European Copper Institute
Copper Alliance

Copper usage in electrical installations in the home

European Copper Institute

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CONTENTS

1. INTRODUCTION

In this study we will look at how much copper (in kg) is used in electrical installations in the home. As house sizes vary, as do the number of installed items within, this is, of course, only a representative guide.

We start by calculating a conventional electrical installation. They consist of circuits with sockets and circuits with switches and light points. We employed common sense and experience to determine the number of sockets and their positioning. The same applies to lighting and switches.

Taking the number of sockets, operating points and light points into account, we also calculate the use of copper for three other installation methods: the remote-controlled switch installation, the home automation system in star topology and the home automation system in bus topology.

For the remote-controlled switch installation, the operating points are operated with push buttons instead of switches. The switching elements themselves are placed centrally in the distribution board (the remote-controlled switches). The operating points operate on 24V. Push buttons are also used in the home automation system. However, 'keypads' are also used in a few places.

For each of the four installation methods, we also calculate the use of copper for additional items such as roll-down shutters, intercom, telephony, computer network, fans, music distribution, etc.

2. THE HOME

For this study, we looked at a plan of a detached home by architect Dirk Vander Borght (Ghent). This home consists of a ground floor with a living room, dining room, kitchen, entrance, stairwell, toilet, small office, pantry, garage, terrace and utility closet.

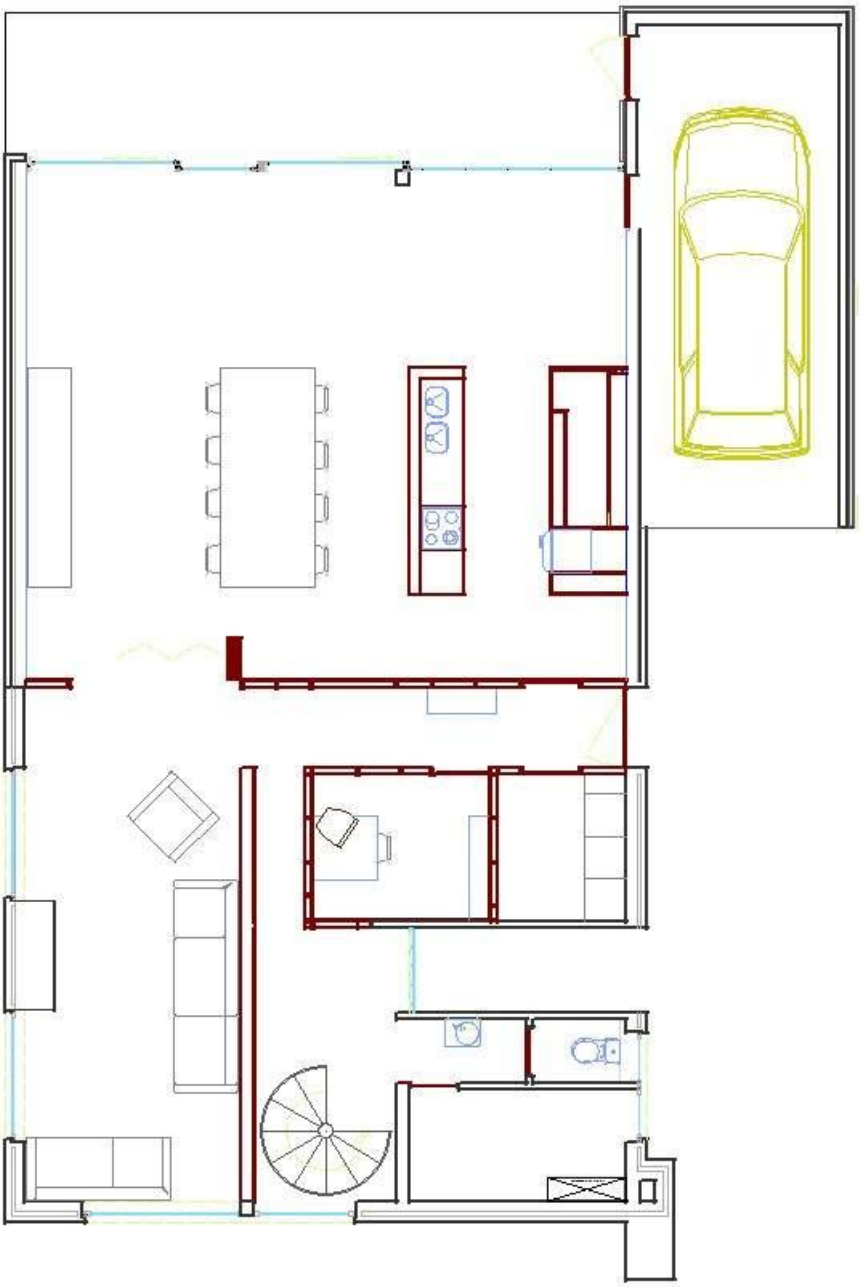


Figure 1: The ground floor.

The ground floor, including terrace and garage, has a total area of 183.43 m².

The space-saving spiral staircase leads to the landing. On the first floor, there is the master bedroom with a dressing room and bathroom, two children's rooms, a small bathroom with shower and a guest room that can also be used as a playroom or study. The master bedroom gives access to a roof terrace. The rest of the roof has been designed as a green roof.

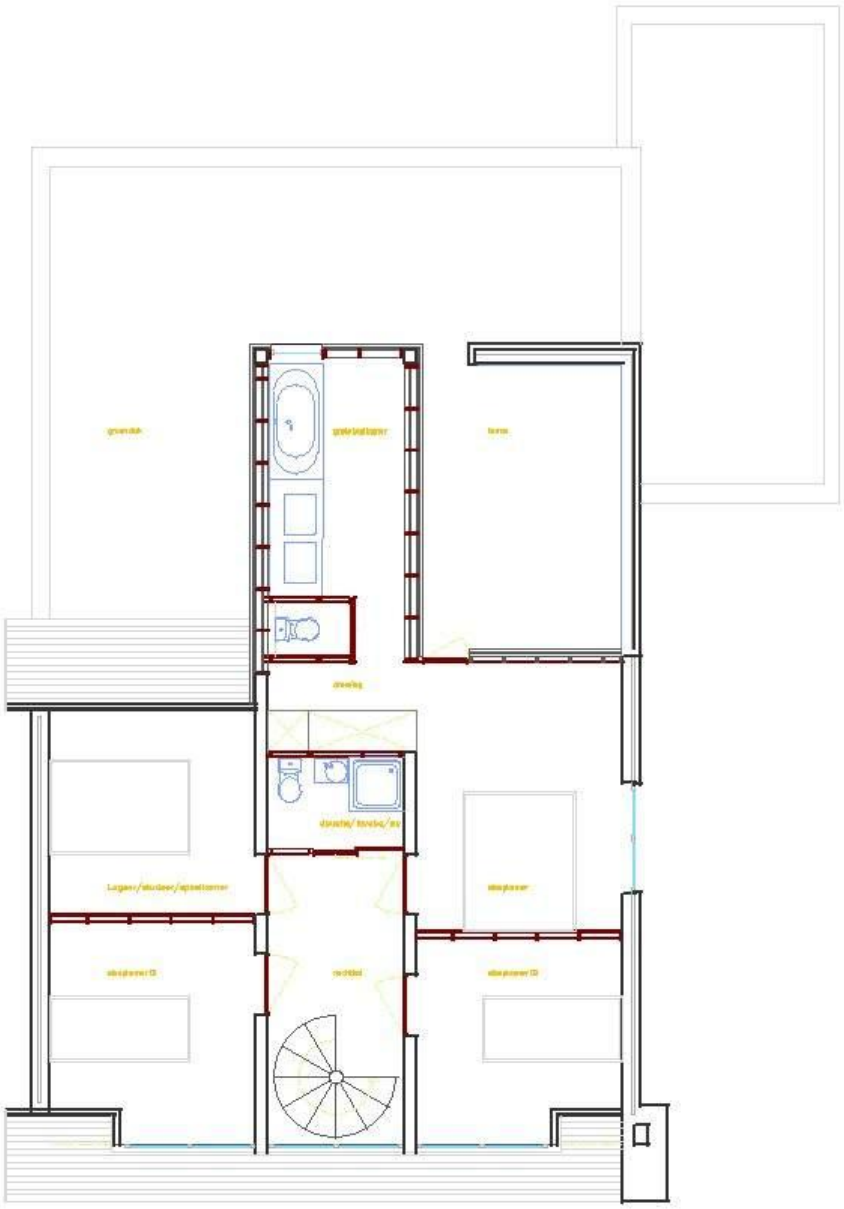


Figure 2: The first floor.

The first floor, including roof terrace, has an area of 137.89 m². The total area for the entire home is 321.32 m², including terraces and garage.

3. THE CONNECTING CABLES AND EARTHING

Whatever installation technique we choose (conventional, remote-controlled switches, home automation system), the home will always have to be connected to a few mains cables. Earthing and a number of equipotential links will also have to be installed. All these connections are the same for every installation technique. We thus calculate them separately here.

3.1. THE ELECTRICITY SUPPLY CABLE

For this home, we assume a single-phase electrical connection of 40 or 50A. For this, a 4 x 10 mm² cable has to be installed to the street according to the connection standards of the distribution network operator. In this way, a subsequent conversion to a multiphase connection can be easily done if desired.

As this home's utilities closet is on the street side, we count a length of 10 m here. This is a total of 40 m of copper with a cross-section of 10 mm². The copper weight per metre for this cross-section is 0.089 kg. The supply cable thus represents a total copper weight of 3.56 kg.

3.2. THE COAX CONNECTING CABLE

For the coax cable, we also count a length of 10 m. Here, we use a CATV distribution cable of type CT15A 75 Ohm with a copper weight of 56 kg/km. For our installation length, this is thus a copper weight of 0.56 kg.

3.3. THE TELEPHONE CONNECTION

Here, too, there is an installation length of 10 m. We install a telephone cable of 5 x 2 x 0.6. This way, a new cable does not have to be installed if more telephone connections are desired later on. The use of copper per metre is 0.0534 kg here. For our installation length, this is 0.534 kg.

3.4. THE GROUND LOOP

For a new house, a ground loop has to be installed according to the General Regulations for Electrical Installations in Belgium (AREI = *Algemeen Reglement op de Elektrische Installaties*). This has to be placed below the outermost foundation of the building. According to these regulations, a bare solid copper cable with a cross-section of 35 mm² can be used, or a cable consisting of a solid copper core of 10 mm², surrounded by a lead sheath. The thickness of the lead sheath is not specified.

In our case we have chosen the solid copper cable of 35 mm². The copper weight per metre is 0.3115 kg. The perimeter of the home, including garage, is 57.44 m. As the cable is placed below the foundation, and we also have to connect it to the earth breaker, we count 2 x 2 m here. For the 61.44 m cable, we arrive at a copper weight of 19.14 kg.

If, however, a ground loop consisting of a copper conductor of 10 mm², surrounded by lead, is chosen, then the copper weight is 5.47 kg.

3.5. THE EQUIPOTENTIAL LINKS

According to the General Regulations for Electrical Installations in Belgium, accessible metal parts of the building have to be earthed, including the water pipe, gas pipe and central heating boiler. These equipotential links have to be made with an insulated copper wire of 6 mm². This has a copper weight per metre of 0.0534 kg. For our installation, we need 6 m, and that represents a copper weight of 0.32 kg.

3.6. SUMMARY

Description	Copper weight in kg
Mains connecting cable	3.56
Coax connecting cable	0.56
Telephone connecting cable	0.53
35 mm² (10 mm²) ground loop	19.14 (5.47)
Equipotential links	0.32
Total	**24.11 kg**

4. THE CONVENTIONAL ELECTRICAL INSTALLATION

The basis of an electrical installation for a home consists of sockets, light points and switches. In this section, we will calculate the use of copper in a conventional electrical installation.

4.1. THE SOCKETS

We have chosen to install a sufficient number of sockets so that the use of extension leads is unnecessary. We have also arranged various electrical circuits so that there are at least two different circuits in most rooms. Should a circuit fail, we can still use another circuit.

4.1.1. OVERVIEW

Outside:

- 1 double socket on the ground floor terrace
- 1 single socket on the facade along the drive to the garage
- 2 single sockets on the roof terrace

Garage:

- 4 double sockets

Dining room:

- 4 double sockets

Kitchen:

- 2 double sockets and a single socket 15 cm from the floor
- Separate single sockets for the oven, the microwave, the kitchen boiler, the dishwasher and electric cooker
- 1 single socket for the hob
- 1 single socket for the fridge
- 4 free double sockets along the counter

Entrance:

- 2 single sockets and a double socket

Study:

- 2 single sockets and a double socket 15 cm from the floor
- 2 double sockets at desk height

Pantry:

- Separate single sockets for the freezer, washing machine and dryer
- 1 free double socket at 110 cm

Sitting room:

- 4 double sockets 15 cm from the floor
- 3 double sockets 60 cm from the floor behind the television and music system

Stairwell:

- 3 single sockets

Toilet:

- 1 single socket for the air freshener dispenser

Utilities closet:

- 2 double and 1 single socket 15 cm from the floor
- 1 single socket for the heating system

Landing:

- 3 single sockets

Master bedroom:

- 3 double and 2 single sockets

Dressing room:

- 1 single socket

Master bedroom toilet:

- 1 single socket for air freshener dispenser

Master bathroom:

- 1 double socket 15 cm from the floor
- 2 double sockets by the washbasins

Children's room 1:

- 2 double sockets next to the bed
- 2 double sockets at desk height by the window
- 1 single socket by the door

Children's room 2:

- 2 double sockets next to the bed
- 2 double sockets at desk height by the window
- 1 single socket by the door

Guest room/playroom/study:

- 2 double sockets next to the bed
- 2 double sockets
- 1 single socket by the door

Small bathroom:

- 1 double and 1 single socket

4.1.2. The measurements

In order to measure the horizontal cables, we drew everything out in a CAD program. As a result, we did not draw a bird's eye view of the cables, but the way in which an installer would actually install them. For the cables installed vertically, we took the following into account:

- For cables from the floor to the distribution board, we count 2 metres. After all, the cable starts to run vertically at around 15 cm below the finished floor, and we have to leave a sufficient length of cable for the connections in the distribution board.
- The same distance is used for cables that run from the first floor to the distribution board.
- For cables that go to the sockets, we count 15 cm of cable from the floor slab to the finished floor, plus the height of the socket above the finished floor, plus 15 cm cable for making the connections. For a socket 15 cm from the finished floor, we thus count 45 cm of cable length.

The sockets on the same electrical circuit are connected together in the Belgian way. The supply runs from one socket to the next. In certain countries (Spain for example), a 'central box' is placed in every room. The supply for the sockets goes to that. The cables for each socket then run in star topology to this central box. We have not calculated the copper used for this installation method.

In the entire home, we have 132 sockets distributed across 83 places. Per m², there are thus 0.41 sockets.
For installing sockets, a cross-section of 2.5 mm² has to be used in accordance with the General Regulations for Electrical Installations in Belgium. For the calculations, we also use cable or wire in flexible conduits of 3 x 2.5 mm².

The total length of 3 x 2.5 mm² cable is 402.43 metres. The length of copper with a cross-section of 2.5 mm² is then 1,207.29 metres.

The copper weight for a cable of cross-section 2.5 mm² is 0.02225 kg per metre. The total copper weight for the cabling of ordinary sockets is 26.86 kg.

For the cooker, we use a 3 x 6 mm² cable with a total length of 13.14 metres. The length of copper is 39.42 metres. The copper weight for a cable of cross-section 6 mm² is 0.0534 kg per metre. The total copper weight for cabling the cooker is 2.10 kg.

After having requested information from a switch manufacturer, we know that a built-in socket with earth pin contains 19.2 g of CuZn37 brass. Every socket thus contains 12.09 g copper. The 132 sockets thus count for 1.60 kg of copper.

4.1.3. SUMMARY

Description	**Copper weight in kg**
Cables 3 x 2.5 mm² sockets	26.86
Cable 3 x 6 mm² electric cooker	2.10
Copper used in 132 sockets	1.60
Total	**30.56 kg**

4.2. THE LIGHTING

The General Regulations for Electrical Installations in Belgium require at least two lighting circuits to be provided in the home. There are five in this home. These lighting circuits are distributed so that when a lighting circuit fails, light can be obtained from the next room.

4.2.1. OVERVIEW

Outside:

- 1 light group (LG) on the ground floor terrace
- 1 LG on the facade along the drive to the garage and on front facade
- 1 LG on the left facade
- 1 LG on the roof terrace
- 1 LG on the green roof

Garage:

- 1 LG

Dining room:

- 1 LG general lighting
- 1 LG above the table
- 1 LG on the wall

Kitchen:

- 1 LG general lighting
- 1 LG for the wet and dry counters

Entrance:

- 1 LG for the corridor to the door

- 1 LG for the corridor to the stairs

Study:

- 1 LG general lighting
- 1 LP (light point) above desk

Pantry:

- 1 LG

Sitting room:

- 1 LG general lighting
- 1 LG wall
- There is also a standard lamp, but this uses a socket.

Stairwell:

- 1 LG along the walls of the spiral staircase

Toilet:

- 1 LG

Utilities closet:

- 1 LG

Landing:

- 1 LG

Master bedroom:

- 1 LG general lighting
- 2 LG, to the left and right of the bed

Dressing room:

- 1 LG

Master bedroom toilet:

- 1 LG

Master bathroom:

- 1 LG general lighting
- 1 LG by the washbasins

Children's room 1:

- 1 LG general lighting
- 1 LG by bed
- 1 LG by the desk window

Children's room 2:

- 1 LG general lighting
- 1 LG by bed
- 1 LG by the desk window

Guest room/playroom/study:

- 1 LG general lighting
- 2 LG, to the left and right of the bed

Small bathroom:

- 1 LG general lighting
- 1 LG by washbasin

4.2.2. THE MEASUREMENTS

In order to measure the horizontal cables, we drew everything out in a CAD program. As a result, we did not draw a bird's eye view of the cables, but the way in which an installer would actually install them. For the cables installed vertically, we took the following into account:

- For cables from the floor to the distribution board, we count 2 metres. After all, the cable starts to run vertically at around 15 cm below the finished floor, and we have to leave a sufficient length of cable for the connections in the distribution board.
- The same distance is used for cables that run from the floor of first floor to the distribution board.
- The first floor is 2.50 m high.
- We count 45 cm for the passage of the cabling through the ceiling for a LP (light point).
- We have put the switches at a height of 110 cm from the finished floor. We count 140 cm for the cable from the floor to the switch (15 cm below the floor and 15 cm for the connections).
- We count 170 cm for the vertical rising cable from the switch to a LP.
- If we place the wall lights 170 cm above the finished floor, then we count 200 cm for the vertical cable.

The light points are connected directly to the switches. Thus the central box system is not used.

In the entire home, we have 80 light points distributed in 41 places. Per m², there are thus 0.25 light points.

For installing lighting sockets, a cross-section of 1.5 mm² has to be used in accordance with the General Regulations for Electrical Installations in Belgium.

The total length of 3 x 1.5 mm² cable is 449.73 metres. The total length of 5 x 1.5 mm² cable is 99.40 metres. The total length of 7 x 1.5 mm² cable is 9.25 metres. The length of copper with a cross-section of 1.5 mm² is then 1,910.94 metres.

The copper weight for a cable of cross-section 1.5 mm² is 0.01335 kg per metre. The total copper weight for the cabling of the lighting circuits is 25.51 kg.

After having requested information from a switch manufacturer, we can calculate the use of copper in the switches. The switches also contain CuZn37 brass:

Type of built-in switch	Brass weight	Copper weight
Single pole	3.7 g	2.331 g
Two pole	7.4 g	4.662 g
Landing switch	6.3 g	3.969 g
Intermediate switch	10 g	6.300 g
Push button NO	5 g	3.150 g

Type of built-in switch	Number of switches	Copper weight
Single pole	19	0.044 kg
Two pole	7	0.033 kg
Landing switch	28	0.111 kg
Intermediate switch	11	0.069 kg
Push button NO		
Total	**65**	**0.257 kg**

4.2.3. SUMMARY

Description	Copper weight in kg
Cabling 1.5 mm²	25.51
Copper used in switches	0.26
Total	**25.77 kg**

4.3. SUMMARY CONVENTIONAL ELECTRICAL INSTALLATION

Description	Copper weight in kg
Sockets	30.56
Lighting	25.77
Total	**56.33 kg**

5. THE REMOTE-CONTROLLED SWITCH INSTALLATION

An installation method that has been around for a long time is one where remote-controlled switches are used. Push buttons rather than switches are used at the operating points. They are connected in star topology to the distribution board in which the actual switching elements (the remote-controlled switches) are incorporated. In order to increase safety, a 24V transformer is used for the control cables (16 x 0.8 mm² multicore cable, for example, to the push buttons). The coils of the remote-controlled switches also operate at this voltage. Coils of 230V can of course also be used, but then thicker cabling (1.5 mm²) has to be used. In practice, it is rarely done in this way.

The cabling from the operating point to the light point to be operated, as used in the conventional installation, disappears. Every light group is connected, via its own cable, to the remote-controlled switch concerned in the distribution board.

5.1. THE SOCKETS

For the sockets, nothing changes compared to the conventional electrical installation. We can use the same data.

Description	Copper weight in kg
Cables 3 x 2.5 mm² sockets	26.86
Cable 3 x 6 mm² electric cooker	2.10
Copper used in 132 sockets	1.60
Total	**30.56 kg**

5.2. THE LIGHTING

Every light group runs to the distribution board with a 3 x 1.5 mm² cable. In total, the cable length is 597.83 m. Converted into copper usage, this means 23.94 kg of copper.

We use SVV signal cable for the low voltage control cables (24 V). This multicore cable contains insulated solid copper conductors with a cross-section of 0.8 mm². In practice, a cable does not go from every operating point to the distribution board. Normally you go from the distribution board to a first operating point, from there to a second operating point, and so on. In order to preserve the greater flexibility of a remote-controlled switch installation, a few wires always have to be left unused in the installation. In this way it is possible to install one or more additional push buttons at an operating point later on without having to install a new cable. When a cable of 16 x 0.8 mm² is used, three wires are left unused, for example. One wire is used as a common conductor. This means that 12 push buttons can be connected to this cable.

For many installers, the temptation is high to connect push buttons that perform the same function for the same light group (for example, in the landing) to the same cable wire. They do this for economic reasons. Nevertheless, it is more sensible to provide a separate wire for such push buttons and to connect them in parallel to the distribution board. After all, the remote-controlled switch installation can be used as an interim stage for a subsequent home automation system. By using a separate wire for each push button, all options are open for programming functions in a home automation system. It would not be the case otherwise.

In this home, we have used a number of control circuits (three for the ground floor and two for the first floor). In most cases, a 16 x 0.8 mm² cable is used. Nevertheless, there is also a cable of 10 x 0.8 mm² and a cable of 4 x 0.8 mm².

Copper wire with a cross-section of 0.8 mm² has a copper weight per metre of 0.00712 kg. We use 134.91 m of 16 x 0.8 mm² cable, 34.93 m of 12 x 0.8 mm² cable and 11.31 m of 4 x 0.8 mm² cable. In total, this amounts to a copper length of 2,622.96 m. This represents a copper weight of 18.68 kg.

In a remote-controlled switch installation, we use NO push buttons. They contain 3.15 g of copper. We will install 65 push buttons. The copper weight is thus 0.20 kg.

5.2.1. SUMMARY

Description	Copper weight in kg
Cables 3 x 1.5 mm² light groups	23.94
Control cables 0.8 mm²	18.68
Copper used in 65 push buttons	0.20
Total	**42.82 kg**

5.3. SUMMARY REMOTE-CONTROLLED SWITCH INSTALLATION

Description	Copper weight in kg
Sockets	30.56
Lighting	42.82
Total	**73.38 kg**

We see that 17.05 kg more copper is used in the remote-controlled switch installation than in the conventional electrical installation. In practice, however, this will be even higher as we have not counted the copper used in the remote-controlled switches. We requested this information from a number of manufacturers, but we did not get any satisfactory answers. Manufacturers consider the amount of copper used in their products as being in-house (and thus a manufacturing secret). In a remote-controlled switch, there are not only the connection terminals and the switching contact, but also the coil. If a NO push button contains 3.15 g of copper, then it will likely be more for a remote-controlled switch.

6. HOME AUTOMATION SYSTEM IN STAR TOPOLOGY

For a home automation system in star topology, we can use the data for the remote-controlled switch installation as a basis. Not only are the consumers (light points) connected to the distribution board with their own cabling, but the push buttons are also installed in the same way and with the same type of cabling. However, we have to assume that there will be several more push buttons installed for controlling atmospheres, all-off functions, panic buttons, etc.

6.1. THE SOCKETS

In a home automation system, we want certain sockets to operate for comfort or safety reasons. For example, we can switch off certain sockets to which appliances that generate heat (stove, oven, iron, etc.) are connected when we are sleeping or not at home, and we can also switch off or dim the socket for the standard lamp so that it can also be included in certain atmospheric functions. Some of these sockets already have their own cable to the distribution board, while others do not. We also fit an additional separate cable for the standard lamp in the living room and the master bedroom, a socket for the coffee machine in the kitchen and for the iron in the pantry.

These separate cables in this home are 44.58 m long. This represents a copper weight of 2.98 kg. As we have not installed any additional sockets, but a few separate cables for sockets are already installed, we do not have to count any additional copper for the sockets.

Description	**Copper weight in kg**
Sockets	30.56
Additional cables	2.98
Total	**33.54 kg**

6.2. THE LIGHTING

For the lighting, the calculations for the light groups of the remote-controlled switch installation still apply. However, as we also want to install a number of atmosphere buttons, we have to take this into account. We assume that there are 10 additional push buttons.

Description	**Copper weight in kg**
Cables 3 x 1.5 mm² light groups	23.94
Control cables 0.8 mm²	18.68
Copper used in 75 push buttons	0.24
Total	**42.86 kg**

6.3. SUMMARY

Description	Copper weight in kg
Sockets	33.54
Lighting	42.86
Total	**76.40 kg**

7. HOME AUTOMATION SYSTEM IN BUS OR TREE TOPOLOGY

Many home automation systems use a BUS cable. This cable comes from the distribution board and runs to a first bus participant (operating point). From there, a connection is made to a second bus participant, and so on. Every bus participant uses the same wires in the cable. This is different to the remote-controlled switch installation, where every push button uses its own wire.

7.1. THE SOCKETS

Here, we use the same values as with the home automation system in star topology.

Description	Copper weight in kg
Sockets	30.56
Additional cables	2.98
Total	**33.54 kg**

7.2. THE LIGHTING

The cabling for the link to the light groups remains the same as for the previous two installation methods. For the bus cable, we have to make a choice. We use Teletask bus cable here. This consists of two thicker wires (2 x 1 mm²) for the supply of the bus participants and two pairs of thinner wires (2 x 2 x 0.20 mm²). One pair is used for data communications. The other pair is still free. We lay a bus line on the ground floor and on the first floor. The NO push buttons are, of course, not connected directly to the bus. An interface has to be used that is installed behind the push buttons in the built-in box.

Description	Copper weight in kg
Cables 3 x 1.5 mm² light groups	23.94
Bus cable 2 x 2 x 0.20 mm² + 2 x 1.0 mm²	4.54
Copper used in 75 push buttons	0.24
Total	**28.72 kg**

7.3. SUMMARY

Description	Copper weight in kg
Sockets	33.54
Lighting	28.72
Total	**62.26 kg**

8. OPTIONS

Sockets and lighting are the basis of the electrical installation in the home. However, this is insufficient for a modern home. In addition to the basic installation, we can also choose certain additional techniques.

8.1. THE FANS

We want to put a fan in certain rooms to remove unpleasant odours or water vapour. This is the case in the two toilets, the two bathrooms and the pantry. In a conventional installation, we use fans that are connected to the lighting circuit and have a built-in timer. When the light is switched off, the fan runs for a few minutes longer. As the fan is connected to the switch of the light point, we do not need any additional switches. The cabling is done with 4 x 1.5 mm². The total cable length to the fans is 8.82 m. The length of copper with a cross-section of 1.5 mm² is 35.28 m. This represents a copper weight of 0.47 kg in a conventional installation.

In a remote-controlled switch installation, the fans are connected to the distribution board with a cable of 4 x 1.5 mm². The length of the cables is 59.25 m. The copper length is 237 m. The copper weight is 3.16 kg.

In home automation systems, we use a fan without a timer. After all, we can program everything. We thus use 3 x 1.5 mm² cable. The cable length is the same as in the remote-controlled switch installation (59.25 m). The copper length is 177.75 m. The copper weight is 2.37 kg.

Description	Copper weight in kg
5 fans conventional installation 4 x 1.5 mm²	0.47
5 fans remote-controlled switch installation 4 x 1.5 mm²	3.16
5 fans star home automation system 3 x 1.5 mm²	2.37
5 fans bus home automation system 3 x 1.5 mm²	2.37

8.2. ELECTRIC GARAGE DOOR

For the garage door, we fit a socket on the garage ceiling, in the vicinity of the garage door motor. We connect it to a nearby socket circuit in the garage.

In a conventional installation and a remote-controlled switch installation, we install a push button by the garage door. This is connected by a 4 x 0.8 mm² cable to the garage door motor.

In home automation systems, we install two push buttons by the garage door. They are either connected to the bus cable (using an interface), or by a separate cable (2 x 0.8 mm²) to the distribution board in an installation in star topology. The common wire is already in place here.

Description	Copper weight in kg
Conventional installation 3 x 2.5 mm² + 4 x 0.8 mm² + 1 push button	0.74
Remote-controlled switch installation 3 x 2.5 mm² + 4 x 0.8 mm² + 1 push button	0.74
Star home automation system 3 x 2.5 mm² + 2 x 0.8 mm² + 2 push buttons	0.81
Bus home automation system 3 x 2.5 mm² + 2 push buttons	0.59

8.3. The roll-down shutters

We install roll-down shutters on the ground floor and the first floor for every window. That is 15 in total.

In a conventional electrical installation, we will install a double, mechanically-latched switch. The supply to the switches uses 3 x 1.5 mm² cable. For the connection between the switches and the roll-down shutters, we use 4 x 1.5 mm² cable. We measure a total 1.5 mm² copper length of 532.15 m. Together with the 15 roll-down shutter switches, this represents a copper weight of 7.17 kg.

In a remote-controlled switch installation, in practice, the roll-down shutters will be installed in a conventional way. We thus count 7.17 kg of copper here.

In a home automation system in star topology, we connect every roll-down shutter motor to the distribution board with a 4 x 1.5 mm² cable. At the operating points, we install two push buttons per roll-down shutter. They are connected to the distribution board with SVV 14 x 0.8 mm². All together this means a copper weight of 15.33 kg.

Also in the home automation system in bus topology, the roll-down shutter motors are connected to the distribution board with a 4 x 1.5 mm² cable. The push buttons are connected back to the bus (2 x 1 mm² + 2 x 2 x 0.20 mm²) via an interface. This amounts to a copper weight of 9.55 kg.

Description	Copper weight in kg
Conventional installation 3 x 1.5 mm² + 15 roll-down shutter switches	7.17
Remote-controlled switch installation 3 x 1.5 mm² + 15 roll-down shutter switches	7.17
Star home automation system 3 x 2.5 mm² + 14 x 0.8 mm² + 30 push buttons	15.33
Bus home automation system 3 x 2.5 mm² + 2 x 1 mm² + 2 x 2 x 0.20 mm² + 30 push buttons	9.55

8.4. Telephony

We provide eight telephone connections: living room, dining room, study, kitchen, every bedroom and the guest room. All cables are installed in star topology with a 2 x 2 x 0.6 mm² telephone cable. We obtain a total copper length of 349.76 m. This represents a copper weight of 1.87 kg.

Description	Copper weight in kg
Eight 4 x 0.6 mm² telephone connections	1.87

8.5. Coax connection for radio and TV

At the same places as the telephone connections, we also provide eight connections for radio and TV. We use RG59 coax for this. The total copper length is 87.44 m. The copper weight per metre is 0.014 kg. The total copper weight for these connections is 1.22 kg.

Description	Copper weight in kg
Eight RG59 coax connections	1.22

8.6. Data network

In the same places as the telephone and coax connections, we also provide a data connection for the computer network. For this, we use UTP cable 4 x 2 x 0.25 mm². The copper weight per metre is 0.002225. The total length of copper for these connections is 699.52 m. This gives us a copper weight of 1.56 kg.

Description	Copper weight in kg
Eight UTP 4 x 2 x 0.25 mm² data connections	1.56

8.7. Intercom

For the intercom, we install five indoor units: at the partition between the living room and dining room, in the study, kitchen, landing and the master bedroom. An electric door lock is also provided for the front door. The more modern two-wire system is used. We use 2 x 2 x 0.6 mm² telephone cable with a copper weight per metre of 0.00534 kg. The total copper length here is 181.44 m. The total copper weight is 1.26 kg.

Description	Copper weight in kg
5 interior intercom units 2 x 2 x 0.6 mm²	1.26

8.8. Smoke detectors

We install 12 smoke detectors in the utilities closet, corridor to the spiral staircase, study, pantry, living room, dining room and kitchen, garage, the three bedrooms, the guest room and the landing. We give them a 230V supply using a 3 x 1.5 mm² cable. The total copper length is 184.11 m. The copper weight is 2.46 kg.

We also use a low voltage connection between all smoke detectors. This way, they will all activate together when one of them goes into the alarm state. We use 4 x 0.8 mm² signal cable for this. The total copper length is 203.48 m. The copper weight is 1.45 kg.

Description	Copper weight in kg
230V supply smoke detectors 3 x 1.5 mm²	2.46
Interconnection smoke detectors 4 x 0.8 mm²	1.45
Total	**3.91 kg**

8.9. Burglar alarm

On the ground floor, we provide seven intruder detectors. They are connected to the alarm panel in star topology. Four keyboards and an outdoor siren are also provided. The alarm cable used contains two thicker wires for the supply (0.8 mm²) and four thinner wires for the communication (0.25 mm²). The cable length is 149.77 m. The copper length for the 0.8 mm² wires is 299.54 m. The copper weight here is 2.13 kg. The copper length of the 0.25 mm² wires is 599.08 m. The copper weight here is 1.33 kg. The total copper weight is thus 3.46 kg.

Description	Copper weight in kg
Alarm cable 2 x 0.8 mm² + 4 x 0.25 mm²	3.46

8.10. Audio distribution

We have also looked for a low-cost standalone audio distribution system and found one from an Italian manufacturer. This system starts from a source selector (for example, the radio). A small amplifier is placed in a wall of the rooms where you want to listen to music. From there, two cables go to small loudspeakers in the wall. We install this system in the study, dining room, garage, the master bedroom and bathroom. A bus cable (2 x 0.8 mm²) is used. The total length of 0.8 mm² copper is 279.52 m. The copper weight here is 1.99 kg.

Description	Copper weight in kg
Audio distribution 2 x 0.8 mm²	1.99

8.11. Hot tap water

In a separate cabinet in the dressing room, we install an electric boiler for hot tap water. For this, we provide a 3 x 2.5 mm² connection to the distribution board. We count a copper length of 37.56 m. This yields a weight of 0.84 kg.

Description	Copper weight in kg
Main boiler supply 3 x 2.5 mm²	0.84

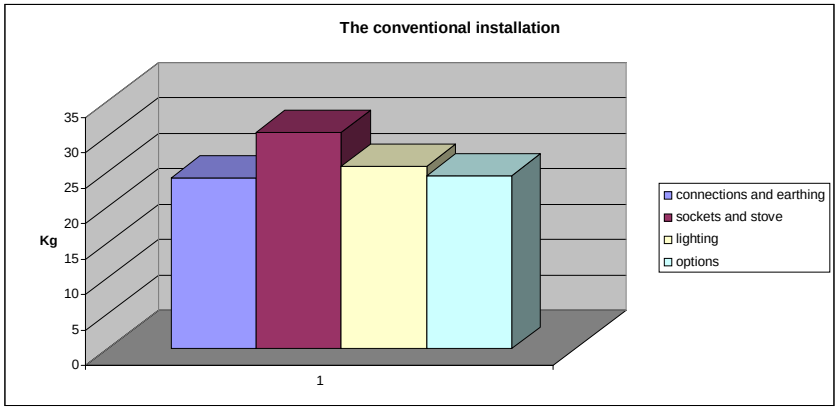
For the hot water in the kitchen, we use a small kitchen boiler under the kitchen sink. This was already given a separate 3 x 2.5 mm² cable (connected to a socket) in the sockets section.

9. SUMMARY AND CONCLUSIONS

9.1. COPPER USED IN THE DIFFERENT INSTALLATION METHODS

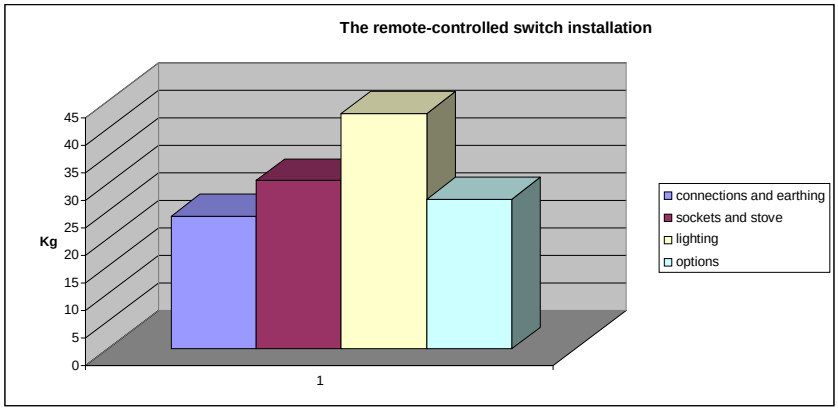
9.1.1. The conventional installation

Description	Copper weight in kg	
Connections and earthing	24.11	22.98%
Sockets and stove	30.56	29.12%
Lighting	25.77	24.56%
Options	24.49	23.34%
Total	**104.93 kg**	**100%**



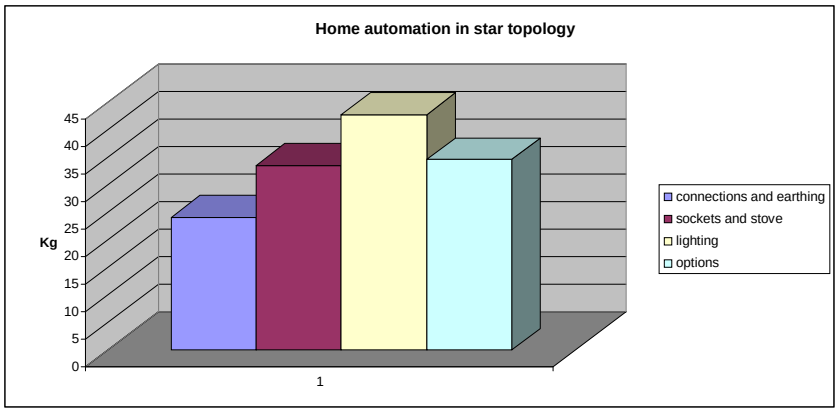
9.1.2. The remote-controlled switch installation

Description	Copper weight in kg	
Connections and earthing	24.11	19.34%
Sockets and stove	30.56	24.51%
Lighting	42.82	34.35%
Options	27.18	21.80%
Total	**124.67 kg**	**100%**



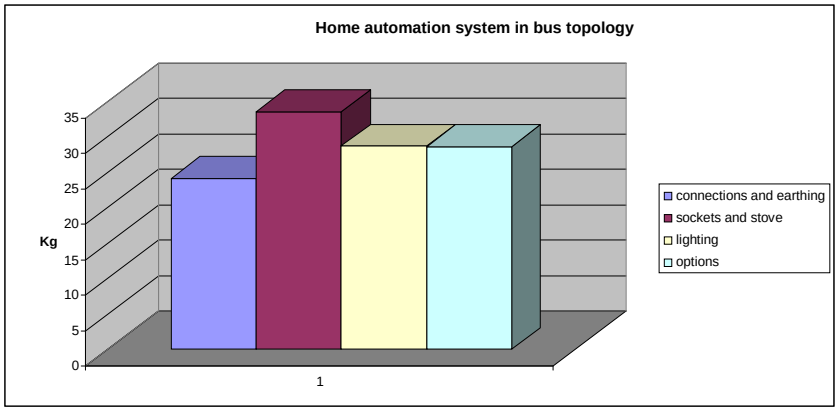
9.1.3. Home automation system in star topology

Description	Copper weight in kg	
Connections and earthing	24.11	17.84%
Sockets and stove	33.54	24.82%
Lighting	42.86	31.72%
Options	34.62	25.62%
Total	**135.13 kg**	**100%**



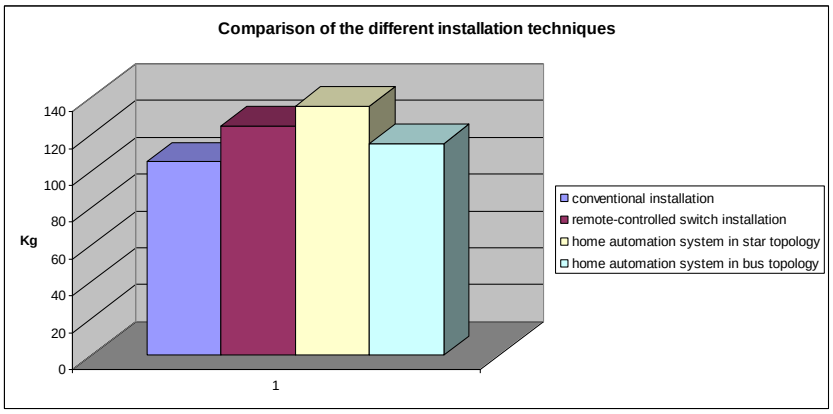
9.1.4. Home automation system in bus topology

Description	Copper weight in kg	
Connections and earthing	24.11	20.96%
Sockets and stove	33.54	29.17%
Lighting	28.72	24.98%
Options	28.62	24.89%
Total	**114.99 kg**	**100%**



9.1.5. Comparison of the different installation techniques

Description	Copper weight in kg	
Conventional installation	104.93	+ 0%
Remote-controlled switch installation	124.67	+ 18.8%
Home automation system in star topology	135.13	+ 28.8%
Home automation system in bus topology	114.99	+ 9.6%



If we take the conventional installation (including options) as a basis for comparison, then we see that the remote-controlled switch installation uses 18.8% more copper (19.74 kg). The home automation system in star topology accounts for an even larger amount. This increases by a good 28.8% (30.20 kg) compared to the conventional installation. Finally, and we found this surprising, the home automation system in bus topology uses only 9.6% (10.06 kg) more copper than the conventional installation. In general, it is thought that an installation with a home automation system goes hand in hand with much more cabling than the conventional installation. This consequently seems to apply to the home automation system in star topology, but certainly not for the bus topology. It even uses substantially less copper than the remote-controlled switch installation.

9.1.6. Copper weight per m²

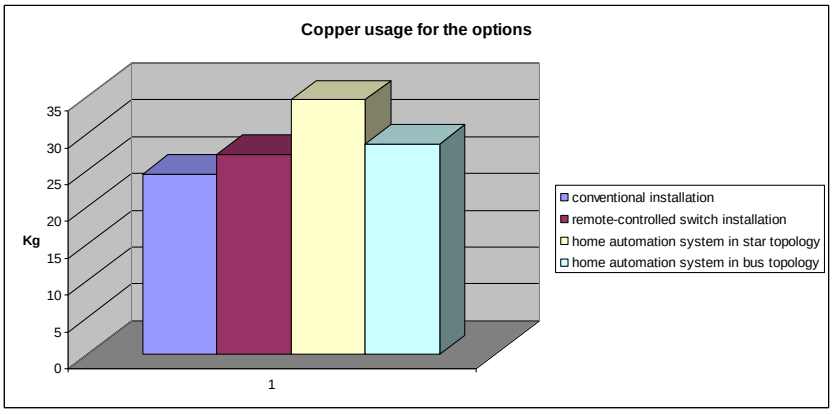
The total usable area of the home (including terraces) is 321.32 m². Per m², the copper usage for the different installation techniques is:

Description	Copper weight in kg/m²
Conventional installation	0.326
Remote-controlled switch installation	0.388
Home automation system in star topology	0.421
Home automation system in bus topology	0.358

9.2. COPPER USAGE FOR THE OPTIONS

Below we specify the copper used per option and per installation method in kg:

Description	Conventional	Remote-controlled switch	Home automation system star	Home automation system bus
Fans	0.47	3.16	2.37	2.37
Garage door	0.74	0.74	0.81	0.59
Roll-down shutters	7.17	7.17	15.33	9.55
Telephony	1.87	1.87	1.87	1.87
Coax	1.22	1.22	1.22	1.22
Data network	1.56	1.56	1.56	1.56
Intercom	1.26	1.26	1.26	1.26
Smoke detectors	3.91	3.91	3.91	3.91
Burglar alarm	3.46	3.46	3.46	3.46
Audio distribution	1.99	1.99	1.99	1.99
Main boiler	0.84	0.84	0.84	0.84
Total	**24.49**	**27.18**	**34.62**	**28.62**



A few options use the same copper weight in the different installation methods. This is the case for the telephony, the coax cabling, data network, intercom, smoke detectors, burglar alarm, audio distribution and boiler.

For the fans, the conventional installation scores the lowest and the remote-controlled switch installation the highest. For the electric garage door, the installation techniques have around the same score, this time with the home automation system in bus topology as the lowest.

However, there are substantial differences for the roll-down shutters. The home automation system in star topology scores the highest with more than double the copper weight in the conventional and remote-controlled switch installations.

The options which use the most copper are the roll-down shutters (with greatest copper use), the fans (except for the conventional installation), the smoke detectors (with 230V supply and interconnection) and the burglar alarm system.

9.3. CONCLUSION

Because no data could be obtained on them, this study does not take into account any of the copper used in the distribution board (circuit breakers, remote-controlled switches, internal cabling, etc.) or in certain electrical equipment (roll-down shutter motors, fans, etc.). In practice, the use of copper will be somewhat higher than specified above.

When we look at the figures, it can be seen that the use of copper for the options is substantial. Depending on the installation method, it can be from almost 22% to more than 25% of the copper used when all options are chosen. For the home automation system in bus topology, we see that the options have the same copper usage as the lighting installation.

The remote-controlled switch installation forms the basis of the more modern installation techniques. At any rate, they offer much more flexibility than the conventional installation. More copper is used in such installations (also in a home automation system), but that does not in any way mean that the installation cost increases substantially. After all, the installer saves a lot of time and work when installing. In a conventional installation, a vertical slot must be ground and cut into the wall from the switch to the ceiling. An opening also has to be drilled in the ceiling (generally concrete, which proves a challenge). In this slot, the cable or the conduit goes from the switch to the light point. With more modern installation methods, this process disappears completely so that much installation time is saved.

The remote-controlled switch installation can form the basis for later conversion to a home automation system in star topology. Generally, however, installations with a home automation system in bus topology have many more facilities available to them and they are more easily expandable.

In this day and age, where people are occupied with communications, comfort, flexibility, energy saving and safety marks, we see that costs and visibility are playing an increasingly important role for third parties in the choice of the installation concept in the home. The visibility, or rather invisibility, of modern techniques in the home means that many people are still choosing conventional electrical installations. This is in stark contrast to the modern electronic gadgets being integrated into the family car. As far as we are concerned, the conventional electrical installation has had its day. But just try selling this to the customer who would rather see his or her budget go to a beautiful kitchen or modernised bathroom. It is an unfair fight.

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