WHITE PAPER
RESIDENTIAL ELECTRICAL SAFETY

HOW TO ENSURE PROGRESS

Forum for European Electrical Safety (FEEDS)

May 2017

ECI Publication No Cu0246

Available from www.leonardo-energy.org

Document Issue Control Sheet

Document Title:	White Paper – Residential electrical safety – How to ensure progress
Publication No:	Cu0246
Issue:	01
Release:	Public
Content provider(s)	Laurent Lhardit, Benoît Dôme, Olivier Tissot
Author(s):	Bruno De Wachter
Editorial and language review	Noel Montrucchio
Content review:	Laurent Lhardit, Benoît Dôme, Olivier Tissot

Document History

Issue	Date	Purpose
1	May 2017	First release
2		
3		

Disclaimer

While this publication has been prepared with care, European Copper Institute and other contributors provide no warranty with regards to the content and shall not be liable for any direct, incidental or consequential damages that may result from the use of the information or the data contained.

CONTENTS

1. SUMMARY

In the past 120 years, electricity has become the overarching energy source in our everyday life. Its applications have improved our comfort and safety, multiplying the means of entertaining and communicating.

However, domestic electricity can be dangerous. Specifically, the safety of older electrical installations is a concern in the countries of the European Union, given the low renovation rate of dwellings and their electrical installations. At the same time, the uses of domestic electricity continues to diversify and develop, progressively posing increasingly important challenges in terms of quality and safety of electrical energy used in households.

The safety deficiencies of obsolete electrical installations generally result from the aging of their components, the lack of maintenance and inappropriate usage. The dangers they represent are also clearly identified. The risks of electrification and electrocution are well known, but fires of electrical origin and their consequences are the most worrying.

It is estimated—in European countries that have statistics on the matter—that electrical fires account for 20 to 30% of all domestic fires. A projection, based on available data, makes it possible to estimate that 280,000 fires of electrical origin would occur every year in the European Union countries. Their consequences are dramatic in terms of deaths and injuries, but also in terms of economic costs for the community.

Although Europe and European countries have advanced standards to ensure the safety of domestic electrical installations, their application is generally reserved for new electrical installations. In order to improve the safety of old electrical installations, the solutions observed so far are to establish reference guides and methods for safety and to carry out awareness campaigns and periodic inspections informing occupants about the risks of their old electrical installations. More rarely, countries have opted for regulations that directly empower homeowners with regard to the safety of their electrical installation.

European Union countries therefore face a major challenge in regards to domestic electrical safety, especially as, in practice, the number of hazardous installations is expected to continue to rise if nothing is done. In response to this, models of cooperation have emerged in some countries. The effectiveness of the resulting solutions is still subject to an important preliminary step: to improve the statistical knowledge on the state of the old domestic electrical installations and their consequences, particularly in terms of fires. Out of such knowledge, suitable solutions can then be proposed.

2. INTRODUCTION—WHY DOES IT MATTER?

In a time span of only 120 years, electricity has become such a vital part of our daily life that is hard to imagine living without. Electrical applications have brought additional efficiency, comfort, entertainment, safety and security to our homes. But as is the case with many good things, the advantages do not come without a downside. Electricity, if managed wrongly, can be dangerous. We are all familiar with the danger of electrocution. Less evident is the danger of electricity to start a fire. In Europe, 20 to 30% of all domestic fires have an electrical origin. Those electrically induced fires are the cause of approximately 1,000 fatalities and 6.25 billion euro of property damage in the EU each year. In some countries, e.g. the US and Japan, this danger has been recognized:

- In the US, the number of fires per year has gone down from 3.3 million (or 44,000/million dwellings) to 1.3 million (or 11,000/million dwellings) between 1977 and 2015. In the same period, the number of fire deaths has decreased from more than 7,000 (94/million dwellings) to roughly 3,000 (26/million dwellings). A major contributor to this success story is the electrical safety promotions of the National Fire Protection Association (NFPA). [1]

- In Japan, an inspection of the electrical installation every 4 years has been mandatory for all dwellings since the early 1960s. A similar law is in force in South Korea since the early 1970s. Fire statistics in both countries demonstrate the positive effect of this measure: the number of fires has been reduced by close to 90% since inspections became mandatory. Moreover, the regulation solved the problem of electrical safety in old buildings.

A deeper investigation into the matter reveals that **if we do not step up with additional measures to improve the domestic electrical safety soon, the issue is likely to become even more urgent in the future**. On a recent congress on the matter in the US, the NPFA president Jim Pauley warned of the new challenges in electrical safety that are facing us, due in no small measure to technology and life-style changes [1]. The downward trend of fatal accidents might sputter and even be reversed if we do not take further action. This is the case for the following reasons:

On the short term, there is the acute problem of the old housing stock with ageing electrical installations.

- **The annual renovation rate for EU dwellings is low** (around 1%), and significantly lower than the growth of the building stock aged 25 years and older (1.75% on the average). As a result, the average age of the electrical installations in EU dwellings is increasing at a speed of 0.75% per year.

On the medium term, there is the issue of new types of electrical applications that are entering the domestic environment and that require a new approach to safety.

- **Europe's population is ageing rapidly**. Thanks to technological assistance (electric stair lifts, remote doctor consultation, safety alarms, et cetera) an increasing number of people can remain in their homes to a much higher age. These technologies create an extra challenge for the electrical installations in what are often old houses.

- Thanks to government support and market development, **the generation of local electricity through PV panels** has become popular in many EU countries. This radically changes the concept of the residential electrical installation, introducing new hazards and in the process demanding new safety requirements.

- Residential heating and private vehicle transport, which have in the past relied primarily upon fossil fuels, are expected to gradually be electrified in the coming decade. **Heat pumps and electric vehicle chargers** will come on top of the regular growth of electrical applications in our homes. Those new applications strongly increase the load connected to the residential electrical installation, demanding an increased emphasis on electrical safety.

3. THE ORIGIN OF ELECTRICAL SAFETY ISSUES

OLD HOUSING STOCK, SLOW RENOVATION RATE

Once dwellings surpass the age of 15 to 20 years, a regular inspection and—if necessary—renovation of the electrical installation starts to be required to prevent electrical safety issues from developing.

The EU has an old housing stock. According to the *OTB Research Institute for the Built Environment* in the Netherlands [2, p.54], the age distribution of houses in the EU is as follows:

per year	**# Dwellings**	**Houses from before 1970 (%)**	**Houses from before 1970 (#)**	**Houses from before 1990 (%)**	**Houses from before 1990 (#)**
Austria	3 778 180	51.4	1 941 985	78.10	2 950 759
Czech Republic	4 537 920	50.1	2 273 498	87.70	3 979 756
Denmark	2 790 751	62.2	1 735 847	87.90	2 453 070
Estonia	613 729	53.6	328 959	94.70	581 201
Finland	2 908 245	37.2	1 081 867	77.20	2 245 165
France	30 117 733	47.6	14 336 041	83.00	24 997 718
Germany	41 550 300	74.3	30 871 873	87.50	36 356 513
Greece	6 384 353	42.1	2 687 813	85.70	5 471 391
Hungary	4 246 045	48	2 038 102	88.90	3 774 734
Ireland	1 815 045	33.3	604 410	60.70	1 101 732
Italy	24 141 324	60.9	14 702 066	91.90	22 185 877
Latvia	915 871	49	448 777	88.60	811 462
Lithuania	1 124 929	62.6	704 206	93.70	1 054 058
Luxemburg	221 828	76.6	169 920	93.30	206 966
Malta	144 474	44.3	64 002	79.60	115 001
Netherlands	6 921 070	47.8	3 308 271	80.20	5 550 698
Poland	14 282 292	50.1	7 155 428	87.10	12 439 876
Portugal	5 661 637	39.3	2 225 023	74.20	4 200 935
Romania	7 769 601	52.7	4 094 580	91.30	7 093 646
Slovakia	1 775 079	45.1	800 561	91.70	1 627 747
Slovenia	710 061	50.6	359 291	89.80	637 635
Spain	25 382 000	46.6	11 828 012	84.30	21 397 026
Sweden	4 763 585	63.8	3 039 167	90.00	4 287 227
UK	27 864 444	55	15 325 444	96.80	26 972 782
Total	**220 420 496**	**51.84**	**114 265 985**	**86.00**	**189 561 627**

Table 1 – Distribution of house age across EU countries (Belgium is left out because no figures after 1990 are available; Bulgaria, Croatia and Cyprus are left out because of a general lack of figures).

We see that 86% of the houses in the EU are more than 25 years old and 51% are more than 45 years old.

35% of houses in the EU date from the period between 1970 and 1990, which are typically the houses requiring a first entire renovation today. The average annual building rate in this period, relative to the total numbers of dwellings today, was 1.75% (= 35%/20 years).

The current renovation rates cannot keep up with the building rates that were shown at that time. In 2011, the *Building Performance Institute Europe (BPIE)* estimated the annual renovation rate of the electrical installation in residential buildings across Europe to be 1% [3, p.103]. This figure included all renovations others than those relating to a single energy saving measure. According to the BPIE, this figure is in line with a study carried out for the European Commission and led by the Fraunhofer Institute.

From these figures we can conclude that the number of European houses 45 years and older that have never seen a renovation of the electrical installations is rising at an annual rate of 0.75% of the total housing stock (= 1.75% minus 1%).

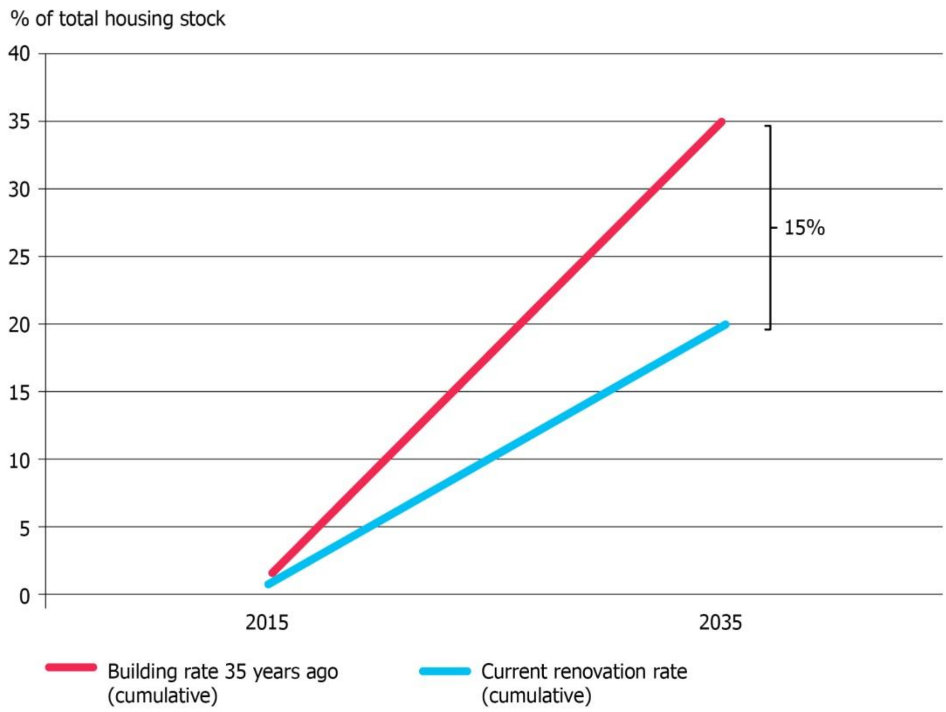


Figure 1—The houses of 45 years and older that have not yet seen a renovation of the electrical installation will grow by 15% of the total housing stock over the next 20 years.

Apart from the slow renovation rate, the quality of the renovations is another point of concern. Studies carried out in the UK by BSRIA [4] and the CFRL [5] at the end of the 1990s showed that in 25% of the renovations of the electrical installation at that time, no complete re-wiring was executed. If no new renovation was carried out since then, those houses—of which many were constructed before 1970—have still never seen a complete rewiring. The wiring from before 1970 will have become inadequate in the large majority of cases taking today's domestic electrical applications and today's standards into account. Moreover, the wires themselves might be subject to ageing. The insulation material, for example, could show signs of wear causing leak currents or short circuits.

THE SOCIAL DIMENSION

Electrical safety and fire protection also have a social dimension. According to [6], demographic groups with lower social living standards run more than average risk of accidents from electrical origin, while it is precisely these groups that tend to be disadvantaged already in other areas.

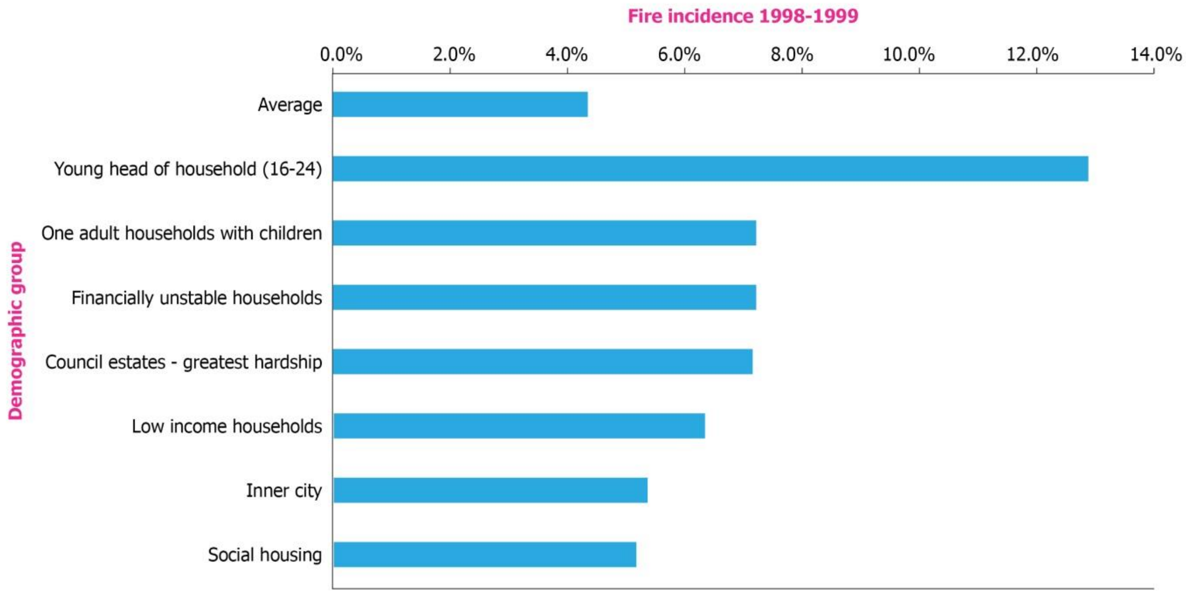


Figure 2—Relation between fire incidence and income [6].

A first cause behind this social gap is that apartments tend to be less safe than houses. In apartments, the maintenance of the electrical installation is often a joint responsibility between all the inhabitants and co-operative owners of the building. A disproportionate number of casualties from fires occur in high rise building (> 3 floors) without connected terraces or fire escapes. As a result, apartments represent 16% of all fires but 50% of the fire casualties [7].

A second cause behind this social gap is that rented dwellings tend to be less safe than owner-occupied ones.

It is also important to note that older people are disproportionally at risk from electrical safety hazards due to their often poor housing conditions, the health issues they may have, or the lack of advice and practical help available to them [8].

- Even if elderly people are house-owners, they still run a risk that is above the average. These houses are often old and the budgets for repair works, inspection or renovation small to non-existent. As a result, the houses lack the necessary features that can protect their occupants from electrical hazards.
- The number of +65 people that rely on the private rented sector for their dwelling is predicted to double by 2035 [8] due to the ageing population, the preference of older people to remain in their own homes for as long as possible, and the lack of social housing (see also the sub-chapter "Changing demography and lifestyles" in Annex 1). Such privately rented dwellings have a safety record that is below the average. On top of that, older people are often vulnerable and open to exploitation by a landlord. Solutions to counter this are proposed in Chapter 5 ("Enforcing electrical safety") and more in particular in the sub-chapter "Inspection of existing electrical installations".

Changing conditions

The ageing European housing stock, the slow renovation rates, and the related social dimension are compromising the efforts that have been made in the past decades to improve electrical safety in many countries throughout Europe. It requires a reaction on the short term to counter this trend.

Other changing conditions will put even more pressure on residential electrical safety in the near future. The energy transition and its technology, as well as changing demography and life styles will demand a reaction on the medium term to avoid them abrogating the positive trend of increasing electrical safety.

- **The energy transition and its technology**. Thanks to various support mechanisms and reducing prices, rooftop PV panels have become popular among residential electricity consumers throughout Europe. Another trend is the electrification of residential heating systems. The environmental balance is shifting in favor of electrical heating thanks to the decarbonization of electricity generation and the development of technologies such as heat pumps and low energy houses. In the near future, private vehicle transport is likely to undergo a similar evolution. All these new electrical devices in the house—PV panels, heat pumps, EV chargers—comprise a serious challenge for the domestic electrical system and its safety. All stakeholders should collaborate to make sure that the advantages of those new technologies do not get overshadowed by the appearance of previously absent safety hazards.

- **Changing demography.** Europe’s population is ageing and this will continue in the near future. A related trend is that older people will continue to live independent lives in their own home until a higher age. This will be partly because they prefer to do so and also partly out of necessity: having the elderly live safely at home for a longer time both takes the pressure off the increasing demand for care and reduces the costs to national health services. Many technological solutions exist to assist elderly people living at home, of which many are electrically operated. This means that the house and the electrical installation need to be adapted to carry out all those functions without introducing new safety hazards. An extra difficulty in this matter is that most elderly people live in houses of a considerable age that have often not seen renovation in a long time, if at all. Technology assisted living should therefore go hand in hand with a well-functioning program that enhances residential electrical safety and prepares dwellings for life-long-living.

- **Changing life-styles.** Life-styles are continuously changing and houses need to be adaptable to cope with those changes. One of the main issues is that most dwellings suffer from a lack of sockets—even relatively new houses. This problem has grown bigger with the increase in electronic devices used at home and with the increasing trend to work from home. To compensate for the lack of sockets, occupants use extension cords—a practice which can lead to dangerous situations.

On the longer term, other additional electrical safety issues await us. With an increasing number of electricity sources providing DC power (PV panels, batteries), as well as an increasing number of appliances that are using DC power (ICT infrastructure, LED lighting, EV charging, et cetera), some people wonder why we still need an AC network in between. A growing number of electricity experts are indeed convinced that we should evolve towards a DC electrical system for residential and office buildings. The first pilot projects of office buildings working on DC are already up and running in the Netherlands. One of the main problems with such a shift to DC could be that our electricity experts are absolutely not familiar with it and are often unaware of the related safety issues.

For a more detailed overview of the changing conditions that are affecting electrical safety, see Annex 1.

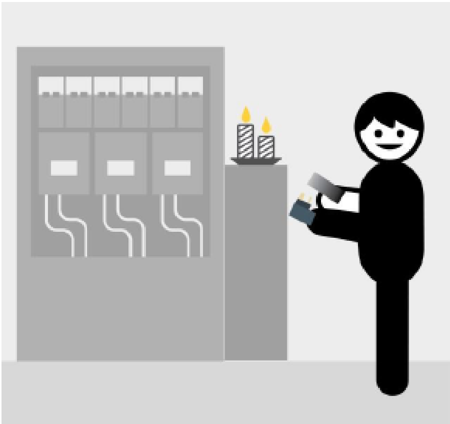
Typical electrical safety issues that added up over the years

The following is a typical story of how electrical safety problems can add up over the years in a house that was inspected and declared safe after construction 40 years ago, but never saw a periodic inspection or a renovation of the electrical installation.

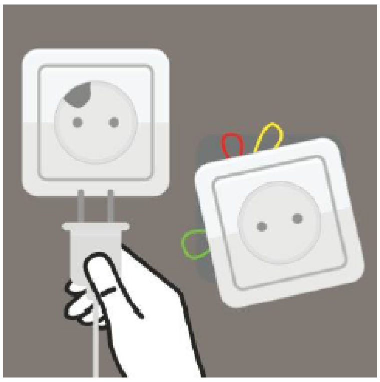
1976 *– Alex is 35 years old and has constructed a new house for the family. The electrical installation is inspected and declared safe before being connected to the electricity grid.*

1984 *– Following new insights in electrical safety, an RCD becomes mandatory on circuits that go through wet areas (bathrooms etc.). Alex is unaware and no adaptation of the electrical installation is made.*

1988 *– In the second part of the eighties, many new devices are being introduced in the house. Alex bought a microwave oven, his son a computer and several adjoining auxiliary devices. Since the house now lacks the necessary power sockets, Alex goes to buy cheap extension cords in the DIY shop around the corner, without verifying whether these products are actually carrying a CE mark…*



1996 *– Some of the fuses are blowing all the time, apparently without any reason. This is very annoying. Alex learns from one of the neighbours how to fix the fuses with pieces of metal.*



2000 *– The house is starting to show wear and tear. One of the sockets that is used very often came loose from the wall. Another socket, continuously connected to one of the extension cords, shows burn marks. Alex doesn't notice.*

2008 *– Now being 67 years old and on a pension, Alex wants to install PV panels on the roof. Being a fan of DIY work and having plenty of time, he/she decides to carry out the installation without any assistance. He / she does not realize that the DC conductor sections that are being used are insufficient and that measures for avoiding leak currents are lacking.*

2014 *– At the age of 73, Alex has an accident that impairs his/her mobility. A wheelchair is the solution. To be able to stay in his/her own house, an electric chairlift is installed. Are the electric circuit and the corresponding safety measures sufficient for such a heavy duty device? Nobody asks the question.*

2015 *– Alex's son is an early adapter and has bought an Electric Vehicle. At home he has his own charging station, but where can he charge his car when he is visiting his parents' house? Via an extension cord through the window, he plugs it into one of the ordinary sockets in the living room…*

2016 *– 40 years after the construction of the house and the initial verification of the electrical installation, the place is full of dangers…*

Figure 3—A typical story of how electrical safety problems can add up over the years.

List of common electrical safety issues

The deficiencies found in the residential electrical installations differ from country to country. The following examples of critical problems are therefore not always applicable to all countries. It is in any case a non-exhaustive list that only has the intention to demonstrate how much can go wrong in the electrical installation of today's dwellings. For examples of lists on what to verify during installation and inspection, see Annex 4.

Inside dwellings

Due to inappropriate design of the electrical installation:

- Power sockets or lighting points that are not earthed
- Absence of a proper earthing electrode
- Mains supply that is not protected by a Residual Current Device (RCD) (often the case in old dwellings)
- Bathroom and wet areas that are not protected by an RCD
- No RCD protection for circuits supplying power to appliances outdoors
- Inappropriate installation of PV panels (often the result of a Do-it-Yourself (DiY) practice):
    - Insufficient sizing of conductors
    - DC wires that are not separated at their entrance into the house
    - Leak currents in the metal parts of the roof and the metal water pipes in the house
    - The use of switches that are not adapted to DC

Due to lack of proper maintenance:

- Wear and tear of the electrical equipment, holding the risk of causing electric shocks
- Frequent, unexplained tripping of circuit breakers. With the increase of electrical appliances in the house, the load on some circuits may become higher than it was originally designed for, causing circuit breakers to trip.
- Sockets, switches and panels that become hot or even display black burn marks. This indicates over-loading or bad contacts and requires immediate action.

Due to inappropriate use of the installation (often related to older installations lacking the required functionality for today's electrical equipment and life style):

- Frequent use of extension cords due to insufficient socket outlets. When these are routed under carpets, the leads may be damaged and are a fire risk.
- Overloading of sockets using multi-way adapters, resulting in a fire risk.
- All kinds of 'Do-it-Yourself' (DiY) modifications carried out by untrained people without knowledge of standards.
- EV charging at a regular household socket without additional protection, holding the risk of overheating wires and switches after several hours of charging at maximum power. Even if the circuit is designed according to the safety standards, components might still get dangerously overheated in those circumstances. If other appliances are connected to the same circuit simultaneously, circuit breakers might trip.

In common parts of apartment buildings

A point of concern in apartment buildings is the *rising mains*. These are the cables that run from the grid connection in the basement up to the various building floors, where they are used to connect the individual apartments. In older apartment blocks, a discrepancy can grow between the load capacity of the rising mains and the increasing number of electrical devices that are used inside the apartments. If this discrepancy grows too big, the rising mains will hold insufficient capacity. Overloading, material wear, insufficient maintenance and ageing of the rising mains can result in repeated electrical failures and a potential source of fire. Moreover, the electricity connections in the common parts are often lacking an earthing conductor. If that is the case, the earthing wires that exist inside the apartments cannot be connected to a proper earthing network and become useless. Another attention point is the behavior of the rising mains in case of fire. For example, insulation material that might produce or propagate flames of toxic smoke must be avoided.

France and the UK are intensively investigating all of these issues related to the electrical safety of rising mains.

Wiring

Studies carried out in the UK by BSRIA [4] and the CFRL [5] at the end of the 1990s showed that in 25% of the renovations of the electrical installation at that time, no complete re-wiring was executed. If no new renovation was carried out since then, those houses—many of which were constructed before 1970—have still never seen a complete rewiring. When taking today's domestic electrical applications and today's standards into account, the conductor cross sections used in the wiring from before 1970 will have become inadequate in the large majority of cases. Moreover, the wires might be subject to ageing:

- The insulation material could show signs of wear. Weak points in the insulation can be the cause of leak currents or short circuits.

- Some types of electrical conductors—for example some types of Aluminium (Al) alloys—age badly. Aluminium (Al) oxide is not an electrical conductor and can create sparks inside the conductor material. Moreover, with older types of Al there could be problems with microfretting and arcing at Al wiring connectors (e.g. at connections between the wire and devices at switches or outlets) which can cause overheating. The connections can become hot enough to start a fire without even ever tripping a circuit breaker. The problem of inadequate Al wiring is an issue mainly— but not limited to—certain Eastern European regions.

- Al conductors with a cross section smaller than 6 mm^2 are not allowed according to the international and European standards, but can nevertheless still be found.

4. The hazards of an unsafe electrical installation

The use of electricity comes with two main safety risks: one an indirect risk and the other a direct one.

The indirect risk of electricity is that it may start a fire, causing substantial human and financial damage. A major share of domestic fires in Europe has been shown to be of electrical origin (20 to 30% according to the numbers of those EU members for which reliable statistics are available). Moreover, the causes for 50% of the fires remain unknown. It cannot be ruled out that many of these could be of electrical origin as well [9]. Ensuring a safe and sound electrical installation is therefore a vital part of maintaining fire safety in the home.

The direct risk of electrification or electrocution due to contact with live parts is a better known risk among the general public. We all learned from a young age that we should be careful with touching parts of the electrical installation in the house. Measures are usually taken to avoid making such a contact possible, as well as minimizing the consequences should it happen. Despite this awareness and measures, accidents still occur.

In this chapter we will discuss the causes and consequences of both types of hazards.

Fires of electrical origin

Causes

For a fire to start, three basic elements need to come together in the so called "triangle of fire":

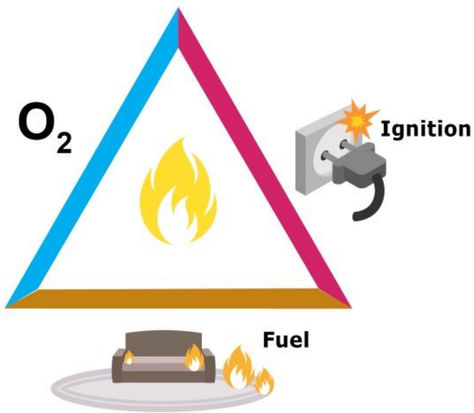


Figure 4

Every house contains the first two elements: oxygen and combustible material. Electricity can be the origin of the heat source that ignites the fire if it has not been properly installed.

When an electric current is flowing through a conductive material, the electrical energy is partly converted into heat—more so if the resistivity of the material is high. This is called the Joule effect. Use is often made of this effect in applications such as electric heating systems and furnaces, but it occurs in every wire and in every device through which an electric current is flowing. In normal conditions, the temperature rise due to the Joule effect in electrical wires and devices is too modest to be hazardous. Under some fault conditions, however, the local temperature can rise to dangerous levels; namely:

1) **If the current surpasses the current-carrying capacity of the conductor.** This can lead to a dangerous situation very quickly, since the amount of heat that is generated rises with the square of the current intensity. Over-currents can be caused by a circuit overload. They can also be caused by short circuit conditions, in which they can reach dramatically high levels.

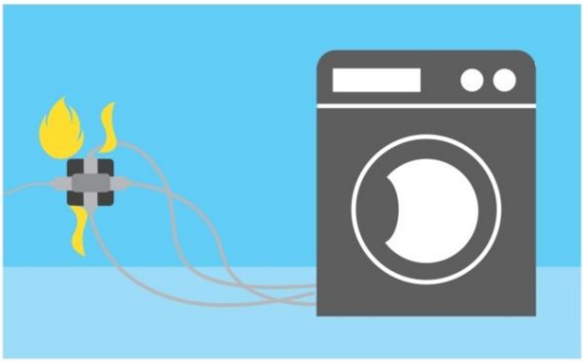


Figure 5—Overusing adapters or using them for connecting heavy duty appliances can lead to overload: the current becomes higher than what the adapter was designed for. The adapter will heat up excessively and becomes a potential source of fire.

2) **If the resistivity of the electrical installation surpasses standard values.** Loose or bad contacts and degraded conductors are typical causes of increased electrical resistivity. Inappropriate design or installation can be another cause.

Figure 6 – Loose contacts, e.g. with a loose socket that was kept on being used, can increase the resistivity, leading to a hot spot and a potential source of fire.

3) **If the heat dissipation to the environment is too slow.** This will make the local temperature rise faster. The cause can be an inaccurate design of the installation, in which heat dissipation was not taken into account. In short circuit conditions, the thermal energy that is generated can be so high that timely heat dissipation becomes difficult.

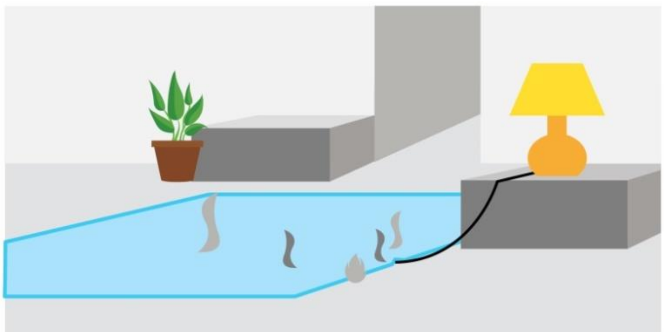


Figure 7—Preventing the heat from dissipating from electric cables or devices can be dangerous. A common example is a cable hidden under a carpet which might heat up excessively. Moreover the carpet might be the perfect combustible material to start a fire.

One of those three conditions, or a mixture of those three, can result in high temperature spots in the electrical installation. Such elevated temperatures can act as an ignition source causing fire, depending upon the environmental conditions in the room and the materials in contact with the installation.

CONSEQUENCES

NUMBERS OF FIRES AND FIRES FROM ELECTRICAL ORIGIN

In some EU countries, statistics were published that represent the number of fires of electrical origin. They all show that this number is substantial.

According to the French ONSE (Observatoire National de la Sécurité Electrique) [10], there was an average of 82,100 reported fires per year between 2010 and 2013. By “reported” we mean that there was an intervention of the fire brigade. The same document estimates the total number of fires to have reached an average of 200,000 per year over the same period. This means that 2 out of 5 domestic fires required an intervention by the fire brigade.

According to the ONSE report, 25% of the fires in France are of electrical origin. This was concluded after the investigation of 6 different independent studies that cover the period from 1995 to 2014. From this we can ascertain that France sees an annual average of 50,000 domestic fires of electrical origin, reported or not.

The figures from the UK show similar tendencies. The UK Electrical Safety Council [11] counted an annual average of 20,000 reported domestic fires of electrical origin. If we suppose that the number of reported fires compared to the total number of fires is the same in the UK as in France (2 out of 5), we can conclude that the UK also has an annual average of 50,000 domestic fires of electrical origin, reported or not.

The total number of dwellings in France and in the UK is almost similar (27,260,000 in France versus 27,765,000 in the UK), which means that we can detect a strong coherence between the figures of both countries.

In Germany, an assessment by the German Fire Brigades calculated a total of 26,100 reported fires from electrical origin per year in the country. Using the same key as for France and the UK concerning the share of reported fires (2/5), the total number of residential fires of electrical origin in Germany (reported or not) is estimated to be 65,250 per year.

Similar statistics exist in Poland [12]. In this country, the State Fire Service reported an average of 22,319 fires per year in residential buildings (figures from 2007-2009). Using the same key as for France and the UK concerning the share of reported fires (2/5), the total number of residential fires in Poland (reported or not) is estimated to be 55,800 per year. According to the statistics of the State Fire Service, 11% of all domestic fires had defect or incorrect operation of electrical equipment as a cause. Fire causes categorized as “unknown” or “other” accounted for 24% of the domestic fires. Supposing a similar division of causes for the unknown cases as for the known cases, an additional 3.5%[1] (76% known cases, 11% had electrical cause or one out of 76/11 = 6.91. 24% unknown cases. Following the same division, 24/6.91 = 3.47% would be electrical) has to be added to the reported figure, bringing the total number of fires from electrical origin to 14.5% of all domestic fires, or 8,090 fires per year.

---

[1] Of the 76% known fire causes, 11% had an electrical origin, or one out of 6.91 (= 76/11). Applying the same division for the 24% of unknown causes, then 24/6.91 = 3.47% of those unknown causes would be electrical.

Spain sees 7,300 reported fires of electric origin in dwellings, according to the International Fire Safety Association and FISUEL [13]. Using the same key as for France and the UK concerning the share of reported fires (2/5), the total number of residential fires of electrical origin in Spain (reported or not) is estimated to be 18,250 per year.

Interpretation and extrapolation of the figures

Some of the statistics presented above (e.g. those of France and the UK) were gathered after extensive research by a network of collaborating expert stakeholders and can be considered to be highly reliable. They clearly show that electrical safety issues constitute a substantial problem regarding fire safety.

Starting from the reliable figures, we constructed conservative extrapolations for other countries in the Northwestern EU. We continued this exercise with the slightly less consolidated data to make even more prudent extrapolations for the other European regions. Even though the resulting figures are not confirmed by assessments in the field, they do provide an idea of the probable size of the problem in those countries. The authors of this document would be eager to collaborate with stakeholders (fire brigades, insurance companies, et cetera) to collect more actual and consolidated numbers for those countries.

Northwestern EU

For the Northwestern EU, we combined the French, German and UK figures. Taking the average of both figures, we calculate that **one out of 578 dwellings experiences a fire of electrical origin each year**. Extrapolating this to the other countries of this region, we come to the following results:

Per year	*# Population*	Number of dwellings	Electrical fires (reported or not)
Austria	8 665 550	3 778 180	6 423
Belgium	10 449 361	4 372 881	7 434
Denmark	5 581 503	2 790 751	4 744
Finland	5 476 922	2 908 245	4 944
France	66 259 012	27 259 012	50 429
Germany	80 854 408	41 550 300	65 250
Ireland	4 892 305	1 815 045	3 086
Luxemburg	570 252	221 828	377
Netherlands	16 947 904	6 921 070	11 766
Sweden	9 801 616	4 763 585	8 098
United Kingdom	64 088 222	27 767 000	51 369
Total	273 587 055	124 147 897	213 920

Table 2 (blue = extrapolation)

Eastern & Central EU

For the Eastern & Central EU, we used the figures from Poland. In this country, **one out of 1,765 dwellings experiences a fire of electrical origin each year**. Extrapolating this to the other countries of this region, we come to the following results:

Per year	*# Population*	Number of dwellings	Electrical fires (reported or not)
Bulgaria (1)	7 186 893	*2 874 757*	1 627
Croatia (1)	4 464 844	*1 785 938*	1 011
Czech Republic	10 627 448	4 537 920	2 568
Estonia	1 265 420	613 729	347
Hungary	9 897 541	4 246 045	2 403
Latvia	1 986 705	915 871	518
Lithuania	2 884 433	1 124 929	637
Poland	38 562 189	14 282 292	8 090
Romania	21 666 350	7 769 601	4 398
Slovakia	5 445 027	1 775 079	1 005
Slovenia	1 983 412	710 061	402
Total	105 970 262	40 636 222	23 006

Table 3 (blue = extrapolation)

(1) *No figures available for number of dwellings. The figure used here was derived from the average number of dwellings per 1,000 inhabitants of the other 9 Eastern & Central EU countries and then multiplying this figure (namely 400) by the number of inhabitants of Bulgaria and Croatia respectively.*

Southern EU

For the Southern EU, we used the figures from Spain. We calculate that **one out of 1,390 dwellings experiences a fire of electrical origin each year**. Extrapolating this to the other countries of this region, we come to the following results:

Per year	*# Population*	Number of dwellings	Electrical fires (reported or not)
Cyprus	1 189 197	493 517	355
Greece	10 775 643	6 384 353	4 590
Italy	61 855 120	24 141 324	17 358
Malta	413 965	144 474	104
Portugal	10 825 309	5 661 637	4 071
Spain	48 146 134	25 382 000	18 250
Total	133 205 368	62 207 305	44 727

Table 4 (blue = extrapolation)

Conclusion

Per year	*# Population*	Number of dwellings	Electrical fires (reported or not)
Northwestern EU	273 587 055	124 147 897	213 920
Eastern and Central EU	105 970 262	40 636 222	23 006
Southern EU	133 205 368	62 297 305	44 727
Total	**512 762 685**	**227 081 424**	**281 653**

Table 5

We can conclude from the above figures that more than **280,000 domestic fires of electrical origin occur in the EU each year** (reported or not) representing more than 0.12% of the entire housing stock.

Property and other damage by fires

Estimated cost of fires in Europe

According to the ONSE report on electrical safety in France of 2015 [10], the insurance cost for property damage was on the average € 10,000 per fire in the period between 2010 and 2013[2]. The total number of fires in this period was 200,000 per year on the average. As a result, the total annual property damage caused by fire in France can be estimated to be € 2 billion. Since the EU has 5.6 times the number of fires of France (see tables 2 and 5) and the GDP per capita in France was 107% the EU average in 2014 (source: Eurostat), the total annual property damage caused by fire for the entire EU can be estimated to be more than € 10 billion.

Estimated cost of fires from electrical origin in Europe

ONSE makes a rough estimate by supposing that the property loss due to electrical fires is one quarter of the total property loss. This is a linear extrapolation from the conclusion (mentioned above) that the number of fires of electrical origin is one quarter of the total number of fires. It was thus estimated that the cost of property damage is € 2.5 billion.

However, strong indications exist that fires from electrical origin have a cost that is a multiple of the average fire cost. This assumption is confirmed by the UK study “Fires in the home: findings from the 2000 British Crime Survey” by the *UK Department for Transport, Local Government and Regions* [6]. According to this study, the mean cost of an electric fire is 5 times the average fire cost. This figure is consistent with the one in [14], based on studying fire statistics in 8 EU countries.

Based on these assumptions, the total annual cost of property damage due to fires of electrical origin in residential buildings in the EU would be € 6.25 billion. Given the approximate character of this figure, we can assume a fork for this total annual property damage **between € 5 and 7 billion**.

Injuries and deaths through fires

Only a few countries have complete data concerning injuries and fatalities caused by fires. According to the French ONSE report, domestic fires in France caused 310 fatalities and 15,830 people injured on the average per year between 2010 and 2013 [10]. This means there was an average of 4.68 deaths per million people.

In the UK, domestic fires caused 268 fatalities and 7,776 people injured in 2010 [11]. This means there was an average of 4.18 deaths per million people.

In Poland, an annual average of 450 fatalities and 24,690 people injured due to domestic fires were counted between 2007 and 2009 [12]. This means there was an average of 11.67 deaths per million people.

In Spain [13], an annual average of 150 fatalities and 1,600 people injured due to domestic fires of electrical origin was reported; or 600 fatalities and 6,400 injuries per year if all types of domestic fires are taken into account.

When aggregating and extrapolating those estimated figures, we conclude that the entire EU counts 4,015 deaths due to fire per year, or 7.82 deaths per million persons per year. A quarter of the fires is estimated to be from electrical origin, leading to an estimation of **1,000 deaths annually due to domestic electrical fires throughout the entire EU, or an average of 1.95 per million persons.**

[2] In the UK, RISC Authority reported an average insurance cost for domestic fires of £13,250 in the period between 2000 and 2014, which is in the same order of magnitude as the figures of France.

Electrification and electrocution

Causes

The term electrification is used to indicate an event where a person is subjected to electrical current. The term electrocution refers to electrification with *lethal* consequences.

An electrification incident can occur due to either of the following:

- Electrically live parts of the installation are accidently exposed to human contact (e.g. damaged power cables with exposed conductor cores, power outlets with missing protective covers, et cetera)

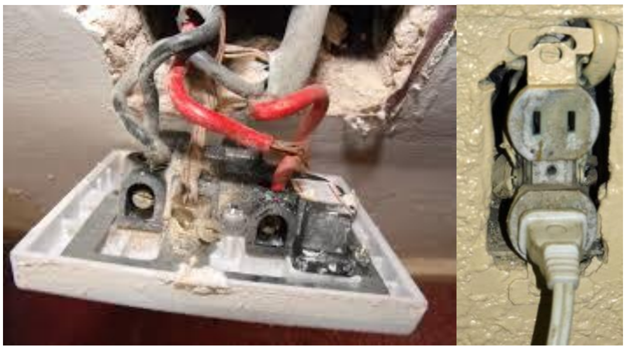


Figure 8

- Exposed, non-electrical parts of the installation are accidently electrically charged (e.g. the metal housing of a device with faulty insulation)

Figure 9

A special case can occur in case of a lightning strike on or near the residential building. The dispersion of the electrical current followed by the strike can create substantial voltage gradients in the ground or in the building structure, which can be dangerous when touched.

Effects

During electrification, the resistance of the person's body is part of the electric circuit. The physiological effects of a 50 Hz current applied to a body vary with the current amplitude, the contact points on the body, and the length of time the current flows through the body. It does not depend directly on the applied voltage, but for a given path the current is almost proportional to the voltage. Current densities in the body are determined by the resistance of the tissues in the path of the current. The skin has the highest resistance—in the order of several kΩ. Once inside the body, the resistance to the current is affected by the density, shape, orientation and size of the tissue cells. The resistance between two limbs is typically a few 100 Ω. Currents paths between both arms and between a leg and an arm are the most hazardous because the current can pass through the heart zone as well as through the muscles controlling breathing.

The following table gives an overview of the effects of electrical currents on the human body at common power frequencies (50Hz and 60Hz) [15]. Minor differences can exist between persons, as well as between the results of various studies, but the general tendencies are consistent.

Indicative effects of electrical current on the human body (common power frequency)	
Current	**Reaction**
< 1 mA	Generally not perceptible
1 mA	Faint Tingle
5 mA	Slight shock felt. Not painful but disturbing. Average individual can let go. Strong involuntary reactions **can lead to other injuries**.
6 to 25 mA (women)	Painful shocks. Loss of muscle control.
9 to 30 mA (men)	The freezing current or so-called let go range. If extensor muscles are excited by shock, the person may be thrown away from the power source. Strong involuntary reactions, however, can render an individual unable let go. In either event, this **can lead to other injuries**.
50 to 150 mA	Extreme pain, **respiratory arrest**, severe muscle reactions. **Death is possible**.
1.0 to 4.3 A	Rhythmic pumping action of the heart ceases (**fibrillation**). Muscular contraction and **nerve damage** occur. **Death is likely.**
10.00 A	**Cardiac arrest**, **severe burns.** Death is probable.

Table 6

Allowing currents of over 30 mA to travel through a person can never be considered safe and even currents as low as 5 mA can constitute a hazard to persons, depending on circumstances.

CONSEQUENCES

According to figures from the *World Health Organization* and the *UK Health and Safety Executive*, 78% of the fatalities due to electrocution in the UK in 2010 happened at home or during leisure activities and only 12% happened at work [11]. The *Electrical Safety Council* estimates that every year, an estimated 2.5 million (or 5% of the 50 million adult population) receive a 230 V electric shock in their home or garden in the UK. Of these, 350,000 are significantly injured [11].

In France, InVs and ONSE calculated an average of 60 fatalities due to electrocution per year [10]. Also in France, ANAH (*Agence Nationale pour l'Amélioriation de l'Habitat*) calculated that about 200,000 individuals suffer burns due to electrification in their home each year [16].

Taking the average of the figures of the UK and France, we calculate an annual rate of 0.6 deaths due to electrocution per million persons. Extrapolation leads to **an annual average of 300 fatalities due to electrocution in the EU**.

Again taking the average of the figures from the UK and France, we estimate the number of injuries due to electrification per million persons per year to be around 4,000. Extrapolation leads to **an annual average of 2,000,000 injuries due to electrification in the EU**.

CONCLUSION ON ELECTRIFICATION AND ELECTROCUTION

Investigating the numbers of electrocutions and injuries due to electrification in detail, we can conclude that they differ significantly from country to country, but show a consistent evolution over the years throughout the entire EU. The introduction of ever more stringent electrical safety standards and regulation has clearly resulted in a positive, downward trend of those figures in all countries. For France, this trend was illustrated in the following timeline:

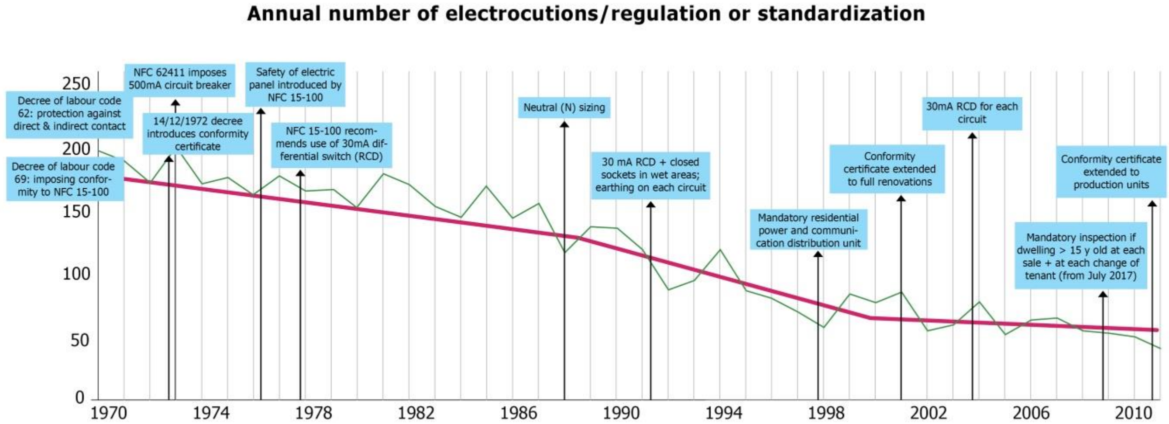


Figure 10—The total number of fatal electrocutions in dwellings per year between 1970 and 2015, in France. The positive influence of regulation and standardization is clearly visible.

The same trend cannot be witnessed in the figures of fires from electrical origin. Electrical safety standardization measures alone have proved to be insufficient in this respect. As we will discuss in the next chapter, periodic inspections that verify whether the electrical safety standards are actually applied could create a similar positive downward trend in the number of fires.

5. ENFORCING ELECTRICAL SAFETY

ELECTRICAL SAFETY STANDARDS

The international standard of the IEC (International Electrotechnical Commission) with number IEC 60364 treats "Low voltage electrical installations and protection against electric shock". This standard has been entirely taken over by the European standardization body CENELEC (*Comité Européen de Normalisation Electrotechnique*)[3] under the code number HD384. The IEC and CENELEC define a solid basis on which the individual countries can inspire themselves to gradually adapt and improve their own historically grown safety standards.

The IEC/CENELEC standard consists of 5 parts[4].

- Part 1 discusses fundamental principles, definitions and the assessment of the general characteristics.
- Part 4 describes technical protection measures for a safe electrical installation.
- Part 5 describes how to select and install electrical equipment.
- Part 6 tackles the inspection of the electrical installation (initial and periodic verification).
- Part 7 treats specific installations (e.g. medical installations, marinas, bathrooms, photovoltaic installations, cetera).

In Part 6, the IEC 60364 recommends an initial inspection after the installation comes into use or after an addition or alteration is made to an existing installation. The goal is to verify whether the other parts of IEC 60364 have been met. The standard describes which visual inspections and measurements should be executed, how often, and how the results should be reported.

---

[3] CENELEC (European Committee for Electro-technical Standardization) was created in 1973 as a result of the merger of two previous European organizations: CENELCOM and CENEL. CENELEC is a non-profit making technical organization set up under Belgian law and composed of the National Electro-technical Committees of 27 European countries. In addition, 8 National Committees from Central and Eastern Europe are participating in CENELEC work with an affiliate status. CENELEC members have been working together in the interests of European harmonization since the 1950s, creating both standards requested by the market and harmonized standards in support of European legislation, which have helped to shape the European internal market.

[4] Parts 2 and 3 no longer exist. The former "Part 2—Fundamental principles" (1970) and "Part 3—Assessment of general characteristics" (1993) were replaced by a new "Part 1 fundamental principles, assessment of the general characteristics, definitions" in 2001.

Part 6 of IEC 60364 **also recommends periodic inspections of the electrical installation**. Such verifications should "*take into account the results and recommendations of former inspections as much as possible*" (6.5.1.1). Moreover, *"All details of damage, wear, faults or dangerous conditions of the installation should be written down in the report*" (6.5.1.4). And "*The inspection should be executed by a qualified person with expertise in the field of periodic inspections*" (6.5.1.5).

Concerning the frequency of inspections, it stipulates that "*the maximum interval between periodic inspections may be laid down by legal or national regulations.*" **A 10-year inspection interval for residential dwellings is mentioned as a good practice.** It furthermore mentions that "*a verification of the electrical installation is strongly recommended with each change of building occupancy*" (6.5.2.1) [17] [18].

Despite this clear general recommendation by CENELEC, only a minority of the EU countries have a system for periodic inspection of electrical installations in place (see next subchapter, "Various types of existing regulations throughout the EU").

The national standards that exist in all EU countries are based on the IEC and CENELEC standards, but differ significantly in their implementation. Changes to those standards generally apply only to new buildings, and sometimes to large renovations. They are, however, almost never to be applied retroactively. As in most EU countries there is also no system of periodic inspections in place, installations continue to contain features that are considered to be unsafe according to the latest standards. A major proportion of the EU housing stock does not yet have the safety features that were introduced in in the standards in the 1970's and 1980's, such as circuit breakers and Residual Current Devices (RCD's)[5].

TYPES OF ACTION IN EUROPE

I. THE IMPORTANCE OF DATA GATHERING

Each regulatory action or adjustment should be based on a thorough knowledge of the actual situation. Two types of data are essential:

1) **Statistics about electrical fires** and the fatalities, injuries and property loss they are causing, and similar figures about electrification incidents.

   The UK provides some of the most detailed fire statistics in the EU. Nevertheless, the Fire Safety Platform expressed its concern in relation to the current data recording systems. They are often "insufficiently integrated, disparate in nature, and not sufficiently accessible to stakeholders". The platform recommends **setting up a National or EU System in place to record the incidence of fires** involving electrical installations, in order to provide robust evidence of performance. [19]

2) **The results of inspections**, namely the number of installations that were considered unsafe, the type of anomalies that were recorded, and the number of corrective measures that were taken following the inspection.

[5] Cf. a survey of 16,000 dwellings on electrical safety in Europe (www.electric-safety.org). On average, 67% of dwellings do not have mains protection by RCD, a safety device which has been available for over 20 years.

II. PREVENTIVE ACTIONS

To ensure electrical safety in dwellings, the first important aspect is to make sure that electrical installations are designed and installed according to proper safety standards right from the beginning.

The following measures have been observed across Europe:

- An established system **for life-long training of electrical installers**. Whether access to the profession is regulated or not, installers need continuous training in the changing requirements and safety standards of an electrical installation.

- A **qualification system for electrical installers**. Hiring a qualified installer should give people the guarantee that works will be executed according to the latest standards. If the work doesn't meet the requirements, the client should have access to a formal complaints procedure.

- **New installations and major renovations should be the work of certified installers**, or verified by certified experts, or both.

- Demanding that all the small electrical works in the domestic environment are carried out by certified electrical installers would be exaggerated. **Continuous information and awareness campaigns** should improve the electrical safety knowledge of do-it-yourself workers that carry out small jobs on the electrical installation. Moreover, it should discourage them to take on jobs for which they are not competent.

- Installers, and even more so do-it-yourself workers, can be misled into buying counterfeit, poor quality or faulty electrical cables and products. A system of **product registration and manufacturer recall arrangements** with the active support of retailers could be a remedy.

The residential electrical safety regulation in the UK (see Annex 3) can serve as a good example on how to organize these actions. It makes a difference between "non-notifiable" and "notifiable" work. For the latter, a registered installer or an inspection by a third party certifier is mandatory. By keeping the second option, access to the profession of electrical installer is kept open, stimulating free competition. This is not the case in Germany, where all electrical installers need to be registered.

Also in the UK, new research by *Electrical Safety First*, a leading consumer safety charity, shows that **do-it-yourself (DiY) work is gaining in popularity** among the younger generation. Electrical Safety First launched a TV and internet video spot (called *DiY Nation*) to warn DiY's about the dangers of electrical work. [20]

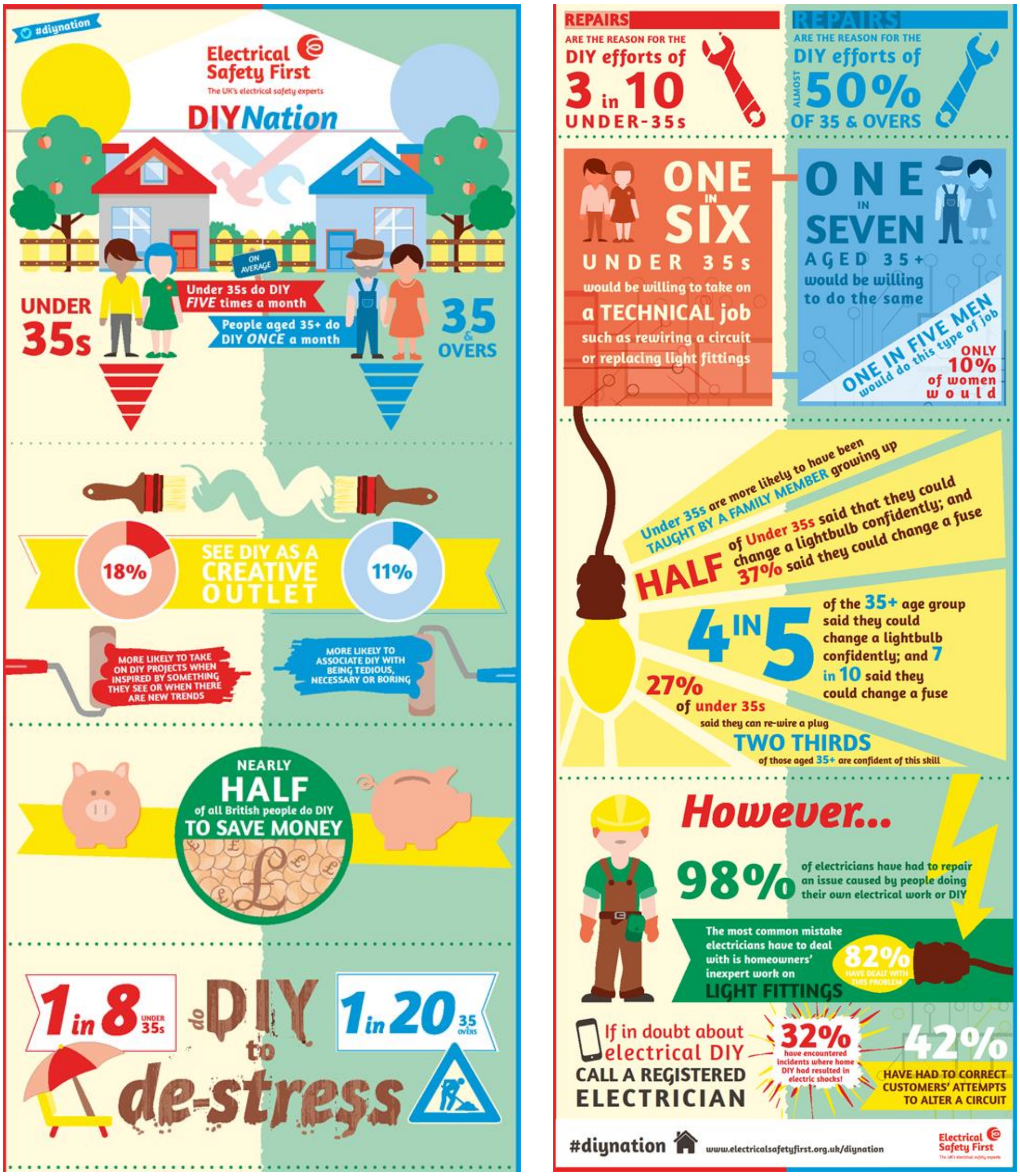


Figure 11—A media campaign by Electrical Safety First warns against the dangers of DIY electrical jobs.

A system of **product registration for electricity products** can enable a recall of products from the moment they are discovered to be counterfeit, non-spec or illegal. However, such a system did not have the desired results in the UK. A major cause could be privacy issues; consumers might not like the idea of registering their purchases in a data bank. The system is currently under evaluation. Stressing more clearly that data are only used in case of product recalls could be one way to improve the system.

In France, a **national information campaign on electrical safety** [21] was launched in March 2015, organized by GRESEL (*Groupe de Réflexion sur la Sécurité Electrique dans le Logement*) with the support of the consumer association INC (*Institut National de la Consommation*). It is another good example of how to make people aware of the dangers of the domestic electrical installation, the regulatory obligations and the necessity to contact professionals for inspections as well as for all renovation jobs.

Figure 12—A French media campaign by GRESEL warns of the danger of an unsafe electrical installation causing a fire.

III. Regulation

Various types of existing regulations throughout the EU

CENELEC

CENELEC (*Comité Européen de Normalisation Electrotechnique*) recommends a periodic inspection of the electrical installation **at least every 10 years and at each change of occupancy** (owner or tenant). [18] This recommendation should enter into force across Europe in the coming years.

Initial verification of the electrical installation

In the majority of the EU countries, **an initial third-party verification of the electrical installation** in new residential buildings is mandatory [22, 23][6]. Who coordinates and who executes those inspections depends upon the country and the type of building. The majority of the inspections in the EU are executed by private

[6] The input from Bulgaria, Latvia and Slovenia on this subject is missing.

inspection companies or third party authorized electricians. In some cases, a central government department, the distribution network operator or the electricity supplier play a role. Municipal inspection regimes, which are common in North America, hardly exist in Europe. An exception is Italy, where the local public authorities can assign private installers to organize the inspections.

In some countries (e.g. Germany, Finland, Norway), third-party inspection of the installation is not mandatory, but **the work on the installation needs to be executed by certified electrical contractors**.

In the Netherlands, the initial inspection of the electrical installation in new buildings are included in the standards but not enforced by public law. As a result, it is often not carried out for small residential installations [22].

Verification that the inspection (or certified installation) has been executed is in the hands of distribution network operators or public authorities. In most EU countries, distribution network operators request an inspection report before connecting the new electricity meters to the grid.

INSPECTION OF EXISTING ELECTRICAL INSTALLATIONS

The majority of European countries do not have regulation for verifying domestic electrical installations after the initial inspection. Among countries that do require periodic inspections, the protocols vary greatly. The following four strategies can be roughly distinguished:

Periodic inspections at fixed intervals

In this system, a periodic inspection of the domestic electrical installation is mandatory after a fixed number of years. Whether this law applies and the precise inspection interval can depend on the type of building and/or the size of the installation. The following are a few examples:

- In Switzerland, the *Low Voltage Installation Norm* (which has statutory power) prescribes a periodic inspection for all residential installations by a *Certified Electrical Contractor* or an *Electrical Security Consultant* every 20 years [24].

- In Belgium, the *General Regulation on Electrical Installations* (AREI/RGIE) prescribes an inspection for all residential electrical installations by a Certified Control Organism every 25 years. An inspection is also required when a circuit is added to the installation or when the installed power is increased. The certificate of conformity following a positive evaluation has to be presented at each change of owner or tenant [25].

- In Finland and Estonia, periodic inspections are mandatory only for classified buildings. Residential installations are classified only if the building contains more than two dwellings. In the latter case, periodic inspections are mandatory every 10 (Estonia) or every 15 years (Finland). Inspections are executed by an Authorized Inspection Body and oversight by the Electrical Safety Authority. [24, 26]

- In Spain, the electrical installation of the common facilities of residential buildings above 100 kW must undergo a periodic inspection each 10 years. The inspections are executed by the Authorized Inspection Organism (OCA). [24]

Inspections with each change of occupant

In this system, an inspection of the electrical installation is mandatory at each change of owner and/or tenant. An inspection report has to be presented to the (potential) buyer or tenant, increasing the transparency of the transaction. Usually, this only applies to buildings of a certain age, and an exemption is being made if such an inspection has been carried out in recent years. The following are a few examples:

- In France, regulation obliges an inspection for electrical installations of 15 years and older at every sales transaction of the property. From 1 July 2017, such inspection will also become mandatory at every change of tenant. An exemption is given if such an inspection has been executed and followed up successfully in the past 3 years (for changes of owner) or 6 years (for changes of occupant). See Annex 2 for more information on the electrical safety regulation in France.

- In Austria, an inspection of the electrical installation must be carried out when a dwelling is being rented out for the first time. After that, the owner must be able to prove the conformity of the installation to standard ÖVE/ÖNORM E 8001-6-2 to each new tenant, but no mandatory interval for periodic inspections is prescribed [24].

All major works must be executed or verified by a certified installer

In this system, the emphasis is placed upon certification of professional skills which obliges the installer to follow the prevailing safety standards. In some cases, non-certified installers are allowed to carry out work if it is verified by a certified third party. Often this system is combined with a voluntary regime of periodic inspections. The following are a few examples:

- In England and Wales, Part P of the Building Regulations prescribes that all major work ("notifiable work") on the electrical installation of new or existing dwellings must either be carried out by a registered electrician, or inspected by a notified third party certifier. Both will provide the owner with a certificate of conformity. Registered electricians will follow standard BS 7671, but following other standards is acceptable as long as you can prove to the third party certifier that you meet the relevant safety requirements. By law, the homeowner or landlord must be able to prove that all electrical installation work meets Part P, or they will be committing a criminal offence. The regulation recommends a periodic inspection of the entire electric installation in the house by a third party certifier **each 10 years for an owner-occupied home, and each 5 years for a rented home**. Those inspections are not mandatory, but buyers or renters can ask for them as a confirmation. See Annex 2 for more information on the electrical safety regulation in England and Wales.

- In Germany, all major work on the electrical installation must be carried out by certified electrical installers. By law, the landlord must be able to prove that all electrical installation work conforms to safety standards, or they will be committing a criminal offence. Periodic inspections are not mandatory, but recommended as a way to ensure this proof.

Owner's responsibility

In some countries, the responsibility for ensuring the safety of the electrical installation is left to the owner. For example:

- In Italy, the responsibility for electrical safety shifts to the owner after the initial inspection. A 2008 Ministerial Decree made the electrical system owner "responsible for adopting the measures needed to preserve the safety characteristics, taking into account the use and maintenance instructions provided by the installer." How exactly to ensure this electrical safety, and whether to organize periodic inspections, is left entirely unstated.
- In France, the landlord is obliged to provide decent housing in accordance with the SRU (Solidarité et Renouvellement Urbain) law dated December 2000. In this respect, he must ensure the safety of the electrical installation and its good state of use and operation.

Beyond Europe: the international perspective

USA

The US National Fire Protection Association (NFPA) could demonstrates that between 1977 and 2015, the number of fires in the US has gone down from 3.3 million to 1.3 million and the number of fire deaths has decreased from more than 7,000 to roughly 3,000. However, the president of the NPFA John Pauley warned of the new challenges in electrical safety that are coming to us, not the least of which are due to technology and life-style changes. In recent years, the NFPA has shifted its focus from writing codes and standards to an information and knowledge centered organization in order to be better equipped to face these new challenges. **Acquiring and analyzing data** to better focus its campaigns became one of primary points of emphasis, as well as **targeted campaigns to provide users with reliable information** on codes, standards and best practices.

Figure 13—Example of an information campaign by the NFPA in the US.

JAPAN

In Japan, an inspection of the electrical installation every 4 years has been mandatory for all dwellings since the early 1960s. Fire statistics demonstrate the positive effect of this measure: the number of fires has been reduced by close to 90% since inspections became mandatory [23].

SOUTH KOREA

A similar law requiring mandatory periodic inspections of the electrical installation has been in force in South Korea since the early 1970s. As in Japan, the number of fires has been reduced by close to 90% since inspections became mandatory [23].

THE WORLD SAFETY BAROMETER

Figure 14—Countries that are currently covered by the World Safety Barometer.

Before taking regulatory action, it is essential to understand and fully appreciate the gaps in current regulations and practice. The *World Safety Barometer* aims to provide a benchmark to policy makers as well as guidance on how they can improve the situation. It is an initiative of the Copper Alliance, supported and endorsed by FISUEL (the World Association for Electrical Safety) and AIE (the European Association of Electrical Contractors).

The barometer uses 13 criteria that are essential in achieving residential electrical safety. Each criterion is given a weighting factor, which is then used to calculate an overall score. The criteria range from product standards and manufacturer engagement, through inspection practices and the qualification of installers, to an adequate regulatory framework. The final barometer score demonstrates how far a country's actual situation is from best practices. It also functions as a benchmark for comparing the situation with other countries. With the assistance of local experts, the barometer is applied in an increasing number of countries. The results are published on the website and are publicly available. [26]

CONCLUSION ON ENFORCING ELECTRICAL SAFETY

In the best practice case, standardization and regulation of the electrical installation are organized according to two feedback circles of continuous improvement.

Data gathering and **periodic inspections** are at the center of the entire system. Unfortunately, it is precisely these two functions that are underdeveloped in most EU countries. They are made all the more essential given the old housing stock and slow renovation rate of EU dwellings, a situation which is creating an increasing deviation between electrical safety standards and the reality throughout the EU. Therefore, standardization and electrical safety inspections for new buildings alone will not suffice to counter the degradation of residential electrical safety in the EU.

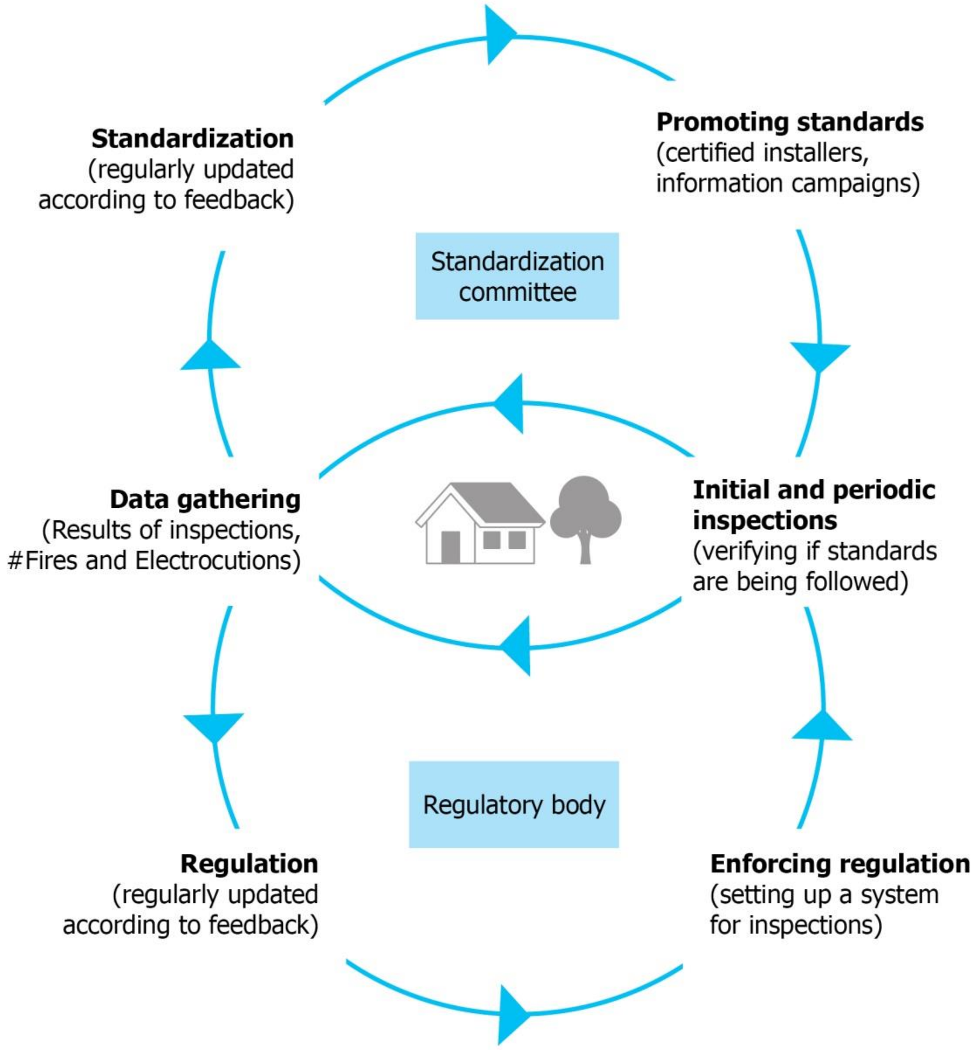


Figure 15

A strong collaboration between the crucial stakeholders will be the shortest way to move towards this best practice, as was proven by the case of France (see Annex 2).

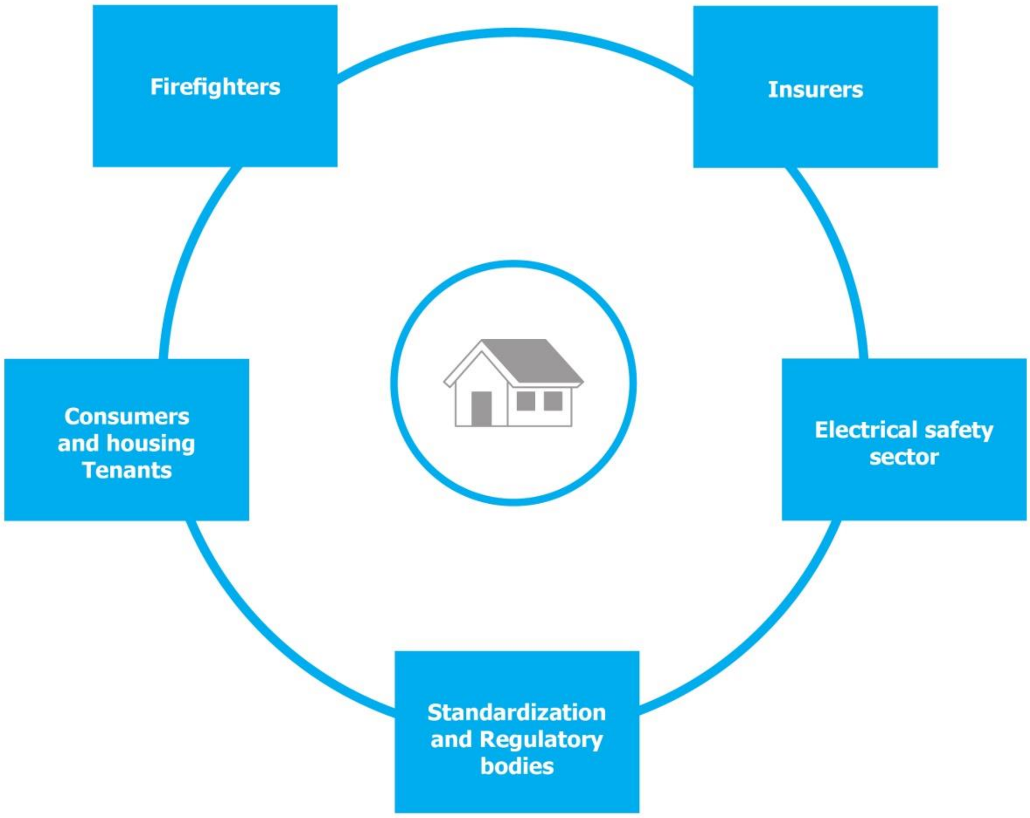


Figure 16—The stakeholders in the electrical safety regulation debate.

6. Economic model of electrical safety regulation

Suppose all recommendations for improving electrical safety in residential buildings would be followed. What would be the economic consequences of such a scenario? Executing periodic inspections and renovations come at a cost, which will partly be compensated by job creation. The costs that are avoided through a reduction of electrical fires and electrocutions include fatalities, injuries, property damage, and fire brigade interventions.

It is yet another question of who will benefit from these cost reductions. Both home occupants (and owners) and the state must come out with a positive financial balance in order to create enough momentum and motivation for change.

The following calculation is a projection from a limited number of national data to the European level. Some data, such as the average cost of making the electrical installation compliant to safety standards and the different savings that can be expected from a reduction of the fires of electric origin, need to be studied more extensively to establish more reliable projections. Nevertheless, this first rough calculation shows that a model is possible in which all stakeholders will profit—house occupants, the state, and insurance companies.

Cost of inspections

The cost of inspections of residential electrical installations in EU countries varies between €110 and €320, depending on the tariffs being used. As a result, the cost of inspecting all 227 million dwellings in the EU can be estimated at 25 to 72.6 billion euro. Following the CENELEC recommendations, those inspections should be spread over 10 years, resulting in an annual cost of **2.50 to 7.26 billion euro.**

Cost of making the electrical installation compliant

In the study "*Towards improved electrical installations in European homes*" [23], dating from 2003, an estimation is made of the cost to make a non-compliant electrical installation compliant to the safety standards. The document mentions that the average cost of such work in the EU-15 at that time varied from €300 for upgrading a consumer unit to €2,000 for a full rewiring. Indeed, a full rewiring represents one man week of work. Out of this, an average cost of €1,000 was estimated for the work to make the electrical installation of a dwelling with two or more safety concerns compliant to safety standards.

Counting with the euro-zone inflation between January 2004 and February 2017 [27], this leads to an average figure for those works today of €1,243.6 or close to €1,250. We are well aware that this figure is a first approximation and that further investigation is required to precisely calculate this cost.

If Europe wants to prevent the average age of its residential electrical installations from rising, the annual rate of the renovation of electrical installations must keep up with the past building rate. The average annual building rate across the EU between 1970 and 1990 was 2% [3]. The current average annual renovation rate in the EU is 0.32% (Sources: Eurostat, Europacable, AIE and UK Health & Safety Executive) [28]. This means that the annual renovation rate has to increase by 1.68%. On an EU housing stock of 227 million dwellings this makes 3.81 million additional renovations of electrical installations per year.

At an average cost of €1,250 for making an electrical installation compliant to safety standards, the total annual cost of those works will be **€4.76 billion**.

Direct Benefits

As assessed in “Chapter 4—The hazards of an unsafe electrical installation”, the EU incurs **6.25 billion euro in property damage annually** due to fires of electrical origin.

Moreover, fires of electrical origin and electrocutions result in 1,300 annual fatalities in the EU. According to the UK parliamentary assessment [28, p. 79], the average cost per fire fatality in the UK is €1,936,000[7]. Extrapolation of this figure to the EU (using the GDP per capita[8]) results in a figure of €1,760,000 per fatality. Consequently, a total of 1,300 fatalities per year in the EU yields **an annual cost of €2.29 billion**.

A similar calculation can be made for the cost of injuries. According to the UK parliamentary assessment [**Error! Bookmark not defined.**, p. 79], the average cost per (minor) injury in the UK is €16,775. Extrapolating he UK injury cost to the EU according to the GDP per capita leads to a figure of €15,250 per injury on the average. A conservative estimation for the number of injuries due to fires of electrical origin in the EU is 20,000 per year (see Chapter 4). This leads to a total annual injury cost of **€0.31 billion per year**.

A final major cost that can be prevented by ensuring a safe electrical installation is the cost of Fire Brigade interventions. As calculated in Chapter 4, the EU experiences an estimated total of 297,407 fires of electrical origin per year. On the average, 2 out of 5 of these fires require an intervention by the fire brigade, resulting in a figure of 118,963 Fire Brigade interventions within the EU each year. According to the UK parliamentary assessment [28, p. 79], the average cost per Fire Brigade Intervention in the UK is €3,700. Extrapolating the intervention cost to the EU according to the GDP per capita leads to an average figure of €3,364 per Fire Brigade Intervention. Using the number of interventions per year given above yields a total cost of Fire Brigade Interventions of **€0.4 billion per year** across the entire EU.

Jobs

Inspection and contracting work are labor intensive compared to other activities. The large majority of the cost consists of wages. Consequently, net job creation is to be expected when investing in electrical safety through regulation and inspections. An additional advantage is that these jobs will be created at a local level.

The following calculation shows that a best practice of periodic inspections every 10 year and a 2% renovation rate will lead to 400,000 additional jobs in the EU, resulting in 3 bn€ in additional revenue through income taxes, VAT from extra buying power, and reduced unemployment cost. The figures are based on a parliamentary study by the UK Health & Safety Executive [28].

---

[7] Calculated at an exchange rate of 1.16 euro for one British Pound.

[8] The GDP per capita in the UK is 110% of the EU average (Eurostat 2012 – 2015: http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Volume_indices_per_capita,_2012-2015_(EU-28%3D100)vJune.png).

A. Number of homes requiring renovation of electrical safety p/y (million) (see: "Cost of renovations")	3.81
B. Required man hours per renovation (24 h/renovation) (million)	91.44
C. Number of qualified electrical contractors in EU [28]	272,414
D. 15% of contractor time available for new work (in number of contractors)	40,862
E. Contractor hours available for new work p.a. (210 h/year /contractor) (million)	8.58
F. Shortage of contractor hours p/y: (B-E) (million)	82.86
G. Shortage of contractors (210 h/year / contractor)	**394,571**
H. Average salary of contractor (€/year) [28]	18,300
I. Increased state income tax: (G x H) x 33% (€ million)	**2,383**
J. Net avg. VAT on additional 20% of income discretionary spent: 17% x (20% (G x H)) (€ million)	**245.5**
M. Average cost per unemployed person (€ p/y) [28]	9,549
N. Reduction in unemployment cost (€ p/y) (million)	**376.72**
Total additional revenue (I + J + N) (€ billion)	**3.00**

Table 7

Cost benefit analysis

A crucial question is determining who will benefit from the reduced property damage that follows from adequate electrical safety. The following example shows that a model is possible in which all stakeholders—house occupants, the state, and the insurance companies—will profit.

As a first rough estimation, we make the assumption that 25% of the 6.25 bn€ of property damage from electrically induced fires is not covered by insurance. Consequently, avoiding this 1.56 bn€ damage will directly benefit the home occupants and owners. From the other 4.69 bn€ that comes to the benefit of insurance companies, suppose that 4/5 will flow back to its clients in the form of reduced insurance rates (= 3.750 bn€). The end result will be that **5.31 bn€ will come to the benefit of the house occupants** due to avoided property damage (= 1.56 + 3.75 bn€). A sum of **0.94 bn€ will benefit the insurance company** (= 4.69—3.75 bn€).

At the other side of the equation, the costs for the inspections (2.5 to 7.26 bn€ – let us suppose an average of 5 bn€) and works to make the installation safety compliant (4.76 bn€), **9.76 bn€ alltogether, will come at the expense of the home owners**.

The state would profit from the reduction of fatalities (2.29 bn€), injuries (0.31 bn€) and fire brigade interventions (0.4 bn€). This total adds up to a benefit of 3 bn€. The benefit of 3 bn€ from job creation should be added to this, resulting in **a total benefit for the public state of 6 bn€.**

Suppose now that the state would foresee a total amount of **5.25 bn€ of financial incentives** for inspections and/or renovations. In this way, **house occupants will have a final benefit of 0.80 bn€** (5.31 - 9.76 + 5.25 bn€). The **state would still retain a benefit of 0.75 bn€** (= 6.00 - 5.25 bn€).

The end result of this model is that all three stakeholders—house occupants, the state, and the insurance companies—will have a total final benefit of approximately 2.50 bn€.

The overall balances for house occupants, the public state and insurance companies of maximum electrical safety can be summarized as follows:

Cost of electrical safety (billion euro)	***Total***	**Insurance companies**	**Home occupants**	**Public state**
Property damage (total) = -6.25				
Property damage (claimed)	-4.69	-0.94	-3.75	
Property damage (not claimed)	-1.56		-1.56	
Fatalities	-2.29			-2.29
Injuries	-0.31			-0.31
Fire brigade interventions	-0.40			-0.40
Inspection cost	5.00		5.00	
Cost of making the installation compliant to safety standards	4.76		4.76	
Tax revenue through employment	-3.00			-3.00
Financial incentives	0.00		-5.25	5.25
Total	**-2.49**	**-0.94**	**-0.80**	**-0.75**

Table 8—Overview of a potential model that distributes the revenue (negative cost) over all the stakeholders.

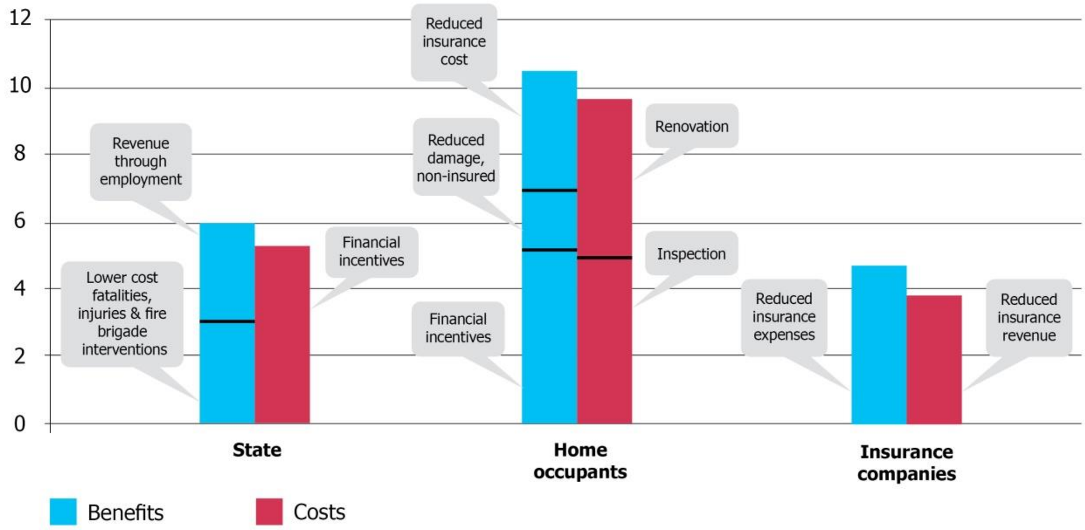


Figure 17—Potential financial balance for the state, home occupants and insurance companies of maximum electrical safety (in bn€). What is called "Renovation" in this graph is limited to the cost of making the electrical installation compliant to safety standards.

7. CONCLUSION

The fight against hazardous domestic electrical installations is far from being won in all EU countries. Especially since the trends are towards an amplification of the phenomenon while the uses of domestic electricity continue to develop and diversify.

The major issue of domestic electrical fires is not yet sufficiently taken into account in most EU countries. The lack of reliable statistical tools partly explains this situation.

In any case, the first positive results regarding the improvement in rate of renovation or safety of old electrical installations appear in the countries where the statistical quantification of the phenomenon has been carried out. In those countries, measures have been taken to generalize the condition assessment of the old electrical installations and to inform their owner about this condition.

Where public policies in that direction have been the subject of a cost-benefit assessment, they have in any case proved positive, both for the parties concerned and for the community as a whole.

ANNEX 1: CHANGING CONDITIONS

ON THE MEDIUM TERM

THE ENERGY TRANSITION AND ITS TECHNOLOGY

The electrical energy system is rapidly changing. The EU Renewable Energy Directive is targeting 20% renewable energy by 2020. This has stimulated national governments of the Member States to set up various support mechanisms for distributed renewable energy systems, including rooftop PV panels for residential electricity consumers. The European Commission is currently working on 2030 targets in order to continue promoting the development of renewables after 2020 [29].

Another trend is the electrification of residential heating systems. In the past, local fossil fuel burners enjoyed a better environmental assessment when compared to electricity. This made policy makers reluctant to support electrical heating. This balance is now shifting in favor of electricity, thanks to the decarbonization of electricity generation and the development of technologies such as heat pumps and low energy houses that enable greater efficiency out of limited amounts of electrical energy.

In the near future, private vehicle transport is likely to undergo a similar evolution. Electric Vehicles (EVs) still have to exhibit a major market breakthrough in most EU countries, but a country like Norway demonstrates where we could be heading to in the coming decade. EVs are considered to be a priority for the EU 2030 Energy Program.

All these new electrical devices in the house—PV panels, heat pumps, EV chargers, et cetera—comprise a serious challenge for the domestic electrical system and its safety. All stakeholders should collaborate to make sure that the advantages of those new technologies do not get overshadowed by the appearance of previously absent safety hazards.

PV INSTALLATIONS

The number of residential PV plants, mostly rooftop panels, has been rising steeply over the past ten years. The total installed PV capacity in the EU increased from 1.9 GWp in 2005 to 80.7 GWp in 2013 [30, p.14]. IEA-REDT estimates the share of the residential PV capacity in the EU varies between 25% and 35%, or 30% on the average [31, p.11].

This means that the total residential PV capacity in the EU in 2013 was close to 25 GWp. Assuming an average residential PV system of 2.5 kWp, we can conclude that approximately 10 million houses in the EU have their own PV installation. This figure is expected to keep on growing in the coming decade.

A residential PV installation poses new challenges to the electrical safety. When a PV panel is integrated into the domestic network, the grid connection will be subjected to bi-directional power flows. This demands a different safety approach. If the grid connection is cut off, the PV panel should switch off as well, or the domestic network might still carry power. Another, albeit technically more complicated option, is to set up the network in such a way that the PV panel can serve as an Uninterruptable Power Supply (UPS) in case of network black outs.

Another point of attention is that the PV panel will produce DC electricity, which is only converted into AC by the inverter inside the house. The DC line going to the inverter brings along new kinds of safety issues. A short circuit happens much faster with DC, requiring a larger gap between the poles of switches. Cables should be separated to avoid short circuits in case of fire. Other potential issues are leak currents that might flow through the metal parts of the roof and through water pipes in the house or the differential switch that might not work properly.

Electric Vehicle (EV) charging

In Norway, the Electric Vehicle (EV) market share of all new cars sold reached 22.4% in 2015 and is rising further this year (Source: Wikipedia). EVs still have to see their big breakthrough within the EU. EV market shares grew only from 0.49% in 2013 to 1.41% in 2015. However, since EVs are a priority for the EU 2030 program, a faster market growth is expected in the coming decade. The expectation is that figures will evolve figures towards those we currently see in Norway.

The EV charging stations pose a major challenge for the residential electrical installation. Residential EV charging can take many forms:

1. The easiest way is to simply connect the car to a household socket through an extension cord. The primary problem with this set-up is many older houses have an electrical installation that does not meet current safety standards. But even if proper wiring, a proper earthing circuit, a residual current device (RCD) and an overload protection are in place, this situation is still not without issues. After several hours of charging the circuit at maximum power, the cable and switch can still overheat and start a fire. If other appliances are connected to the same circuit during the EV charging, the overload protection might trip and shut off the circuit. Therefore, connecting an EV to an ordinary household socket can never be considered a safe practice.

2. Slightly better is the set-up with a special single or three phase charging cable instead of an ordinary extension cord. This charging cable has a built-in overload protection device and an earthing conductor. This improves safety, but charging will remain slow and may be interrupted due to cable overload.

3. A good practice would be to install a dedicated electrical circuit in the house with a dedicated socket to charge the EV. This circuit could then be designed for carrying higher currents (e.g. up to 40 A) than the usual household circuit (typically 16 or 24 A). Adding such a circuit to the residential installation requires dedicated knowledge from the electrical installer.

4. A faster vehicle charge can be achieved through a DC connection with an external charging station. This charging station, containing an AC/DC converter and all the required control and protection devices, is installed on a dedicated electrical circuit of the residential network.

The former set-ups are listed according to rising safety and functionality, which brings along rising investment costs. Without clear standards and a regulation to verify the standards, EV owners risk choosing the cheapest option with all of its related safety problems.

Even more popular than electric cars are the electric bicycles and motorbikes. Even though their battery power is lower than that from electric cars, the charging can still pose overload and safety problems on circuits that are already significantly loaded or poorly designed. DIY charging sockets that are installed for this purpose in the garage or on the outside of the house are often problematic.

Heat pumps

Heat pump compressors have a high power load compared to the average residential application. They have to be connected through dedicated two or three phase circuits that will carry higher currents than the average residential circuit. This requires additional attention for electrical safety. Proper cable conductor sizing, a dedicated and well rated circuit breaker, an RCD and a proper earthing circuit are required. Therefore, the electrical works must be installed by a qualified person that is familiar with this kind of installations.

CHANGING DEMOGRAPHY AND LIFESTYLES

AGEING POPULATION, AGEING INHABITANTS OF DWELLINGS

Europe's population is ageing and this will continue in the near future. The base of the age pyramid is shrinking, while the elderly population increases. The proportion of the population above 65 years old in the EU is projected to rise from 17% in 2007 to 24.6% in 2030 [32, p.19].

A second, related trend is that older people will continue to live independent lives in their own home until a higher age. This is partly because people of 65 years old are increasingly in good health, partly because they prefer to do so, and partly also out of necessity. Indeed, a consequence of the ageing population pyramid is that there are going to be fewer people around to look after the elderly. The projected old-age dependency ratio for 2030 indicates that in Germany and Italy there might be only two persons of working age supporting one elderly person over the age of 65 [32, p. 31]. Having the elderly live safely at home for a longer time takes both the pressure off the increasing demand for care and reduces the costs to national health services.

Many of the various technological solutions that exist to assist elderly people living at home are electrically operated. Think about electric stair-lifts, various types of remote controls, safety alarms, tele-monitoring systems or a video link to the doctor, among other solutions [33].This means that the house and the electrical installation need to be adapted to carry out all those functions without introducing new safety hazards. Many houses and their electrical installations will also need to be adapted for disabled people. An extra difficulty in this matter is that most elderly people live in houses of a considerable age that have often not seen renovation in several decades. Technology assisted living should therefore go hand in hand with a well-functioning program that enhances residential electrical safety and prepares dwellings for life-long-living.

OTHER FLEXIBILITY ISSUES

Life-styles are continuously changing and houses need to be adaptable to cope with those changes. One of the main issues that most dwellings suffer from is a lack of sockets. This is true of even relatively new houses. This problem has grown larger with the increase in electronic devices used at home and with the increasing trend to work from home. One of the problems is also that rooms are often changing function (e.g. a sleeping room becomes a work room) or new functions are added to it (e.g. computer, TV or gaming station in the sleeping room). To compensate for the lack of sockets, occupants often rely upon extension cords. This is a practice which can lead to dangerous situations, among other reasons because the extension cords are often not manufactured according to the standards or even blatantly counterfeited. Some countries (Germany, France)[34] have recognized this problem and created standards in an attempt to deal with this problem.

ON THE LONGER TERM

TOWARDS DC NETWORKS?

With an increasing number of electricity sources providing DC power (PV panels, batteries), as well as an increasing number of appliances that are using DC power (ICT infrastructure, LED lighting, EV charging…), some people wonder why we still need an AC network in between. A growing number of electricity experts are indeed convinced that we should evolve towards a DC electrical system for residential and office buildings. The first pilot projects of office buildings working on DC are already up and running in the Netherlands. One of the main problems with such a shift to DC could be that our electricity installation experts are absolutely not familiar with it and are often unaware of the related safety issues. Potential safety issues include the following:

- A short circuit happens much faster with DC, requiring a larger gap between the poles of switches. Cables should be separated to avoid short circuits in case of fire.
- Leak currents might flow through metal parts in the house, causing the danger of electrocution and being a potential source for a fire.

- If a low DC voltage is chosen, high currents will run through the wires, creating an increased risk of hot spots becoming a source of fire. If a high DC voltage is chosen, the currents will be so low that the fuses or circuit breakers will not work properly.

The solution for the latter problem is to change from passive DC to active DC. In active DC, the network and its protections are electronically controlled. It consists of a network that has the intelligence to cut off the current when necessary. Since microchips react 1,000 times faster than a fuse, low currents are not problematic anymore. Such an active DC network has the potential to be safer than an AC system, but only if it is designed and installed properly.

Annex 2: Case study France

The preparation process

The field for a new regulation on mandatory electrical safety inspections in France was leveled by GRESEL (*Groupe de Réflexion sur la Sécurité Electrique dans le Logement*). GRESEL was founded in 2003 as a unique coalition between consumer organizations and professional associations from the sector. Together and based on consensus they formulated recommendations for the government. Those recommendations ware based on extensive data and statistics gathered by fire brigades and consolidated by insurance companies and by *l'Observatoire National de la Sécurité Electrique* (ONSE).

The regulation in force

The new French regulation ENL n° 2006-872 on the inspection of electrical installations in dwellings was passed 13 July 2006 and came into force on 1 January 2009. It obliges an inspection of electrical installations which are 15 years or older at every sales transaction of the property (*Diagnostic Electrique Obligatoire* or *DEO* in French). An exemption is given if such an inspection has been executed and followed up successfully in the past 3 years.

The inspections within the framework of this regulation are goal-oriented. They do not verify whether the installation is built in conformity with the electrical standard NF C15-100, but rather aim at mapping the risk for electrocution and fire of electrical origin. This risk has been defined in the new standard NF C 16-600, which stipulates a list of minimum safety requirements. All anomalies to these requirements are codified (B1 to B11), facilitating reporting. The inspection report informs the purchaser on the state of the property they intend to buy, thereby increasing the transparency of the sales transaction.

Residential electrical safety categories according to French inspection standard UTE XP-C 16-600	
Anomaly code	**Electrical safety requirement that is breached**
B1	An easy accessible General Control and Protection Appliance (GCPA), containing the general connection switch
B2	Presence of at least one appropriate differential connection device
B3	Presence of an appropriate earthing and earthing connections
B4	Presence of an overcurrent protection device on each circuit, adapted to the conductor section on the circuit
B5	Equipotential bonding in rooms containing a bath or shower
B6	Keeping zones with different rules in rooms containing a bath or shower
B7	An insulating case for all electrical connections, avoiding the risk of direct contact with live parts
B8	Absence of worn-out or inappropriate equipment + use of the right color codes for wiring
B9	Correct installation of equipment powered from a common space but situated in a private dwelling, or vice versa
B10	Correct installation of the electrical equipment related to a private swimming pool
B11	Other recommended verifications

Table 9—Safety categories on which mandatory residential electrical safety inspections in France must report.

A new law has recently passed in France which extends the system of mandatory inspections to rented dwellings with an electrical installation older than 15 years. This law will come into force 1 July 2017. The inspections will verify that the electrical installation is in accordance with six safety criteria that greatly correspond with codes B1 to B8 of XP-C 16-600 (see table x above) (B2-B3 and B5-B6 taken together). Following the inspection, a certificate of conformity that is valid for six years can be issued.

Main results

According to the Impact Assessment of GRESEL [35], mandatory electrical inspections were carried out on over 2.5 million residential electrical wiring systems between 2009 (when the new law came into force) and 2013. Those inspections directly led to over 1.5 million safety upgrades or renovations of existing electrical wiring in the same period. Every year, **between 43% and 45% of the sales of existing homes in France are followed by safety upgrades or renovations** that directly result from a mandatory electrical inspection.

Detected anomalies of electrical safety

Promotelec and FIDI (*Fédération interprofessionelle du diagnostic immobilier*) investigated 6,000 diagnostic inspection reports from the first year of the new regulation (2009) [36]. This sample contained a balanced mix of houses and apartments. It also contained a high diversity of locations throughout the country (85 *départements*), of diagnostic companies who executed the inspection (80 companies), and of the year of of the dwelling's construction.

The investigation revealed that in 72% of the cases, the electrical installation violated at least three of the minimum safety requirements. Such a figure is not at all surprising, since half of the EU housing stock dates from before 1970, and many of those homes have not yet undergone a renovation of the electrical installation.

The evaluation of the detected anomalies was as follows:

- B1: In 20.6% of the buildings, there was no easy accessible General Control and Protection Appliance (GCPA). The most common violation was that the GCPA was not placed inside the home.
- B2: In 21.9% of the cases, there was no appropriate differential protection device.
- B3: A large majority of the dwellings (78.7%) was lacking an appropriate earthing installation.
- B4: In 42.9% of the cases, not every circuit was having an appropriate overcurrent protection device.
- B5: In 47% of the dwellings, the equipotential bonding in rooms containing a bath or shower was not provided or not correctly installed.
- B6: In 38.7% of the cases, the zones for electrical equipment in rooms containing a bath or shower were not respected.
- B7: 43% of the dwellings hold electrical connections that are not placed inside an insulating case, entailing the risk of direct contact with live elements. In 51.7% of the dwellings, conductors are not adequately protected by insulating pipes, moldings or skirting boards.
- B8: In 35.4% of the cases, worn-out electrical equipment is still used. 26.5% of the dwellings make use of inappropriate equipment and 4.4% use green-and-yellow earthing cables as active conductors.

The study by Promotelec and FIDI also investigated the rate of adoption of the recommendations expressed in these 6,000 inspection reports. In 90% of the cases where unsafe features were found, the owner expressed the intention to improve the installation to meet safety requirements.

Economic evaluation

According to an impact assessment of the impact of the mandatory electrical inspection (DEO) by the Working Group on Electrical Safety in Housing (GRESEL), an average of approximately 500,000 inspections were carried annually during the first 5 years of the new law (2009 – 2013). Following these inspections an annual average of approximately 300,000 renovations were carried out. [35] According to TNS Sofres and Promotelec studies, carried out by order of ONSE at the end of 2009, the new French regulation also has a significant socio-economic impact. Extrapolation of those studies leads to an annual turnover of inspections and renovations of 500 million euro, saving or creating approximately 7,200 jobs. [37]

Evaluation of the regulation

The old housing stock in France contains abundant unsafe electrical features. The mandatory inspections and the NF C 16-600 standard appear to be effective instruments for tracing those deficiencies. The adoption rate of the resulting diagnostic reports is high to very high: the average number of safety upgrades carried out each year as a result of the mandatory inspections was approximately 300,000 in the period between 2009 and 2013. This is close to the estimated number of homes whose electrical wiring systems become worn or obsolete each year as a result of their age (approximately 300,000 per year as well, according to an estimate by ONSE). This means that the mandatory electrical inspections have a stabilizing effect on the number of run-down residential electrical wiring systems in France.

The new addition to the law that will come into force on 1 July 2017 will be crucial to gradually remedying the existing backlog. It widens the system of mandatory inspections to residential buildings with shared ownership and to rented dwellings.

In addition, GRESEL recommends a few actions to be combined with the current system of mandatory inspections:

- Public assistance to low income households for renovating their electrical installations according to safety standards
- Information and awareness campaigns on the safety of electrical installations
- The establishment of a statistical tool that regularly measures the state of the electrical installations throughout the country

Those measures could make the law on mandatory electrical safety inspections even more effective.

ANNEX 3: CASE STUDY ENGLAND AND WALES

THE REGULATION IN FORCE

Since 2005, all electrical work in dwellings in England and Wales must meet the requirements of Part P of the Building Regulations [38].

These requirements apply both to work carried out by professionals and to do-it-yourself work, as well as to new dwellings and to alterations or additions in existing dwellings. By law, the homeowner or landlord must be able to prove that all electrical installation work meets Part P, or they will be committing a criminal offence.

Part P states that anyone carrying out work on the electrical installation of a dwelling must ensure that reasonable provision has been made in order to protect any persons who might use the electrical installation from fire and electric shock. This calls for the use of approved products and materials and a sound design and sound installation practices; i.e. ensuring conformity to the British Standard BS 7671. The latter is not an obligation, however; following other standards is sufficient if you can prove that you can meet the relevant safety requirements.

In April 2013, the requirements of Part P were amended, with the major aim to make the system less bureaucratic. These amendments are discussed later in this paper.

DIFFERENCE BETWEEN NOTIFIABLE AND NON-NOTIFIABLE WORK

Part P of the Building Regulations differentiates between *notifiable* and *non-notifiable* electric work. In April 2013, the regulation became less stringent by shifting some of the formerly notifiable work to the list of non-notifiable work. Currently, the following work is notifiable:

- The installation of a new circuit (at any voltage, also below 230 V). This includes, among many other works, the installation of electric floor heating systems and of PV or micro CHP supply units.
- The replacement of a consumer unit (fuse-box)
- Any alteration or addition to an existing circuit in the space surrounding a bath or shower (at any voltage, also below 230 V)
- Any alteration or addition to an existing circuit in a room containing a swimming pool or sauna heater (at any voltage, also below 230 V)

All other kind of electric work is non-notifiable. This includes alterations to an existing circuit in a bathroom at sufficient distance of the actual bath or shower. It also includes, among other work, replacing or adding socket-outlets, light outlets and control switches on an existing circuit, and the installation of equipotential bonding.

RULES FOR NON-NOTIFIABLE WORK

Work that is non-notifiable has to meet the requirements of Part P, but may be executed by anyone, also by non-professionals. Standard BS 7671 can be a guideline, just like other valuable electrical safety standards.

RULES FOR NOTIFIABLE WORK

Two different procedures are allowed for notifiable work.

With the first, the owner asks a registered electrician to execute the work. The list of all registered electricians in every commune can be found on the Internet. After the work, the owner will receive two certificates: one that confirms compliance to the BS 7671 standard and one that confirms compliance to Part P of the Building Regulation. If later it turns out that the work doesn't meet the requirements of Part P, the owner will have access to a formal complaints procedure.

The second option for notifiable work was introduced by the amendments to Part P of April 2013. The owner may employ a non-registered electrician or do the work himself, according to BS 7671 or another valuable standard. In that case he has to notify a registered third party certifier within five days of completing the work. This certifier will then carry out an inspection of the work. If the result is positive, the owner will receive an Electrical Installation Condition Report. The non-registered electrician will most probably be cheaper than a registered one, but the owner will have to pay a *building control fee* to the third party certifier.

When selling or renting the building

With each transaction, e.g. selling or renting out, you can be asked to show the certificates of all notified work that was executed on the electrical installation in the course of its life time.

Voluntary periodic inspections

Apart from the obligation for notifiable work, Part P recommends a periodic inspection of the entire electric installation in the house by a third party certifier each 10 years for an owner-occupied home, and each 5 years for a rented home. Those inspections are not mandatory, but buyers or renters can ask for them as a confirmation, creating an economic driver for those inspections.

Voluntary registration of electrical appliances

A system was set in place for consumers to voluntarily register their purchases of electrical appliances and cables. This enables to organize a product recall in case the products appear to be counterfeit, faulty or non-approved regarding quality standards.

The Approved Cable Initiative (ACI) estimated that one fifth of all cable in the UK supply chain to be unsafe, non-approved or counterfeit. For example, in 2015 the ACI took test samples of products from a non-EU cable manufacturer. The samples were found to have insufficient copper resulting in a high conductor resistance. The product did not comply with the appropriate British Standard. Quick action was taken to intercept this product in the supply chain [39, 40]. There have been also numerous cases of electrical chargers, adaptors, extension and spare product leads, hairdryers and small kitchen appliances reported as faulty or dangerous [39].

These trends demonstrate that a good system of product recall would be required, but its success is very low; approximately 20% can be recalled on the average [39]. Concerns over data security are probably at the basis of the high reluctance of consumers to have their purchases registered.

Main results

Over the past decade, the total number of fires in dwellings and related deaths and injuries has been dramatically reduced in the UK. However, according to an analysis by EC Harris [39], it is difficult to determine how much of this reduction is down to Part P of the Building Regulation. Without regulation, the accident rates would have fallen as well, as older installations would have been modernized during renovations. On the other hand, this trend would have been moderated by the increase of electrical appliances and the potential hazards that come along.

A similar reasoning can be followed concerning the risk of electrocution.

- According to the estimation of EC Harris, taking into account a reasonable attribution, Part P of the Building Regulation helps to annually prevent [39]: 2.6 fatalities and 421 injuries from electric shock each year (mainly due the fact that Part P has been a major factor in the increase of RCD installations)

- 2.8 fatalities, 10 serious injuries, and 77 minor injuries from electrical fires

Evaluation of the regulation

The regulation of electrical safety in England and Wales intends to influence conduct when carrying out electrical work, rather than to restrict access to the market of electrical installation. Moreover, it is focused on reducing fatalities and injuries, not on reducing property damage.

Examination of the figures above shows that the regulation can be called a moderate success. The fact that the system can rely on an appropriate standard (BS 7671) that is constantly improved is one of the keys to this success. The registration of professional electrical installers is another essential part of the system.

However, the success of Part P of the Building Regulation should not be overstated. The number of electrically induced fires in dwellings decreased less drastically (-25% to -30% from 2010 to 2014 [41]) than the total number of fires in all buildings in the UK (-50% from 2010 to 2014 [41]). This means that electrical safety still requires major attention for reducing fires and their consequences in dwellings.

- The following recommendations can be derived from the assessment of the regulation by the UK Fire Safety Platform [40, 41**Error! Bookmark not defined.**], Electrical safety must have high priority in fire isk assessments.

- There is a concern with the lack of routine testing, which could hamper the detection of degrading material and equipment in older houses, as well as the detection of faulty equipment and cables.
- A system of product registration and manufacturer recall arrangements did not have the expected results. Retailers should be more effective in improving confidence in product recall, for instance by ensuring that the information will only be held and used for product recall. Non-standard cable in the supply chain should be a concern to national standardization bodies.
- The Government English Housing Survey assessed 4% of the homes as being at high risk, particularly in the area of private rented, older homes. Mandatory inspections of electrical installations at regular intervals and by a competent person should be introduced for this category and for all lower quality social housing.
- A further report by Electrical Safety First (ESF) identified older people as a particular risk group. Risk reduction programs should be implemented that focus on this group.

Annex 4: Electrical Safety Checklists

FISUEL Manual—Essential requirements for electrical safety

The organization for electrical safety FISUEL published a guide of 5 requirements that enable installers to quickly verify the compliance of an installation with the essential requirements for electrical safety. [42]

Requirement 1

A manually operated switching and isolating device and a protecting device, must be present at the origin of the installation.

Why? To enable the total electrical power supply to be cut off at a single, known and accessible point at the head of the installation during work on the installation or if an incident occurs.

Requirement 2

Ensure protection against all risks of direct contact with electrically live parts.

Why? Avoid the risk of electrocution. Because direct contact with a voltage of 230 V may result in a current (normally around 150 mA) passing through the human body. This is above the limit of 35 mA, at which the risk of cardiac fibrillation begins and can cause injury and/or electrocution.

Requirement 3

Protection against indirect contacts suited to the earth connection system of the installation. Example: contact with the metallic enclosure of class 1 equipment with an insulation fault. This will leave the user in the presence of a dangerous electrical contact if there is no suitable protective measure.

Why? To protect persons against injury and electrocution risks resulting from fault currents travelling through the human body.

Requirement 4

Implementation of special measures in damp rooms and compliance with the rules related to the zones in these rooms.

Why? Wet rooms such as bathrooms, kitchens, laundries, et cetera present a special risk due to the presence of moisture, which increases the risk of electrocution (if special measures are not taken) due to the reduction of the body's resistance, deterioration of the insulation, et cetera.

Requirement 5

Protection against

- Overcurrents in the customer unit/board in respect to the cross-section area of the cables
- Overvoltages

Why against overcurrent? To protect all circuits against overcurrent due to overloads or short circuits, which could damage the equipment of the installation or even start fires if suitable measures are not taken.

Why against overvoltages? To protect circuits and sensitive appliances (computers, telecommunications, et cetera) against the effects of voltage surges such as destruction of electronic circuits and fire, especially in areas with high lightning risk where distribution is by overhead lines. It should be noted that failure of the equipment concerned can have consequences for personal safety (medical supervision) and property (local or remote fire/intruder alarms).

18 INITIAL CHECKS OF ELECTRICAL INSTALLATIONS EVERY ELECTRICIAN MUST PERFORM (IET)

The UK Institution of Engineering and Technology (IET) has published clear guidelines regarding how to carry out an inspection of a residential electrical installation and what exactly must be inspected. [43, 44]

A first important point of attention is that certain information must be available to the inspector before he or she is able to carry out their job. This information should include at least a simple wiring diagram, but can also contain instructions from manufacturers and similar documents.

Before the actual testing procedure can start, the inspector must carry out a detailed physical inspection to verify whether the electrical installation and equipment is:

1. Installed according to a relevant national standard (or harmonized European standard)
2. Erected/installed in compliance with the IET regulations
3. Not damaged or degraded in such a way that it could cause danger

In order to comply with these requirements, the IET provides the following checklist:

CHECK #1—CONNECTION OF CONDUCTORS

Are all terminations electrically and mechanically sound? Is the electrical insulation and sheathing removed only to a minimum to allow satisfactory termination?

CHECK #2—IDENTIFICATION OF CONDUCTORS

Are conductors correctly identified in accordance with the regulations?

CHECK #3—ROUTING OF CABLES

Are cables installed such that account is taken of external influences, such as mechanical damage, corrosion and heat?

CHECK #4—CONDUCTOR SELECTION

Are conductors selected for a current carrying capacity and voltage drop in accordance with the design?

CHECK #5—CONNECTION OF SINGLE POLE DEVICES

Are single pole protective and switching devices connected in the line conductor only?

CHECK #6—ACCESSORIES AND EQUIPMENT

Are all accessories and items of equipment correctly connected?

CHECK #7—THERMAL EFFECTS

Are fire barriers present where required and protection against thermal effects provided?

CHECK #8—PROTECTION AGAINST SHOCK

What methods have been used to provide protection against electric shock?

CHECK #9—MUTUAL DETRIMENTAL INFLUENCE

Are wiring systems installed so that they can’t have any harmful effect on non-electrical systems, and so that systems of different currents or voltages are segregated where necessary?

CHECK #10—ISOLATION AND SWITCHING

Are the appropriate devices for isolation and switching correctly located and installed?

CHECK #11—UNDER-VOLTAGE

Are there protective devices present where under-voltage may give rise for concern?

Check #12—Protective devices

Are protective and monitoring devices correctly chosen and set to ensure automatic disconnection in case of over-voltage and/or over-current?

Check #13—Labelling

Are all protective devices, switches (where necessary) and terminals correctly labeled?

Check #14—External influences

Have all items of equipment and protective measures been selected in accordance with the appropriate external influences?

Check #15—Access

Are all means of access to switchgear and equipment adequate?

Check #16—Notices and signs

Are danger notices and warning signs present where necessary?

Check #17—Single line diagrams/Wiring schemes

Are diagrams, instructions and similar information related to the installation available?

Check #18—Erection methods

Have all wiring systems, accessories and equipment been selected and installed in accordance with the requirements? Are fixings for equipment adequate for the environment?

REFERENCES

[1] YouTube Video: *NFPA President Jim Pauley talks about progress at the 2016 Conference & Expo in Las Vegas*.

[2] *Housing statistics in the European Union*, OTB Research Institute for the Built Environment, September 2010

[3] *Europe's Buildings under the Microscope*, Building Performance Institute Europe, October 2011

[4] Samuelson-Brown, G. Thornton, M. Repair, *Maintenance & improvement in housing - electrical supply, the supply side*, BSRIA, 1997 (see Reference 43 of *Towards improved electrical installations in European homes* [23])

[5] *The GB Private Home Improvement Market - the demand side for electrical & security system improvements*, Construction Forecasting and Research Limited, 1998 (see Reference 50 of *Towards improved electrical installations in European homes* [23])

[6] Aust, R, *Fires in the home: findings from the 2000 British Crime Survey*, UK Department for Transport, Local Government and Regions, 2001

[7] D. Phillips, Councillor Mid and West Wales Fire Authority, http://www.the-fic.org.uk

[8] *A Shock to the System / Electrical Safety in an Ageing Society*, George Holley-Moore and Jonathan Scrutton – The International Longevity Centre, UK, January 2015

[9] ISO/cd 17755-2 (= the international standard for how to define the sources of fire)

[10] *Les feux d'habitation et accidents d'origine électrique*, ONSE 2015

[11] M. Allen, *Safety of new and existing electrical installations*, FISUEL and the Electrical Safety Council, 2011

[12] S. Zajac, *Fire Statistics / Concerning fatalities and injured*, HQ of the State Fire Service Hazard Recognition Department

[13] *La revisión de las instalaciones eléctricas de los hogares reduciría 7.000 accidentes por instalaciones deficientes*, press release by the Spanish Copper Institute, 17 July 2012

[14] J. Manson, *Improving electrical wiring safety standards, inspection periodicity and providing more effective controls*, European Copper Institute, 2000 (see Reference 75 of *Towards improved electrical installations in European homes* [23])

[15] B. Brouwers, *Design for electrical safety,* Egemin Consulting for Leonardo Energy, June 2014

[16] *Limiter les risques de brulures et d'électrocutions*, ANAH, 2001, 8 pages

[17] IEC 60364-6-61 and IEC 60364-6-62 at www.iec.ch. Standardization work in progress is not published. Information may be obtained from national standards committees (see members listing of IEC)

[18] ES 59009:2000, May 2000 (www.cenelec.org)

[19] *Electrical Fire Safety, the UK Experience / A strategic approach to reducing electrical fire risk in the domestic environment*, Fire Safety Platform, December 2015

[20] Electrical Safety First DiY campaign

[21] GRESEL Electrical Safety leaflet

[22] *Questionnaire on the inspection of LV electrical installations*, CENELEC TC 64

[23] *Towards improved electrical installations in European homes*, aie, Europacable, European Copper Institute, Fisuel and UIE, 2003

[24] *2013 Technical Guideline for Electrical Contracting Companies in the EU*, AIE

[25] *L'évolution de la réglementation en Belgique,* FISUEL, 2013

[26] Leonardo Energy Electrical Safety Barometer

[27] Inflation calculator and change of price between 2 dates

[28] EC Harris, Further economic and analytical support for proposals to amend the Building Regulations in 2013, the UK Department for Communities and Local Government, December 2012

[29] *Trends 2014 in Photovoltaic Applications*, IEA PVPS, 2014

[30] *PV Status Report 2014*, European Commission, DG Joint Research Centre, Institute for Energy and Transport, November 2014

[31] *Residential prosumers – Drivers and policy options*, IEA – RETD, June 2014

[32] *The Ongoing Population Ageing*, Marija Mamolo and Sergei Scherbov, Vienna Institute of Demography of the Austrian Academy of Sciences, 2007

[33] *Living needs for the elderly*, Guy Kasier, Leonardo Energy, 2010

[34] D. Wijnants, *Advocating a more flexible electricity installation*, Leonardo Energy, 2015

[35] *Assessment of the impact of the mandatory electrical inspection (DEO) law on the market for safety upgrades or renovations of electrical wiring in France*, Working Group on Electrical Safety in Housing, GRESEL, December 16, 2014

[36] Promotelec and FIDI study after one year of mandatory inspections in France

[37] TNS Sofres and Promotelec studies, carried out by order of ONSE at the end of 2009

[38] The Building Regulations, part P1 – Electrical Safety – Dwellings – Design and installation of electrical installations (Edition of April 2006, incorporating 2010 amendments that came into force April 2013)

[39] M. Hagen, *Electrical Fire Safety, the UK Experience*, the Fire Safety Platform, 18/09/2015

[40] *Electrical Fire Safety, the UK Experience / A strategic approach to reducing electrical fire risk from counterfeit, poor quality or faulty electrical cables and electrical products*, Fire Safety Platform, December 2015

[41] *Electrical Fire Safety, the UK Experience*, Fire Safety Platform, December 2015

[42] FISUEL Manual / Essential requirements for electrical safety (Existing installations in dwellings), FISUEL, 5 April 2007

[43] IET

[44] Electric Wiring: Domestic – Brian Scaddan IEng, MIET