliance - Tumble dryer	2644
Other domestic style appliance - Dishwasher	2137
Other domestic style appliance - Fridge/freezer	972
Other domestic style appliance - Washer/dryer combined	481
Other domestic style appliance - Spin dryer	213
TOTAL	10217

For some item types, BRE Global has adopted a more concise description than that in the fire statistics. These cases are shown in Table A4.38 for clarity.

Table A4.38: Single-category items, concise and fire statistics descriptions, and numbers of fires 2010-2018

Concise description	Fire statistics description*	Fires
Animal products	Animal - Animal products	1068
Batteries, generators	Electricity supply - Apparatus - batteries, generators	3681
Battery charger	Other domestic style appliance - Battery charger	230
Blow lamp/paint remover	Other domestic style appliance - Blow lamp/paint remover	11
Chimney	Chimney - Chimney	18
Fullroom	This includes all fires spreading beyond the item ignited first and producing a fire-damaged area in excess of $5m^2$	43826
Garden shed	Wood - Garden shed	60
Gardening equipment	Other domestic style appliance - Gardening equipment	8
Naked flame	Naked flame - Lighted paper or card, or other naked flame	43
Natural occurrence	Natural occurrence - Natural occurrence	3
None	None	1862
Not known	Not known	4216
Other	Other	9876
Other appliance or equipment	Other appliance or equipment	570
Spread from secondary fire	Spread from secondary fire - Spread from secondary fire	20
Wiring, cabling, plugs	Electricity supply - Wiring, cabling, plugs	15060
Wood	Wood - Other wooden	3985

* This may either be the description of the item ignited first, if caused by a fault, or the material ignited first.

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