Home Electrical Installation Upgrades: A fitness check for Zero-Emission readiness

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EuropeOn has been the European voice of the electrical contracting industry since 1954. With 2.7 million professionals in over 420.000 businesses and with a turnover of over 300 billion euros, electrical contractors provide electrical installations for buildings and infrastructure, enabling cities and citizens to take part in the Energy Transition. EuropeOn addresses energy, climate, mobility, building and skills policies. The association is campaigning in favour of #Skills4Climate and is part of the Electrification Alliance, Construction 2050, the Platform for E-mobility, and the Forum for European Electrical Domestic Safety.

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Preface

A fitness check for zero-emission readiness

In the pursuit of decarbonising the EU's building stock, policy makers have developed various tools to support stakeholders in accelerating home renovations for higher energy performance[1]. However, it is concerning that none of these tools adequately address one of the most crucial components in achieving zero-emission homes: the electrical installation. A robust electrical installation allows for the efficient and integrated operation of zero-emission technologies, ensuring their optimal performance without overloading existing circuits.

While tools like Energy Performance Certificates (EPCs), the Smart Readiness Indicator (SRI), building renovation passports, and digital logbooks have become familiar in the field of energy renovation, they often overlook the significance of the electrical installation or assume it is always fit for purpose. This oversight hampers the transition to zero-emission homes and undermines the potential of renewable energy technologies.

This guide aims to shed light on the importance of a zero-emission-ready domestic electrical installation and put forward best practices and solutions. It urges decision makers to integrate home electricity into renovation policies and roadmaps to truly drive the decarbonisation of EU buildings.

If you are involved in EU's Renovation Wave[2], aimed at achieving a highly energy-efficient and decarbonised built environment by 2050, whether as a politician or national authority, this guide is essential.
It provides valuable information and guidance on how to achieve this goal.

[1] To boost the energy performance of buildings, the EU has established a legislative framework that includes the Energy Performance of Buildings Directive (2024/1275/EU) and the Energy Efficiency Directive (2023/1791/EU).

[2] Renovating both public and private buildings was singled out in the European Green Deal (COM(2019) 640 final) as a key initiative to drive energy efficiency in the sector and deliver on objectives. To pursue the dual ambition of energy gains and economic growth following the COVID-19 pandemic, the Commission published in 2020 the strategy "A Renovation Wave for Europe – Greening our buildings, creating jobs, improving lives" (COM(2020) 662 final)

A necessity for today, a vision for tomorrow

It is easy to believe that when renovating a house, following the applicable building code is safe to be ready for the affordable future deployment of zero-emission electrical technologies, but that is far from the truth. While building codes continue to improve minimum performance requirements, in most countries they are following rather than leading.

As the average home will need to be equipped with electrified equipment and appliances to comply with the applicable minimum energy performance standards (MEPS) or to become a zero-emission building (ZEB), we are best to factor that into our designs right now.

When renovating or constructing a home today, we should be building better homes, and hence deploying a resilient electrical installation that is characterised by:

1. **Robust and flexible electrical hardware infrastructure**, capable of accommodating increased electricity demand.
2. **A comprehensive data and communication network**, enabling seamless interaction with consumers, appliances, and the grid.

Therefore, it is important to reach beyond the basic electrical installation and build smarter homes from the start. Unfortunately, this is rarely the case in house renovation or construction projects today. This may be due to the following reasons (Wijnants, 2015):

- During the design phase of the project, homeowners and architects tend to **focus** more on functional space layout and architectural aesthetics considerations.
- Even during discussions on the required electricity installation, homeowners are **insufficiently aware** and fail to anticipate future needs.
- It's not uncommon for homeowners to make choices based on **short-term thinking**, only to realise later that they've excluded themselves from crucial equipment that could make their building more climate friendly.
- Installers report that anticipated amenities, such as additional wiring and cabling for future needs, are often one of the first elements that homeowners tend to cut from the specifications for **budget reasons**.
- The draft layout of the electrical installation is being designed by the homeowner or the architect without input from an **expert electrician**.

Fully qualified professionals, the enablers of zero-emission readiness

Hiring the right professionals to implement the recommendations in this guide is essential for ensuring that electrical installations are suitable for zero-emission buildings. The safety, efficiency, and performance of electrical systems rely on the expertise of the individuals carrying out the work, as they must tailor the installation to meet the specific needs of the user(s).

This is why **it is paramount that all the electrical work is carried out by fully qualified and, where relevant, registered and certified electrical installers.** This includes:

- Having completed the full curriculum for electricians (often including an apprenticeship)
- Having pursued the appropriate specialisation courses
- Having obtained the required certifications, which may vary based on local regulations
- Being registered with the local trade association or similar organisation

Make sure to abide by local rules

The regulation of professions is usually dealt with by national or local authorities rather than at the European level. In Germany, for instance, only workers possessing the higher Meister qualification are allowed to sign off on an electrical installation that is connected to the grid, while in Scandinavian countries, collective agreements can regulate the type of competence required for electricians.

In addition, **building codes and electrical installations can vary from one country to another**, and sometimes from one region to another. European or international standards are also adapted into the corresponding national standards. Fully qualified electricians can guarantee the compliance of their work with local rules and standards. Similarly, the professionals carrying out inspections must also be adequately competent to ensure that any fault or non-compliance in an electrical installation is detected.

Making this reference guide work at the national level

This guide presents recommendations on how to adapt electrical installations to ensure they are fit for zero-emission buildings, a concept that was enshrined in EU law through the Energy Performance of Buildings Directive. For further information on how these recommendations fit in the national or even local framework, readers can contact national trade associations representing electrical contractors.

Indeed, **national associations provide guidance on how to implement national standards for electrical installations, on how to ensure the highest level of safety, and on the most energy-efficient solutions available**. Further, all their members are fully qualified and national associations are the best contact point to find a competent electrical contractor.

A list of national electrical contractors' associations can be found on the website of the European Association of Electrical Contractors, EuropeOn.

HOW TO USE THIS GUIDE?

This publication only covers home electrical installations for single-family houses. While some general considerations may apply to multi-family dwellings (see Chapter 5 – Design principles for multifamily houses), their set-up and design differ significantly and warrant a separate publication.

This document offers guidance and suggestions for designing and installing domestic electrical systems. However, it is important to note that it is **separate from safety standards and building codes, but still complies with them**. Our intention is not to interfere with existing standards, but rather to acknowledge and adhere to them.

Chapter 1 of this publication provides the necessary context and justification for focusing on electrical installations when decarbonising residential buildings. It presents evidence as to why this shift in attention is crucial. Additionally, the chapter explains the concept of 'zero-emission building' and how electrical installations play a vital role in achieving this goal.

It is essential to get the design of the electrical installation right from the very beginning. **Chapter 2** provides a framework to facilitate discussions about electrical needs, whether at the individual level between owners and architects or installers, or at the policy level for designing regional renovation strategies. This framework consists of five fundamental questions that should be asked when considering the design of an electrical installation to ensure its futureproofing: how to make it safe, flexible, reliable, smart, and cost-effective for its entire lifetime.

The subsequent two chapters form the essence of this publication: they delve into design principles and offer practical examples for ZEB-ready electrical installations. **Chapter 3** focuses on a layered approach to design principles. It covers everything from grid connection to individual outlets and switches, emphasising the importance of future-proofing the installation by ensuring that all parts and components are capable of meeting evolving needs. In **Chapter 4**, readers will find a comprehensive overview of the key considerations to keep in mind when renovating or constructing a building, specifically related to different types of equipment. This chapter provides valuable insights into the planning and decision-making process, helping readers make informed choices for their projects. **Chapter 5** briefly mentions some general considerations that may apply to multi-family dwellings.

Chapter 6 serves as a guide for policy makers at various levels, including European, regional, national, and local authorities. It emphasises the importance of prioritising the understanding and consideration of electrical installations as the fundamental enabler for achieving zero-emission homes and fully harnessing the potential of zero-emission technologies.

TABLE OF CONTENTS

NO TWO HOMEOWNERS ARE ALIKE

Renovating or constructing a house is a daunting task. It involves a lot of decisions and choices that have vast implications on the construction and investment budget.

Let us introduce you to three homeowners who are about to renovate their homes: Carl, Samira, and Frank.

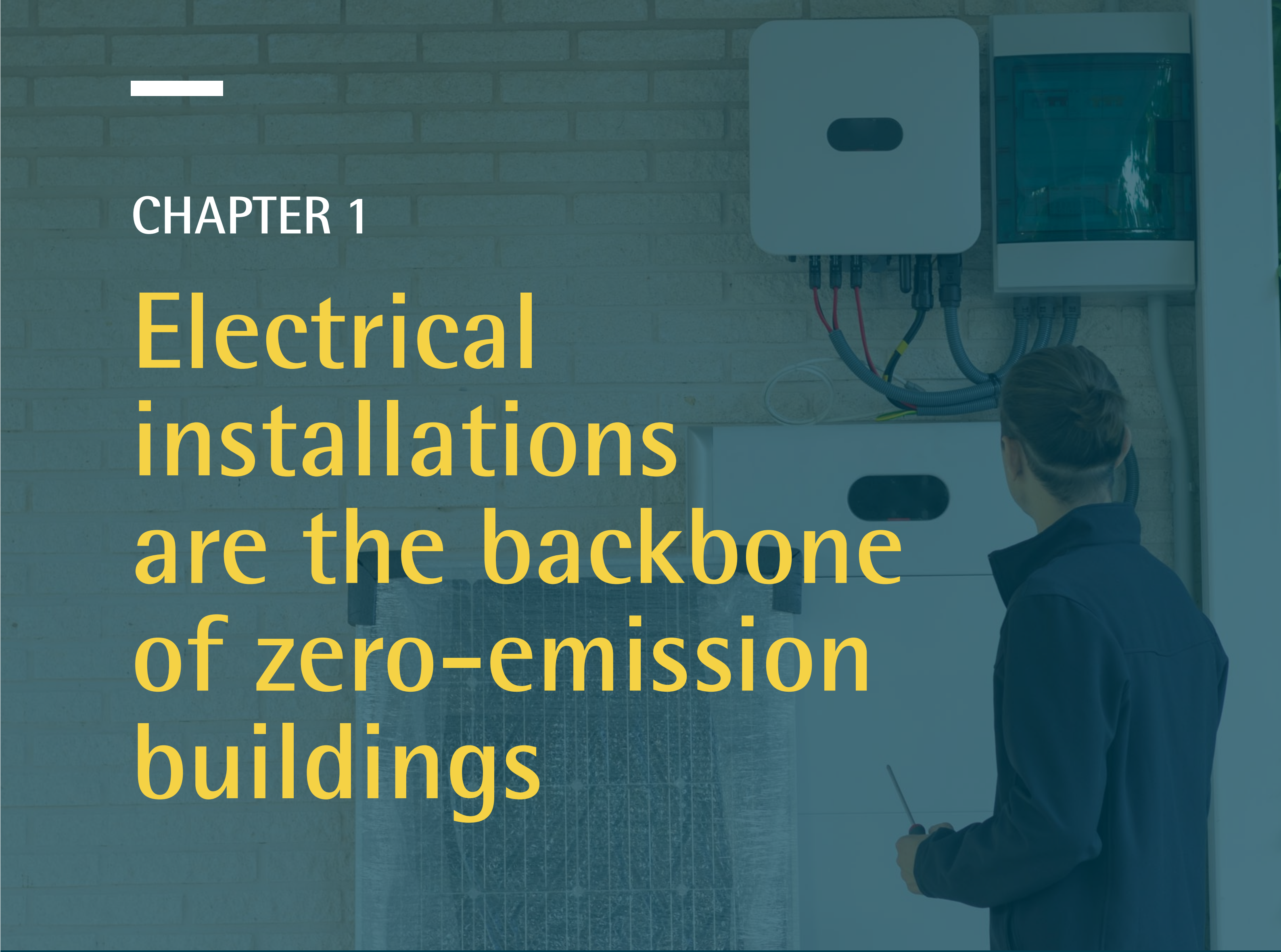
CARL is the type of person who prefers to wait and see. He never bothers to look too far ahead, always content with taking life as it comes. Time and again, Carl finds himself bumping into problems that could have been averted had he been more mindful of the future.

SAMIRA, on the other hand, is seeking peace of mind. She follows the recommendations in this guide to ensure that she's not excluding herself from adopting current available solutions on their way to becoming mainstream.

Finally, there's FRANK, the frontrunner. He's always one step ahead of the game. He knows that innovation and development is happening fast and for some technologies he foresees wider deployment soon. For Frank this guide provides trendsetter suggestions.

All three will share their experiences with us throughout each chapter. They will tell us how they made their choices and what the implications were.

So, whether you're a Carl, Samira, or Frank, this guide has something for everyone.



CHAPTER 1

Electrical installations are the backbone of zero-emission buildings

Most electrical installations are obsolete (and thus far from future-ready)

The existing building stock in the EU is largely outdated and inefficient, with more than 75% of buildings having been built before 1990 and only 1-3% being renovated each year. Moreover, **most of the electrical installations in these buildings are not designed to cope with the increasing demand for electricity and the integration of renewable energy sources and electric transport.** A minimum of 130 million dwellings, built before 1990, have not undergone an electrical system upgrade (FEEDS, 2020).

The EU has launched a renovation wave strategy[3] to transform the buildings sector, which is one of the largest energy consumers and greenhouse gas emitters in Europe. The strategy aims to double the annual energy renovation rate by 2030 and deliver a fair and just green transition. However, national long-term renovation strategies—putting aside whether they show the right level of ambition—currently lack a focus on the necessary upgrading of domestic electrical installations. This poses a serious risk of creating a lock-in effect of poorly performing buildings that will not be able to achieve the 2050 climate neutrality goal.

[3] Renovation Wave (COM/2020/662 (final))

Renovation strategies not only need to accelerate, but also shift their scope

The renovation strategies have focused on enhancing the building envelope to improve the thermal performance of residential buildings. This 'fabric first' has historically been widely advocated. However, the urgency of complete decarbonisation challenges this approach in existing buildings. Some authors even state that in many cases no additional fabric improvement is needed to decarbonise heating; a heat pump, or other zero-carbon heat supply, will be enough (Eyre, et al., 2023). While improving the building envelope will continue to have an important role, **retrofitting 'fabric first' may not be feasible across the whole housing stock on timescales necessary** for rapid decarbonisation and could therefore slow housing decarbonisation.

Therefore, the energy transition will drive even further the need to electrify buildings, so up to date electrical installations are crucial. We don't only need to accelerate renovation, but also to improve the quality and scope of renovation. Upgrading the electrical installation is a key element of this process, and it should be taken seriously by all stakeholders involved in the renovation wave.

It is essential to shift attention to the electrical installation when renovating buildings, and to make them 'ready' for zero-emissions. By doing so, the electrical installation can contribute to reducing energy consumption, curbing greenhouse gas emissions, increasing comfort and safety, and optimise the system-wide efficiency of our electricity grids.

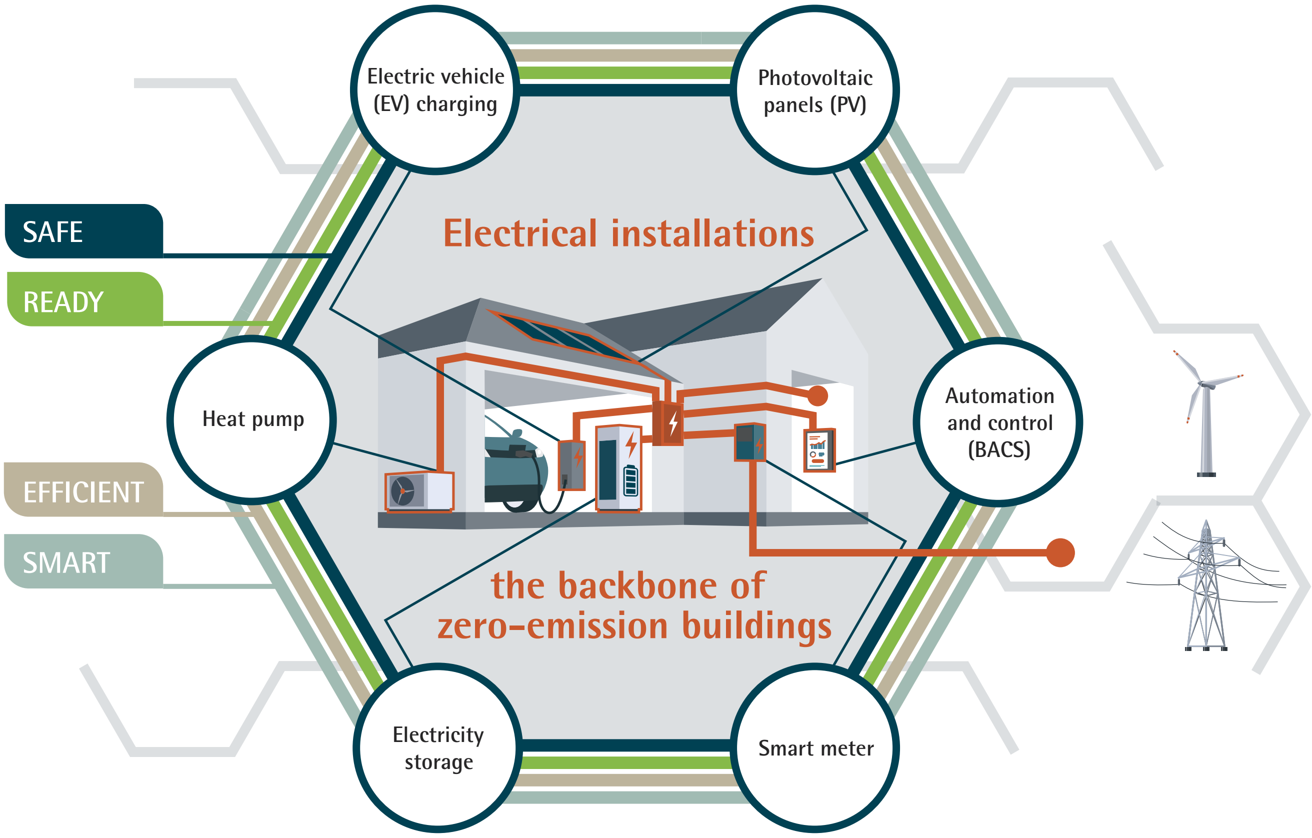


Figure 1 – Electrical installations are the backbone of zero-emission buildings (ECI, EuropeOn, cecapi, EUEW, 2021)

But what does a 'ZEB-ready' electrical installation mean?

To ensure clarity, it is important to define what we mean by electrical installation at this point in the text. In its position to amend the European Commission's proposal for a new Directive on the energy performance of buildings (EPBD)[4] , the European Parliament proposed to define an **electrical installation** as

> *"a system composed of fixed components, including switchboards, electrical cables, earthing systems, sockets, switches and light fittings, which have the purpose of distributing electrical power within a building to all points of use or transmit electricity generated on-site."*[5]

The concept of **zero-emission building** is defined by the revised EPBD[6] as

> *"a building with a very high energy performance (...), requiring zero or a very low amount of energy, producing zero on-site carbon emissions from fossil fuels and producing zero or a very low amount of operational greenhouse gas emissions (...)"*

There are two significant implications of zero-emission buildings for residential electrical installations:

- Firstly, the average home's **electrical energy demand will grow significantly**—with 30% by 2030 and with almost 50% by 2050 (Eurelectric, 2023). The power supply and in-house electrical hardware infrastructure need to be adjusted to accommodate the increased loads.
- Secondly, these increased loads will **require more flexible control** as they need to be fully covered by renewables and to keep the grid in balance. This requires effective data collection and seamless communication between different applications and the grid.

As a result, an electrical installation could be qualified as 'ZEB-ready' when it is designed and equipped to handle the increased demand for electricity in a flexible and integrated way. A ZEB-ready electrical installation turns the building into a true 'clean electricity hub'.

A ZEB-ready electrical installation provides the necessary infrastructure to install —now or later— and seamlessly integrate renewable energy sources, energy storage systems, electric vehicle charging stations, heat pumps, electric cooking appliances and other zero-emission technologies. A real fitness check would also anticipate to installing and using smart meters and appliances, home energy management systems, energy sharing and advanced demand side flexibility services to the grid.

[4] Proposal for a Directive of the European Parliament and of the Council on the energy performance of buildings (recast) (COM/2021/802 final)

[5] Amendments adopted by the European Parliament on 14 March 2023 on the proposal for a directive of the European Parliament and of the Council on the energy performance of buildings (recast) (P9_TA(2023)0068)

[6] Art.2(2) of the EBPD (2024/1275/EU)

SUMMARY

- The energy transition will drive the need to electrify buildings, with a significant increase in electrical demand requiring flexible control.
- Current electrical installations in European buildings are not prepared for the higher electricity needs and the integration of renewable energy and electric vehicles.
- Renovation policies need to focus more on upgrading electrical systems alongside thermal improvements for zero-emission homes.
- Upgraded electrical systems, referred to as 'ZEB-ready', seamlessly integrate heat pumps, solar panels, batteries, electric vehicle chargers, and other zero-emission technologies.
- ZEB-ready electrical installations facilitate the efficient operation of zero-emission technologies, preventing circuit overload and ensuring optimal performance.
- A comprehensive fitness check includes provisions for smart meters, home energy management systems, and advanced demand-side flexibility services for the grid.

CHAPTER 2

Avoiding common mistakes: five basic questions to ask when designing home electrical installations

If the electrical installation is the backbone for the home's zero-emission infrastructure it is crucial to get it right from the very beginning. For the installation to be 'future proof', it should remain *safe, flexible, reliable, smart, and cost-effective*—for its entire lifetime.

These five principles serve as a framework to facilitate discussions on electrical needs, whether at the individual level between owners and architects or installers, or at the policy level for designing regional renovation strategies.

Standing in the empty shell of their newly purchased home, Carl, Samira and Frank's minds swirl with endless possibilities. They envision a modern kitchen with state-of-the-art appliances, a comfortable bathroom with a rain shower, and a cozy living room with a fireplace. But before getting carried away with the aesthetics, it's important to consider how to make the house energy-efficient and ZEB-ready.

CARL reflects on how to improve the insulation, calculates the cost of replacing the single-glazing windows and explores the possibility of installing solar shading on the southern side of his home. Despite the suggestion to replace his gas boiler with a heat pump, Carl has decided against it. Heat pumps cost more upfront compared to gas systems. Plus, the high electricity taxes make running them pricier. It would take forever to recover the money he initially invested! In Carl's eyes, purchasing a condensing boiler remains the most cost-effective option today, and he prefers to stay with a technology that he knows well.

SAMIRA realises that the electrical installation is the backbone for the home's infrastructure and how crucial it is to get it right from the very beginning. She makes a mental note to discuss its design with the architect and the electrician before starting any renovations.

FRANK, the frontrunner, is already bombarding his architect with online resources and ideas on how to make his home future-proof. Unlike the architect, who is hesitating to involve the electrical installer at this stage of the design process, Frank insists on having a meeting with them. He has noticed that many innovative design practices are not yet incorporated into the daily routines of electrical installers, and he believes that adequate preparation and time will be required to ensure a seamless integration of these practices into his home.

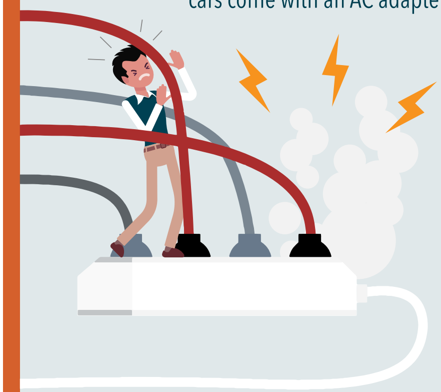
Safe: Will the electrical installation remain safe, even years after the electrical inspection?

The requirements for designing and maintaining safety in electrical installations are governed by national and international standards. They keep users safe from the dangers of electric shock and they prevent damage to the installation caused by the dangers of heat from overcurrent. In most countries an official inspection is necessary (FEEDS, 2024). However, even after passing inspection, general safety can be compromised if the electrical system is not properly designed, introduces the need for makeshift solutions or doesn't prevent for **unsafe behaviour**. Some common mistakes are:

- **Overloading**: A well-designed electrical system anticipates the evolving power needs of the household, ensuring that the circuits and wiring can handle future loads.
- **Insufficient outlets**: Strategically placed outlets throughout the home **avoid the need for excessive use of extension cords or power strips**. Overreliance on extension cords increases the risk of tripping hazards, overheating, and overloading.

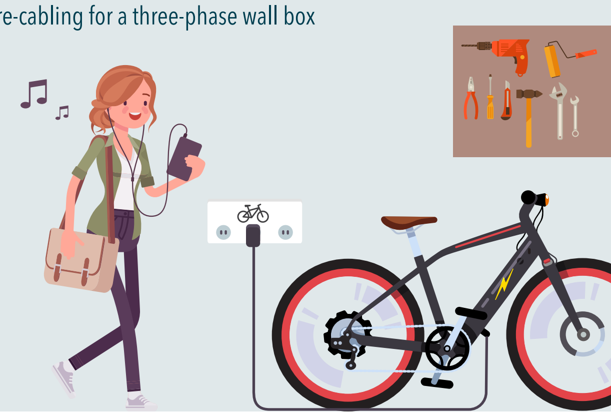
In relation to evolving needs, the adequacy of the electrical installation in a home should be regulatory checked. CENELEC, the European Committee for Electrotechnical Standardization, suggest a periodic inspection every 10 years[7]. However, it is strongly recommended to verify the electrical installation when there has been a change in occupancy or major works such as installing new equipment, increasing power capacity, or retrofitting. Surprisingly, most European countries do not have regulations in place for verifying domestic electrical installations after the initial inspection (FEEDS, 2024).

CARL hopes to continue driving his diesel car for many more years. He doesn't think it is necessary to plan ahead for installing a wall box for EV charging. If he ever invests in an electric car, the standard household socket in his garage will do. And he can always use an extension cord to leave his car outside and charge it up for the next trip. In principle, Carl is right. Most electric cars come with an AC adapter and can be charged from a household socket. It looks simple enough.



But it's not quite that simple. **Charging from such a socket should be limited to exceptional situations as it has major drawbacks and can pose dangers that should not go unnoticed.** Apart from the long charging times, single-phase charging from a regular outlet can pose a risk of overheating and fire due to high charging currents and continuous load. Regular sockets are designed for domestic use and can handle a maximum current of 16 amps but are not made with high and continuous load in mind. A lot worse is if the wiring is old or has a dodgy connection somewhere, or if Carl uses an extension cord that is too thin to handle the load. This kind of situation could result in a fire because an electric vehicle is continuously pooling maximum current. Thus we recommend Carl to install pre-cabling for a three-phase wall box to his garage and outside parking space.

SAMIRA is aware of the potential dangers associated with e-bikes and scooters and takes precautions to ensure her safety. Smart move! Charging batteries in a garage or under a carport, and not in the house, is a wise decision. Additionally, it's crucial to keep the charging area clear of flammable materials. To create a safe charging setup, she considers installing dedicated socket outlets on a separate circuit with appropriate safety features like specific breakers.



[7] International Standard IEC 60364-6:2016 on Low-voltage electrical installations—Part 6: Verification

Flexible: Is the electrical installation able to adapt to meeting evolving needs?

As we journey through life, we encounter changes that challenge our homes' ability to adapt. As our preferences and priorities shift, our families grow and change, and climate poses challenges, our homes must be able to adapt to meet our evolving needs while complying with ZEB standards.

Firstly, **technologies** are constantly evolving, and it is important to plan for their integration into the home. The electrical system should be designed in a way that allows for easy installation of new devices and systems, such as smart home automation, energy-efficient appliances, and renewable energy solutions. It is not always possible to plan for the future and to make a home ready for whatever comes the way. But with an extensible electrical installation, home occupants can keep up with the times and improve ZEB-readiness while making their living space more comfortable, convenient, and efficient.

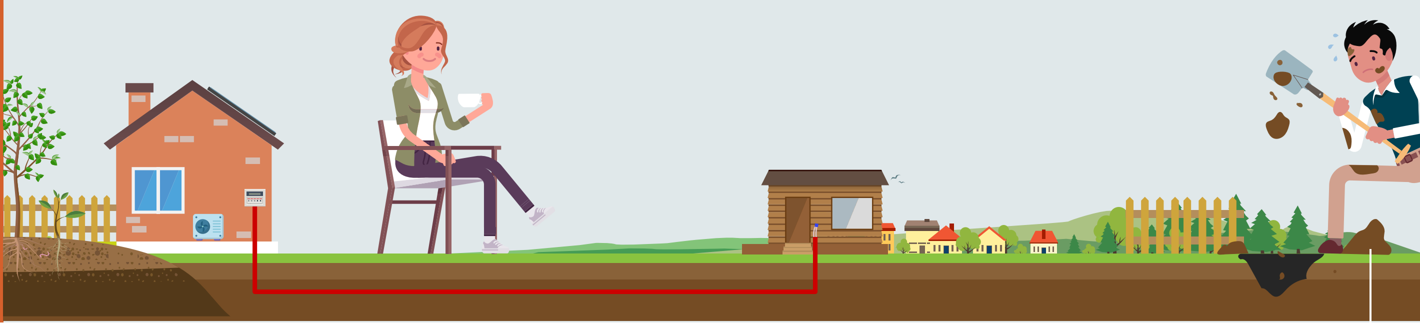
Secondly, as individuals age, they may require additional support to stay in their own homes for longer. By 2050, the global population of individuals aged 60 and above will double (WHO, 2022). While Aging at Home, Assisted Living, and other designing concepts for an elderly population are emerging, they only give little attention to electrical installations. Preparing for **aging at home** includes anticipating the installation of features such as stair lifts, night lights, distress alarms, and fall detection systems to enhance safety and accessibility. Furthermore, charging points for disability scooters and the electrification of shutters and doors can improve convenience and mobility for elderly residents.

Lastly, adapting the electrical installation to withstand **climate challenges** is becoming increasingly important (IEA, 2021). As temperatures continue to rise, it is crucial to anticipate the need for additional cooling mechanisms to maintain a comfortable living environment. This may involve installing solar shading systems to reduce heat gain and reliance on air conditioning. Additionally, incorporating energy-efficient technologies and renewable energy sources, such as solar panels, can help mitigate the impact of climate change on residential electricity consumption.

CARL tries to minimise the initial investment by barring optional features such as a PV system on the roof, an EV charging station or full electrification of the garden shed. He postpones these subprojects for a few years until fresh funds are available. Unfortunately, he then will require additional distribution panels and wiring, forcing the installer to dig in the garden or cut into walls, introducing additional costs and nuisances.

SAMIRA considered from the start to make her installation easily extensible, vertically as well as horizontally. She asked her installer for at least additional cable conduits from the ground floor to the attic to allow the necessary wiring for installation of a PV system on the roof and full electrification of the attic. She discussed with the architect to provide a real vertical shaft for extensibility purposes. She asked to install at least cable conduits or a horizontal shaft between the house or terrace and the garden shed or garage. This will allow easy wiring later.

FRANK took his plans to the next level. He decided to incorporate dropped ceilings in the halls and corridors that allow for easy installation of additional wiring whenever needed. But Frank didn't stop there. Instead of having just one distribution panel centrally located, he came up with the idea of having a distribution panel for each storey of the building. This way, he would have more flexibility and options when it came to managing the electrical distribution throughout the building.



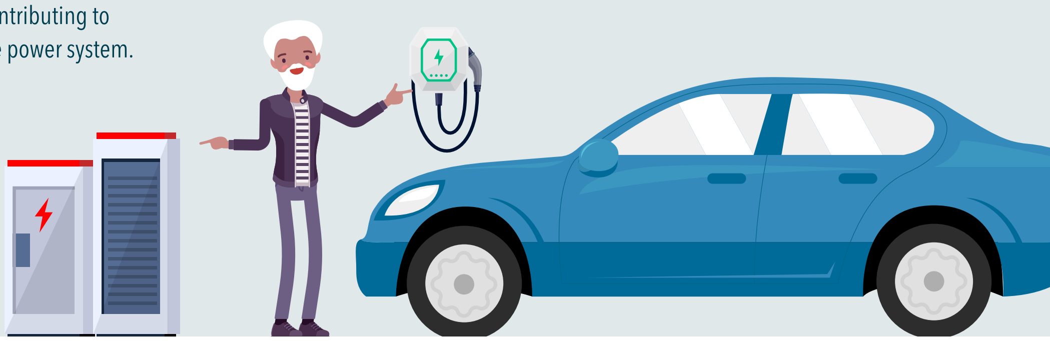
Smart: Will the electrical installation enable the growing demand-side flexibility requirements?

Grid operators are responsible for maintaining a balance between power supply and demand to ensure a reliable and stable electricity system. Traditionally they managed this through the coordination of large-scale power plants and transmission infrastructure. However, with the increasing penetration of renewable energy sources and the decentralisation of power generation, **the role of residential consumers has become more important**. With the increasing electrification of our homes, there is a growing trend of involving residential consumers in this process. This has implications on the design of the residential electrical installation:

- **Maximising PV-self consumption**. One central control system for both a PV system and a heat pump used for heating, cooling and domestic hot water can maximise the PV electricity self-consumption. The thermal energy storage capacity of the storage tank can be used as a short-term buffer for variations in PV output. Also, better integration of rooftop solar and smart electric vehicle (EV) charging can play a significant role in mitigating imbalances in power grids. The same central control system could also be connected to window shading and light dimming.
- **Adding capacity of small-scale renewable energy systems**, exceeding what is needed for self-consumption, might be encouraged in the future to help achieving the renewable energy targets. This would also apply for solar panels on residential properties. Anticipating higher production capacity can be beneficial.
- **Smart grid technologies and advanced metering** systems enable distribution network operators to communicate with residential consumers in real-time, providing them with information on electricity prices and grid conditions. This empowers consumers to make informed decisions about their energy usage, helping to balance supply and demand more effectively.
- One step further is active participation in **demand response programs**, where consumers voluntarily reduce their electricity consumption during peak demand periods in exchange for incentives or lower electricity bills.

Overall, the need for flexibility in homeowners' consumption patterns necessitates certain adaptations in the design of residential electrical installations. This includes **anticipating increased electrical loads, upgrading distribution panels for better control and monitoring, and optimising the integration of on-site generation (rooftop solar) and demand (smart heat pump control and smart EV charging) to help balance power grids.**

FRANK is exploring ways to decrease his reliance on the grid during peak demand periods. He has two options: installing a home battery system or exploring smart charging for his electric vehicle (EV). By doing so, Frank can not only decrease his own demand but also assist in balancing the overall load on the grid and reduce the risk of blackouts or grid instability. During high electricity demand, Frank can tap into his home battery or EV storage to lower his demand, thus easing the strain on the grid. Conversely, during low electricity demand, he can recharge his batteries, contributing to the overall stability of the power system.



Reliable: Have all critical applications stable data connectivity?

When it comes to making a home zero-emission, incorporating digital technology is crucial, particularly in terms of data and communications. Energy monitoring systems, solar inverters, and battery storage solutions rely on precise, real-time data collection. This information is crucial for optimising energy consumption, identifying opportunities for savings, and ensuring the efficiency of a zero-emission home. Where possible, using wired (Ethernet) connections leads to stable, uninterrupted communication and minimises the risk of signal interference. For wireless networks, a robust Wi-Fi system that supports the latest standards is necessary. A mesh Wi-Fi system can ensure consistent coverage throughout the entire dwelling, and setting up a dedicated Wi-Fi network for energy monitoring and management devices can reduce congestion on the main network and enhance security.

Cost-effective: Are upfront investments in the electrical installation balanced with long-term costs and benefits?

While it may be tempting to choose the lower-cost option for electrical installations and main electrical equipment, this can often end up being more expensive in the long run. **Making informed choices during the renovation process means considering the long-term costs and benefits; like increased energy efficiency, resilience against energy price spikes, improved safety, and reduced maintenance and replacement costs.**

As an example, studies find that medium-sized residential solar PV owners have enjoyed substantial savings on their energy bills in 2022 (savings up to 64%), especially in combination with a heat pump (savings up to 84%). These households will continue to benefit from their investment in the coming years in all scenarios, even as gas prices stabilise at lower levels compared to 2022, even at pre-crisis price levels of 20 EUR/MWh (SolarPower Europe, 2023). Analysis of nine cities in the US shows that all-electric single-family new construction is more economical to build and operate than a home with gas appliances (Tan, Fathollahzadeh, & Taylor, 2022).

But also, the energy efficiency of the electrical installation itself can no longer be ignored as we move to a low-carbon future. In 2019, a dedicated part on energy efficiency[8] was added to the international standard *IEC 60364 Electrical Installations for Buildings*. It considers various design and operational factors for energy efficiency in electrical installations, from different perspectives to provide a holistic view (Steel, 2021), of which the most relevant for residential buildings are: (a) the availability of local renewable energy generation and storage, (b) the reduction of energy losses in the electrical installation, (c) avoiding peak consumption (load shifting and shedding) and (d) and the introduction of dynamic time-of-use-tariffs.

Regarding point b), **to reduce energy losses in residential electrical installations, it is recommended to use the selection practices of indoor low-voltage cables**, following applicable standards[9] or national building codes.

[8] Low-voltage electrical installations - Part 8-1: Functional aspects - Energy efficiency (IEC 60364-8-1:2019)

[9] Electric cables - Calculation of the current rating - Part 3-2: Sections on operating conditions - Economic optimization of power cable size (IEC 60287-3-2:2012)

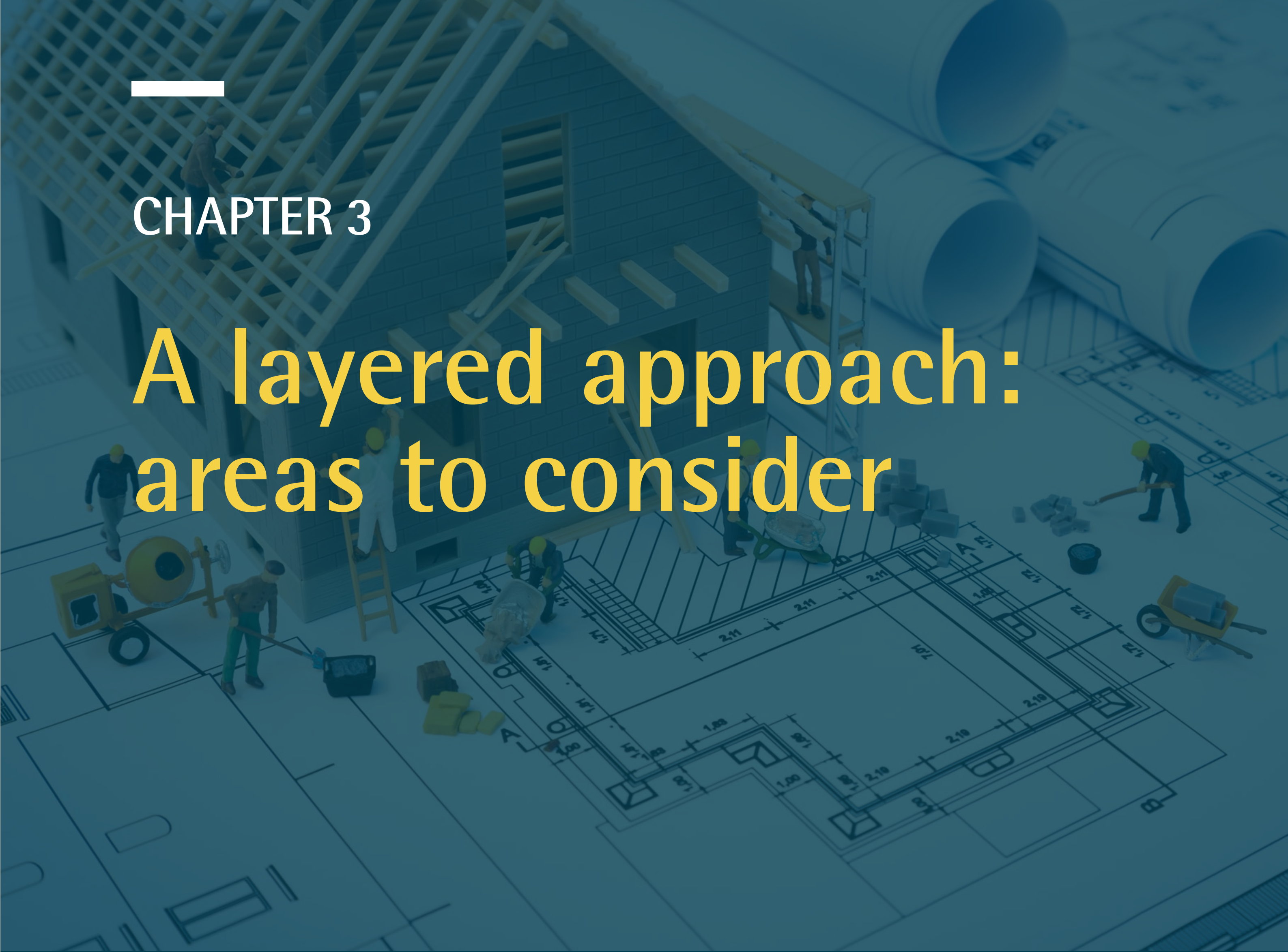
A few years ago, **CARL** was aware of the benefits of investing in a rooftop solar photovoltaic installation. However, being someone who preferred to live in the present, he did not anticipate the rising energy prices. As a result, Carl faced higher electricity bills and missed the opportunity to generate his own clean energy. In terms of cost-benefit, Carl's decision to delay the investment ended up costing him more in the long run.

SAMIRA believed in being proactive and seeking peace of mind. She carefully considered the benefits of investing in a rooftop solar photovoltaic installation a few years ago. By adopting this sustainable solution early on, Samira not only reduced her carbon footprint but also enjoyed substantial financial savings. With the help of government incentives and the decreasing cost of solar panels, she hopes that her initial investment will be paid back in less than 10 years. Samira's decision to be mindful of the future and take advantage of available solutions paid off both economically and environmentally.

SUMMARY

If the electrical installation is the backbone for the home's zero-emission infrastructure it is crucial to get it right from the very beginning. For the installation to be 'future proof', it should remain safe, flexible, reliable, smart, and cost-effective—for its entire lifetime.

PRINCIPLE	RECOMMENDATION
Safe	Anticipate future loads by carefully selecting electrical cables and avoid overload and overheating. Ensure enough power outlets and avoid excessive use of extension cords. Make sure the electrical installation is inspected after renovation works, after the installation of additional equipment, when the occupancy of the dwelling changes, and at least every 10 years.
Flexible	Make the electrical installation easy to extend for the easy accommodation of new devices and systems. Prepare for aging at home and long-lived living by anticipating more thorough electrification for improved convenience and mobility for the elderly. Help mitigate the impact of climate change by anticipating automated solar shading and additional cooling mechanisms.
Smart	Upgrade distribution panels for better control and monitoring. Optimise the integration of on-site generation (rooftop solar) and demand (smart heat pump control and smart EV charging) to help balance power grids.
Reliable	Consider wired connections for data communication where possible and ensure a robust Wi-Fi network with good coverage.
Cost-effective	Anticipate the maximum availability of local renewable energy generation and storage. Reduce energy losses and maximise demand-side flexibility options.



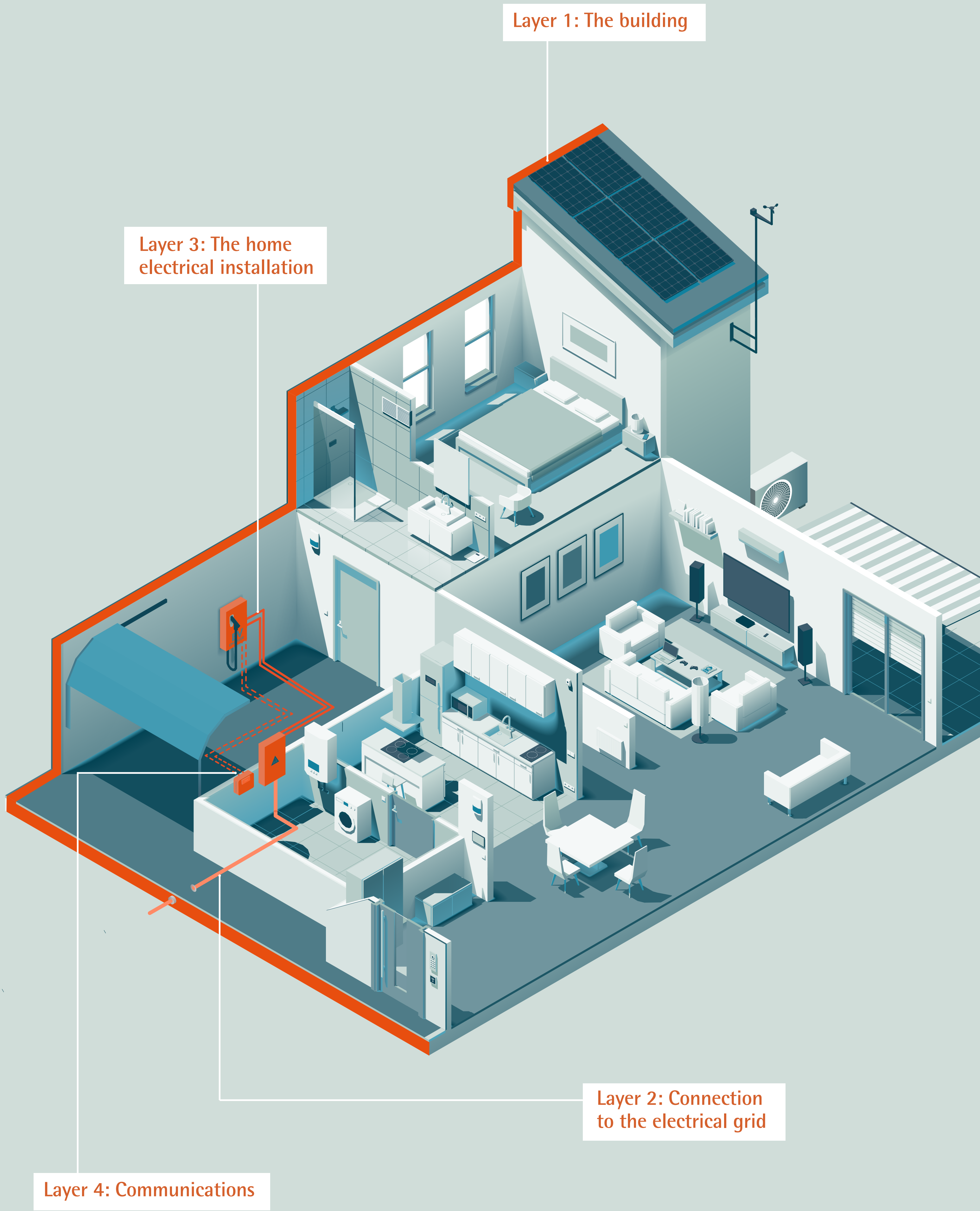
CHAPTER 3

A layered approach: areas to consider

Future-proofing a home's electrical setup goes beyond mere functionality; it's about ensuring every component is primed for what lies ahead. From the initial grid connection to individual switches and outlets, a forward-looking design ethos is paramount. To achieve this, meticulous consideration across various domains is essential.

Consideration spans the building's structural layout, integration with the local power grid, internal circuits, and communication systems. During the design phase, comprehensive assessments anticipate future needs, mitigating the necessity for later hardware additions. Anticipating increased electrical demands prompts planning for additional circuits and pre-wiring. Simultaneous deployment of hard-wired digital infrastructure alongside the electrical setup ensures seamless integration and future reliability.

This chapter covers design principles for all layers of the electrical installation. Making an installation future-ready involves ensuring that all its parts and components are prepared for the future.


Layer 1: The building
Layer 3: The home electrical installation
Layer 2: Connection to the electrical grid
Layer 4: Communications

Layer 1: The building

Cable feedthroughs: Preserve thermal insulation and airtightness of the building envelope

When renovating a home, it is important to anticipate future feedthroughs (via pre-cabling[10] and conduits) through the building envelope to avoid violating insulation and airtightness when cables are installed at a later stage. Common examples of equipment that should be expected include rooftop photovoltaics (PV), heat pump outdoor unit, electric vehicle (EV) charging stations, outdoor power supply and lighting, weather station, automated screens or shutters, and security systems.

Floorplan: plan for adequate space and convenient positioning

Strategically positioning electrical equipment and appliances can help installers avoid serious challenges:

- Avoid overcrowding and ensure that there is enough space around the electrical equipment for easy **maintenance and servicing**.
- Consider the positioning of electrical equipment in relation to the cable and wiring: **avoid lengthy cables**, which can result in heat losses and unnecessary energy costs.
- Ensure that the electrical equipment is installed in a **well-ventilated** area. This will help prevent overheating and other issues that can lead to malfunctioning.
- Keep in mind that electrical equipment should be installed away from moisture-prone areas like bathrooms or laundry rooms. This will help **prevent safety hazards** and ensure that the electrical equipment lasts longer.

Layer 2: Connection to the electrical grid

Connection power: expect higher loads

The nominal connection power depends on the electrical equipment and appliances that are present in the home. As always, it is good practice to anticipate future loads. Grid operators charge the customer for each grid connection upgrade, which is more costly than building in some overcapacity from the start. Customers could make *four times* as many connection requests to their grid operator for their growing number of EV charging points and local renewable generation in the coming years, which will challenge the grid operator's existing processes and systems (Future of Utilities, 2023).

Having a higher nominal connection power does not always result in higher peak consumption, which could lead to increased energy bills in certain countries. This is because peak load tariffs are calculated based on the *actual* peak consumption of the connection, rather than the *potential* peak consumption.

[10] In the EPBD (2024 recast), pre-cabling is defined as "all measures that are necessary to enable the installation of recharging points, including data transmission, cables, cable routes and, where necessary, electricity meters." (Article 2(34), (2024/1275/EU))

Single-phase or three-phase?

In general, three-phase systems enable more efficient distribution of electricity, reducing the risk of power outages and improving overall energy efficiency. Older homes are still commonly connected to a single-phase supply in some European countries, such as Belgium and France. However, there is a growing trend for new homes in Europe to be connected to three-phase supplies, driven by the need for higher capacity and more efficient energy distribution. For applications requiring higher power outputs, such as specific heat pumps, larger kitchen appliances, or for solar PV systems with a capacity exceeding 5,000 watt-peak, a three-phase connection is advisable.

Typical electricity consumption in households

(in kWh per year)

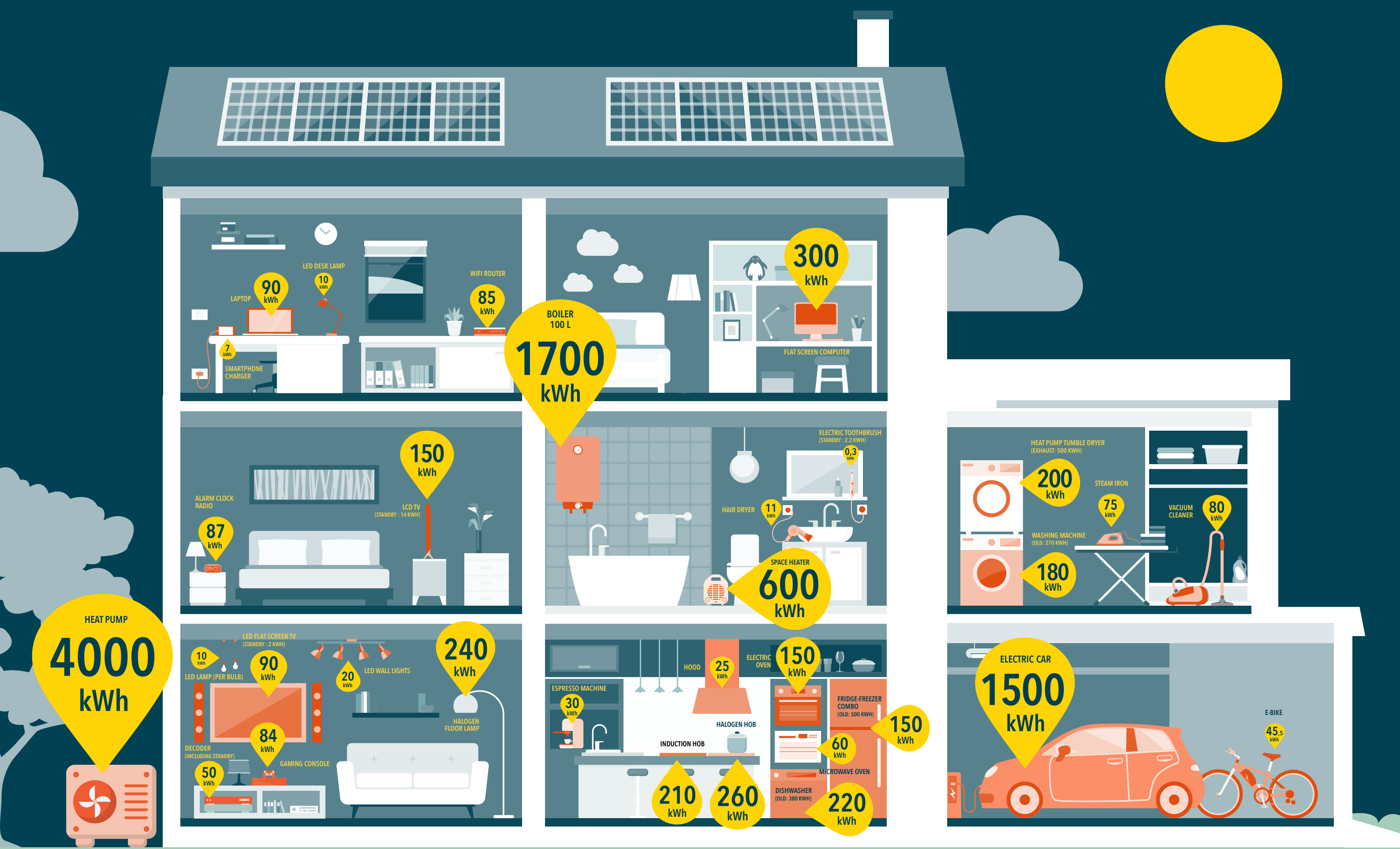


Figure 2 – Average energy consumption per household appliance in a typical Belgian home. Actual consumption may vary significantly depending on the type of equipment, regional factors, climate conditions, and user behaviour.

Partly based on (Sibelga, 2019)

Layer 3: The home electrical installation

The circuit board: Planning for expansion and accessibility

The switchboard or circuit board serves as the main hub for electrical distribution and safety devices in a home. It is crucial to ensure its easy accessibility and sufficient space for potential expansions or upgrades and for maintenance purposes. Consider installing the switchboard at a convenient height for easy access and maintenance. Keep the surroundings clean and free from combustible materials. In larger homes or if future needs arise, it may be necessary to install multiple switchboards.

When renovating a house with the goal of future readiness and flexibility to implement zero-emission electrical technologies, it is important to consider the design of the number and topology of electric circuits. Dedicated circuits are essential for efficient and independent operation of zero-emission technologies, such as electric vehicle charging stations, heat pumps, and solar power systems. These technologies often require several kilowatts of power during prolonged periods of operation, which can overload existing circuits. By having dedicated circuits specifically designed for these technologies, their operation is not only more efficient but also avoids the risk of overloading the circuit. Incorporating extra conduits and wiring pathways during the renovation process can help accommodate future additions without the need for extensive rewiring.

Cabling and wiring: Pre-wiring and pre-cabling avoids costly construction works

Pre-cabling and pre-wiring of renovated buildings should be considered a no-brainer. The costs associated with doing this during the construction phase are minimal compared to the overall cost of constructing or renovating a building. In contrast, the failure to ensure pre-cabling could result in costs that are up to nine times higher if retrofitting is required (Platform for Electromobility, 2022).

Pre-cabling of buildings refers to both the technical cabling (cable path, technical sheaths, drilling) and the electrical pre-equipment in electrical installations (switchboard, horizontal electrical column, bus cable). It involves installing additional cables from the distribution board to strategic areas and corners of the house.

Smart cable selection: Ensuring safety, efficiency, and longevity

In residential installations, detailed calculations for cable selection and cross-sectional area are generally not required. Applicable standards[11] and building codes specify the nominal cross-sectional areas of copper wires based on safety and functionality criteria. Safety considerations involve limiting the maximum temperature rise to ensure fire safety and the longevity of the cable insulation throughout its lifespan. At the same time, functionality focuses on minimising voltage drop along the cable's length. These standards are widely adopted and enforced through safety inspections. However, some national wiring regulations adapt these international standards to meet local conditions and safety requirements, often providing detailed tables and guidance for selecting cable sizes. While specific adaptations and additional requirements may vary between countries, the fundamental principles of cable sizing—based on load, installation conditions, and safety considerations—remain consistent across these standards.

In general, good practices in cable selection can be summarised as follows:

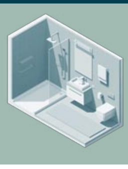
- **Load assessment:** Carefully assess the cable's load, considering both continuous and peak demands.
- **Environmental considerations:** Consider the installation environment, including temperature, humidity, and potential exposure to chemicals or mechanical stress.
- **Voltage drop:** Ensure that the voltage drop along the cable is within acceptable limits to avoid performance issues.
- **Future-proofing:** Consider potential future increases in load and select a cable cross-section that accommodates possible growth.
- **Manufacturer's guidelines:** Always consult the manufacturer's guidelines on cable selection, including technical data sheets and recommendations based on the specific characteristics of their products.

[11] Such as Low-voltage electrical installations - Part 5-52: Selection and erection of electrical equipment - Wiring systems (IEC 60364-5-52:2009)

Socket-outlets: You can never have too much of a good thing

There is nothing so tedious and annoying as finding that, as a resident of a newly built or renovated house, you have too few socket-outlets, data, telephone, and TV connections, and that likely as not, they are in the wrong place. To avoid the residents using extension cables or giving in to their DIY spirit (with likely repercussions for the safety of the installation), it is advisable to make a considered choice of the number of sockets, data, telephone and TV connections and their locations within the home. The lack of socket provision is not only found in older dwellings, where it might be expected that installations were not designed to meet future needs. Surveys have shown that 50% of new homeowners require additional socket-outlets installing within twelve months of purchase of a new dwelling (Electrical Safety First, 2018).

The required number of socket-outlets in a dwelling varies with the size of the rooms and the type of occupancy, but they should be suitably distributed around the room and anticipate future change of use. In the UK, Electrical Safety First published a guidance with the minimum number of twin socket-outlets to be provided per location type (Electrical Safety First, 2018). Germany has more detailed functional recommendations with three levels of installation: the minimum (one star), standard equipment (two stars), and comfort equipment (three stars). Their RAL-RG678 guideline describes the number of electrical circuits, sockets, lighting connections and connections for other consumables such as washing machines, instantaneous water heaters or electric vehicles (Deutsches Institut für Gütesicherung und Kennzeichnung, 2023). Of particular concern are high-load devices, such as electric vehicles, which may have portable, plug-in versions available. However, it is important to note that these portable versions do not adhere to the same strict safety standards as built-in electrical installations. Therefore, it is advisable to avoid using such portable high-load devices and instead install dedicated circuits for these appliances.

Room		Number of sockets	Number of lighting points	Communications connections
KITCHEN 	* Minimum	3	2	1
	** Standard	3	3	2
	*** Comfort	5	3	2
DINING AREA 	* Minimum	3	1	2
	** Standard	5	1	2
	*** Comfort	7	2	2
LIVING ROOM ≤ 20 m² 	* Minimum	4	1	2
	** Standard	8	2	3
	*** Comfort	10	3	3
LIVING ROOM > 20 m² 	* Minimum	5	2	4
	** Standard	11	3	5
	*** Comfort	13	4	5
BEDROOM ≤ 16 m² 	* Minimum	6	1	2
	** Standard	8	2	2
	*** Comfort	10	3	2
BEDROOM > 16 m² 	* Minimum	8	2	2
	** Standard	11	3	3
	*** Comfort	13	4	4
STUDY 	* Minimum	4	1	2
	** Standard	8	3	3
	*** Comfort	12	4	4
BATHROOM 	* Minimum	2	2	-
	** Standard	4	3	-
	*** Comfort	5	3	2

Continued on next page >>>

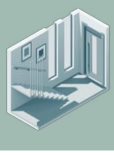
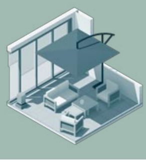
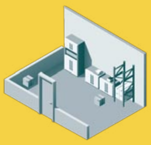
* Minimum Equipment
According to DIN 18015-2:2019

** Standard Equipment
Provisions for standard equipment

*** Comfort Equipment
Provisions that prepare for comfort and flexibility

Table 1 – Guidelines for electrical installations in residential buildings, based on common practice in Germany (HEA, 2023). Practices may vary in other countries.

>>> Continued from previous page

Room	Level	NUMBER OF SOCKETS	NUMBER OF LIGHTING POINTS	COMMUNICATIONS CONNECTIONS
WC 	* Minimum	1	1	-
	** Standard	2	1	-
	*** Comfort	2	2	-
HALL WAY ≤ 4 m 	* Minimum	1	1	-
	** Standard	2	2	1
	*** Comfort	3	2	1
HALL WAY > 4 m 	* Minimum	2	2	-
	** Standard	3	2	1
	*** Comfort	4	2	1
OUTDOOR SEATING AREA 	* Minimum	1	1	-
	** Standard	2	2	2
	*** Comfort	3	3	2
UTILITY ROOM 	* Minimum	2	1	-
	** Standard	6	2	-
	*** Comfort	8	3	-
HOBBY ROOM 	* Minimum	3	1	-
	** Standard	6	2	2
	*** Comfort	8	2	2
STORAGE ROOM 	* Minimum	1	1	-
	** Standard	2	1	-
	*** Comfort	2	1	-
BASEMENT OR GARAGE 	* Minimum	1	1	1
	** Standard	2	1	1
	*** Comfort	2	1	1

* Minimum Equipment
According to DIN 18015-2:2019

** Standard Equipment
Provisions for standard equipment

*** Comfort Equipment
Provisions that prepare for comfort and flexibility

Table 1 – Guidelines for electrical installations in residential buildings, based on common practice in Germany (HEA, 2023). Practices may vary in other countries.

Sensors, switches, motors: From basic comfort to assisted living

The same applies to controls such as buttons and switches. There are no hard and fast rules here, most switch manufacturers provide their own checklists on their website. Lighting controlled by presence detectors can be switched off when a room is empty, saving energy and hence money. With an ageing population the demand for health monitoring and assisted living systems in homes will rise and these will require installations with increased functionality and the highest level of reliability.

Inverters and battery packs: They are always bigger than you wanted

Anticipating the installation of home batteries and inverters is an essential aspect of building or renovating a house. Technical discussions with the architect are necessary to ensure that the necessary space required for mounting the equipment is available (dimensions of batteries and inverters vary but are often underestimated) and that all necessary cabling can be foreseen. Modern home batteries are modular systems, allowing for easy expansion of battery capacity by adding additional modules in the future. Therefore, it's important to ensure adequate space for future upgrades. Also, batteries perform best at temperatures like those preferred by humans. Indoor locations are the preferred choice, as they shield batteries from extreme weather conditions. If one opts to place batteries in a cold area like the basement during winter, insulating the battery system might become necessary to retain warmth. Conversely, when batteries are positioned in a poorly insulated area, ensuring adequate ventilation is crucial to prevent overheating during the summer. Additionally, fire safety concerns are paramount when installing a home battery. These systems, if they catch fire, can be challenging to extinguish, so careful selection of their location is critical. Always follow the guidelines provided by the local fire safety authority to ensure compliance and safety.

Layer 4: Communication

Internet connectivity: Go for quality and reliability

Zero energy buildings and decarbonised homes are increasingly relying on digital communication and data collection and exchange. By leveraging digital communication, these buildings can optimise energy consumption, monitor and control systems remotely, and gather real-time data for analysis and decision-making. Digital communication allows for seamless connectivity between different components of a building's energy system, such as smart meters, sensors, and control systems.

Therefore, **when renovating or constructing a house, it is highly recommended to roll out digital infrastructure simultaneously with the electrical installation.** This means incorporating the necessary wiring and outlets for internet connectivity, home automation systems, security systems, and other digital devices during the electrical wiring process. For the most critical digital equipment, considering hard-wired data communication is advisable. Relying on wireless networks often results in reduced connectivity and performance when signals need to pass through obstacles such as walls. Moreover, wireless networks are more vulnerable to external disturbances, which can further affect signal quality and reliability.

Smart meters: Not the meter, but the user should be smart

An estimated 70% EU consumers have a smart meter (although adoption rates vary significantly from one member state to another), and this share is expected to rise to 77% by 2024 (IEA, 2024). Smart meters provide real-time and detailed energy consumption data, which allows consumers to monitor and manage their energy usage more effectively. Smart meters communicate directly with grid operators or utility companies, providing accurate and timely data on electricity usage. For the consumers this ensures accurate billing, while grid operators can better plan and manage their supply and improve grid stability. In certain countries such as Germany, smart metering serves the additional purpose of allowing grid operators to remotely manage heat pumps, EV charging stations, or PV systems if necessary to prevent grid overload.

Privacy and data protection are important considerations throughout the roll-out of smart meters. The EU has implemented strict regulations to ensure consumer data is properly protected by utility companies and only used for legitimate purposes. Residents have the right to access their own energy data and can choose to share it with third-party service providers, fostering innovation and competition in the energy market.

In the EU, digital smart meters rely on various communication protocols to facilitate communication with utility companies. Notably, some of these protocols utilise wireless network technologies such as 3G, necessitating a connection between the smart meter and the network. It is advisable to check the availability and strength of the network signal when choosing the location for the smart meter to be installed, especially in areas like basements where the signal might be weak, unless the distribution system operator requires a specific location. Solutions for addressing weak network signal in the basement for smart meters, like signal boosters or rooftop antennas, exist, but they can be expensive and sometimes require additional wiring. Not all utility companies or distribution network operators responsible for the smart meter offer alternative communication protocols or technologies that might work better in areas with weak network signals.

Smart meters have the potential to offer numerous benefits to end users, but to fully reap these benefits, efforts must be made to present the smart meter data in a user-friendly format. This involves equipping smart meters with user ports that allow for easy access and interpretation of the data. By providing user ports, smart meter manufacturers enable users to view real-time energy usage information and track their consumption patterns. These ports serve as a crucial interface for users, allowing them to analyse their energy usage and make informed decisions about how to optimise their consumption. By leveraging these user ports, the data from smart meters can be easily interpreted, ultimately empowering users to take control of their energy usage and make more sustainable choices.

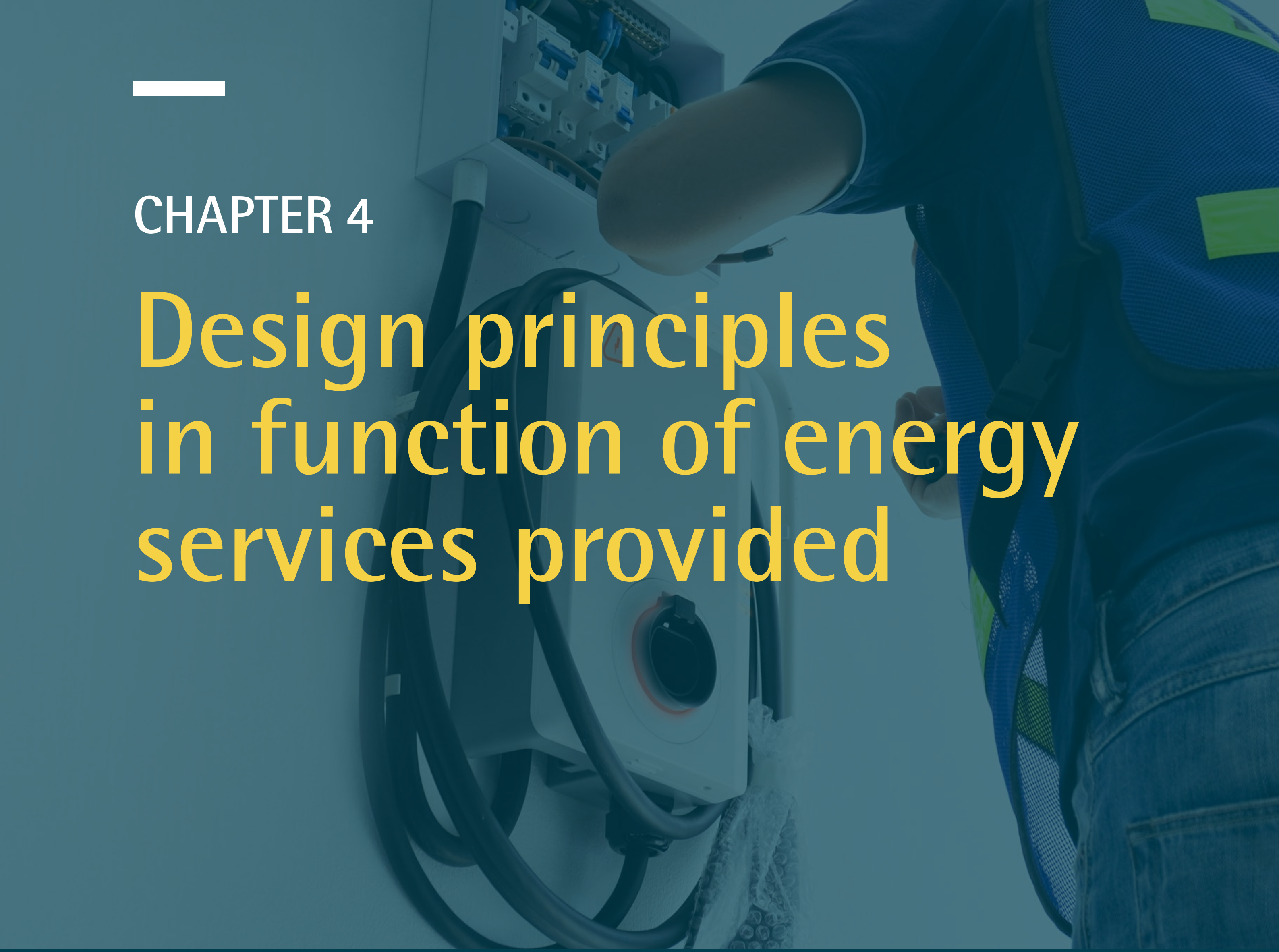
The Belgian website maakjemeterslim.be (in Dutch); maconsosouslaloupe.be (in French); energieverbrauchimblick.be (in German), provides a list of nearly 100 applications that users can connect to their digital meter to analyse and control their energy consumption. Both end-users and installers can easily search, filter, and rank the applications based on their preferences, budget, and personal situation.

SUMMARY

- To prepare the electrical installation for the future, it's important to consider all areas of the building: the building's structure and layout, its connection to the local power grid, internal circuits (from the switchboard to outlets and light fixtures), and communication systems.
- During the design phase, thoroughly assess all required services and their needs to avoid the need for additional hardware cabling and wiring later on.
- Plan for future expansion by anticipating increased electrical demands. Expect higher loads and plan for additional circuits in the switchboard, installing pre-wiring and pre-cabling accordingly.
- Carefully consider the cable selection for PV systems, EV charging stations, and heat pumps. These circuits often carry heavy loads for extended periods, so the optimal cross-section can reduce energy losses.
- Simultaneously deploy hard-wired digital infrastructure alongside the electrical installation to ensure quality and reliability.

CHAPTER 4

Design principles in function of energy services provided



This chapter provides a comprehensive overview of the important considerations associated with different types of equipment during the renovation or construction of a building. It highlights the crucial need to evaluate the potential impact on the electrical installation, regardless of whether the equipment is being installed immediately or in the future.

To ensure a safe and compliant installation, it is essential to review and adhere to the manufacturer's installation instructions and local building codes and regulations. By following those guidelines, one can not only avoid damaging expensive equipment but also identify opportunities for cost savings by understanding the electrical specifications. It is important to note that while the manufacturer's instructions may not always comply with local building codes, it is always essential to follow the building codes.

In terms of safety, all wiring should be performed by qualified professionals. Additionally, electrical installers serve a vital role as 'systems integrators', ensuring seamless collaboration among electrical devices and systems to achieve peak efficiency. Their coordination with professionals like roofers, plumbers, and HVAC technicians guarantees proper installation and smooth interaction between systems, optimising electricity usage and enabling demand flexibility.

However, it is important to acknowledge that specific requirements may vary based on the type, brand, and grid conditions. Therefore, it is crucial to refer to the equipment manufacturer's detailed documentation, which can span multiple pages, for a comprehensive list of requirements.

Heating

Heating homes through heat pumps is one of the key methods to achieve decarbonisation in buildings. However, switching to heat pumps comes with implications for the electrical installation in the building.

Flexible • Cost-effective First, for higher power outputs a multi-phase connection is required (FEEDS, 2024). Next, it is important to design the switchboard in a way that allows for the future extension of (multiple) dedicated circuits, which are often required for a heat pump system. These circuits have specific voltage and current requirements, as prescribed by the manufacturer. Therefore, it is essential to ensure that there is enough electrical capacity and space in the electrical panel to accommodate future additions, such as additional zones or units that provide heating and cooling to different areas of the home.

Safe • Reliable The guidelines for sizing heat pump conductors and breakers deviate from those applicable to other residential circuits, adhering to specific building codes that may vary across different member states.

Smart An internet connection is essential for a heat pump. It guarantees optimal performance by enabling remote control and monitoring by the user, proactive maintenance, and more advanced functions like receipt of local weather forecasts. Additionally, it facilitates smart integration with a home energy management system and other connected devices. This integration allows for balancing energy consumption over time and providing flexibility to the grid, ultimately resulting in reduced energy bills.

Flexible In certain cases, homeowners may choose to install direct booster heaters in specific areas of their homes, such as bathrooms, when floor heating is not yet activated. Other rooms where localised heating is advisable are home offices, study rooms, and basements. To ensure safe installation, it is recommended to pre-cable for a dedicated circuit. These devices typically draw a significant amount of power, ranging from several kilowatts or higher. Running such high-load appliances continuously at maximum power can overload the circuit. Therefore, it's important to rely on the careful and professional planning of an electrical installer who sets up dedicated circuits with circuit breakers that can handle the heavy load of a single appliance without causing any issues.

Cooling

Cooling demand is expected to increase globally due to climate change and rising incomes, especially in emerging economies (IEA, 2023). Across Europe, rising temperatures, combined with an ageing population and urbanisation, mean that the population is becoming more vulnerable to heat and that demand for cooling in buildings is rising rapidly. Buildings, as long-lasting structures, can offer protection from heatwaves and high temperatures if appropriately designed, constructed, renovated and maintained (European Environment Agency, 2022). Cooling energy demand in buildings is largely overlooked in many attempts to achieve climate change mitigation and related carbon neutrality targets (Castaño-Rosa, et al., 2021). **Building design needs to be based on the implications of projected climatic scenarios in the cooling energy demand rather than on past climatic data**. Technological progress can limit greenhouse gas emissions from active cooling systems, but the demand for electricity may still increase significantly. If active cooling is necessary (e.g. because of long heatwaves and/or critical health issues), cooling systems should be as efficient as possible and equitably accessible by vulnerable and other groups (European Environment Agency, 2022).

Safe • Flexible Air conditioners require a significant amount of power, so it is crucial to ensure that the electrical system can handle the additional load. Upgrades, such as increasing the electrical panel's capacity or adding dedicated circuits, are often necessary. As air conditioning units usually require a dedicated circuit to prevent overloading the electrical system, during the renovation process, it is recommended to install new electrical wiring and outlets specifically for the future air conditioning units.

Cost-effective When installing air conditioning units, opt for energy-efficient models that can help reduce energy consumption and lower utility bills. Additionally, consider installing programmable thermostats or smart home automation systems to optimise cooling and energy usage.

Indoor air quality

Reliable • Cost-effective Zero emission buildings necessitate careful monitoring and control of indoor air quality. To ensure the health and comfort of occupants, it is recommended to install demand-controlled ventilation systems. These systems adjust the amount of outdoor air brought into the building based on the occupancy and actual air quality, resulting in more efficient ventilation and energy usage. They require CO_2 (and sometimes humidity) measurements in key areas of a dwelling, such as the kitchen, living rooms, and bedrooms. Outdoor sensors are not always required, but they can provide additional context such as outdoor temperature, humidity, and pollutants. They allow the system to adjust outdoor air intake based on external conditions, which can enhance overall performance. This may require additional wiring for sensor installation and data transmission.

Domestic hot water

Safe Direct electric heating involves using electric resistance heaters to directly heat the water. This option is relatively simple to install and requires a dedicated electrical circuit and a water storage tank or instant water heater. Integrated electric heat pump systems are in most cases more energy-efficient than direct electric heating but require more complex installation. The decision to choose integration with a heat pump for space heating or a local direct heating system, or a combination of both, depends on various factors such as climate, home size, and energy consumption habits. Assessing these specific needs and circumstances will help determine the best option. When considering these options, electrical installers must ensure that the existing electrical system can handle the additional load. In some cases, upgrades to the electrical system may be necessary.

Cost-effective The installation of wastewater heat recovery (WWHR) systems under a shower can contribute to energy savings for domestic hot water heating. WWHR systems capture and utilise the excess heat from shower water that would otherwise be wasted. This reduces the energy needed to heat the incoming cold water and thus lowers energy consumption. Although it may not directly impact the electrical installation, it indirectly allows for a reduction in the required capacity for heating water, such as a lower rated heat pump or smaller storage tank.

Lighting

Flexible • Smart • Reliable • Cost-effective When renovating the lighting systems in a residential building, electricians should consider the incompatibilities between LED lights and older bulbs. These can include differences in voltage requirements and the need to ensure that fixtures and dimmers are physically compatible. Installing Home Automation Systems and Smart Lighting can help save energy on lighting. However, adding such controls may require the installation of additional wiring, primarily for communication and control purposes.

Cooking

Safe • Flexible • Reliable • Cost-effective When it comes to the electrical installation in a kitchen, it is important to expect heavy concurrent loads and to consider the specific requirements of the appliances being used.

With the increasing popularity of induction cooktops, it is essential to anticipate the higher peak electrical demand compared to ceramic electric cooktops. While they are overall more efficient, induction cooktops typically draw higher current, so it is recommended to ensure that the electrical system can handle the load and that the appropriate cabling and circuit breakers are installed.

In addition to the induction cooktop, it is crucial to anticipate heavy concurrent loads when using various kitchen appliances. Appliances such as toasters, microwave ovens, food steamers, kettles, electric grills, and slow cookers can all contribute to a significant electrical load in the kitchen. To avoid overloading the electrical system, it is recommended to have dedicated circuits for these appliances. This will help distribute the electrical load evenly and prevent any potential tripping of circuit breakers. Anticipating heavy concurrent loads and ensuring the electrical system can accommodate them will not only enhance the safety of the kitchen but also ensure optimal performance of the appliances.

Solar shading

Flexible • Reliable • Cost-effective Window solar shading is becoming increasingly important for net-zero energy homes due to its ability to reduce solar heat gain and improve energy efficiency. To accommodate sunscreens on each window, power cables must be installed in advance. Additionally, careful consideration must be given to the control mechanisms for the shading, such as hard-wired switches, wireless remote control, or integration with the home energy management system. This integration optimises the performance of the shading system and allows it to work in conjunction with other house systems, like the cooling system.

On-site renewable energy

Safe • Flexible • Smart • Reliable • Cost-effective When deciding to invest in solar PV panels, one crucial factor to consider is the size or capacity of the installation. Typically, the capacity is chosen to cover one's own self-consumption. However, to ensure the installation remains future proof, it is recommended to anticipate the wiring and cabling requirements for potential future expansions with additional panels. Indeed, the quality of solar panels is constantly improving, with increased yields per panel even under less optimal orientation and angle. This means that the suitable roof area for PV panels may increase in the future. Another consideration is the possibility of energy sharing or active participation in energy communities, which is expected to become common practice in most European countries. Incentives may be provided to encourage homeowners to increase the PV capacity on their roofs to help achieving the renewable energy targets.

Oversizing the inverter with the intention of later adding more solar panels may not be a wise choice. When you want to expand your existing inverter system by adding solar panels, it is important for them to match the solar panels from your original installation. However, finding matching panels in the fast-evolving solar market after a few years may be challenging. In such cases, you would have to create a separate system with a new inverter to expand your solar array. In any case, the location of the inverter should be carefully considered as it impacts the cabling, particularly the DC cable that connects the panels and the inverter. It is important to use durable and outdoor-rated DC connectors, following the applicable product standards and building codes.

Data connectivity of the inverter, and even integration with a Home Energy Management System (see further) are recommended (FEEDS, 2024).

Energy storage

Safe • Flexible • Smart • Reliable • Cost-effective All renovation and new construction designs should ensure that there is sufficient space for an electric home battery. Storing excess solar power allows for greater independence from the grid by using it during other times of the day when sunlight is not available. This reduces dependency on grid power and provides a reliable source of energy. Certain batteries can provide protection against blackouts, which can be a concern for some. A home battery has the potential to lower peak power demand and decrease the associated tariff on energy bills. It can also assist in diminishing the required nominal connection power. However, it is still recommended to over-dimension the nominal power connection since the cost difference is not significant and utilities only charge for actual peak consumption, not the nominal power capacity.

Home battery systems should be in an easily accessible area, with proper ventilation and minimal exposure to extreme temperatures. Always bear fire safety and evacuation routes in mind. Therefore, it is important to adhere to the guidelines provided by the local fire safety authority.

To integrate batteries into a solar power system, a bi-directional inverter is necessary. There are two options for installing this inverter: it can be a separate unit installed alongside the existing PV inverter, or a hybrid inverter that combines the functions of both PV and battery inverters in one unit. The battery inverter and batteries need to be within 1 meter of each other and their dimensions differ depending on type, brand, and capacity (Tanjent-energy, 2023).

When installing a home battery system, a digital meter is indispensable. A Home Energy Management System (see below) could further optimise the performance of a battery by reducing the number of charge-discharge cycles it goes through. This process helps extend the lifespan of the battery (FEEDS, 2024).

Electromobility

The necessary charging infrastructure and associated wiring and cabling in a house for electric vehicles (EVs) depend on various factors such as the number and type of vehicles, desired charging speed, and the power capacity of the house. As the EV market continues to evolve rapidly, international standards are still being developed to meet the changing needs of consumers (All About Circuits, 2022). There are four modes of EV charging, each with its own characteristics and considerations (see Table 2). Many European utilities and distribution grid operators have released guidelines to help e-mobility users in deciding how to install electric vehicle (EV) charging equipment in their homes[12].

Safe • Flexible Requirements for the electrical installation for electric vehicles include determining the desired power supply and providing smart charging functionalities. The power supply needed, in terms of nominal power and number of phases, depends on the type and use of the vehicle. While not all electric vehicles currently support three-phase charging, this capability may be expected in the future. Depending on the average daily kilometres, electricity consumption, and available time for recharging, a higher connection power may be required.

Cost-effective All cable paths from the power source to the charger should be planned and the cross-section for those cables chosen appropriately. The installation should be designed to be easily expandable, allowing for the inclusion of additional (hardwired) communication cables in the duct and the availability of residual space in the electrical panel for future needs, including for new protections devices (FEEDS & AVERE, 2024). The sizing principles for EV charging conductors and breakers differ from those governing other residential circuits, conforming to distinct building codes that can vary among member states. While these codes specify nominal cross-sectional areas for indoor low-voltage power cables based on safety and functional needs, they frequently neglect energy efficiency concerns.

[12] Such as https://electrify.brussels/en/how-to-install-a-charging-point (Brussels, available in French and Dutch).

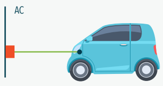
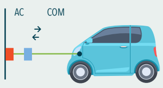
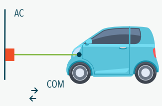
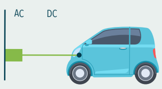
				EXAMPLE	
Mode	**Diagram**	**Description**	**Impact on home electrical installation**	**Power**	**Charging time and speed***
Mode 1 No longer used for full-sized EVs		Directly connecting the vehicle to a standard domestic power outlet, without any communication between EV and charging point. Mode 1 was around in the early days, but is now restricted or even prohibited in many countries due to safety concerns.	Standard domestic power outlet but prohibited in many countries.	2.3 kW (230 V / 1x10 A)	17 h 4 min (11 km/h)
Mode 2 Portable charger 'Slow AC' (occa-sional use only)		Utilises a dedicated charging cable with integrated control and protection devices (IC-CPD), designed to perform all the necessary control and safety functions. Intended for occasional use.	Can be used with regular household sockets for home charging without requiring any modifications to the electrical installation. However, recommended for occasional use only because the power outlet may not be sufficiently protected from the impact of charging high loads over long periods of time. Therefore, in certain countries, the building code may necessitate a dedicated socket outlet for EV charging, along with specific security and cabling requirements.	3.7 kW (230 V / 1x16A)	10 h 47 min (19 km/h)
Mode 3 Wall box 'fast AC'		Involves a dedicated charging station (wall box) with an electric vehicle supply equipment and a separate charging cable. This mode is considered safer, more efficient, and allows for faster charging speeds. It is the most recommended solution for EV charging. Chargers available on the market can handle up to 7.4 kW in single-phase and up to 22 kW in three-phase configurations.	Upgrading the grid connection to a three-phase connection may be necessary to accommodate the additional power demand, especially if other high-power appliances are being used concurrently (Fluvius, 2023).	7.4 kW (230 V / 1x32 A) ---------------- 22 kW (400 V / 3x32 A	5 h 15 min (38 km/h) ---------------- 3 h 32 min (56 km/h)
Mode 4 Roadside public 'fast DC'		Fastest charging mode available. Commonly used in commercial charging stations for long-distance travel or time-sensitive charging needs, like fast charging stations alongside highways.	Charging at home occurs overnight or during extended parking periods. Therefore, slower AC (Mode 3) home charging systems are better suited and provide a more affordable option for mass adoption.	50 kW DC ---------------- 150 kW DC	47 min (258 km/h) ---------------- 16 min (774 km/h)

Table 2 – EV charging modes according to IEC 61851-1

* In this example, a full electric vehicle (EV) with a battery capacity of 65 kWh and a vehicle efficiency of 19 kWh/100 km. Estimated timing to charge from 20 to 80 percent (at 95% charging efficiency). Exact charging times depend on the type of vehicle.

Smart • Cost-effective • Reliable To further optimise charging efficiency and power management, it is recommended to implement 'smart charging'. Smart charging dynamically adjusts the charging speed on the basis of information received through electronic communication, such as price signals. Charging the vehicle with self-generated green electricity or during off-peak hours for instance, is cheaper for the end-consumer and helps balancing the grid. As of May 2025, such smart charging functionalities are mandatory for all new and replaced non-publicly accessible power recharging points installed in the EU[13]. One step further is vehicle-to-grid (V2G), which enables the vehicle to send energy back to the power grid when needed. Cabling for smart charging and V2G incorporates communication cables, specifically Ethernet cables, alongside provisions in the electrical switchboard for the installation of devices such as an anti-islanding device and a decoupling device to efficiently re-inject electricity into the network. Furthermore, the smart cabling system should include a meter or meters capable of measuring flows in both directions - incoming and outgoing. Apps are often required to install the EV supply equipment and for the management of functions. Vehicle-to-grid contributes to a more reliable and resilient power grid, while the vehicle owner can earn revenue by selling excess electricity back to the grid. Vehicle-to-grid systems can also be used to provide backup power during emergencies or blackouts, offering an added level of resilience and energy security. While vehicle-to-grid technology is still in its early stages of development, several pilot projects are underway around the world to study its feasibility and potential impact. As the adoption of electric vehicles continues to grow, V2G has the potential to play a significant role in the transition to a clean and sustainable energy future.

Monitoring, automation and control

Smart • Reliable • Cost-effective Home automation can enhance comfort and flexibility for occupants. However, homeowners and architects lack awareness of its functionalities and many people are apprehensive about automated systems controlling their daily lives (Wijnants, 2015). Nevertheless, it is essential to anticipate future installation of such systems as needs and perspectives may change. Installers should include the potential installation of certain functionalities in the electrical system design, preparing homeowners for the future.

Easy-to-install home automation ideas

A few simple ideas that don't require advanced home automation systems include:

- The 'night-time button', which could mean switching off all lights as well as several appliances and turning the heating to eco-mode; and the 'wake-up button', which may involve switching on some lights and turning the heating on.
- Motion sensor lights to automatically turn on when someone enters the key areas of the house, such as entryways and hallways, help improve safety and convenience.
- Timers for electrical outlets like stand-alone electric heaters, can be set to turn off the power after a certain amount of time, preventing unnecessary energy consumption.
- The 'at home simulator', intended to deceive potential burglars when the occupant is out of town for a few days.

Home energy management systems: Essential for optimising the energy demand

Implementing a home energy management system (HEMS) is essential for optimising the load profile and energy demand of a dwelling. Thorough automation and coordination between different energy-using systems, such as heat pumps, electric vehicle charging stations, and photovoltaic panels, can be achieved through the HEMS. To successfully

[13] Art.20a(4) of the revised Renewable Energy Directive (2023/2413/EU)

implement a HEMS, specific requirements must be met for the wiring, cabling, and switchboard of the dwelling. The switchboard should have the capability to monitor and control the main energy-using systems individually. This integration of advanced technologies, such as controllers, in the switchboard enables real-time data collection, remote control, and effective communication between different energy sources and loads.

A home energy management system (HEMS) is a combination of hardware and software components that work together to efficiently manage energy usage in a home. Key requirements with an impact on the electrical installation include smart metering and sub-metering, reliable communication networks, the integration of renewables and storage capabilities, circuit load management, and smart appliances.

The Home Energy Management Systems (HEMS) market is experiencing rapid evolution. By 2028, it is projected that the number of active households with installed HEMS will approach 150 million users (Statista, 2023). This growth can be attributed to three factors. Firstly, the increasing penetration of large electrical loads in households across Europe. Secondly, the evolving regulatory framework, including the widespread adoption of smart meters. Lastly, technological and business innovations like dynamic time-of-use tariffs.

Real-life experiments show that HEMS reduce the total consumption of electricity in the winter months by up to 30%, shift the consumption to off-peak hours and decrease the number of high consumption hours (Tuomela, de Castro Tomé, Iivari, & Svento, 2021). These changes occurred even in the homes that valued comfort over savings or ecological sustainability.

Smart grid integration

To enable demand response and smart grid integration, a dwelling's electrical installation needs several key components. This includes advanced components in the switchboard and pre-cabling for power supply and bidirectional communication.

Energy sharing or participating in an energy community

Smart • Cost-effective Energy sharing or participating in an energy community refers to the concept of individuals or households actively sharing and exchanging energy with each other. It involves the collaborative use of renewable energy sources, such as solar panels or wind turbines, and the distribution of excess energy among community members. By pooling resources and sharing energy, participants can reduce their dependence on traditional energy sources and promote sustainability. The legal and contractual conditions for energy communities vary across EU countries. However, it is anticipated that energy sharing will become a valuable commodity and therefore, when renovating a house, it is advisable to consider accommodating the potential for energy sharing. To actively participate in an energy community, the only essential electrical infrastructure needed in the home is the installation of a digital (smart) meter with the appropriate measurement regime activated. This meter enables accurate monitoring and measurement of energy consumption and generation, as well as tracking of energy exchanged within the community.

Demand response or demand side flexibility

Smart • Cost-effective Demand response or demand side flexibility refers to the ability of residential consumers to adjust their electricity usage based on grid needs, enabling them to participate in providing services to the grid. Smart meters or advanced metering infrastructure are essential for real-time bidirectional communication between the utility and the dwelling. This allows for remote monitoring and control of energy consumption, enabling efficient demand response strategies.

However, to optimise energy use and support demand response initiatives, it is necessary to go beyond smart meters. The ability to program and schedule appliances and systems to respond to demand signals from the grid is crucial. By strategically using high-load appliances during non-peak periods, consumers can prevent overloading the electrical grid.

Starting January 1, 2024, Germany mandates that all newly installed heat pumps or charging stations must be controllable by the network operator. Homeowners are given the choice between direct system control (such as for heat pumps) or utilising their home energy management system for control. As an incentive, they are entitled to compensation in the form of reduced network fees.

Dynamic time-of-use tariffs for residential customers refer to a pricing structure where the cost of electricity varies based on the time of day. This means that during certain periods, such as peak hours when demand is high, the price of electricity will be more expensive compared to off-peak hours when demand is low. However, it is not enough for consumers to just have smart meters; they also need the ability to react to price signals and shift their electricity consumption accordingly during different time periods. This can be achieved with home batteries, heat pumps, or electric vehicles. For consumers to benefit from dynamic tariffs, they must have a sufficient level of knowledge and understanding of the advantages of load shifting. Smart appliances such as dishwashers, washing machines, and tumble dryers can be remotely controlled, aiding in effective usage planning. However, these appliances, despite being called 'smart', cannot respond to signals from the electricity network, such as price signals. Integration with a Home Energy Management System (HEMS) is needed to enable this functionality. Without automation, residential customers will struggle to react to price signals in real-time and may end up paying higher prices during peak tariff periods when their electricity demand cannot be reduced. Therefore, anticipating the need for automated control in the form of a home energy management system is key. It removes the barrier for implementing dynamic time-of-use tariffs, allowing residential customers to take full advantage of cost savings and optimise their energy usage.

Reliable Ensuring compatibility between the technology used in the dwelling and the grid is crucial. Communication protocols such as Zigbee, Z-Wave, or Wi-Fi allow different devices and systems to communicate effectively. Nevertheless, the lack of interoperability of solutions is still found the main technical barrier for demand side flexibility deployment at residential scale.

Other electricity uses

Planning and installing sufficient socket outlets in and outside the home is important for safety and convenience. Relying on extension leads can be unsafe, as they increase the risk of accidents and damage to the cords. Using extension leads in wet environments, such as the bathroom, is particularly hazardous. And good quality extension leads are not cheap either. By strategically placing power outlets, homeowners can enhance safety, reduce clutter, and create a more functional and aesthetically pleasing living space. Extension leads can be useful but should be used correctly and sparingly to minimise potential risks (Kasier, 2015).

Overview table

Snapshot of critical design principles and renovation considerations for creating ZEB-ready home electrical installations

		FOR ZERO-EMISSION READINESS, CHECK WITH THE **UTILITY** ABOUT
		POWER SUPPLY
General principles		Opting for a higher nominal connection power anticipates future loads and prevents the need for costly connection upgrades later on.
Heating	Heat Pump	Check required power connection (nominal power and phases)
	Direct booster heaters (resistance heating)	Anticipate concurrent loads
Cooling	Air Conditioner	Anticipate additional units
Indoor air quality	Demand-controlled ventilation	
Domestic hot water	Integrated in Heat pump	(see heat pumps)
	Standalone electric boiler	Anticipate concurrent loads
	WWHR	
Lighting	LED lights	
Cooking	Induction cooktop, ovens, micro-wave ovens, toasters, grills, kettles, …	Anticipate heavy concurrent loads
Dynamic building envelope	Window solar shading	
Onsite renewable energy	Solar PV	Monitor incentives for increase PV capacity (subsidies, feed-in tariffs, energy-sharing)
Electromobility	Electric vehicle, bicycle, scooter, …	Determine desired power supply based on type and use of the vehicles
Energy storage	Electric home battery	Don't lower nominal power connection (savings are related to peak consump-tion, not power connection)
Monitoring, automation and control	Home Energy Management System (HEMS)	
Smart Grid Integration		Digital smart meter with appropriate metering and communication regimes activated
Other appliances		

General remark: these are general recommendations. National building codes and specific requirements of the equipment should be followed and all installations should be designed and erected by a certified electrical installer.

		FOR ZERO-EMISSION READINESS, CHECK WITH THE **ARCHITECT** ABOUT	
		CABLE FEEDTHROUGHS	**FLOORPLAN**
General principles		Pre-cabling and pre-tubing from the circuit board to outdoor (expected) electricity uses helps prevent damage to the building's insulation and airtightness	Adequate space and convenient positioning of electrical equipment and appliances in well-ventilated areas ensure proper maintenance and servicing, minimise the need for lengthy cables, and prevent safety hazards
Heating	Heat Pump	Piping and wiring to connect outdoor and indoor unit(s) Wired connection with outdoor temperature sensor at shadow side of the building (weather compensation)	Optimal positioning of outdoor and indoor units Single or multiroom indoor (wired) thermostate(s)
	Direct booster heaters (resistance heating)		Consider all rooms where localised heating is advisable, eg. when the floor heating is not yet activated. Particularly bathrooms.
Cooling	Air Conditioner	Piping and wiring to connect outdoor and indoor unit(s)	Optimal positioning of outdoor and indoor units
Indoor air quality	Demand-controlled ventilation	Outdoor sensors enhance overall performance	Occupancy, CO_2 and humidity measurements in key areas
Domestic hot water	Integrated in Heat pump	(see heat pumps)	(see heat pumps)
	Standalone electric boiler		Minimise distance between thermal storage and point of use
	WWHR		Room or vertical shaft for heat exchanger under shower drain
Lighting	LED lights	Sufficient outdoor lighting points (incl. sensors)	
Cooking	Induction cooktop, ovens, microwave ovens, toasters, grills, kettles, …	Anticipate for outdoor kitchen appliances	
Dynamic building envelope	Window solar shading	Power cables for motorised outdoor solar shades	Evaluate building orientation and consider solar shading to avoid overheating
Onsite renewable energy	Solar PV	Anticipate additional panels on full available rooftop area as increased residential PV capacity may be incentivised	Locate inverter to minimise cable lengths and power losses
Electromobility	Electric vehicle, bicycle, scooter, …	Sufficient outdoor charging points	Ensure safe location of charging stations for electric vehicles, including cars, bicycles, scooters, …
Energy storage	Electric home battery	Some battery types can be installed outdoors	Sufficient space for modular battery pack in easily accessible area with proper ventilation and minimal exposure to extreme temperatures
Monitoring, automation and control	Home Energy Management System (HEMS)	Outdoor sensors enhance overall performance	Consider placing sensors (motion, temperature, and air quality) strategically
Smart Grid Integration			
Other appliances			

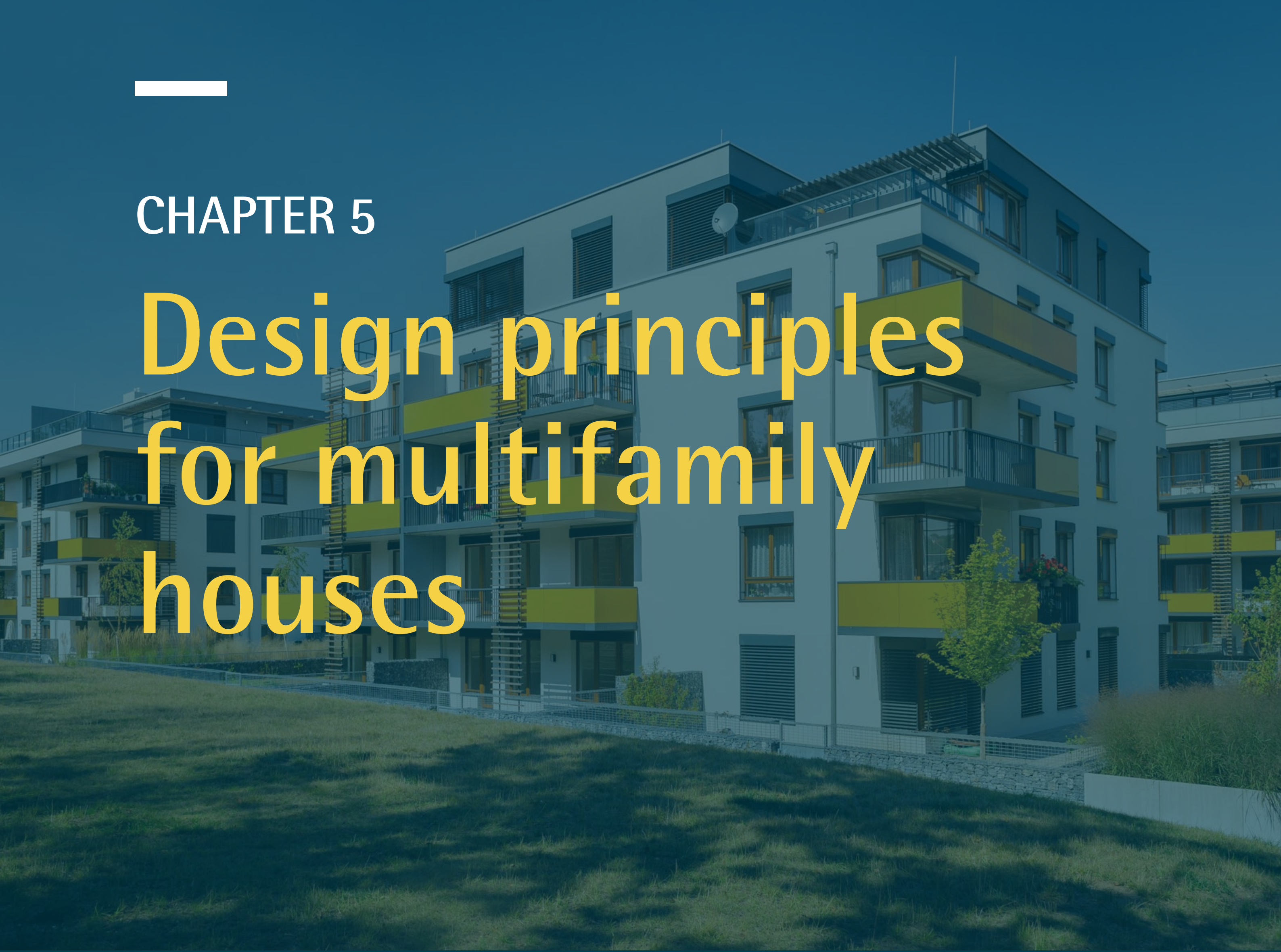
General remark: these are general recommendations. National building codes and specific requirements of the equipment should be followed and all installations should be designed and erected by a certified electrical installer.

		FOR ZERO-EMISSION READINESS, CHECK WITH THE **INSTALLER** ABOUT	
		CIRCUIT BOARD	**CABLING AND WIRING**
General principles		An easily expandable circuit board ensures there is ample residual space available for future needs	Carefully select the cables for dedicated circuits that are heavily loaded for many hours per day to minimise energy losses and to allow for flexibility to accommodate higher future loads. Pre-cabling for power supply and data communication anticipates future electrical equipment and services
Heating	Heat Pump	Multiple (at least 3) dedicated circuits required for a single heat pump. Ensure space for future additional zones or units	Follow specific building codes for sizing heat pump conductors (may vary across countries) Wired communication cables to connect sensors and controllers
	Direct booster heaters (resistance heating)	Dedicated circuit	Pre-cable future needs
Cooling	Air Conditioner	Dedicated circuit Ensure space for future additional zones or units	Pre-cable future needs
Indoor air quality	Demand-controlled ventilation		Wiring for sensor installation and data transmission
Domestic hot water	Integrated in heat pump	(see heat pumps)	(see heat pumps)
	Standalone electric boiler	Dedicated circuit	
	WWHR		
Lighting	LED lights	Check compatibility of switches and dimmers	
Cooking	Induction cooktop, ovens, microwave ovens, toasters, grills, kettles, …	Dedicated circuits for all high load appliances	Cross-section and length for high load appliances Cabling for ceramic electric cooktops might not be suitable for induction cooking
Dynamic building envelope	Window solar shading		Prefer hard-wired controllers
Onsite renewable energy	Solar PV		Anticipate additional future power capacity
Electromobility	Electric vehicle, bicycle, scooter, …	Provisions for anti-islanding and decoupling device	Smart cabling system: incorporates Ethernet cables for bi-directional communication
Energy storage	Electric home battery	Bi-directional inverter, digital meter	
Monitoring, automation and control	Home Energy Management System (HEMS)	Advanced controllers for real-time data collection, remote control, communication Control main energy-using systems individually	Data cables or robust wireless network for bi-directional communication
Smart Grid Integration			
Other appliances		Sufficient residual availability for additional loads	Planning (pre-cabling) or installing sufficient power outlets in and outside the home

General remark: these are general recommendations. National building codes and specific requirements of the equipment should be followed and all installations should be designed and erected by a certified electrical installer.

		FOR ZERO-EMISSION READINESS, CHECK WITH THE USER ABOUT ENERGY MANAGEMENT
General principles		Consider the smart use of electrical equipment by evaluating the operability of various solutions and their compatibility with a Home Energy Management System
Heating	Heat Pump	Smart thermostat and integration with PV and home battery system via HEMS
	Direct booster heaters (resistance heating)	Use a timer to limit the heating time
Cooling	Air Conditioner	Smart thermostat and integration with PV and Home Battery system via Home Energy Management System
Indoor air quality	Demand-controlled ventilation	
Domestic hot water	Integrated in Heat pump	(see heat pumps)
	Standalone electric boiler	
	WWHR	
Lighting	LED lights	Mind interoperability of smart LED lighting with other control and automation systems
Cooking	Induction cooktop, ovens, micro-wave ovens, toasters, grills, kettles, …	Avoid high peak-loads
Dynamic building envelope	Window solar shading	Integrate with Home Automation System for automated control
Onsite renewable energy	Solar PV	Optimise self-consumption Integrate with a Home Energy Management System
Electromobility	Electric vehicle, bicycle, scooter, …	Implement smart charging
Energy storage	Electric home battery	Integrate with Home Energy Management System
Monitoring, automation and control	Home Energy Management System (HEMS)	Mind interoperability and integration of individual equipment with the system
Smart Grid Integration		Implement smart controls on key end-uses; the system benefits of smart meters can only be achieved if the electricity use in the building can be sufficiently (and automaticly) managed
Other appliances		

General remark: these are general recommendations. National building codes and specific requirements of the equipment should be followed and all installations should be designed and erected by a certified electrical installer.



CHAPTER 5

Design principles for multifamily houses

In Europe, nearly half of the population resides in apartments (Eurostat, 2021). The design and implementation of electrical installations in multi-family buildings or apartment blocks differ significantly from those in single-family dwellings. While this publication primarily focuses on home electrical installations for single-family houses, this chapter provides general considerations that may be applicable to multi-family dwellings.

Planning and coordination to deal with complexity

One key difference is the complexity of the electrical system in multi-family buildings. With multiple units and possibly shared common areas, the electrical design must account for a larger number of electrical loads and circuits. This requires careful planning to ensure that the electrical system can handle the expected growing demand and that each unit receives a sufficient and consistent power supply.

Furthermore, the installation process itself can be more complex and time-consuming for multi-family buildings. Coordinating with multiple units, occupants, and potentially other contractors can add logistical challenges to the process. Additionally, the larger scale of the project may require more manpower, materials, and time for completion.

Lastly, safety regulations and codes play a vital role in the design and erection of electrical installations in multi-family buildings. These regulations may require the installation of additional safety features such as fire alarms, emergency lighting systems, and interconnected smoke detectors to ensure the safety of all occupants in case of emergencies.

This must be considered within the context of a complex ownership structure in apartment buildings. Homeowners' associations with varying requirements and preferences can pose challenges to ensuring an efficient energy supply within the building.

Integrating individual and collective electrical improvements

Revamping the electrical setup in a multi-family building requires careful attention to its shared infrastructure. While individual unit upgrades typically focus on rewiring from the meter to accommodate increased loads or modern amenities, it's crucial to also address improvements to the collective electrical system extending from the building's grid connection to the individual meters. Taking a comprehensive approach is vital to ensure that upgrades to shared components align with the evolving needs of the entire building while adhering to relevant codes and standards.

Anticipating high electrical loads for each unit

When designing the electrical system for multi-family dwellings, it is crucial to prioritise flexibility and design the electrical system with future upgrades and changes in mind. The changes in occupancy and usage patterns are more frequent than in single-family homes. One solution is to install additional conduits and wiring to accommodate future needs. This approach not only facilitates easier system modifications but also minimises the disruption caused to other residents during renovations.

Digital meter for each unit

The installation of individual smart meters for each unit in a condominium allows for effective energy management and facilitates the organisation of energy sharing with optimal self-consumption. Numerous cases have already demonstrated the benefits of this approach, and both national and local authorities are currently conducting experiments to further explore its potential.

EV charging

Shutterstock.com Hadrian

In multi-family buildings, it is strongly recommended to install pre-cabling for smart charging at all parking spaces. This cabling should be sized to accommodate the simultaneous use of recharging points at every parking space. The revised EPBD[14] outlines provisions aimed at accommodating widespread future installation of EV charging points. For residential buildings with more than three car parking

[14] Energy Performance of Buildings Directive (2024/1275/EU)

spaces, the Directive mandates the installation of at least one charging point, pre-cabling for at least half of the parking spaces, and ducting for the remainder. Additionally, the directive encourages the integration of smart and bi-directional recharging functionalities to enhance energy system integration.

Shared ownership of PV panels

Co-owned photovoltaic (PV) installations on condominiums pose distinctive challenges, primarily administrative and financial rather than technical. Coordinating decisions among multiple owners and ensuring fair cost-sharing can be intricate, often resulting in delays or disputes during implementation. However, the installation of individual smart meters per unit serves as a fundamental technical requirement that establishes the groundwork for addressing these challenges. Smart meters provide accurate data on individual energy consumption, offering essential insights for future energy sharing arrangements within the association of owners. With precise measurements and transparent data, condominium associations can develop systems for efficient energy distribution and equitable cost allocation, facilitating the seamless integration of co-owned PV installations and fostering sustainable energy practices within residential communities.

CHAPTER 6

Guidance for policy makers

To fully harness the potential of zero-emission technologies, it is essential to prioritise understanding and considering the electrical installation itself as the key enabler for making homes zero-emission. By recognising its significance and implementing appropriate strategies, we can accelerate the transition to a sustainable and low-carbon future. Bans on fossil fuel cars or the extension of the Emission Trading Scheme (ETS) to the building sector will be a harder sell for policymakers if consumers find out they'll have to spend thousands of euros first for an electricity upgrade before being able to adopt an electric vehicle or a heat pump.

Renovation policies and roadmaps at all governance levels—from the European to the national and local administrations—should consider and incentivise electrical installation upgrades as a prerequisite for the deep decarbonisation of the building stock.

Here's how:

- **Assess the status and the readiness:** In many countries the actual status of the electrical installation of residential buildings is not known nor documented. Dedicated inspection regimes could provide an accurate assessment of the status of electrical installations in homes, including their readiness to enable the minimum energy performance standards (MEPS) and Zero-Emission Building (ZEB) standards.
- **Inform homeowners:** Ensure that building owners are informed about the status and readiness of their electrical installations particularly in the view of electrification of heating and transport. Such information must be integrated into tools such as the Energy Performance Certificate (EPC), the renovation passport, digital building logbook, and the Smart Readiness Indicator (SRI) of the building.
- **Raise awareness**: Educate stakeholders, including homeowners, syndics, architects, contractors, and electricians, about the significance and the co-benefits of a ZEB-ready electrical installation in achieving zero-emission homes.
- **Incentivise upgrades**: Provide financial incentives and subsidies to encourage homeowners to upgrade their electrical installations to be ZEB-ready during renovations. The Energy Efficiency Directive currently requires the installation of energy management systems in specific categories of larger buildings[15]. This presents an opportunity to also assess and upgrade the electrical installations as necessary.
- **Incorporate electrical installation provisions in building related policies.** A good practice can be found in the Energy Performance of Buildings Directive, which says that for residential buildings (new or undergoing significant renovations) with more than three parking spaces, at least half of the parking spaces should have wiring installed so electric vehicle charging stations can be easily added later. For the remaining spaces, there should be conduits (ducting) for future wiring[16]. This provision avoids expensive retrofits and therefore accelerates electrification of transport.
- **Rely on adequately qualified installers and integrators**. The quality, impact, and effectiveness of any measure hinge to a significant extent on the proficiency of the staff implementing it. In this case, it is essential to promote the use of adequately qualified electrical installers or integrators who have the full array of electrical competences to assess, improve, and certify increasingly complex and integrated electrical installations. In addition, it is key to ensure that one-stop shop advisors, inspectors, and all other relevant workers are adequately qualified to implement building-related policies and recommendations presented in this guide.

On the longer term, ZEB-ready requirements must be incorporated in building codes and regulations to ensure that all new and renovated homes are equipped to handle zero-emission technologies.

Zero-Emission Buildings (ZEB) definition

The Energy Performance of Buildings Directive recast sets the vision for achieving a highly energy-efficient and decarbonised built environment by 2050, and defines **zero-emission building** as

> *a building with a very high energy performance (...), requiring zero or a very low amount of energy, producing zero on-site carbon emissions from fossil fuels and producing zero or a very low amount of operational greenhouse gas emissions (...)*[17]

[15] Article 11 of the EED (2023/1791/EU)

[16] Article 14(4) of the EPBD (2024/1275/EU)

[17] Art.2(2) of the EPBD (2024/1275/EU)

The same Directive also mentions that

> *Zero-emission buildings can contribute to demand-side flexibility for instance through demand management, electrical storage, thermal storage and distributed renewable generation to support a more reliable, sustainable and efficient energy system.*[18]

However, the role of the electrical installation is not mentioned. As an example, the EPBD states that

> *In order to enable the cost-effective installation of solar technologies at a later stage, all new buildings should be 'solar-ready', that is, designed to optimise the solar generation potential on the basis of the site's solar irradiance, enabling the installation of solar technologies without costly structural interventions.*[19]

...but doesn't specify the necesity of a forward-looking electrical installation to make this possible.

Therefore, **a useful addition to the EPBD recast would at least have been** a recital stating:

> *To be qualified ZEB-ready, new buildings and existing buildings undergoing major renovation should be equipped with an electrical installation that is designed and equipped to handle the increased demand for electricity in a flexible and integrated way and turns the building into a true 'clean electricity hub.' A ZEB-ready electrical installation provides the necessary infrastructure to install—now or later—and seamlessly integrate renewable energy sources, energy storage systems, electric vehicle charging stations, heat pumps, electric cooking appliances and other zero-emission technologies. A real fitness check would also anticipate to installing and using smart meters and appliances, home energy management systems, energy sharing and advanced demand side flexibility services to the grid.*

Consumer information tools

The Energy Performance of Buildings Directive has introduced various tools to inform building owners and users, such as the Energy Performance Certificate (EPC), the Smart Readiness Indicator (SRI), the Renovation Passport (RP), and the Digital Building Logbook (DBL). At least some, if not all, of these tools should include information about the electrical installation and its zero-emission readiness.

- As a minimum requirement, incorporating **a reference to the most recent electrical safety inspection report** (which is mandatory in many EU member states) into the Energy Performance Certificate (EPC) wouldn't increase costs significantly. It would simply require assessors to check for the availability of a recent report and assess if the installation complies with it.
- A next step, without significantly expanding the assessment, could involve **a relatively simple checklist for assessors to review the electrical installation on key requirements for its zero-emission readiness** in the Smart Readiness Indicator (SRI). The answers to this checklist should be easily accessible from the electrical documentation of the building.
- A further level of detail would involve **integrating the electrical system into the renovation passport (RP)**. This would entail suggesting necessary upgrades to ensure the system is prepared for future needs, providing advice on the best timing for these upgrades (connected to specific milestones and aimed at minimising future integration costs), and offering estimates of the expected investments involved.
- **Digital Building Logbooks** (DBL) can keep track of the 'as-built' status of the electrical installation after each renovation step.

[18] Recital 23 of the EPBD (2024/1275/EU)

[19] Recital 28a of the EPBD (2024/1275/EU)

Energy Performance Certificates (EPC)

Annex V of the EPBD already highlights the importance of linking different instruments:

> *The energy performance certificate may include the following links with other initiatives if these apply in the relevant Member State:*
>
> *(a) a yes/no indication whether a smart readiness assessment has been carried out for the building;*
>
> *(b) where available, the value of the smart readiness assessment;*
>
> *(c) a yes/no indication whether a Digital Building Logbook is available for the building.*[20]

Adding a yes/no option to indicate whether an electrical safety inspection report is available for the building, and another yes/no option to indicate if it meets safety standards compliance, would be a low-cost and straightforward enhancement with significant impact.

Smart Readiness Indicator (SRI)

The Smart Readiness Indicator (SRI)[21], a part of the Energy Performance of Buildings Directive since 2018, recognises the importance of interoperability and connectivity in implementing smart technologies. However, it overlooks the significance of electrical installations. Current national tests show that the SRI is primarily seen as a 'digital' certification scheme, focusing on software. However, the acknowledgment of pre-installed, adequate basic infrastructure (the hardware layer), including wiring and connectors, is crucial for cost-effective implementation of smart technologies in the future.

For instance, a newly constructed building equipped with proper pre-cabling and connectors for electric vehicle charging should be deemed more 'ready' than one lacking such provisions. However, under the current SRI methodology, both buildings would receive the same readiness level (level=0), which doesn't align with the definition of readiness as *"the potential to take action exists, though it may not be actualised"*.

We advocate for readiness to mirror the presence of foundational infrastructure, in line with the layer hierarchy outlined in relevant standardisation documents[22].

A relatively simple checklist can be created, either following the nine technical domains or based on the smart service catalogue outlined in the SRI framework. This checklist would consist of straightforward questions, easily extracted from the electrical documentation, such as:

- Is there (pre)cabling or pretubing from the circuit board to accommodate future outdoor electricity uses such as rooftop PV, EV charging, climate sensors, automated shutters, etc., to avoid later issues with insulation and airtightness of the building?
- Have we considered the nominal connection power to anticipate future loads, as upgrades for later connections will be more costly?
- Is the circuit board easily expandable, ensuring there is enough residual space for future needs?
- Are there provisions for pre-cabling and pre-wiring for both power supply and data communication wherever future electric equipment or services may be expected? Is the cross-section of cables sufficient to accommodate higher future loads?

[20] Annex V(3) of the EPBD (2024/1275/EU)

[21] The European Commission's maintains a dedicated web page on the Smart Readiness Indicator

[22] Such as Cenelec' standards mapping (SGAM) - retrieved from: ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/Fields/EnergySustainability/SmartGrid/SmartGridSetOfStandards.pdf

Renovation Passports (RP)

The EPBD recast mandates Member States to introduce a scheme of renovation passports[23]. The Renovation Passport[24] introduces the long-term perspective (15-20y) to renovation and the importance of 'lock-in effects' (renovation step precluding necessary subsequent steps) (BPIE, 2017). To avoid such lock-ins, building renovations should be carefully planned with attention not only to the envelope but also to the technical building systems—including the domestic electrical installation that enables their integration. Therefore, it is recommended that Renovation Passports provide homeowners with:

- **Sound information about the condition and capacity of their electrical installation,** addressing key inquiries such as the connection power and phase count, the presence of a smart meter, compliance with safety inspections, and whether the heating is electrified.
- **A renovation roadmap that includes the domestic electrical installation**, including recommendations on which upgrades are needed to make the installation future-ready, guidance on the optimal time schedule (linked to trigger points and minimising costs for future integration of technologies), and estimations of the foreseeable investments.

Digital building logbook

A digital building logbook means

> *a common repository for all relevant building data, including data related to energy performance such as energy performance certificates, renovation passports and smart readiness indicators, as well as data related to the life-cycle GWP[25], which facilitates informed decision making and information sharing within the construction sector, and among building owners and occupants, financial institutions and public bodies[26]*

A notable example in the EU is the "Woningpas", the digital building passport for residential properties in Flanders, Belgium[27]. It consolidates information on the dwelling, building plot, surroundings, and administrative requirements involved in building, renovating, selling, buying, or renting a house. The Woningpas is generated in real-time from government data sources when accessed by users, without a dedicated database behind it.

The Woningpas comprises various attestations, including the EPB declaration, EPC, soil attestation, and asbestos attestation. In 2023, the inspection report on the heating installation was also incorporated. However, for the electrical installation, currently, only a notification is provided to users that the electrical safety inspection report is among the mandatory attestations required at key trigger points such as selling, buying, renting, building, or renovating a property.

Homeowners can choose to upload their own digital copy of the inspection report, which is then labeled as *"Uploaded by the owner"* rather than *"Uploaded by the government"*.
The Woningpas also features a check tool and guidance on dwelling quality, utilising self-assessment questionnaires on various topics. The *"Safe Technical Installations"* section includes a concise set of questions for homeowners to answer with YES/NO/UNKNOWN. This results in an overall evaluation (OK or Not OK) of the safety of technical installations. Two questions pertain to the electrical system:

- *Does the dwelling have a safe electrical installation? (A safe electrical installation ensures there is no risk of electrocution, explosion, or fire.)*
- *Is the electrical installation suitable for the occupants? (An installation is suitable when there are an adequate number of sockets and light points, and occupants can use electrical devices without issues.)*

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[23] Art.12 of the EPBD (2024/1275/EU)

[24] Such as the Sanierungsfahrplan in Germany

[25] Global Warming Potential

[26] Art.2(41) of the EPBD (2024/1275/EU)

[27] https://woningpas.vlaanderen.be

An excellent enhancement, simple to implement yet highly effective in raising respondents' awareness of their electrical installation's condition, would be to include a straightforward question:

- **Is there a recent inspection report available for the electrical installation?**
- **According to this inspection report, is the electrical installation compliant with applicable safety standards?**

Additionally, users should be given the option to upload a digital copy of the inspection report.

One-Stop Shops (OSS)

One-stop-shops serve as advisory tools aimed at informing and assisting consumers regarding energy efficiency renovations and financing options. To accelerate the rate of building renovations, the European Commission has endorsed one-stop-shops through initiatives such as *"Smart financing for smart buildings"* initiative (Serrenho, Stromback, Bertoldi, & Streng, 2021), the revised EED[28] and the EPBD recast[29]. Both Directives mandate Member States to establish and operate technical assistance facilities (one-stop shops) that provide streamlined information, holistic support, and independent advice on technical and financial aspects, to all who is involved in building renovations. Moreover, there is an emphasis on providing specialised services for vulnerable households, individuals affected by energy poverty, and those in low-income households.

Similarly, it is advisable that one-stop shops also offer access to electrical inspection services and recommendations to ensure the safety, the energy efficiency, and the readiness of electrical installations for installing charging points, PV panels, heat pumps, and storage solutions. One-stop shops should also guide individuals toward certified installers and integrators. Indeed, the quality, and consequently, the efficiency of an installation—whether it's electrical or HVAC—depends on the proficiency of the installer and the quality of the installation itself.

Technical Building Systems (TBS)

Technical Building Systems, as defined by the EPBD[30], refer to

> *technical equipment of a building or building unit for space heating, space cooling, ventilation, domestic hot water, built-in lighting, building automation and control, on-site renewable energy generation and energy storage, or a combination thereof, including those systems using energy from renewable sources*

However, this definition does not encompass electrical installations. This omission is a missed opportunity, as recognising electrical installations within the Technical Building Systems would entail several practical benefits:

- That the safety and the readiness of electrical installations, in combination with on-site renewable energy, should be assessed and increased; and that electrical installations are subject to regular maintenance and inspections;
- That Renovation Passports should include the available information related to fire and electrical safety and the renovation steps needed to replace obsolete and inefficient electrical installations; and Member States will need to inform the Commission about the enhancement of fire and electrical safety;
- Each time the electrical installation is retrofitted or replaced, the energy performance as well as the economic and environmental performance of the system is optimised according to applicable standards

[28] Article 22 of EED (2023/1791/EU).

[29] Recital 62 and Article 18 of the EPBD (2024/1275/EU)

[30] Art.2(6) of the EPBD (2024/1275/EU)

Electrical Safety inspections

The primary safety concern associated with introducing new electrical loads or electricity production into a household environment lies not in the safety of the devices and equipment themselves, but rather in the condition of the electrical installation they are integrated into. To effectively navigate the energy transition, Member States are confronted with a significant challenge regarding domestic electrical safety, particularly as the number of outdated installations is expected to rise if left unaddressed. Implementing electrical inspection regimes has proven to be an effective measure in preventing electrical fires and identifying obsolescence. For instance, Japan experiences 24 times fewer electrical fires compared to the EU, attributed to a four-year inspection regime (FEEDS, 2024). Assessing the status of electrical installations enables determination of their safety level and readiness to accommodate major electrical loads and electricity production sources such as heat pumps, EV charging points, photovoltaic panels, or battery storage systems. However, significant disparities in existing electrical inspection regimes across the EU exist, indicating insufficient measures in light of the current circumstances (FEEDS, 2024). Nonetheless, this also highlights existing best practices and numerous opportunities for improvement.

Based on these findings, FEEDS strongly recommend the development of electrical domestic inspection regimes by Member States in order to prevent a predominant risk of fire and better prepare an energy transition mainly based on electrification. Mostly two types of inspection regimes are existing: for new or completely renovated installations and for existing installations.

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